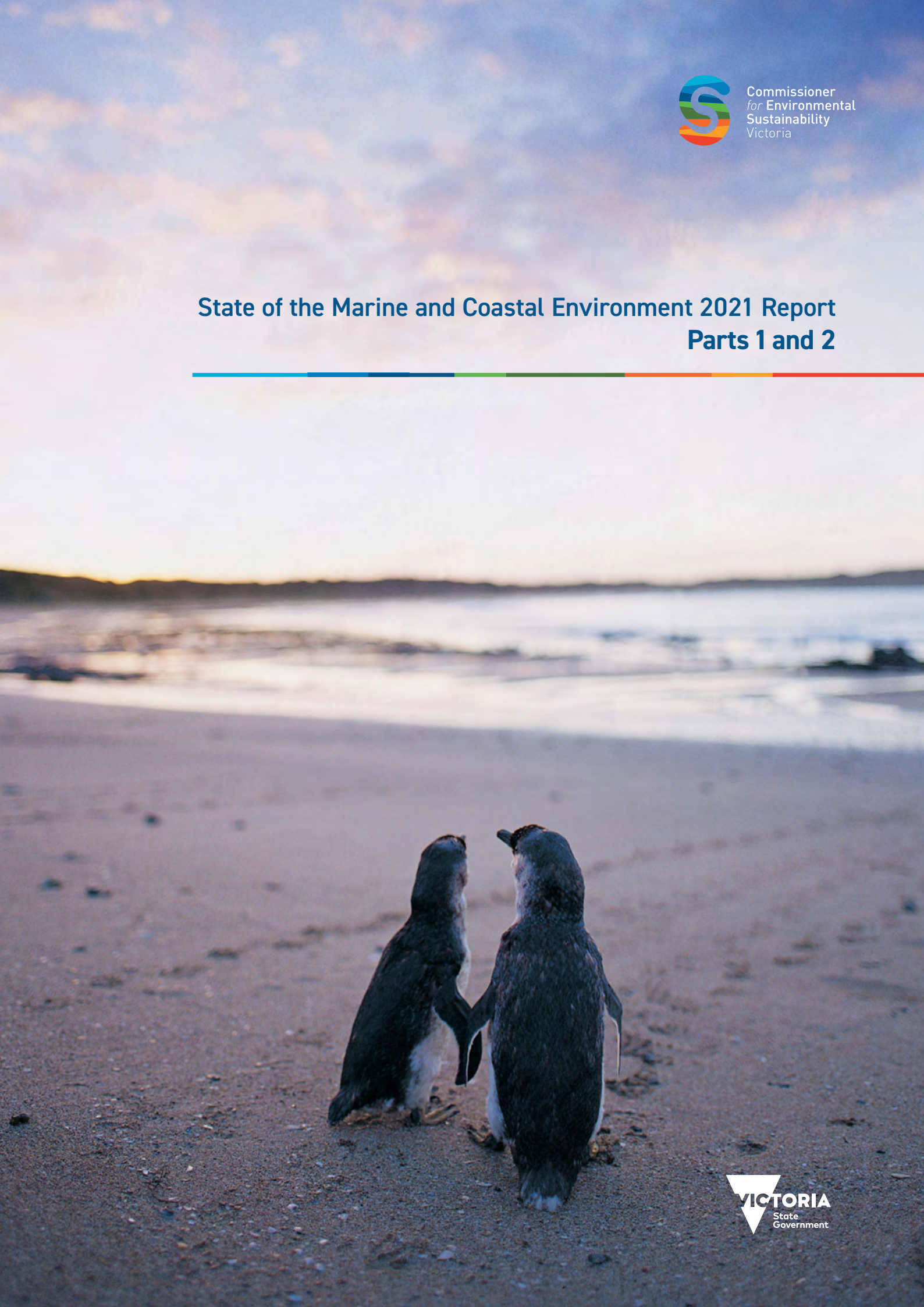
Commissioner *for* Environmental Sustainability Victoria

State of the Marine and Coastal Environment 2021 Report
Parts 1 and 2



VICTORIA State Government

Wedge-tailed eagle (*Aquila audax*)
© Parks Victoria

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

Commissioner *for* Environmental Sustainability Victoria

Traditional Owners

The Commissioner for Environmental Sustainability proudly acknowledges Victoria's Aboriginal community and their rich culture and pays respect to their Elders past and present. We acknowledge Aboriginal people as Australia's First Peoples and as the Traditional Owners and custodians of the land and water on which we rely. We recognise and value the ongoing contribution of Aboriginal people and communities to Victorian life, and how this enriches us. We embrace the spirit of reconciliation, working towards the equality of outcomes and ensuring an equal voice.

Little penguins (*Eudyptula minor*) on Phillip Island
© Visit Victoria

Commissioner's Foreword

Welcome to Victoria's first State of the Marine and Coastal Environment (SMCE) Report, an historic baseline study of the health of five important Victorian marine and coastal environments: Port Phillip Bay, Western Port, Corner Inlet and Nooramunga, the Gippsland Lakes, and Victoria's system of marine national parks and sanctuaries. This report assesses the overall health of these five regions, based on existing marine and coastal science. It builds on our State of the Bays 2016 Report, is a timely stocktake of current knowledge, and coincides with a period of great legislative and policy reform for marine and coastal management in Victoria – reform that recognises the environmental, social and economic values of Victoria's marine and coastal environments, and their importance to our health, happiness and prosperity.

This report is prepared according to the *Marine and Coastal Act 2018* (Vic), which requires the Commissioner for Environmental Sustainability (CES) to issue a five-yearly State of the Marine and Coastal Environment Report on:

- the condition of the marine and coastal environment
- the environmental, social and economic benefits of the marine and coastal environment
- threats to the marine and coastal environment.

The first full SMCE Report is not due until five years after the release of the Marine and Coastal Policy 2020. However, because five years have passed since the State of the Bays 2016 Report, it is timely to provide an independent update on the health of Victoria's marine and coastal environments for those regions where adequate science is currently available.

This SMCE Report expands on the two regions reported on in the State of the Bays 2016 Report (Port Phillip Bay and Western Port), to assess five regions. It compiles science and other information from many sources: Commonwealth and Victorian government agencies, local governments, catchment management authorities, universities, citizen scientists and non-government organisations.

Working closely with the Victorian Department of Environment, Land, Water and Planning (DELWP) and associated agencies, and expanding our science program to include non-government organisations, we have attempted in this inaugural SMCE Report to use a method that can be applied to the first full SMCE Report in 2024, which will assess Victoria's entire marine and coastal environment.

The Victorian Auditor General's audit Protecting Victoria's Biodiversity was tabled in Parliament after this report was finalised, however the findings of the audit, specifically concerns related to the availability of science and data, are consistent with those presented here.

This SMCE Report presents 215 assessments of 82 indicators of ecosystem health and social science. It includes some challenging findings and aims to highlight areas where our interventions and practical actions are improving environmental outcomes. For example, and consistent with the findings of the recently released Sixth Assessment Report of the United Nations Intergovernmental Panel on Climate Change,[1] none of the climate change impacts indicators in this report was assessed as good, with deteriorating trends observed for 21 of the 22 regional climate change indicators.

Nevertheless, this report does highlight some areas where our interventions and practical actions are improving the environment. For instance, we report promising statistics on the involvement of community members in coastal and marine volunteering, Coastcare, and citizen science activities. The Coastcare program supports hundreds of community groups and volunteers working to protect and improve Victoria's coastline. In 2019-20 a total of 13,444 people participated in Coastcare activities – a 28% increase on the previous financial year – and citizen scientists remained actively involved in marine and coastal programs.

1. Intergovernmental Panel on Climate Change (IPCC) 2021, 'Climate Change 2021: the physical science basis, contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, report prepared by V Masson-Delmotte, P Zhai, A Pirani, SL Connors, C Péan, S Berger, N Caud, Y Chen, L Goldfarb, MI Gomis, M Huang, K Leitzell, E Lonnoy, JBR Matthews, TK Maycock, T Waterfield, O Yelekçi, R Yu, and B Zhou (eds.), Cambridge University Press https://www.ipcc.ch/report/ar6/wg1/ Accessed 5 October 2021.

Even during the COVID-19 lockdowns, virtual projects enabled seal counts, for example (via webcam), and other activities to continue.

The report assesses 82 indicators covering nine themes of ecosystem health and social science:

- water quality and catchment inputs
- litter and pollution
- biodiversity
- seafloor integrity and health
- pests and invasive species
- climate and climate change impacts
- managing coastal hazard risks
- communities
- stewardship and collaborative management.

The report is in three parts. This Summary Report, which comprises Parts 1 and 2, provides a comprehensive overview of the science and strategic analysis of the complete report. Part 3 provides the comprehensive, peer-reviewed scientific assessments of specific issues and regions that form the evidence base for the indicator report card, summaries and main findings distilled in Part 1.

Part 1 includes the legislative and policy context for marine and coastal reporting, and summaries of all assessments by theme, region and indicator – including an indicator report card and a summary of the main findings. It also identifies gaps in knowledge and recommends future priorities. Importantly, it includes a section on cultural landscape health and management, and the critical role of Traditional Owners in managing and protecting sea Country and coastal environments.

Part 2 reviews the application of spatial information and international frameworks and proposes a method for applying the United Nations Sustainable Development Goals (SDGs) for future reporting on the state of the environment. A subset of 40 SDG targets were aligned with the 82 indicators in this report. Also included is a qualitative assessment of progress against six of these SDG targets, along with important work undertaken in collaboration with coastal managers and practitioners to identify local priorities for reporting.

The five future priorities proposed for marine and coastal management and reporting are:

1. Use spatial information and Earth observation to identify and protect Victoria's marine assets.
2. Update Victoria's Marine and Coastal Knowledge Framework to reflect the scientific assessments of this report.[2]
3. Develop thresholds to improve future reporting.
4. Ensure that the Victorian Government continues to implement existing policies and management plans to benefit the environment.
5. Trial different models and ways to represent the complex interlinkages between selected SDG targets, to fully understand the interactions between the environment, community and economy of Victoria.

We need to apply a 'catchment-to-reefs' philosophy in Victoria. Many of the pressures on our coasts, bays, estuaries, lakes and ocean are caused by activities on land, so management and regulatory actions that link activities in our catchments to benefits for Victoria's marine and coastal environment are critical. So too is the need for strong action to mitigate, adapt and protect our marine and coastal environments and communities against the effects of climate change.

The challenge for all Victorians is to take full advantage of the potential of the recent reform of marine and coastal legislation and policy, and to continually strive for a whole-of-system approach to guide action. This will require the tools presented by the reform to be coherent and coordinated. They must be applied holistically: integrated water quality and pest management, adaptation to climate change, and conservation and protection priorities. This undertaking is twofold. It requires that commitments be kept, and that the policies established under this new legislative and policy framework lead to continuing improvement and protection of our marine and coastal environments.

2. Following the State of the Bays 2016 Report, Victoria put in place a Marine and Coastal Knowledge Framework to support planning for Victoria's marine and coastal areas. The framework is available at: https://www.marineandcoasts.vic.gov.au/coastal-programs/marine-and-coastal-knowledge-framework

Spatial information and Earth observation offer new paths to environmental understanding. These capabilities are growing in range and importance as enablers of better decision-making and more targeted environmental management. This report provides a comprehensive assessment of the contributions that spatial information can make to marine and coastal management and reporting – now and in the future.

It is an honour to be Victoria's Commissioner for Environmental Sustainability, and a privilege to have led the scientific and consultative endeavour that has resulted in this inaugural SMCE Report – a report that has been made possible only by a collaboration of many talented people. My team and I acknowledge and thank all of those who have generously contributed their time and effort to help prepare and review this report.

Also, we thank the dedicated members of the Commissioner's Reference Group, and colleagues from across DELWP and other agencies, without whom we cannot do our work. Finally, my sincere thanks to my team for their tireless efforts in preparing this report.

I am pleased to present the State of the Marine and Coastal Environment 2021 Report.

The report is also available in an interactive, simplified form and as visual web pages (www.ces.vic.gov.au/smce-2021), to encourage Victorians to care more, and know more, about our precious marine and coastal environment.

Dr Gillian Sparkes AM
Commissioner for Environmental Sustainability, Victoria

Acknowledgements

We thank the following individuals and organisations for their contributions to the State of the Marine and Coastal Environment 2021 Report:

Commissioner's Reference Group	
Kathryn Arndt	Victorian Local Governance Association
Dr Angie Bone	Victorian Department of Health
Dr Anthony Boxshall	Victorian Marine and Coastal Council
Professor Chris Chesterfield	Independent water sector expert
Claire Dunn	Municipal Association of Victoria
Dr Rohan Henry	Independent Traditional Owner and Aboriginal water expert
Jono La Nauze	Environment Victoria
Jane Lovell	Victorian Farmers Federation
Victoria Marles	Trust for Nature
Sharyon Peart	Vic Catchments
Joan Phillips	Victorian Environmental Assessment Council
Matt Ruchel	Victorian National Parks Association
Amelia Young	Wilderness Society
Previous members	
Janine Haddow	Victorian Environmental Assessment Council
Don Matthews	Local Jobs First Commissioner
Dr Kaye Rodden	National Landcare Network
Steve Sheridan	Victorian Farmers Federation
Dr Kirsten Shelly	Victorian Catchment Management Council

Non-government Stakeholder Technical Advisory Group	
BirdLife Australia	Landcare Victoria Inc.
Conservation Volunteers Australia	Marine Mammal Foundation
Deakin University	Royal Society of Victoria
Dolphin Research Institute	University of Melbourne
Port Phillip EcoCentre	Victorian Farmers Federation
Environment Victoria	Victorian National Parks Association
Field Naturalists Club of Victoria	Werribee River Association
Greening Australia	Yarra Riverkeeper Association

Technical Advisory Group	
Better Boating Victoria (Department of Transport)	Local Jobs First
Bureau of Meteorology	Municipal Association of Victoria
City of Port Phillip	Melbourne Water
Conservation Volunteers Australia	Parks Victoria
Corangamite Catchment Management Authority	Phillip Island Nature Parks
Commonwealth Scientific and Industrial Research Organisation	Port Phillip and Westernport Catchment Management Authority
Deakin University (Blue Carbon Lab)	Ports Victoria
Department of Environment, Land, Water and Planning	Royal Botanic Gardens Victoria
Victorian Department of Health	Sustainability Victoria
Department of Jobs, Precincts and Regions	The Nature Conservancy
Department of Transport	Trust for Nature
East Gippsland Catchment Management Authority	University of Tasmania
Environment Protection Authority Victoria	University of Wollongong
Fishcare Victoria	Victorian Environmental Assessment Council
Fishwell Consulting	Victorian Fisheries Authority
Glenelg Hopkins Catchment Management Authority	Victorian Marine and Coastal Council
Great Ocean Road Coast Committee	West Gippsland Catchment Management Authority
La Trobe University	Zoos Victoria

Abbreviations

ABS ..... Australian Bureau of Statistics
ARI ..... Arthur Rylah Institute for Environmental Research
AURIN ..... Australian Urban Research Infrastructure Network
BoM ..... Bureau of Meteorology
CES ..... Commissioner for Environmental Sustainability Victoria
CIN ..... Corner Inlet–Nooramunga
CMAs ..... Catchment Management Authorities
CPUE ..... catch per unit effort
CSIRO ..... Commonwealth Scientific and Industrial Research Organisation
DE ..... denitrification efficiency
DEA ..... Digital Earth Australia
DELWP ..... Victorian Department of Environment, Land, Water and Planning
EEA ..... environmental–economic accounting
EMP ..... Environmental Management Plan
EO ..... Earth observation
EPA ..... Environment Protection Authority Victoria
ERS ..... Environment Reference Standard
ESD ..... ecologically sustainable development
GDP ..... Gross Domestic Product
GIS ..... geographical information system
GL ..... Gippsland Lakes
GNSS ..... global navigation satellite system
GPS ..... global positioning system
IEC ..... Index of Estuary Condition
IMOS ..... Integrated Marine Observing System
IMU ..... inertial measurement unit
IoA ..... Internet of Animals
IoT ..... Internet of Things
IPA ..... Indigenous Peoples' Protected Area
LAC ..... limit of acceptable change
LiDAR ..... light detecting and ranging
MKF ..... Marine Knowledge Framework
ML ..... machine learning
MPA ..... marine protected area
NOAA ..... National Oceanic and Atmospheric Administration (USA)

NRM ..... National Resource Management
OMPA ..... other marine protected areas
PFAS ..... per and polyfluoroalkyl substances
PPB ..... Port Phillip Bay
RAP ..... Registered Aboriginal Party
RCS ..... Regional Catchment Strategies
RPV ..... remotely piloted vehicle
SAR ..... synthetic aperture radar
SDGs ..... United Nations Sustainable Development Goals
SEEA ..... United Nations System of Environmental–Economic Accounting
SMCE ..... State of the Marine and Coastal Environment
SoE ..... State of the Environment
SotB ..... State of the Bays
TOLMA ..... Traditional Owner Land Management Agreement
TOS ..... Traditional Owner Settlement Agreements
UN ..... United Nations
UNESCO ..... United Nations Educational, Scientific and Cultural Organisation
VEAC ..... Victorian Environmental Assessment Council
VFA ..... Victorian Fisheries Authority
VNPA ..... Victorian National Parks Association
WP ..... Western Port
WQIP ..... Water Quality Improvement Plan

Contents

Tables and figures

Tables

Figures

Commissioner *for* Environmental Sustainability Victoria

Part 1A
Key findings and future priorities

Report structure

Part 1A provides a summary of findings from the State of Marine and Coastal Environment 2021 Report and includes the legislative and policy context for marine and coastal reporting, summaries of assessments by theme, region and indicator and the report card (Table 1), summary pie charts and key findings. Part 1A concludes by proposing five future priorities, which are based on the evidence presented in the Scientific assessments (Part 3).

Part 1B includes information on the critical role of Traditional Owners in cultural landscape health and management, and more detailed information on the legislative and policy context for marine and coastal management. Part 1B concludes with indicator summaries for all 82 indicators assessed in Part 3, presenting metrics for each indicator, a comment arising from the assessment, summary of status, trend and confidence, the region to which the indicator applies, and identification of the data custodian.

Part 2 contains an environmental scan of current, emerging and future spatial information technologies and data coordination for state of environment reporting, the description of a proposed method for adopting the SDGs for environmental reporting in Victoria (including a process for identifying local priorities and an SDG synthesis and evaluation of specific targets) and an overview of environmental–economic accounts being developed by DELWP.

Appendix B in Part 2, at the end of this summary document, provides a useful analysis aligning 40 SDG targets (those assessed as relevant to marine and coastal reporting in Victoria) with the indicators in this report.

Part 3 contains the scientific assessments for each of the 82 indicators, presented across nine themes:

- Theme 1: water quality and catchment inputs
- Theme 2: litter and pollution
- Theme 3: biodiversity
- Theme 4: seafloor integrity and health
- Theme 5: pests and invasive species
- Theme 6: climate and climate change impacts
- Theme 7: managing coastal hazard risks
- Theme 8: communities
- Theme 9: stewardship and collaborative management.

Each theme commences with an overview and analysis of the key findings. The scientific assessments rely on publicly available scientific data, including reports, journal articles, submissions to parliamentary and government inquiries, citizen science projects, and interviews with experts in relevant fields. The data are subsequently assessed and synthesised by the science team supporting the CES.

The assessments have been conducted on a statewide and/or regional scale, based on the localisation of the impacts associated with each indicator and the spatial scale of the available evidence.

The scientific evidence and findings on Theme 8: Communities, and Theme 9: Stewardship and collaborative management, are presented on a statewide scale, unlike the regional structure of the biophysical science themes (Themes 1–7). However, where the data enable regional analysis, that disaggregation is provided.

Each indicator's scientific assessment includes:

- metrics used to measure the status and trend
- data confidence
- data custodian (the source of the data)
- region covered by the indicator (statewide or a particular region)
- reason for assessing the indicator
- indicator's performance
- thresholds for determining the status of each indicator (where available)
- a summary of the 2021 assessment
- an updated assessment and commentary where new data has become available since 2018.

The Science for Sustainable Development Framework approach to reporting embraces three levels of synthesis:

1. environmental condition reporting
2. assessing interlinkages across the SDG targets
3. tracking progress on selected SDG targets.

Part 2 delivers the second and third levels of synthesis and should aid further interpretation of the scientific assessments in Part 3. It proposes a Method, informed by the approach outlined in the Science for Sustainable Development Framework. This Method aims to provoke discussion with our partners and co-creators that will be tested throughout 2022 on a pathway to applying the SDGs as an operating framework for the Victorian State of the Environment 2023 Report.

Part 3 of this report delivers the evidence base and scientific assessments for the first level of synthesis.

The findings from the analyses in both Parts 2 and 3 contribute to the development of the five future priorities presented in Part 1 of this SMCE 2021 Report.

Dragonet (*Bovichtus angustifrons*), San Remo Channel, Western Port
© Julian Finn, Museums Victoria

Marine and coastal reporting

This State of the Marine and Coastal Environment 2021 Report is the first in Victoria's series of state of environment reports in the 2020–24 reporting cycle, and is a transitional report, updating the State of the Bays 2016 Report and widening the scope in preparation for the first full State of the Marine and Coastal Environment Report, due in 2024.

Figure 1 provides context for the reader, demonstrating how the Victorian Government's marine and coastal legislative and policy reform – particularly the objectives and guiding principles of the Marine and Coastal Policy – inform a broader adaptive cycle for marine and coastal management.

The emphasis here is on the crucial role of environmental reporting – not only in providing evidence and strengthening the frameworks for marine and coastal knowledge and marine spatial planning, but also in providing essential information for future iterations of the Marine and Coastal Policy and the Marine and Coastal Strategy.

In turn, the policy and strategy will guide the prioritisation and science focus of future SMCE Reports, identifying emerging policy and strategy interventions that require more robust evidence.

A more detailed description of the Marine and Coastal Policy and Marine and Coastal Strategy is provided in 'Public policy context – Victorian'.

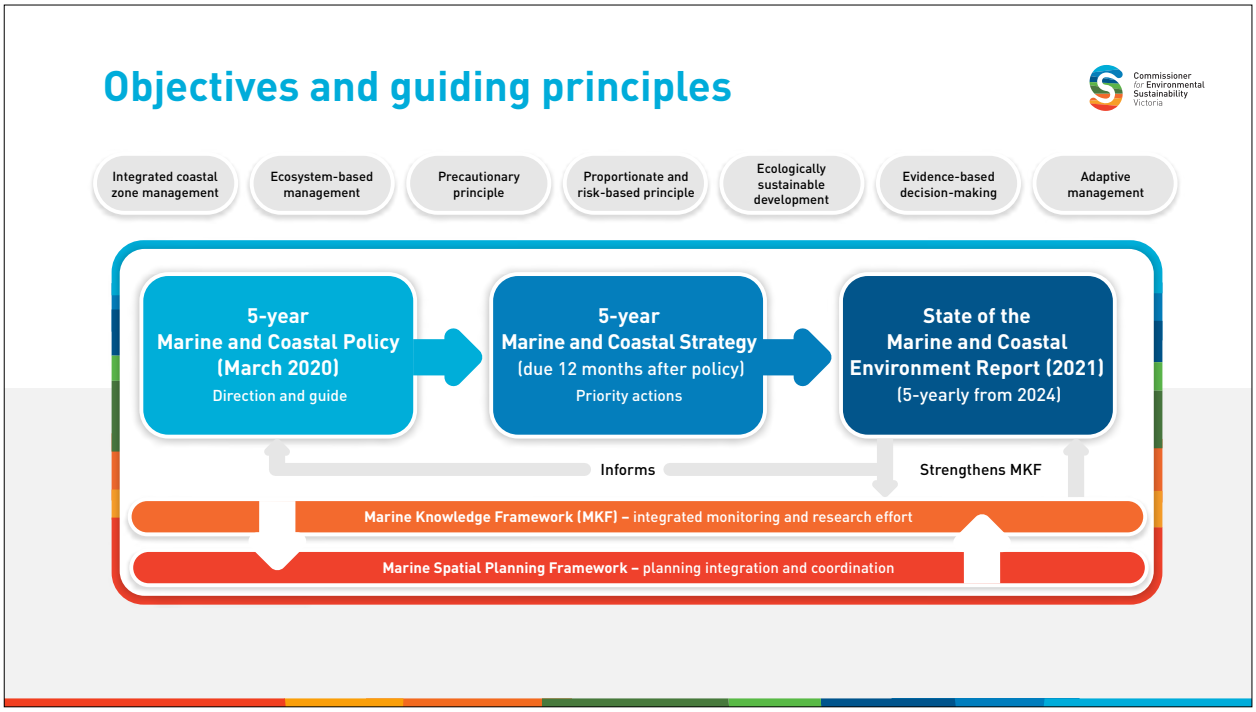


Figure 1: Marine and Coastal Act 2018 (Vic).

Figure 2 maps the Marine and Coastal Policy decision pathway against the structure of this report. This shows how the evidence is presented to support the policy priorities and to inform decision-makers of the science needed to make informed decisions at each point in the pathway. The themes, and accompanying indicators, of Part 3: Scientific assessments, are identified to the right of the complementary policy priorities.

This report has expanded the geographical scope of the State of the Bays 2016 Report, to include scientific assessments of Port Phillip Bay, Western Port, Gippsland Lakes, Corner Inlet and Nooramunga, Victoria's system of marine national parks and sanctuaries, and statewide analysis (where possible). The analysis of what constitutes 'marine and coastal' conforms with the definition in the Marine and Coastal Act 2018.

The marine and coastal environment includes all private and public land and waters between the outer limit of Victorian coastal water and 5km inland of the high-water mark of the sea, including:

a. the land (whether or not covered by water) to a depth of 200 metres below the surface of that land

b. any water covering the land referred to in sentence (a) above from time to time

c. the biodiversity associated with the land and water referred to in sentences (a) and (b).

The definition includes bays, inlets and estuaries, and the Gippsland Lakes.

This executive summary provides an overview of findings from Part 3: Scientific assessments. Each theme in Part 3 is introduced with a summary section as well. For a more detailed analysis of the issues presented below, see Part 3.

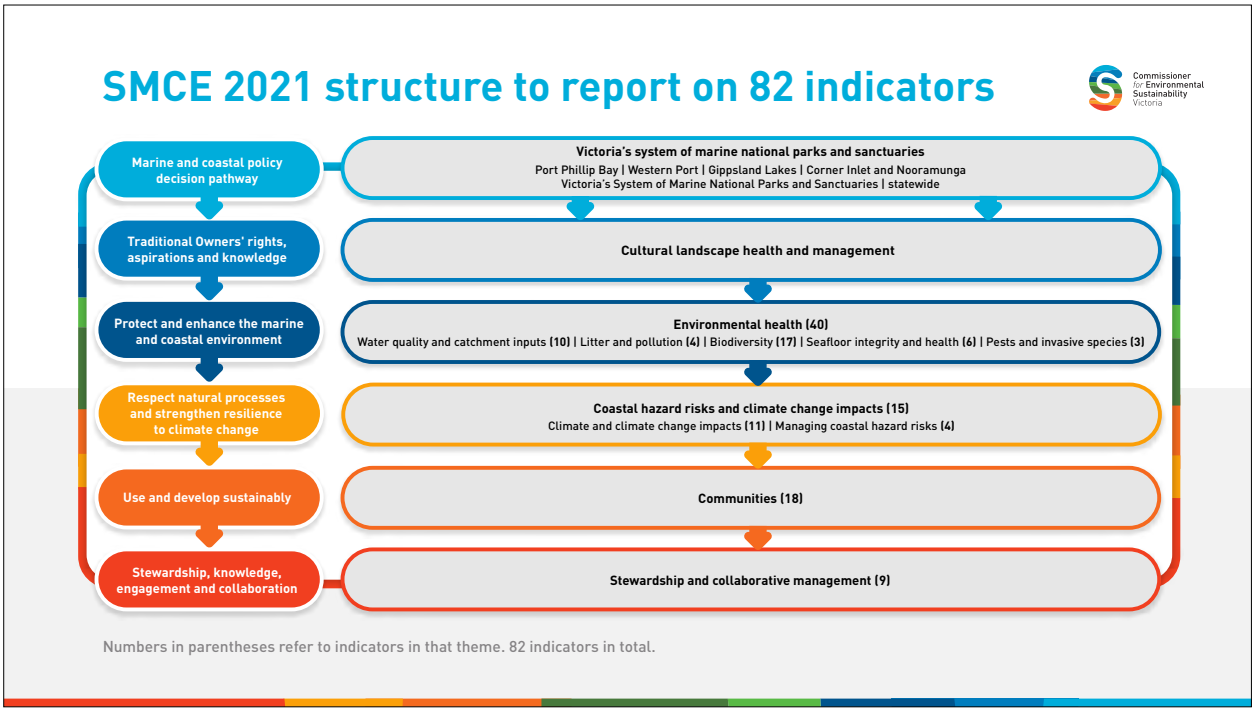


Figure 2: SMCE 2021 structure to report on indicators.

Summaries

Table 1 (on the next page) provides a summary of the Status, Trend and Data in the 82 indicator assessments for 2021. The colour keys for the assessments are as follows:

Key to status

Good	Fair	Poor	Unknown	Narrative but not assessed	Not assessed and no narrative

Key to trend

Improving	Stable	Deteriorating	Unclear

Key to data

High	Moderate	Low	Unknown	Not Applicable

Theme 1 indicator summaries: Water quality and catchment inputs

Indicator 01: Water quality (physicochemical)

Region		2021 status	2021 trend	2021 data
Port Phillip Bay			→	
Western Port			→	
Corner Inlet-Nooramunga			?	
Gippsland Lakes	Lake King		→	
	Lake Victoria		→	
	Lake Wellington		→	
Data source:	Environment Protection Authority Victoria (EPA), Melbourne Water, DELWP			

Indicator 02: Toxicants

Region	2021 status	2021 trend	2021 data
Port Phillip Bay		?	
Western Port		?	Moderate (status), Low (trend)
Corner Inlet-Nooramunga		?	
Gippsland Lakes		?	Moderate (status), Low (trend)
Data source:	EPA, Melbourne Water, academic researchers		

Indicator 03: Water quality (estuaries)

Region	2021 status	2021 trend	2021 data
Port Phillip Bay		?	High (status), Low (trend)
Western Port		?	High (status), Low (trend)
Corner Inlet-Nooramunga		?	High (status), Low (trend)
Gippsland Lakes		?	High (status), Low (trend)
Statewide		?	High (status), Low (trend)
Data source:	DELWP		

Table 1: SMCE 2021 report card.

Indicator 04: Plankton

Region		2021 status	2021 trend	2021 data
Port Phillip Bay			→	
Western Port			↗	
Corner Inlet-Nooramunga			?	
Gippsland Lakes	Lake King		↗	
	Lake Victoria		↗	
	Lake Wellington		→	
Statewide		N	N	N
Data source:	EPA, Integrated Marine Observing System (IMOS)			

Indicator 05: *Enterococci* bacteria

Region	2021 status	2021 trend	2021 data
Port Phillip Bay		→	
Data source:	EPA		

Indicator 06: Regulated point source discharges to marine waters

Region	2021 status	2021 trend	2021 data
Port Phillip Bay		?	
Corner Inlet-Nooramunga		?	
Data source:	EPA		

Indicator 07: Stormwater

Region	2021 status	2021 trend	2021 data
Port Phillip Bay		?	Moderate (status), Low (trend)
Western Port		?	Moderate (status), Low (trend)
Corner Inlet-Nooramunga		?	
Gippsland Lakes		?	
Data source:	Melbourne Water		

Indicator 08: Total nutrient loads

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	Good	→	Good
Western Port	Moderate	→	Low (status), Moderate (trend)
Corner Inlet-Nooramunga	Moderate	?	Moderate (status), Low (trend)
Gippsland Lakes	Moderate	↙	Good
Data source:	Melbourne Water, academic researchers		

Indicator 09: Total sediment loads

Region		2021 status	2021 trend	2021 data
Port Phillip Bay		Good	→	Good
Western Port		Poor	→	Good
Corner Inlet-Nooramunga		Good	?	Poor
Gippsland Lakes	Lake King	Moderate	?	Poor
	Lake Victoria	Moderate	?	Poor
	Lake Wellington	Poor	?	Poor
Data source:	Melbourne Water, academic researchers			

Indicator 10: Coastal acid sulfate soils

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	Unknown	?	Unknown
Western Port	Unknown	?	Unknown
Corner Inlet-Nooramunga	Unknown	?	Unknown
Gippsland Lakes	Unknown	?	Unknown
Data source:	Department of Jobs, Precincts and Regions		

Theme 2 indicator summaries: Litter and pollution

Indicator 11: Litter and plastics

Region	2021 status	2021 trend	2021 data
Port Phillip Bay		↙	
Western Port		?	
Corner Inlet-Nooramunga		?	
Gippsland Lakes		?	
Data source:	Port Phillip EcoCentre, Tangaroa Blue Foundation, academic researchers		

Indicator 12: Light pollution

Region	2021 status	2021 trend	2021 data
Port Phillip Bay		?	
Western Port		?	
Corner Inlet-Nooramunga		?	
Gippsland Lakes		?	
Data source:	https://www.lightpollutionmap.info/, academic researchers		

Indicator 13: Coastal contaminated land

Region	2021 status	2021 trend	2021 data
Port Phillip Bay		?	
Western Port		?	
Corner Inlet-Nooramunga		?	
Gippsland Lakes		?	
Data source:	EPA		

Indicator 14: Coastal air quality

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	(ozone, nitrogen dioxide, carbon monoxide, sulfur dioxide) (fine particle pollution)	→	(near shipping terminals) (elsewhere)
Western Port		?	
Corner Inlet-Nooramunga		?	
Gippsland Lakes	(fine particle pollution during bushfire periods) (all other times)	?	(during bushfires) (all other times)
Data source:	EPA, academic researchers		

Theme 3 indicator summaries: Biodiversity

Indicator 15: Conservation of coastal ecosystems in protected areas

Region	2021 status	2021 trend	2021 data
Statewide		?	
Data source:	Parks Victoria		

Indicator 16: Saltmarsh

Region		2021 trend	2021 data	2021 data
Port Phillip Bay			→	
Western Port			→	
Corner Inlet-Nooramunga	Corner Inlet		→	
	Nooramunga		→	
	Nooramunga islands		→	
Gippsland Lakes			?	
Data source:	Academic researchers, DELWP			

Indicator 17: Mangroves

Region	2021 status	2021 trend	2021 data
Port Phillip Bay		?	
Western Port		↗	
Corner Inlet-Nooramunga		→	
Data source:	Academic researchers, DELWP		

Indicator 18: Wetland and estuarine vegetation

Region	2021 status	2021 trend	2021 data
Port Phillip Bay		?	
Western Port		?	
Corner Inlet-Nooramunga		?	
Gippsland Lakes	(estuarine flora) (wetland habitat extent) (condition of paperbark-dominated wetlands)	?	(estuarine flora) (wetland habitat extent, condition of paperbark-dominated wetlands)
Statewide		?	
Data source:	Academic researchers, DELWP		

Indicator 19: Species of conservation concern

Region	2021 trend	2021 data	2021 data
Port Phillip Bay		?	
Western Port		?	
Corner Inlet-Nooramunga		?	
Gippsland Lakes		?	
Statewide		?	
Data source:	Victorian Biodiversity Atlas		

Indicator 20: Mobile invertebrates on intertidal reefs

Region	2021 status	2021 trend	2021 data
Port Phillip Bay			
Other marine protected areas			
Data source:	Parks Victoria		

Indicator 21: Sessile invertebrates on intertidal reefs

Region	2021 status	2021 trend	2021 data
Port Phillip Bay			
Other marine protected areas			
Data source:	Parks Victoria		

Indicator 22: Invertebrates on subtidal reefs

Region	2021 status	2021 trend	2021 data
Port Phillip Bay		(north) (south)	
Other marine protected areas		?	
Data source:	Parks Victoria, Reel Life Surveys		

Indicator 23: Commercially and recreationally important invertebrates

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	(commercial scallop, short-spined sea urchin)	(commercial scallop, short-spined sea urchin)	(commercial scallop, short-spined sea urchin)
Statewide	(southern calamari, Maori octopus) (southern rock lobster) (blacklip abalone) (pipi, greenlip abalone)	(southern calamari, Maori octopus, southern rock lobster) (blacklip abalone) (pipi, greenlip abalone)	(southern calamari, southern rock lobster) (Maori octopus, blacklip abalone) (pipi, greenlip abalone)
Data source:	VFA		

Indicator 24: Commercially and recreationally important fish

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	(snapper, King George whiting) (southern sand flathead)	(King George whiting) (snapper, southern sand flathead)	(snapper, King George whiting) (southern sand flathead)
Western Port	(snapper, King George whiting)	(King George whiting) (snapper)	(snapper) (King George whiting)
Corner Inlet-Nooramunga	(King George whiting, rock flathead)	(King George whiting) (rock flathead)	(King George whiting, rock flathead)
Gippsland Lakes	(black bream, dusky flathead)	(dusky flathead) (black bream)	(black bream, dusky flathead)
Statewide	(bluethroat, purple wrasse)	(bluethroat, purple wrasse)	(bluethroat, purple wrasse)
Data source:	VFA, academic researchers		

Indicator 25: Subtidal reef fish

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	(north) (south)	(north) (south)	
Other marine protected areas			
Data source:	Parks Victoria, Reef Life Surveys, ReefWatch		

Indicator 26: Diadromous fish

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	N	N	N
Western Port	N	N	N
Gippsland Lakes	N	N	N
Statewide	●	?	●
Data source:	Academic researchers, DELWP, Melbourne Water		

Indicator 27: Marine and coastal waterbirds

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	●	→	●
Western Port	●	↙	●
Corner Inlet-Nooramunga	●	→	●
Gippsland Lakes	●	?	●
Data source:	BirdLife Australia, academic researchers, DELWP, Melbourne Water		

Indicator 28: Migratory shorebirds

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	●	↙	●
Western Port	●	↙	●
Corner Inlet-Nooramunga	●	↙	●
Gippsland Lakes	●	?	●
Data source:	BirdLife Australia, academic researchers, DELWP, Melbourne Water		

Indicator 29: Piscivorous (fish-eating) birds

Region	2021 status	2021 trend	2021 data
Port Phillip Bay			
Western Port			
Corner Inlet-Nooramunga			
Data source:	BirdLife Australia, academic researchers, DELWP, Melbourne Water		

Indicator 30: Little penguins

Region	2021 status	2021 trend	2021 data
Port Phillip Bay			
Western Port			
Data source:	Earthcare St Kilda, Phillip Island Nature Parks		

Indicator 31: Marine mammals

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	(dolphins)	(dolphins)	(dolphins)
Western Port	(dolphins and seals)	(dolphins) (seals)	(seals) (dolphins)
Gippsland Lakes	(dolphins)	(dolphins)	(dolphins)
Data source:	Dolphin Research Institute, Marine Mammal Foundation, Phillip Island Nature Parks, academic researchers		

Theme 4 indicator summaries: Seafloor integrity and health

Indicator 32: Conservation of marine ecosystems in protected areas

Region	2021 status	2021 trend	2021 data
Other marine protected areas			
Data source:	Parks Victoria		

Indicator 33: Nitrogen cycle

Region		2021 trend	2021 data	2021 data
Port Phillip Bay				
Western Port				
Gippsland Lakes	Lake King			
	Lake Victoria			
	Lake Wellington			
Data source:	DELWP, Melbourne Water, academic researchers.			

Indicator 34: Seagrass

Region	2021 status	2021 trend	2021 data
Port Phillip Bay		?	
Western Port		↗	
Corner Inlet-Nooramunga		↗	
Gippsland Lakes		?	
Other marine protected areas			
Data source:	Academic researchers, Melbourne Water		

Indicator 35: Shellfish reefs

Region	2021 status	2021 trend	2021 data
Port Phillip Bay			
Western Port			
Corner Inlet-Nooramunga			
Gippsland Lakes			
Data source:	Academic researchers		

Indicator 36: Macroalgae on intertidal reefs

Region	2021 status	2021 trend	2021 data
Port Phillip Bay			
Other marine protected areas		?	
Data source:	Parks Victoria		

Indicator 37: Macroalgae-dominated subtidal reefs

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	(Port Phillip Heads Marine National Park) (Ricketts Point Marine Sanctuary) (Point Cooke and Jawbone marine sanctuaries)		
Other marine protected areas		?	
Data source:	Parks Victoria		

Theme 5 indicator summaries: Pests and invasive species

Indicator 38: Invasive marine species

Region	2021 status	2021 trend	2021 data
Port Phillip Bay		↙	
Western Port		↙	
Corner Inlet-Nooramunga		↙	
Gippsland Lakes		↙	
Other marine protected areas		?	
Data source:	Department of Jobs, Precincts and Regions		

Indicator 39: Coastal invasive plants

Region	2021 status	2021 trend	2021 data
Statewide		?	
Data source:	DELWP, Department of Jobs, Precincts and Regions, Parks Victoria		

Indicator 40: Coastal invasive animals

Region	2021 status	2021 trend	2021 data
Statewide		?	
Data source:	Statewide		

Theme 6 indicator summaries: Climate and climate change impacts

Indicator 41: Rainfall

Region	2021 status	2021 trend	2021 data
Port Phillip Bay			
Western Port			
Corner Inlet-Nooramunga			
Gippsland Lakes			
Data source:	Bureau of Meteorology (BoM), Commonwealth Scientific and Industrial Research Organisation (CSIRO), DELWP		

Indicator 42: Air temperature

Region	2021 status	2021 trend	2021 data
Port Phillip Bay			
Western Port			
Corner Inlet-Nooramunga			
Gippsland Lakes			
Statewide	N	N	N
Data source:	BoM, CSIRO, DELWP		

Indicator 43: Water temperature

Region	2021 status	2021 trend	2021 data
Statewide			
Data source:	BoM, CSIRO, DELWP		

Indicator 44: Ocean acidification

Region	2021 status	2021 trend	2021 data
Statewide			High (status) Low (trend)
Data source:	BoM, CSIRO, DELWP		

Indicator 45: Areas of coastal vulnerability

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	●	?	●
Western Port	●	?	●
Corner Inlet-Nooramunga	●	↙	●
Gippsland Lakes	●	↙	●
Statewide	N	N	N
Data source:	DELWP, academic researchers		

Indicator 46: Sea-level and coastal inundation

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	●	↙	●
Western Port	●	↙	●
Corner Inlet-Nooramunga	●	?	●
Gippsland Lakes	●	?	●
Statewide	●	↙	●
Data source:	BoM		

Indicator 47: Wave climate

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	●	?	●
Statewide	●	?	●
Data source:	Academic researchers		

Indicator 48: Coastal erosion

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	Yellow	?	Yellow
Western Port	Yellow	↙	Yellow
Corner Inlet-Nooramunga	Yellow	↙	Yellow
Gippsland Lakes	Red	↙	Yellow
Statewide	Yellow	?	Yellow
Data source:	DELWP		

Indicator 49: Seawater intrusion into coastal aquifers

Region	2021 status	2021 trend	2021 data
Statewide	Grey	?	Grey
Data source:	Academic researchers		

Indicator 50: Frequency and impact of fire on marine and coastal ecosystems

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	Yellow	?	Yellow
Data source:	Academic researchers		

Indicator 51: Climate change impact on marine and coastal infrastructure

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	Grey	?	Grey
Western Port	Yellow	↙	Yellow
Gippsland Lakes	Yellow	↙	Red
Statewide	Red	↙	Red
Data source:	DELWP, AURIN (Australian Urban Research Infrastructure Network)		

Theme 7 indicator summaries: Managing coastal hazard risks

Indicator 52: Considering climate change risks in land-use planning

Region	2021 status	2021 trend	2021 data
Statewide		?	
Data source:	DELWP		

Indicator 53: Climate change adaptation plans

Region	2021 status	2021 trend	2021 data
Statewide		↗	
Data source:	Catchment management authorities (CMAs)		

Indicator 54: Nature-based adaptation

Region	2021 status	2021 trend	2021 data
Statewide		?	
Data source:	DELWP		

Indicator 55: Emergency planning and preparedness

Region	2021 status	2021 trend	2021 data
Statewide		↗	
Data source:	Emergency Management Victoria		

Theme 8 indicator summaries: Communities

Indicator 56: Population (resident)

Region	2021 status	2021 trend	2021 data
Statewide	N	N	
Data source:	Australian Bureau of Statistics (ABS), DELWP		

Indicator 57: Population (visitors)

Region	2021 status	2021 trend	2021 data
Statewide	N	N	
Data source:	DELWP Planning, Business Victoria 2020, Phillip Island Nature Parks		

Indicator 58: Significant landscapes

Region	2021 status	2021 trend	2021 data
Statewide		→	
Data source:	DELWP Planning		

Indicator 59: Coastal settlements

Region	2021 status	2021 trend	2021 data
Statewide	N	N	
Data source:	ABS, Agriculture Victoria, DELWP Planning		

Indicator 60: Cultural heritage

Region	2021 status	2021 trend	2021 data
Statewide		→	
Data source:	First Peoples – State Relations Group, Heritage Victoria		

Indicator 61: Use of marine and coastal areas

Region	2021 status	2021 trend	2021 data
Statewide		?	
Data source:	DELWP (Ipsos Social Research Institute), Parks Victoria		

Indicator 62: Tourism

Region	2021 status	2021 trend	2021 data
Statewide			
Data source:	Business Victoria 2020, Parks Victoria, Tourism Victoria		

Indicator 63: Recreational boating and fishing contribution to the Victorian economy

Region	2021 status	2021 trend	2021 data
Statewide			
Data source:	Better Boating Victoria, VFA		

Indicator 64: Recreational boating

Region	2021 status	2021 trend	2021 data
Statewide			
Data source:	VFA, Better Boating Victoria, academic researchers		

Indicator 65: Recreational fishing

Region	2021 status	2021 trend	2021 data
Statewide		?	
Data source:	VFA, academic researchers		

Indicator 66: Shipping and ports

Region	2021 status	2021 trend	2021 data
Statewide			
Data source:	Bureau of Infrastructure and Transport Research Economics; Department of Infrastructure, Transport, Regional Development and Communications; Port of Melbourne, Gippsland Ports, Department of Agriculture, Water and the Environment		

Indicator 67: Commercial fishing

Region	2021 status	2021 trend	2021 data
Statewide			
Data source:	ABS, Fisheries Research and Development Corporation, VFA, academic researchers		

Indicator 68: Aquaculture

Region	2021 status	2021 trend	2021 data
Statewide			
Data source:	Fisheries Research and Development Corporation, Agriculture Victoria		

Indicator 69: Resources and energy generation

Region	2021 status	2021 trend	2021 data
Statewide			
Data source:	Department of the Environment and Energy, DELWP, Department of Jobs, Precincts and Regions, academic researchers		

Indicator 70: Agriculture

Region	2021 status	2021 trend	2021 data
Statewide			
Data source:	Agriculture Victoria, DELWP Planning, Melbourne Water		

Indicator 71: Built and public benefit infrastructure

Region	2021 status	2021 trend	2021 data
Statewide			
Data source:	DELWP Coastal Programs, Victorian Auditor-General's Office		

Indicator 72: Recreational boating infrastructure

Region	2021 status	2021 trend	2021 data
Statewide			
Data source:	Better Boating Victoria, DELWP, Victorian Environmental Assessment Council (VEAC)		

Indicator 73: Illegal activities

Region	2021 status	2021 trend	2021 data
Statewide			
Data source:	EPA, Maritime Safety Victoria, VFA, DELWP, Office of the Conservation Regulator		

Theme 9 indicator summaries: Stewardship and collaborative management

Indicator 74: Stewardship

Region	2021 status	2021 trend	2021 data
Statewide		?	

Data source:	DELWP

Indicator 75: Community connection to the coast

Region	2021 status	2021 trend	2021 data
Statewide		→	

Data source:	Ipsos Marine and Coastal Community Attitudes and Behaviour Report, VFA creel surveys

Indicator 76: Volunteering

Region	2021 status	2021 trend	2021 data
Statewide		→	

Data source:	ABS, DELWP, Parks Victoria

Indicator 77: Citizen science

Region	2021 status	2021 trend	2021 data
Statewide		↗	

Data source:	DELWP, Parks Victoria, VFA, Victorian National Parks Association (VNPA), Tangaroa Blue Foundation, EstuaryWatch, Redmap, Atlas of Living Australia

Indicator 78: Planning and implementation

Region	2021 status	2021 trend	2021 data
Statewide	N	N	N

Data source:	VEAC, Geoscience Australia, DELWP

Indicator 79: Committees and councils

Region	2021 status	2021 trend	2021 data
Statewide	N	N	N

Data source:	VEAC, Geoscience Australia, DELWP

Indicator 80: Institutional knowledge and capacity

Region	2021 status	2021 trend	2021 data
Statewide		?	
Data source:	N/A		

Indicator 81: Engagement and inclusiveness

Region	2021 status	2021 trend	2021 data
Statewide	N	N	N
Data source:	Engage Victoria		

Indicator 82: Delivery and accountability

Region	2021 status	2021 trend	2021 data
Statewide		↗	
Data source:	Parks Victoria, Victorian Auditor-General's Office		

Summary of status assessments

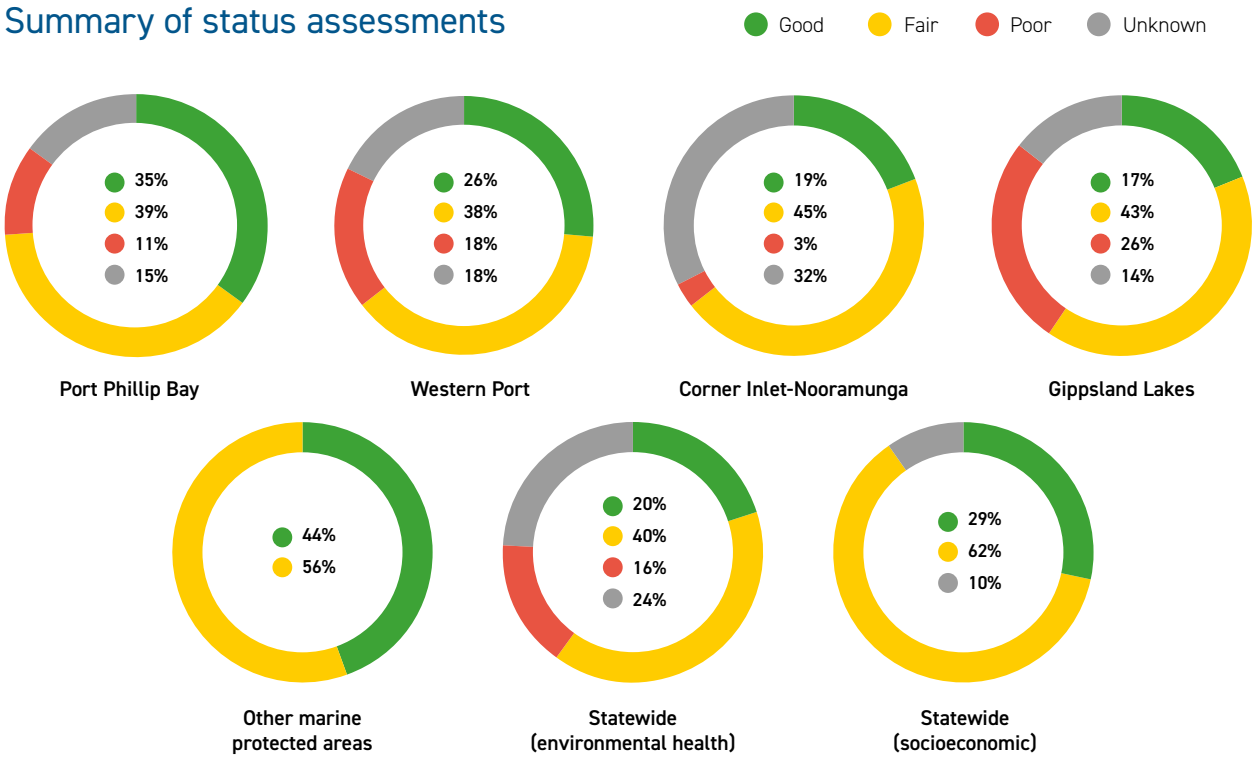


Figure 3: SMCE 2021 summary of regional indicator status assessments.

Statewide (environmental health) = statewide indicator assessments for Themes 1-7: Environmental health.

Statewide (socioeconomic) = statewide indicator assessments for Theme 8: Communities and Theme 9: Stewardship and collaborative management.

Summary of trend assessments

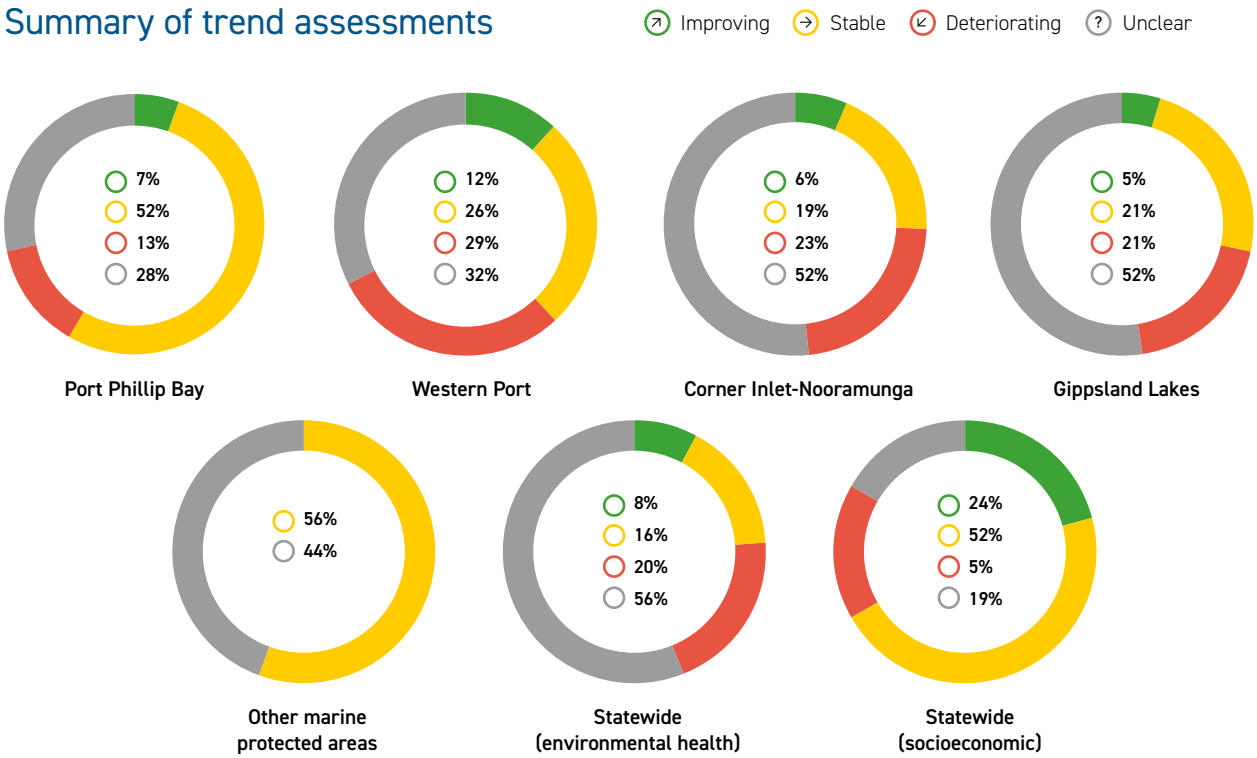


Figure 4: SMCE 2021 summary of regional indicator trend assessments.

Summary of data confidence assessments

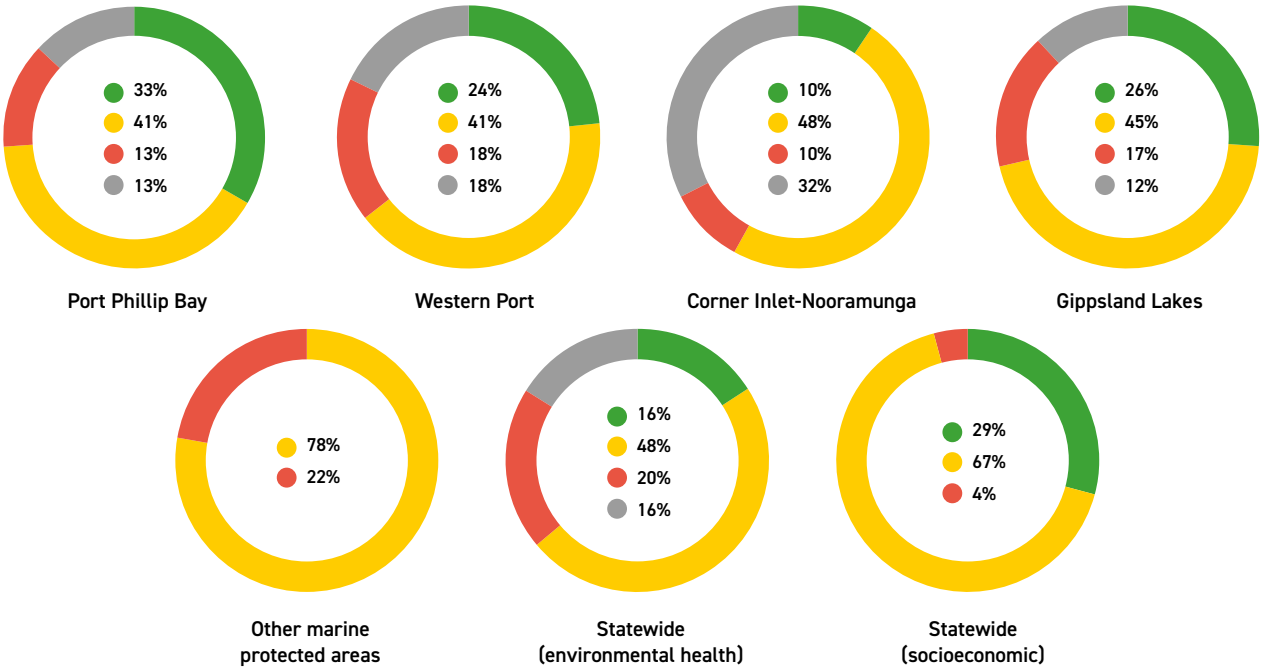


Figure 5: SMCE 2021 summary of regional indicator data confidence assessments.

Statewide (environmental health) = statewide indicator assessments for Themes 1-7: Environmental health.

Statewide (socioeconomic) = statewide indicator assessments for Theme 8: Communities and Theme 9: Stewardship and collaborative management.

Crested terns (*Thalasseus bergii*) at Mordialloc Pier, Port Phillip Bay
© Parks Victoria

Key findings

Environmental health indicators (Themes 1–7)

Theme 1: Water quality and catchment inputs

Poor water quality in marine environments harms marine ecosystems and discourages their use for human recreation. Water quality is monitored regularly in Port Phillip Bay, Western Port and the Gippsland Lakes.

- Water quality in Port Phillip Bay has been rated as fair or good each year since monitoring and reporting began in 2002.
- Water quality in Western Port has been good every year since monitoring and reporting began in 2000 except in 2017 (when it was rated as fair).
- Water quality in the eastern Gippsland Lakes (Lake King and Lake Victoria) has been good in six of the past seven years, while in Lake Wellington it has been poor for the past three years, and poor or very poor in seven of the past 10 years.

EPA provides daily forecasts on the suitability of more than 30 Port Phillip Bay beaches for swimming and other recreational uses during the warmer months, when there is greater recreational use of Port Phillip Bay. EPA's Beach Report program detects infrequent breaches of the short-term recreational water quality standards. All beaches have met long-term standards for secondary contact (for example, boating and canoeing) and most have met long-term standards for primary contact (for example, swimming) during dry weather. However, most beaches do not meet standards for all-weather primary contact. Stormwater pollution is often the main reason for beaches not meeting standards.

The consequences of poor water quality in Western Port are apparent in seagrass extent, which is strongly correlated with light availability. Thus, turbidity caused by sediment loads and variation in water depth plays a major role in seagrass decline or growth. Five of the nine estuaries flowing into Western Port and assessed for water quality in the 2021 Index of Estuary Condition received a rating of very poor, with elevated turbidity noted as a serious water quality problem for the estuaries that flow into Western Port.

Water quality in the Gippsland Lakes is generally characterised by divergent ratings. The eastern lakes (Lake King and Lake Victoria) are often rated as good, whereas Lake Wellington to the west has a higher frequency of poor water quality. Lake Wellington is a sink for sediments, nutrients and contaminants. Wind and waves in its shallow waters can re-suspend sediments and nutrients, with algal blooms often developing because of the high availability of nutrients. Catchment works have attempted to reduce the sediment and nutrient loads transported into Lake Wellington. These works have included riparian protection and revegetation, wetland restoration (sediment sinks), bed and bank stabilisation, and on-farm nutrient use and effluent loss reduction.

In the marine environment of the Corner Inlet and Nooramunga biounits, water quality is not currently routinely measured.

The effects of stormwater vary across Port Phillip Bay's catchments. In the Werribee catchment, stormwater has only minor effects on stream health, while in the Dandenong catchment stream health is being severely diminished. Importantly, urban development presents further risks to waterways, as catchment imperviousness expands.[3]

Stormwater condition for Western Port was rated as high (on a scale from very high to very low) in Melbourne Water's Healthy Waterways Strategy 2018.[4] This rating reflects an assessment that stormwater is having only minor effects on stream health. Much of Western Port's catchment is rural or forested, but urban areas of the growth corridor rate lower. For example, the Mornington Peninsula North-Eastern and Western Creeks sub-catchments both had low stormwater condition.[5]

As reported by Parks Victoria in 2005, about 30 stormwater and agricultural drains discharge into Corner Inlet,[6] but the consequences of urban stormwater drains are largely unknown because of the lack of information on water quality and quantity. Similarly, there are no available assessments of the contribution of stormwater to pollutant loads entering the Gippsland Lakes.

3. Melbourne Water 2018, 'Healthy waterways strategy 2018' https://www.melbournewater.com.au/media/6976/download Accessed 22 February 2021.
4. Ibid.
5. Melbourne Water 2018, 'Co-designed catchment program for the Werribee catchment region: working together for healthy waterways' https://healthywaterways.com.au/sites/default/files/2021-03/HWS-werribee-co-designed-catchment-program.pdf
6. Parks Victoria 2005, 'Corner Inlet marine national park management plan'., Melbourne, Victoria.

The Port Phillip Bay Environmental Management Plan 2017–2027[7] and the Corner Inlet and Nooramunga Water Quality Improvement Plan (WQIP) 2013[8] are examples of authorities developing targets to monitor water quality. However, no measurements of actual nutrient and sediment loads against the targets have been published.

The Annual Report and Delivery Plan Update 2019–20 (which contributes to regular reporting on the Port Phillip Bay Environmental Management Plan 2017–2027) did not include estimates of nutrient loads in relation to the specific strategy of 'ensuring nutrient and sediment loads do not exceed current levels and pollutant loads are reduced where practicable'.[9]

Similarly, although we are nearly halfway to the 2033 deadline for reaching the targets in the Corner Inlet [and Nooramunga] WQIP 2013, it is unclear whether any progress has been made towards meeting those targets. Only a limited number of the annual activities recommended in the WQIP 2013 have been reported, and this has hindered the tracking of progress.[10]

The Water Quality theme highlights the importance of the interconnected nature of our coastal communities and marine environment. The Port Phillip Bay Environmental Management Plan provides a strategic approach to managing water quality. Consideration should be given to the suitability of similar plans elsewhere in Victoria, to establish a catchment-to-reefs approach to water quality management.

Comparison with State of the Bays 2016 Report and State of the Environment 2018 Report

Generally, water quality in Port Phillip Bay and Western Port has remained consistently good since the State of the Bays (SotB) 2016 Report and SoE 2018 Report. Apart from algae and water clarity in Western Port, water quality in Port Phillip Bay and Western Port was assessed as good or fair in SotB 2016. These water quality parameters have been assessed as good in this report.

In SoE 2018, a single indicator encompassed water quality in both marine environments and catchments. The rating was poor for Western Port and fair for Port Phillip Bay. The present (2021) report separates assessment of water quality in marine environments from water quality in the catchments, enabling the generally good surface water quality in Port Phillip Bay and Western Port to be more clearly understood and reported, while drawing attention to the problem of catchment inputs.

The catchment inputs information provided in this report is disaggregated into discrete indicators (regulated point source discharges to marine waters, stormwater, total nutrient loads, and total sediment loads). Reporting on each of these separately represents a progression in our marine and coastal reporting, enabling water quality stressors and the scale of their effects to be individually understood. These focused catchment inputs indicator assessments can be used to prioritise resource allocation for research and management interventions. Regulated point source discharges to marine waters are still a knowledge gap in 2021, as in previous reports.

7. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Port Phillip Bay Environmental Management Plan 2017–2027 supporting document', East Melbourne, Victoria, https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0034/88756/PPB-EMP-2017-Supporting-Doc.pdf Accessed 16 November 2021.
8. West Gippsland Catchment Management Authority (WGCMA) 2013, 'Corner Inlet water quality improvement plan 2013', Traralgon, Victoria, https://www.wgcma.vic.gov.au/wp-content/uploads/2019/08/WGCMA-Corner-Inlet-Water-Quality-Improvement-Plan-2013.pdf Accessed 16 November 2021.
9. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Port Phillip Bay Environmental Management Plan 2017–2027. 2019–2020 annual report and 2020 delivery plan update', East Melbourne, Victoria, https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0023/511844/PPB-EMP-2019-2020-Annual-Report-and-2020-Delivery-Plan-Update-1.pdf Accessed 16 November 2021.
10. West Gippsland Catchment Management Authority (WGCMA) 2013, 'Corner Inlet water quality improvement plan 2013', Traralgon, Victoria, https://www.wgcma.vic.gov.au/wp-content/uploads/2019/08/WGCMA-Corner-Inlet-Water-Quality-Improvement-Plan-2013.pdf Accessed 16 November 2021.

Theme 2: Litter and pollution

The number of litter items and microplastics flowing into Port Phillip Bay from the Yarra and Maribyrnong Rivers each year is estimated at more than 2.5 billion. About 85% are microplastics.[11] A deteriorating trend is confidently provided, based on the observed amount of litter increasing in both the Maribyrnong and the Yarra. Industrial precincts were responsible for a large majority of microplastics, with the Dandenong local government area the location with the most microplastics among the six local government areas studied.

No specific analyses of litter and plastics have occurred in Western Port, Corner Inlet and Nooramunga, or the Gippsland Lakes.

Like other places with a history of significant settlement and industrial activity, Victoria has a legacy of waste and pollution. Contaminated sites in coastal areas range from landfills and industrial facilities, to sites requiring active management to reduce the risk to human health and the environment. Various datasets published on Victoria Unearthed provide good information on the numbers of contaminated and potentially contaminated land locations within 5km of the coastline.[12]

Good air quality is essential for human health. The links between air quality, population exposure and health are an increasing focus for research and policy development. The coastal air quality indicator in this report is believed to be the first instance of focused coastal air quality reporting in Australia.

Coastal air quality surrounding the Port Phillip Bay is generally good. However, focused research on air quality near shipping terminals using lower-quality air monitoring sensors provides evidence of poor air quality, due to high concentrations of fine particle pollution near Station Pier (with a moderate confidence). This requires further investigation and research.

Large bushfires have occurred in coastal Victoria in recent years. Bushfire smoke has been measured at levels significantly higher than health-based standards. Quality of the air surrounding the Gippsland Lakes was closely monitored during the 2019–20 bushfire season, during which time the daily air quality standard for $PM_{2.5}$ was frequently breached.

Comparison with State of the Bays 2016 Report and State of the Environment 2018 Report

The present report significantly advances litter and pollution reporting by including dedicated pollution indicators with a coastal focus. It also contains a synthesis of the latest microplastics research in Victoria.

The SotB 2016 Report did not contain any litter or pollution indicator assessments, but a litter narrative was provided in the 'Threats to the bays' chapter. The SoE 2018 Report included indicators for light pollution, contaminated land and air quality, but these lacked the coastal focus of the present report. Litter and marine debris were included as a pressure in the 'Marine and coastal environments' chapter of the SoE 2018 Report and received a one-page commentary.

11. Charko F, Blake N, Seymore A, Johnstone C et al. 2020, 'Clean bay blueprint: microplastics in Melbourne', Port Phillip EcoCentre, Melbourne, https://ecocentre.com/sites/default/files/images/Documents/Programs/Baykeeper/EcoCentre_CleanBayBlueprint_FinalEdits%20(2).pdf
12. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria unearthed', East Melbourne, Victoria.

Theme 3: Biodiversity

The Biodiversity theme contains comprehensive indicator assessments on coastal vegetation, invertebrates on intertidal and subtidal reefs, fish, birds and marine mammals.

A few important stories emerged from the analysis of the information for commercially and recreationally important fish and invertebrates:

- Black bream (*Acanthopagrus butcheri*) and dusky flathead (*Platycephalus fuscus*) have both been rated as having a poor status in the Gippsland Lakes.
- The two fisheries management units with the largest catches of blacklip abalone (*Haliotis rubra*) in Victoria both have depleting stocks. Thus, the status of blacklip abalone has been assessed as poor, with a deteriorating trend.
- The recreational fishery for adult snapper (*Chrysophrys auratus*) in Port Phillip Bay is considered sustainable at its current level, but there is a declining trend in the recreational fishery for adult snapper in Western Port. However, recent strong recruitment[13] of snapper in Port Phillip Bay is expected to reverse any declining biomass trends and lead to a rebuilding of adult biomass and improved fishery performance in Western Port over the next five to 10 years.
- King George whiting (*Sillaginodes punctatus*) is expected to remain sustainable in Port Phillip Bay, Western Port and Corner Inlet.

The conservation status of coastal ecosystems in protected areas serves as a broad indicator for a range of coastal ecosystems and conservation efforts. The protection levels for coastal ecological vegetation classes vary. Parks Victoria manages around 70% of the Victorian coast, as national and state parks or coastal reserves. However, analysis reveals limited data on several coastal ecological vegetation classes in protected areas.

CES's collaboration with our co-creation partners to develop a Method for localising the SDGs (Part 2, Phase 3) has revealed a need for complementary top-down and bottom-up approaches to improve biodiversity at the local scale.

Greater collaboration is required among Victorian Government agencies to manage current threats to coastal fringe ecosystems at risk from climate change (salt marsh, mangroves, seagrasses). We also need collaborative strategies for working with local management authorities, non-government organisations and volunteers. Actions to conserve coastal ecosystems could include assessing threats to biodiversity and Ramsar areas, understanding conservation and protection needs, removing hard barriers to inland migration of marine species, and delivering programs coordinated between several agencies and community groups.

The status and trend assessments for the bird indicators are generally consistent with previous CES reports. The main declines noted in the marine and coastal waterbirds and migratory shorebirds indicators were among trans-equatorial migratory shorebirds. These declines are most likely to be due to habitat loss on their migratory flyways in east Asia, particularly over the Yellow Sea.

13. Recruitment is the process of very young, small fish surviving to become slightly older, larger fish. It is often measured as the number of new young fish that enter a population in a given year.

Little penguins (*Eudyptula minor*) continue to thrive on Phillip Island and around the St Kilda breakwater. Their numbers on Phillip Island are estimated at 32,000, and at St Kilda 1,400.[14]

There is a stable population of approximately 100 dolphins in Port Phillip Bay. Western Port has a small but stable resident population of 20 dolphins. There is also a population of between 60 and 100 dolphins living in the Gippsland Lakes, but there has been significant mortality recently, linked with severe bushfire effects in the region in 2019–20 and associated with skin infections observed on several dolphins.

The health of Australian fur seal (*Arctocephalus pusillus doriferus*) colonies, in terms of numbers, pup production and disease (including toxicants in the environment), can indicate trends in the general health of the marine environment. Fur seal colonies at Cape Bridgewater, Chinaman's Hat, Phillip Island and Wilsons Promontory have also become major tourist assets. There are an estimated 20,000 to 30,000 Australian fur seals in the Seal Rocks colony at the western entrance to Western Port.

Parks Victoria's study of macroinvertebrate species in Point Addis Marine National Park found consistent declines over the last 15 years of blacklip abalone and turban shell (*Lunella undulata*). The study also compares southern rock lobster populations (*Jasus edwardsii*) inside and outside the Point Addis Marine National Park protected waters. More than 3.5 times the abundance and 4.5 times the number of legal rock lobsters were captured inside the park than outside. Abundance and biomass of southern rock lobsters outside the park increased closer to the park boundary, suggesting that the Point Addis Marine National Park may be increasing the supply of lobsters to surrounding waters that are open to fishing.[15]

Comparison with State of the Bays 2016 Report and State of the Environment 2018 Report

Several indicators for this theme have an identical or similar scope to indicators in the 'Marine and coastal environment' chapter of the SoE 2018 Report, which means that clear comparisons can be made. In SoE 2018, reasonably good data was available for invertebrates in Port Phillip Bay and marine protected areas, and for birds. The information and assessments in the indicator assessments for these indicators are generally consistent with previous reporting by the CES.

This report contains more detail and new data on the fish indicators, to provide a significant update for this theme since previous CES reports. The fish assessments in the SotB 2016 Report were based on good data, while the data quality was rated as poor and assessments could not be made for the Impacts of fisheries production indicator in the SoE 2018 Report. For southern sand flathead in Port Phillip Bay, the indicator has been assessed as poor in this report, as it was in the SotB 2016 Report, but the more recent data show that the stock has now stabilised at a lower biomass under a lower recruitment regime, and recruitment has been sufficient to balance natural and fishing mortality at this lower level. This report also updates on the recreational fishery for adult snapper in Port Phillip Bay, with record snapper spawning in the region in 2018 likely to result in a snapper population boom in Port Phillip Bay in 2022 and 2023.

The inclusion of a marine mammals indicator in this report, which was not part of the SotB 2016 or SoE 2018 Reports, highlights the threat to the critically endangered dolphin population in the Gippsland Lakes from skin irritations.

14. Commissioner for Environmental Sustainability Victoria (CES) 2018, 'Victorian state of the environment 2018 report', Victoria State Government, Melbourne https://www.ces.vic.gov.au/reports/state-environment-2018 Accessed 23 September 2021.
15. Ierodiaconou D, Wines S, Carnell P, Tinkler P et al. 2020, 'An enhanced Signs of Healthy Parks monitoring program for Victoria's marine national parks and marine sanctuaries: Point Addis Marine National Park', Parks Victoria technical series no. 114, Melbourne, Victoria.

Theme 4: Seafloor integrity and health

The indicators in this theme contain assessments on the conservation of marine ecosystems in protected areas, and–more broadly across the assessed regions–seagrass, nitrogen cycling, macroalgae and shellfish reefs.

Seagrass meadows are critical habitat for many marine species, including fish targeted by commercial and recreational fishers. They also protect shorelines and store significant amounts of carbon. Changes in their condition can have environmental, social and economic consequences. Considerable losses in seagrass have been observed in Port Phillip Bay (in conjunction with the millennium drought from 1997 to 2009), in Western Port (in the mid-1970s and early 1980s) and in Corner Inlet (a slow decline from 1965 to 2013).

Macroalgae on intertidal and subtidal reefs has been monitored and reported on by Parks Victoria, with technical reports periodically published and generally focusing on individual marine protected areas. The condition and extent of macroalgae on subtidal reefs in Port Phillip Bay has been assessed as poor for Point Cooke and Jawbone marine sanctuaries, fair for Ricketts Point Marine Sanctuary, and good for Port Phillip Heads Marine National Park.

In 2020, a Parks Victoria study in Point Addis Marine National Park revealed an alarming decline in the previously dominant species, golden kelp (*Ecklonia radiata*), since 2012. While some other canopy-forming brown algae have increased since then (as shown in the 2018 survey), canopy-forming algae has now fallen below the lower control limit.[16] On the east coast of Port Phillip Bay (Cape Howe Marine National Park and Beware Reef Marine National Park), macroalgal beds have been under threat, and Parks Victoria advises that there has been a dramatic increase in urchin barrens.

Substantial losses of giant kelp (*Macrocystis pyrifera*) have been observed this century in marine areas off the coast of southeastern Australia, not restricted to Victoria's marine protected areas. Broad-scale temporal patterns in giant kelp canopy cover are correlated with El Niño–Southern Oscillation events, while regional patterns are related to rising sea-surface temperatures, raising concerns for the future of this species as a major habitat-forming kelp in Australia.[17]

Shellfish reef ecosystems support unique assemblages of associated fauna and valuable ecosystem services, including fish production, coastal protection, erosion mitigation and nutrient cycling. Historically, there were large reefs of native flat oyster (*Ostrea angasi*) in Port Phillip Bay, Western Port and Corner Inlet, and large reefs of blue mussel (*Mytilus edulis galloprovincialis*) in Port Phillip Bay. The extent of these shellfish reefs is now minimal, and the status of the shellfish reefs indicator has been rated as poor for these regions. Large mussel reefs can still be found in the entrance region of the Gippsland Lakes, which is why the status is fair in this region, despite the extent of shellfish reefs being noted to decline during the 20th century.

Comparison with State of the Bays 2016 Report and State of the Environment 2018 Report

Since the SotB 2016 Report and SoE 2018 Report, significant new research has been published and incorporated for this theme. Most notably, Parks Victoria technical reports, specifically for Point Addis Marine National Park, contain a comprehensive update to the macroalgae indicators. Additionally, there is a new indicator inclusion: shellfish reefs.

The Conservation of Marine Ecosystems in Protected Areas indicator includes fresh Parks Victoria data showing the condition of natural values as good or very good in 93% of marine parks. This indicator status assessment remains at fair, as it was in the SoE 2018 Report.

16. Ibid.
17. Butler CL, Lucieer VL, Wotherspoon SJ, Johnson CR 2020, 'Multi-decadal decline in cover of giant kelp *Macrocystis pyrifera* at the southern limit of its Australian range', *Marine Ecology Progress Series*, 653, pp. 1–18 https://doi.org/10.3354/meps13510

Theme 5: Pests and invasive species

The establishment and spread of invasive species are widely recognised as one of the greatest threats to global biodiversity. Monitoring is essential to knowing whether their range is expanding, with new incursions requiring rapid responses.

There are now more than 160 invasive marine species in Port Phillip Bay. The negative effects of some of these invasive species are significant, notably the northern Pacific seastar (*Asterias amurensis*), which causes changes in fish populations in Port Phillip Bay. New invasive species continue to arrive in Port Phillip Bay, most recently the Asian shore crab (*Hemigrapsus sanguineus*), which was first detected at Mount Martha in late 2020.

Western Port has several known invasive marine species, although the size and number of infestations is significantly less than in Port Phillip Bay.[18]

Corner Inlet has remained relatively free of invasive marine species. Japanese kelp (*Undaria pinnatifida*) has been detected at Port Welshpool, and the northern Pacific seastar has previously been detected at nearby Tidal River. The northern Pacific seastar was first detected in the Gippsland Lakes in 2015 and was observed again in 2019.[19] Both detections resulted in surveillance and removal efforts. The species is extremely difficult to eradicate and can rapidly establish large populations in new areas. To illustrate the risk posed to the Gippsland Lakes, the population of northern Pacific seastar in Port Phillip Bay had reached 165 million just five years after the species was first detected.[20]

The detection, monitoring and management of invasive plants are a complex and important process, essential for minimising harm. The State of the Parks 2018 reported on the effects of weeds and pest animals along the Victorian coastline. Those findings, along with analysis of datasets from DELWP and the Department of Jobs, Precincts and Regions, are presented in Part 3.

The coordination of marine pest management across agencies remains difficult, especially once a pest has become established in Victoria and is thus no longer a biosecurity threat managed by the Department of Jobs, Precincts and Regions. An end-to-end pest management plan is required, starting with prevention and preparedness and covering every stage through to on-ground asset-based management.

Comparison with State of the Bays 2016 Report and State of the Environment 2018 Report

New invasive species continue to arrive in Victoria's marine environments and spread to new areas. Thus, the trend of invasive marine species is rated as deteriorating for each geographic region in this report. The following species have recently been detected in new areas:

- The Asian shore crab (*Hemigrapsus sanguineus*) was first detected at Mount Martha in Port Phillip Bay in late 2020.
- *Undaria pinnatifida*, a seaweed also known as wakame, has been observed in Corner Inlet since 2018.
- The northern Pacific seastar was first recorded in the Gippsland Lakes in 2015 and has since been found in several locations in the Lakes.

The SotB 2016 Report did not contain any pests or invasive species indicator assessments, although a marine pests narrative was provided in the 'Threats to the bays' and 'Habitats and their dependent species' chapters. For the SoE 2018 Report, the status of the invasive marine species indicator was rated as poor for Port Phillip Bay, as it is in the present report.

18. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Western Port Ramsar site management plan', East Melbourne, Victoria. https://www.water.vic.gov.au/__data/assets/pdf_file/0021/66270/Western-Port-Ramsar-Site-Management-Plan_revised.pdf
19. Australian Government Inspector-General of Biosecurity 2019, 'Pest and disease interceptions and incursions in Australia', p. 53, Mascot, NSW https://www.igb.gov.au/sites/default/files/documents/qid52819_igb_interceptions_and_incursions_report_-_final.docx Accessed 8 October 2021.
20. Parry G, Heislers S and Werner G 2004, 'Changes in distribution and abundance of *Asterias amurensis* in Port Phillip Bay 1999–2003', Department of Primary Industries technical report, Victoria, DOI:10.13140/2.1.4058.4484

Theme 6: Climate and climate change impacts

This theme assesses changes to Victoria's climate, and the consequences of those changes. None of the Climate and Climate Change Impacts indicators in this report were assessed as having a good status. Indeed, deteriorating trends were observed for 21 of the 22 regional indicators where the trend was assessed.

Tidal gauge measurements show that sea levels at Williamstown have been rising by approximately 1.8 cm per decade since 1981, and at Stony Point by 3.5 cm per decade since 1981. Future rises are projected with high confidence.[21] Research published in 2020 found significant change in shoreline position along 13% of the Victorian coast between 1986 and 2017.[22] The researchers estimated that erosion hotspots extend along 76.6 km of the coastline, equivalent to approximately 6.2% of the Victorian coast. Progradation hotspots (sediment deposits shifting the shoreline seaward) were estimated to extend along 72.7 km of coast, equivalent to approximately 5.9% of Victoria's coast. A 2017 assessment rated more than 100 km of the Gippsland coastline as highly vulnerable to coastal erosion.[23] This means that more than a quarter of the entire Victorian coastline most at risk to erosion is located along the Gippsland Lakes.

By the 2050s, average temperatures in Victoria are projected to be 1.4 to 2.4°C warmer under a high-emissions scenario (RCP 8.5) or 0.9 to 1.8°C warmer under a medium-emissions scenario (RCP 4.5), compared to 1986–2005. By the 2090s, average temperatures in Victoria are projected to be 2.8 to 4.3°C warmer under a high-emissions scenario (RCP 8.5) or 1.3 to 2.2°C warmer under a medium-emissions scenario (RCP 4.5), compared to 1986–2005 (high confidence). It is likely that Victoria's coastal regions have already warmed by more than 1°C, with areas of the Port Phillip Bay coastline now regularly experiencing years with temperatures approximately 1.5°C warmer than an indicative pre-industrial era baseline.

The increasing frequency of marine heatwaves around Australia in recent years has irreversibly changed marine ecosystem health, habitats and species. Effects include depleted kelp forests and seagrasses, a poleward shift in some marine species, and increased occurrence of disease. A 2019 international study found that the ocean off southeast Australia is particularly vulnerable to marine heatwaves.[24]

A fluctuating pressure is being exerted on the water resources and agricultural sectors by wetter years interspersing a predominantly drying climate. Rainfall reduction during the cool seasons is particularly important, given the consequent reductions in streamflows and the reduced reliability of water storage filling seasons. A reduction in annual rainfall of 7–12% has been observed along the Port Phillip Bay coastline during the 21st century, and a 13–20% reduction in cool-season rainfall. Notably, the biggest percentage rainfall reductions have occurred on the western side of Port Phillip Bay, which is also projected to have faster population growth in coming decades,[25] placing increasing pressure on water resources.

Comparison with State of the Bays 2016 Report and State of the Environment 2018 Report

The SotB 2016 Report did not contain any climate change indicator assessments, although a climate change narrative was provided in the 'Threats to the bays' chapter:

> *Climate change impacts are likely to include peak rainfall events that transport high loads of nutrients and pollutants to the bays in short time periods, and sea level rise that encroaches on important habitat. Water chemistry, water temperature, wind and storm patterns also contribute to a complex mix of potential impacts.*

21. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019', East Melbourne, Victoria.
22. Konlechner TM, Kennedy DM, O'Grady JJ, Leach C et al. 2020, 'Mapping spatial variability in shoreline change hotspots from satellite data: a case study in southeast Australia', *Estuarine, Coastal and Shelf Science*, 246, 107018 https://dx.doi.org/10.1016/j.ecss.2020.107018.
23. Spatial Vision 2017, 'Victorian coastal hazard assessment 2017 technical report 1'. Melbourne, Victoria. https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0021/122709/VCHA2017_R1_Victorian_Coastal_Hazard_Assessment_2017_Final_R1.compressed.pdf
24. Smale DA, Wernberg T, Oliver ECJ, Thomsen M, et al. 2019, 'Marine heatwaves threaten global biodiversity and the provision of ecosystem services', *Nature Climate Change*, 9, pp. 306–312.
25. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria in future 2019: population projections 2016 to 2056', East Melbourne, Victoria, https://www.planning.vic.gov.au/__data/assets/pdf_file/0032/332996/Victoria_in_Future_2019.pdf.

The SoE 2018 Report assessed air temperature, rainfall, sea level, and sea-surface temperature, all rated as fair to poor, and the trends all rated as deteriorating.

Data available for the three most recent years generally show further deteriorations in the climatic indicators. Importantly, change in many climatic variables may be detectable only over longer periods than the five-yearly state of environment reporting cycle. Furthermore, even the smallest changes in climatic variables can have significant environmental consequences.

To complement the indicators previously reported, this report includes new climate change indicators on ocean acidification, wave climate, coastal erosion, seawater intrusion into coastal aquifers, and impact on built infrastructure.

Theme 7: Managing coastal hazard risks

DELWP has analysed the extent and quality of Victorian councils' consideration of climate change in land-use planning. A strong pattern emerged when comparing inland and coastal councils, with coastal councils three times more likely than inland councils to have an intermediate, high or advanced consideration of climate change in land-use planning. Nevertheless, 30% of coastal councils in 2018 had no or only basic integration of climate change in land-use planning.

Catchment management authorities are playing an important role in helping Victoria adapt to climate change. All 10 authorities in Victoria are implementing climate change adaptation plans or strategies. These are based on CSIRO's latest climate change projections and have been developed in collaboration with Australia's principal research organisations.

Protecting and restoring coastal blue carbon ecosystems such as mangroves, tidal marshes and seagrasses offers opportunities for carbon sequestration and avoidance of greenhouse gas emissions. Better management of blue carbon ecosystems can also improve fisheries and increase a coastline's resilience to rising sea levels and storm surges. Research published in 2019 found that allowing coastal wetlands in Victoria to naturally retreat with sea-level rise could sequester 1.6 million tonnes of carbon by 2050 with a value of $65 million.[26]

Comparison with State of the Bays 2016 Report and State of the Environment 2018 Report

The only indicator for this theme that was previously reported on by the CES is 'Considering climate change risks in land-use planning'. This was included in the SoE 2018 Report, which found consensus across local councils, particularly coastal councils, that land-use planning should be informed by up-to-date climate science. No further quantitative analysis has been undertaken for this indicator since that report. The only additional commentary for that indicator in the present report is on updated planning guidance materials developed in recent years.

Climate change adaptation plans, nature-based adaptation, and emergency planning and preparedness indicators are all new indicators in this report. Nature-based adaptation is a particularly important addition, as it reveals missed opportunities to capture carbon via saltmarshes, mangroves and seagrasses.

26. Carnell PE, Reeves SE, Nicholson E, Macreadie P et al. 2019, 'Mapping ocean wealth Australia: the value of coastal wetlands to people and nature', The Nature Conservancy, Melbourne, DOI:10.13140/RG.2.2.15789.84969.

Socioeconomic indicators (Themes 8 and 9)

Theme 8: Communities

Socioeconomic assessments

The Marine and Coastal Act 2018 introduced a socioeconomic objective into state of the environment reporting. While a healthy environment is fundamental to meeting our socioeconomic needs, a healthy environment relies upon communities having social wellbeing and the economic resources to contribute to good environmental outcomes.

The inclusion of a socioeconomic objective in environmental reporting in the Marine and Coastal Act 2018 offers an opportunity to incorporate the social sciences and economics into DELWP's Marine and Coastal Knowledge Framework (MACKF) and to integrate the measures and thresholds for future reporting on communities' indicators with the biophysical science priorities.

The application of the SDGs to environmental reporting can achieve this. In the Method described in Part 2, Phase 3 (Localisation of SDG reporting) and Phase 4 (Reporting on SDG targets) provide an approach to both identify priority issues of importance to coastal communities and, through the synthesis of socioeconomic and biophysical data, assess our progress against targets, identifying opportunities for co-benefits and recognising where trade-offs will need to be managed. This process has also identified knowledge gaps that the MACKF, expanding its scope to include the three science objectives of the Marine and Coastal Act 2018, could fill in the future.

Coastal communities

The Communities theme focuses on activities undertaken by, and the liveability of, coastal communities.

The development of **coastal settlements** represents a significant change in land use, potentially reducing natural habitat and introducing impervious surfaces. It is often assumed that population in coastal areas is increasing faster than in non-coastal areas. In Victoria this is not the case.

Recent rates of coastal population growth (1.6%) have been lower than for non-coastal areas (2.2%). In 2019, the coastal population of Victoria formed a slightly smaller proportion of the Victorian population than it had a decade earlier.[27] Population growth in coastal suburbs of Melbourne has been rapid, with increasing density of development, while coastal locations near Melbourne and Geelong, particularly on the Bellarine Peninsula and around Torquay, have also experienced rapid population growth. Work is currently underway to protect significant landscapes in several coastal areas that are under development pressure. On balance, planning controls are being strengthened to protect important landscapes, but we have no monitoring systems in place to determine whether these are actually protecting the qualities of these significant landscapes.

Legislative protection is given to a range of **cultural heritage** for both Aboriginal and non-Aboriginal Victorians, on land and in marine environments. Data on the number of registered sites having cultural significance are available, subject to certain restrictions in the case of Aboriginal cultural heritage. While cultural heritage can be assessed quantitatively — in March 2021 there were 38,827 registered Aboriginal places on the Victorian Aboriginal Heritage Register and 1,143 cultural heritage management plans — it is important to monitor the qualitative status of sites and the degree to which investment is supporting their preservation and protection.

Tourism and recreation (especially boating and fishing) are supported through Victorian Government policy and are seen as valuable sources of jobs and revenue for Victorian coastal communities. A recent study estimated that recreational fishing and boating in Victoria in 2018/19 generated:

- $14 billion combined direct and indirect output, including $6.14 billion direct output
- $5.83 billion combined direct and indirect value added, including $2.12 billion direct added
- 55,780 combined direct and indirect full-time equivalent jobs, including 25,058 direct jobs.[28]

27. Data based on coastal Statistical Areas Level 2 (SA2) average annual population growth between 2009 and 2019. Australian Bureau of Statistics (ABS), 'Regional population growth', cat. 3218.0.

28. Ernst & Young, for Better Boating Victoria and Victorian Fisheries Authority 2020, 'The economic value of recreational fishing and boating in Victoria': Final report, p.7 https://vfa.vic.gov.au/__data/assets/pdf_file/0003/629256/The-economic-value-of-recreational-boating-in-Victoria-2020-Ernst-and-Young-Report.pdf.

At present there appear to be limited links between tourism growth policies and visitor management or environmental management strategies. While data are available, it tends to be geographically broad and survey-based, which makes detailed assessment of tourist impact very difficult. Environmental certification schemes do not yet enable comprehensive assessment of tourism operators' environmental credentials.

Recreational fishing is a popular activity, contributing to people's wellbeing. But increases in recreational fishing may lead to increased pressures on fisheries and the broader ecosystem. Management strategies and education are required to prevent this. While some data on recreational fishing are available, there are gaps in our understanding of its scale and consequences. Increasingly, programs aim to foster responsible fisher behaviour, which improves environmental outcomes.

While Victoria's systems for managing **commercial fisheries** are generally effective, some threats are still evident: overfishing, illegal and unreported fishing, introduction of pests, bycatch, and entanglements. State and Commonwealth commercial fisheries provided $101 million of gross production value to the Victorian economy and added value of $223 million.[29] More than 2,000 full-time equivalent jobs were provided in the industry, which translated into $129 million in household income.

Aquaculture is an increasingly important source of seafood in Victoria, for both the domestic and export markets. The main species farmed in Victorian coastal waters are abalone and blue mussels. Regulations are in place to prevent the spread of invasive marine species in the aquaculture industry. However, disease outbreaks remain a threat to the industry – in 2021 an outbreak of abalone viral ganglioneuritis led to a local marine area closure near Portland. Coastal aquaculture contributed an estimated $35 million of added value and 427 full-time equivalent jobs to the Victorian economy in 2016–17.[30]

Victoria uses both renewable and non-renewable resources from marine and coastal environments to generate electricity. **Resources and energy generation** are undergoing major change at present due to the decarbonisation of Victoria's energy sources. Development of wind and solar energy has been increasing in recent years and more projects are planned. There are nine operational wind farms along Victoria's coastline, including Victoria's first wind farm built in 2001 at Codrington, east of Portland.[31] This wind farm alone generates enough electricity each year to supply 10,000 Victorian homes, avoiding the emission of 49,000 tonnes of greenhouse gas emissions annually.[32] Global initiatives towards decarbonisation are likely to place pressure on Victoria's fossil fuel use in the coming decade, requiring a more rapid transition to renewable energy sources.

Agriculture is a major use of land in Victoria. It provides economic benefits and food for the wider community. Agriculture can be done in a sustainable way: farmers can be stewards of their land by maintaining or improving soils, vegetation and other environmental features. However, some environmental risks from agriculture require management. Water runoff from farming land may have high nutrient loads from fertiliser or contain toxins from agricultural chemicals like pesticides.

Melbourne Water and CSIRO have undertaken studies to estimate fine sediment loads in runoff from the Western Port catchment. This catchment has been subject to increasing urbanisation, particularly in the urban growth areas of Casey and Cardinia Shires, although much of the catchment still comprises agricultural land use with some significant areas of remnant vegetation. Although the largest proportion of fine sediment load in catchment runoff comes from grazing and cropping (21%), this reflects the fact that grazing and cropping comprise a high proportion of catchment land use (31%). By contrast, roads, which represent only 3.4% of land use in the catchment, account for 24% of fine sediment load running into Western Port. Low-density residential use also causes significant runoff (12%) despite being a small proportion of overall land use (2%).[33]

Coastal infrastructure is under threat from climate change, due to rising sea levels and increasingly frequent severe weather events. The condition of coastal assets and infrastructure is currently undergoing review. It is therefore difficult to fully assess their status.

29. Abernethy K, Barclay K, McIlgorm A, Gilmour P et al. 2020, 'Victoria's fisheries and aquaculture: economic and social contributions', Fisheries Research and Development Corporation and University of Technology Sydney.
30. Ibid.
31. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Wind energy projects. As at 08/10/20' https://www.planning.vic.gov.au/permits-and-applications/specific-permit-topics/wind-energy-facilities/wind-energy-projects-planning?_ga=2.189197033.318809511.1602653626-245237306.1598233448 Accessed 14 October 2020.
32. Pacific Hydro 2020, 'Codrington wind farm' https://www.pacifichydro.com.au/projects/operations/codrington-wind-farm/ Accessed 14 October 2020.
33. Melbourne Water and CSIRO 2021, 'Westernport catchment planning tool' https://www.flowmatters.com.au/viz/#/mw-cpt?_page=0 Accessed 20 July 2021.

Theme 9: Stewardship and collaborative management

The Stewardship and Collaborative Management theme ranges from participation in stewardship activities at the local level through to Victorian Government legislation and policy. By working in partnership, agencies and communities can create policy that leads to strong stewardship of Victoria's marine and coastal environments.

While it is relatively easy to measure the number of participants involved in a program, it is more difficult to measure institutional characteristics or the effectiveness of policies and processes. For this reason, some of the indicators for this theme of Part 3 of the SMCE provide a narrative exploration and assessment rather than specific or precise measurements. We anticipate that this approach will raise issues and lead to new ways of measuring these aspects of stewardship and collaborative management in future reports.

There is a growing recognition of the importance of people being connected to nature. **Stewardship** activities involve many participants. At the community level are farmers and other land managers, fishers and others who rely on marine industries, Traditional Owners caring for Country, and various volunteer groups involved in environmental protection and improvement. A wide range of government departments and agencies are also involved in stewardship activities, through funding processes, policy making, and management of programs. Although stewardship is difficult to define or measure, DELWP has made progress recently by developing a Marine and Coastal Stewardship Index. While it is too early to measure trends using this index, benchmark data are starting to be collected for Port Phillip Bay programs, and this should provide a model for future data collection and indicator assessment.

Volunteering is one activity for which data are available. This data show that, although many committed volunteer groups contribute to protecting, conserving and improving marine and coastal environments, fewer than 6% of Australians who volunteer are involved in environmental activities.

A survey of community attitudes undertaken in 2018 by market research company Ipsos examined community participation in relation to Victoria's coast, and potential financial contributions to the preservation of the Victorian coast and marine environments.[34] Forty-two percent of respondents indicated an interest in joining a coastal volunteer group, while 39% indicated their willingness to contribute financially to improve coastal management.

Coastcare Victoria is a community-based program that supports community stewardship of Victoria's marine and coastal environments. Volunteering is central to Coastcare's activities, and the program aims to foster community appreciation of marine and coastal areas. Coastcare supports hundreds of community groups and volunteers working to protect and improve Victoria's coastline. Activities include revegetating coastal areas, building boardwalks and tracks, fencing, monitoring native shorebirds and animals, presenting educational and awareness-raising sessions, planting, landscaping and protecting cultural sites.[35] A total of 13,444 people participated in Coastcare activities in 2019–20,[36] an increase from 10,500 in the previous financial year.[37]

Citizen scientists have been involved in marine and coastal programs, even during COVID-19 lockdowns, when virtual projects enabled seal counts (via webcam) and other activities to continue. These broad-ranging programs can provide important data for scientific analysis, as long as appropriate levels of rigour are applied to data collection and analytical methods. It is important for the DELWP MACKF to identify the role of, and constraints on, volunteers and citizen scientists in contributing to the evidence base of critical marine and coastal scientific knowledge. The current development of a citizen science framework for Victoria is a promising development that can help address some of these requirements and challenges to expand citizen science activities.

34. Ipsos 2018, 'Wave 5 Marine and Coastal Community Attitudes and Behaviours Report', prepared for the Victorian Marine and Coastal Council (VMaCC), Parks Victoria and Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria, https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0029/438329/Final-Report-Wave-5-Victorian-Marine-and-Coastal-Attitudes-Research.pdf
35. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Coastcare Victoria strategy 2020–2025: Have your say on our draft Coastcare Victoria Strategy', Victorian Government, Melbourne https://engage.vic.gov.au/coastcare-victoria-strategy-2020-2025 Accessed 24 February 2021.
36. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Annual report 2020', Victorian Government, Melbourne, p. 52 https://www.delwp.vic.gov.au/__data/assets/pdf_file/0025/494134/Annual-Report-2019-20-3.pdf
37. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Annual report 2019', Victorian Government, Melbourne, p. 42 https://www.delwp.vic.gov.au/__data/assets/pdf_file/0032/438188/DELWP-Annual-Report-2018-19-web.pdf

This report's assessment of the Victorian Government's role in stewardship activities takes a narrative form, exploring Victoria's marine and coastal planning regimes and implementation strategies. In the past, Victoria's marine and coastal planning and policy arrangements have been criticised for being overly complex and multi-layered, thus limiting policy coherence. The introduction of the *Marine and Coastal Act 2018* and the subsequent Marine and Coastal Policy 2020 have helped to streamline and clarify aspects of coastal policy.

Institutional knowledge and capacity are critical for effective environmental policy. At the aggregate level, a meaningful assessment of institutional knowledge and capacity is unrealistic, because of the large number, variety and complexity of institutions that have responsibilities for marine and coastal management. Following the State of the Bays 2016 Report, Victoria has put in place a MACKF to support the knowledge needs of planning for Victoria's marine and coastal areas. One outcome has been CoastKit – an online system for marine and coastal spatial data. While the development of data systems for marine and coastal management is welcome, analysis of what the data tell us and the degree to which it is being used in decision-making is still unclear and unable to be fully assessed yet. It is important that the MACKF considers the supply of analysis and interpretation to complement datasets, to provide clarity for future state of the environment reporting.

Part 2 Spatial analysis and applying international frameworks

This is the first report to be produced using the approach described in the Science for Sustainable Development Framework, which was tabled in the Parliament of Victoria in June 2020. Part 2 of this report focuses on the application of three of the framework's strategic enablers, to improve state of the environment reporting and enable better decision-making by strengthening the evidence base and its application. This analysis also contributes to the implementation of relevant recommendations (18, 19 and 20) from the Victorian State of the Environment 2018 Report, which were supported in principle or in part by the Victorian Government in 2020.[38]
The three strategic enablers are:

- spatial information, the technologies that deliver it, and spatial data coordination for state of the environment reporting
- the United Nations (UN) Sustainable Development Goals (SDGs)
- the UN System of Environmental–Economic Accounting (SEEA).

Spatial analysis

Harnessing the scientific and technological developments and availability of Earth observation and spatial information for monitoring and protecting Victoria's marine assets is a major opportunity to support and protect Victoria's marine and coastal environments and communities. An analysis of the current, emerging and future opportunities in this area is provided in Part 2, with further detail included as Appendix A.

The opportunity for future SMCE Reports to include data sourced via spatial technologies is evident. The importance of Earth observation and spatial technologies for coastal and marine protection and management is increasing–and will continue to increase. Exploiting these opportunities and developing a process for continuous improvement in Victoria's investment, adoption and use of Earth observation and spatial technologies for marine and coastal monitoring and management will also enable continuous improvement in our science and reporting programs.

38. Victorian Government 2020, 'Victorian Government response to the State of the Environment 2018 Report', https://www.environment.vic.gov.au/reports/state-of-the-environment-report-response Accessed 26 August 2021.

Applying international frameworks: the United Nations Sustainable Development Goals

The Science for Sustainable Development Framework assumes that using the SDGs can help Victoria achieve the four objectives of the *Commissioner for Environmental Sustainability (CES) Act* (the Act) in a way that was not possible for state of the environment (SoE) reporting before 2015. Hence the framework extends the aims of the SoE 2023 report beyond the limitations of previous cycles to meet objectives (s. 7) of the Act.

The first four phases of a formative Method for achieving this are presented in Part 2:

Phase 1 Selection of relevant SDG targets – proposes a list of SDG targets that are relevant to marine and coastal reporting in the SMCE 2021 Report. This section describes the process for selecting a subset (40) of the 169 SDG targets relevant to marine and coastal reporting in Victoria.

Phase 2 Evaluating comprehensiveness of indicators – assigns indicators from the SMCE Report's scientific assessments (Part 3) to the 40 SDG targets identified in Phase 1 of the Method. The assigned indicators were also weighted, as not all indicators mapped to a specific target are equally important in assessing the target; critical indicators were given a heavier weighting.

The comprehensiveness assessment is included in Part 2, Appendix B.

Phase 3 Localisation of the Sustainable Development Goals – working with local coastal and land managers and practitioners to understand local priorities.

Phase 4 Reporting on SDG target assessments – applies the Method to specific SDG targets that were identified in Phase 1 (as relevant to marine and coastal reporting in Victoria) and assessed in Phase 2 (evaluated for comprehensiveness of indicators to report progress in a meaningful way). Qualitative reporting on the SDG targets in Phase 4 draws on the information and evidence base in Part 3, but with a focus on the system and the telling of interconnected stories (narratives) to inform holistic policy interventions and management.

The narrative approach adopted in this report is one of a range of methods for assessing interlinkages but is limited to a qualitative assessment. Semiquantitative (matrix/network analysis), quantitative (statistical correlation), and dynamic quantitative (modelling) methods will require a targeted research project and an analysis of the applications across all themes to measure Victoria's progress on the SDGs: identifying areas in which we are lagging; exploring how economic, social and environmental targets interlink; and modelling how recommendations from SoE reporting can improve progress on ecological sustainable development.

Applying international frameworks: the United Nations System for Environmental–Economic Accounting

DELWP is developing accounting applications based on the United Nations System of Environmental–Economic Accounting to provide better-integrated and more consistent information on, and analysis of, our environmental assets in Victoria: information on which assets have been depleted or lost, which are declining in condition, and how the health of these assets affects our wellbeing as a society.

This will support the Victorian Government's policy, planning and investment decisions that affect the environment. It will also strengthen the ability of local government, business, not-for-profit and community stakeholders to recognise the benefits of protecting and investing in the environment.

DELWP's initial ecosystem accounting work (in the early 2010s) aimed to demonstrate concepts using available information. The more recent program of work (since 2020) responds to an identified policy need and to the recommendations of the SoE 2018 Report. The existing Victorian ecosystem accounts are a snapshot of ecosystem status and productivity at a point in time and have been developed for much of Victoria's land and water area.

Future priorities

The CES proposes five future priorities, which recognise that research outcomes will benefit from better integration and coordination of effort and from the adoption of new technologies and methods. These will enable more frequent and extensive monitoring and will ultimately improve our understanding of the marine and coastal environment.

1. Use spatial information and Earth observation to help identify and protect Victoria's marine assets.
2. Update Victoria's Marine and Coastal Knowledge Framework to reflect the scientific assessments of this report.[39]
3. Develop thresholds to improve future reporting.
4. Ensure that the Victorian Government continues to implement existing policies and management plans to benefit the environment.
5. Trial different models and ways to represent the complex interlinkages between selected SDG targets, to fully understand the interactions between Victoria's environment, community and economy.

Together, these five priorities enable a shift from issues-based marine and coastal management to an integrated, systems approach that recognises the interlinkages of the SDGs and is built on a catchments-to-reefs philosophy. The first four priorities would benefit from the SDG modelling proposed in the fifth priority.

The SDG modelling will improve our understanding of interlinkages and enable predictive analysis (i.e., which interventions will maximise benefits and limit trade-offs). It would provide the frame, logic and rationale for the system presented in Figure 6. The data for the decision-making system described can be applied to any policy domain, but in Figure 6 it is applied to marine and coastal policy.

The spatial information and Earth observation data would contribute significantly to the evidence base for decision making. The perspectives and values of Traditional Owners, local management authorities, community groups and volunteers would provide the operational intelligence–identifying the local priorities for specific regions of Victoria's coasts and marine assets. The MACKF, environmental–economic accounts and the independent reporting and assessments of the State of the Marine and Coastal Environment, would address the knowledge

Figure 6: Data for decision making applied to the SMCE 2021 Report.

39. This priority supports the proposed activity of the Marine and Coastal Strategy to underpin evidence-based marine planning and management by updating Victoria's Marine and Coastal Knowledge Framework (including CoastKit).

gaps (identified in the SMCE Report; addressed by the MACKF) informed by local priorities. Finally, the Marine Spatial Planning Framework provides the integration–ensuring planning and management decisions consider all sectors and the application of sectoral decisions across all Victoria's marine and coastal regions–and that these decisions are reflected in future iterations of strategy and policy.

Future priority 1: Use spatial information and Earth observation to help identify and protect Victoria's marine assets.

An analysis of the current, emerging, and future opportunities to harness spatial information and Earth observation technologies to improve marine and coastal management is provided in Part 2, and a detailed summary at Appendix A. The opportunity for future SMCE reporting to adopt more spatial technologies is evident. Part 3 of this SMCE Report relies on a plethora of diverse mapped and measured data to assess an indicator at a point in time.

We found that emerging technologies will improve both the spatial resolution and temporal resolution of data. Consequently, data volumes will increase. Over time, synthesising this data into insights may become more technically complex, but the opportunity to create information that better represents change over time, at more local scales, is an exciting one. Many of these data collection types and technologies discussed should not be used in isolation as they will be more valuable in combination. The analysis presented in Part 2 should inform and contribute to Victoria's first Marine Spatial Planning Framework, which is currently being developed under the Marine and Coastal Policy 2020. This Framework is intended to provide overarching guidance and a process for achieving integrated and coordinated planning and management of the marine environment.

Future priority 2: Update Victoria's Marine and Coastal Knowledge Framework (MACKF) to reflect the scientific assessments of this report.

The State of the Bays 2016 Report proposed a Marine Knowledge Framework to guide an ecosystem-wide understanding of the bays and enable forward-looking and well-considered policy making. Policies should account for economic and social benefits, as well as environmental ones. They can inform robust urban planning decisions, and positively and pre-emptively deal with the effects of climate change.

In 2017, the Victorian Government funded the Marine Knowledge Framework. When the SoE 2018 Report recommended a broadening of the scope of the Framework, DELWP responded by including coastal issues – thereby expanding the research program and monitoring beyond Port Phillip Bay and Western Port. The resulting MACKF has made an important contribution to this report, through DELWP and other agencies that support the science investment and research undertaken.

The marine science component of the MACKF would be further improved by stronger ties to national efforts (e.g., the Integrated Marine Observing System (IMOS)).

Future priority 3: Develop thresholds to improve future reporting.

The indicator assessments presented in Part 3 are based on the best available science, and contributions by technical experts in all areas of Victorian marine and coastal science. Where possible, thresholds are used for transparency of reporting, to ensure consistent standards are adopted across reporting cycles, and to raise awareness of the environmental conditions required for an indicator to improve (e.g., from fair to good) or deteriorate (e.g., from fair to poor).

These thresholds are adopted from pre-existing reporting regimes (for example, EPA's Environment Reference Standards (ERS) or Ramsar's limits of acceptable change). However, for many critical indicators – from microplastics to contaminated land, from light pollution to coastal acid sulfate soils – thresholds have not been developed. For efficiency, it will be important that current initiatives, such as the Marine Biodiversity Index, the Port Phillip Bay EMP Monitoring Evaluation Reporting and Improvement strategy, and the Victorian Coastal Monitoring Program, develop these thresholds for future reporting.

Future priority 4: Ensure that the Victorian Government continues to implement existing policies and management plans to benefit the environment.

Since the publication of the State of the Bays 2016 Report, the Victorian Government has significantly reformed marine and coastal legislation, policy and planning. The Marine and Coastal Act 2018 and Policy are central to this reform – with the Strategy out for consultation as well. Planning documents such as Biodiversity 2037, Water for Victoria, and the Port Phillip Bay EMP have also helped shaped policy and management over the past five years.

These initiatives create a very robust legislative and policy framework for managing Victoria's marine and coastal environments. The challenge for all Victorians is to maximise the potential of this reform and to take a whole-of-system approach to guide our actions. This will require that the tools presented by the legislation, policy, strategy and plans are coherent and coordinated and applied with a catchment-to-reefs philosophy that integrates water quality and pest management, adaptation to climate change, and conservation and protection priorities.

This undertaking is twofold. Firstly, actions must be delivered, and commitments kept. Secondly, the policy levers of the new legislative and policy framework must be applied to bring real change and environmental benefits.

Future priority 5: Trial different models and ways to represent the complex interlinkages between selected SDG targets, to fully understand the interactions between Victoria's environment, community and economy.

In this report we have broadened the scope of the SMCE analysis required under the legislation, to include both environmental and socioeconomic indicators, and we have explored their interlinkages. Further research is required to fully realise the vision of the Science for Sustainable Development Framework, to:

1. show how the environment and natural capital underpin Victoria's social and economic wellbeing
2. identify trade-offs and areas of tension, and potential co-benefits
3. highlight potential opportunities for collaboration between management sectors in the SDG network (e.g., environment, health and infrastructure)
4. enable predictive analysis to assess the causal interlinkages of specific interventions and inform future recommendations.

The narrative approach adopted in this report is one of a range of methods to be trialled for assessing interlinkages but is limited to qualitative assessment. Semiquantitative (matrix/network analysis), quantitative (statistical correlation), and dynamic quantitative (modelling) approaches will require a targeted research project and an analysis of the applications across all SoE reporting themes.

In this way, the SoE 2023 can be both retrospective (extending the scientific baseline another five years) and prospective. It will measure Victoria's progress on the SDGs, identifying areas in which Victoria is lagging; exploring how economic, social and environmental targets interlink; and showing how recommendations help progress the ecologically sustainable development of Victoria.

Part 1B
Policy context

Commissioner *for* Environmental Sustainability Victoria

Cultural landscape health and management

Introduction

Victoria's cultural landscapes are unique. They are host to one of the oldest continuing cultures in the world, and home to a vast array of flora, fauna and sites that have both symbolic and practical value to Aboriginal Victorians – and to all other Victorians. Today's cultural landscapes reflect Aboriginal people's interactions with their world and experience of their surroundings. They are the product of generations of economic activity, material culture and settlement patterns. Although colonisation resulted in the landscape being broken up into different land tenures, and brought in different management regimes, Aboriginal people remain connected to Country, and cultural landscapes span such artificial boundaries.[40]

Country is both a place of belonging and way of believing and living. It relates to all aspects of an Aboriginal person's existence, including culture, spirituality, language, law, family and identity.[41]

The Draft Marine and Coastal Strategy highlights the role of Traditional Owners in marine and coastal management.

The full integration of Traditional Owner values, uses and practices in the rehabilitation and management of Country will foster continuity of Traditional Owner cultures, knowledge, and practices to heal our coastal and marine environment for current and future generations.[42] The Strategy proposes that Traditional Owners be involved in research, planning, management and monitoring of land and sea Country.

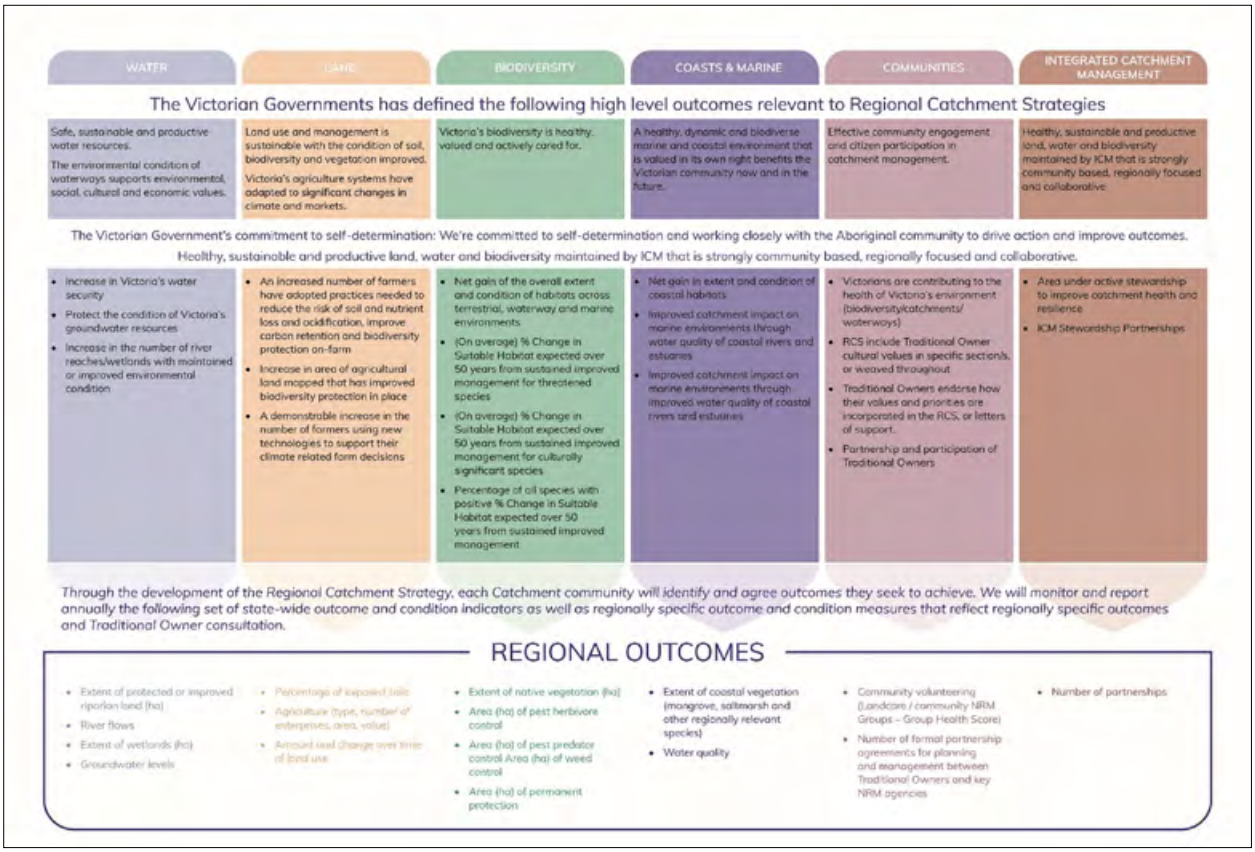


Figure 7: Regional catchment strategies outcomes framework.[43]

40. Parks Victoria 2020, 'Managing Country together' https://www.parks.vic.gov.au/managing-country-together Accessed 16 April 2020.
41. Aboriginal Victoria 2020, 'Victorian Government Aboriginal Affairs report 2019: Culture and Country' https://www.aboriginalvictoria.vic.gov.au/victorian-government-aboriginal-affairs-report-2019/culture-country Accessed 23 April 2020.
42. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Draft marine and coastal strategy', Victoria State Government, p. 8 https://engage.vic.gov.au/draft-marine-and-coastal-strategy Accessed 24 September 2021.
43. North East Catchment Management Authority 2021, 'Monitoring and reporting' https://northcentral.rcs.vic.gov.au/this-strategy/monitoring-and-reporting/ Accessed 7 October 2021.

Traditional Owners are also being recognised through Regional Catchment Strategies with a common statewide reporting indicator being developed for partnership with, and participation by, Traditional Owners. The indicator is in the Statewide Communities Outcome (Figure 7) and focuses on partnerships between NRM agencies and Traditional Owners. Such partnerships represent collaborative work to improve natural resource management and to realise Traditional Owners' aspirations and plans for their Country. This indicator is in the section on the localisation of SDG indicators in the SDG synthesis and evaluation in this Summary Report. Future reporting on this indicator by Traditional Owners and CMAs will be incorporated into SoE reporting. The indicator is also aligned with SDG 17: Partnerships for the Goals, specifically Target 17.17: Encourage and promote effective public, public–private and civil society partnerships, building on the experience and resourcing strategies of partnerships.

State of environment reporting

The SoE 2018 Report made a transition from a singular focus (reporting on Aboriginal cultural heritage only), to assessment of cultural landscape health and management. This new reporting approach includes indicators aligned to four themes:

- connection to Country
- building capacity
- land justice, self-determination, governance and mechanisms for sustainability
- funding and pathways to other organisations.

These four themes aim to incorporate the social, economic, spiritual, cultural, environmental and health and wellbeing values of Victorian Traditional Owners, Registered Aboriginal Parties and Aboriginal Victorians. The intention is to respect and support Aboriginal Victorian advancement for Treaty, self-determination and empowerment, as defined in the *Advancing the Treaty Process with Aboriginal Victorians Act 2018* and as advocated by Australia's Human Rights Commission.[44]

Aboriginal Victoria language families

Aboriginal people have lived in Australian coastal areas for the past 65,000 years,[45] and are often termed 'saltwater people'.[46] Under Aboriginal interpretations, saltwater people are Australian Aboriginal peoples from coastal areas across the nation who are the Traditional Owners, guardians and custodians of the lands and waters characterised by saltwater environments.[47] There are more than 250 known Australian Aboriginal languages across the nation.[48] Each saltwater Aboriginal culture group has a Country-specific relationship to its own particular lands and waters. Language and traditional knowledge are integral parts of this relationship.[49] Thus, a generic language or set of traditions does not exist.

At the time of British colonisation, there were approximately 38 languages and 11 language families across Victoria (Note: Languages are shown in lower case text; language families in upper case text. (Figure 7).[50]

Many of the 38 languages were further divided according to family groups and their traditional lands, while the 11 language families were grouped according to shared words, grammar and sounds.[51] During British colonisation, there were approximately eight known Aboriginal language families across coastal Victoria.[52,53] Listed geographically from west to east they are: Buandig, Dhauwurd Wurrung, Keerray Woorroong, Gadubanud, Wadawurrung, Boon Wurrung, Gunai Kurnai and Bidwell.

44. Australian Human Rights Commission 2019, 'Right to self-determination' https://www.humanrights.gov.au/our-work/rights-and-freedoms/right-self-determination Accessed 28 May 2019.
45. Clarkson C, Jacobs Z, Marwick B, Fullagar R et al. 2017, 'Human occupation of northern Australia by 65,000 years ago', *Nature*, 547, pp. 306–310.
46. Thurstan R, Brittain Z, Jones D, Cameron E et al. 2018, 'Aboriginal uses of seaweeds in temperate Australia: an archival assessment', *Journal of Applied Phycology*, 30, pp. 1821–1832, https://doi.org/10.1007/s10811-017-1384-z.
47. Ibid.
48. Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS) 2020. 'Mabo v Queensland' (No. 2) [1992] HCA 23; (1992) 175 CLR 1 https://jade.io/article/67683 Accessed 6 October 2021.
49. Thurstan R, Brittain Z, Jones D, Cameron E et al. 2018, 'Aboriginal uses of seaweeds in temperate Australia: an archival assessment', *Journal of Applied Phycology*, 30, pp. 1821–1832, https://doi.org/10.1007/s10811-017-1384-z.
50. Victorian Aboriginal Corporation for Languages (VACL) 2020, Map: 'Aboriginal languages of Victoria' https://vacl.org.au/home Accessed 16 April 2020.
51. ANTaR Victoria 2020, 'Local Nations: language groups' https://antarvictoria.org.au/local-nations Accessed 16 April 2020.
52. Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS) 2020. 'Mabo v Queensland' (No. 2) [1992] HCA 23; (1992) 175 CLR 1 https://jade.io/article/67683 Accessed 6 October 2021.
53. Victorian Aboriginal Corporation for Languages (VACL) 2020, Map: 'Aboriginal languages of Victoria' https://vacl.org.au/home Accessed 16 April 2020.

Figure 8: Aboriginal languages and language families across Victoria at the time of British colonisation.[54]

Since British colonisation, many languages in the larger language families have dissipated or disappeared, due to the displacement or dispossession of family groups from their Country, and to laws enforced during colonisation that forbade communities from speaking their own language or practising their culture. The importance of language in a Country-specific relationship to lands and waters, coupled with the diversity of languages and language families along Victoria's coastline and marine waters, highlights the need to support Traditional Owners and Aboriginal Victorians in practising and using their languages and language families.

Victorian Aboriginal rights to access, care and manage Country

In Victoria, Aboriginal Victorians can use several federal and state mechanisms to exercise their rights to access, use and manage lands and water on Country, as a basis for self-determination and economic independence.[55] These mechanisms include:

- *Native Title Act 1993* (Cth) – native title determination covering 14,899 km² in Victoria[56]
- *Aboriginal Heritage Act 2006* (Vic) – A Traditional Owner community can be formally recognised in Victoria as a Registered Aboriginal Party (RAP) and hold decision-making responsibilities for protecting Aboriginal cultural heritage in a specific geographical area. As at July 2020, there were 11 RAPs, covering 74% of Victoria[57]
- *Traditional Owner Settlement Act 2010* (Vic) – A Traditional Owner community can achieve legally enforceable recognition by the Crown of its rights to Country, through Traditional Owner Settlement Agreements (TOS). As at June 2020, TOS covered 50,976 km² of Victoria.[58]

54. Ibid.
55. Petrie A 2018, 'Land and water rights of Traditional Owners in Victoria', Research paper no. 3, Research and Inquiries Unit, Parliamentary Library and Information Service, Department of Parliamentary Services, Parliament of Victoria https://www.parliament.vic.gov.au/publications/research-papers/send/36-research-papers/13877-land-and-water-rights-of-traditional-owners-in-victoria Accessed 16 April 2020.
56. Aboriginal Victoria 2020, *Victorian Government Aboriginal Affairs report 2020*, Victorian Government, Melbourne, p. 96 https://www.firstpeoplesrelations.vic.gov.au/victorian-government-aboriginal-affairs-report-2020 Accessed 6 October 2021.
57. Victorian Aboriginal Heritage Council (VAHC) 2020, 'Victoria's current Registered Aboriginal Parties' https://www.aboriginalheritagecouncil.vic.gov.au/victorias-current-registered-aboriginal-parties Accessed 23 July 2021.
58. Aboriginal Victoria 2020, *Victorian Government Aboriginal Affairs report 2020*, Victorian Government, Melbourne, p. 96 https://www.firstpeoplesrelations.vic.gov.au/victorian-government-aboriginal-affairs-report-2020 Accessed 6 October 2021.

The lack of an overarching legislative mechanism is a significant barrier to developing a comprehensive and broadly accepted system of recognition for Aboriginal Victorian rights to land and water. This creates complexity for individual Aboriginal Victorians, their communities, governments, private bodies and the broader public as they try to navigate the different mechanisms.[59] Additional complexities arise from the different concepts of land ownership and use held by Aboriginal Victorians and legislators.[60]

It should also be noted that there are many other mechanisms to support self-determination and economic prosperity for all Aboriginal Victorians. These include the *Victorian Charter of Human Rights and Responsibilities Act 2006* (Vic), *Corporations (Aboriginal and Torres Strait Islander) Act 2006* (Cth) and *Advancing the Treaty Process with Aboriginal Victorians Act 2018* (Vic).

Native title

Mabo v Queensland (No. 2) [1992] HCA 23 (commonly known as Mabo) was a landmark decision of Australia's High Court that recognised native title in Australia for the first time. The High Court rejected the doctrine of *terra nullius* in favour of the Common Law doctrine of native title. This saw the passing of the Native Title Act 1993 (Cth), enabling Indigenous people throughout Australia to claim traditional rights to unalienated land.[61] Native title is a set of rights and interests over land or waters where Aboriginal and Torres Strait Islander groups have practised traditional laws and customs since before the time of European occupation and continue to do so. Native title determinations of relevance to the geographic scope of this SMCE 2021 Report include:

- Gunditj Mirring Traditional Owners Aboriginal Corporation Native Title Determination 2007, covering almost 140,000 hectares across south-west Victoria. Consent determination area is bounded on the west by the Glenelg River and to the north by the Wannon River.[62]
- Gunditj Mirring Traditional Owners Aboriginal Corporation and Eastern Maar Aboriginal Corporation Native Title Determination 2011, for the land and waters between the Shaw and Eumeralla Rivers from Deen Maar (Lady Julia Percy Island), including Yambuk, to Lake Linlithgow.
- Gunaikurnai Native Title Determination 2010.

A native title proceeding still underway, and relevant to the scope of this report, is the Eastern Marr Aboriginal Corporation's native title claim in the Federal Court, lodged in 2012.

Traditional Owner Settlement Agreements

The Traditional Owner Settlement Act (TOS Act) provides a framework for the Victorian Government to recognise Traditional Owners and their rights to Country. At the time of publication, three Victorian Traditional Owner Corporations had negotiated such an agreement, of which one is within the scope of the SMCE 2021 Report:

- Gunaikurnai Land and Waters Aboriginal Corporation
- Dja Dja Wurrung Clans Aboriginal Corporation
- Taungurung Clans Aboriginal Corporation.

New Traditional Owner Settlement Agreements continue to be negotiated alongside native title determinations, and include:

- Eastern Maar
- First Peoples of the Millewa Mallee
- Barengi Gadjin Land Council (represents Traditional Owners from the Wotjobaluk, Jaadwa, Jadawadjali, Wergaia and Jupagulk communities who already hold native title rights).

Registered Aboriginal Parties

In Victoria, there are currently 11 Registered Aboriginal Parties (RAPs), covering approximately 75% of the state. Five of these have Country along the Victorian coastline and which extends out into marine waters:

- Bunurong Land Council Aboriginal Corporation
- Eastern Maar Aboriginal Corporation
- Gunaikurnai Land and Waters Aboriginal Corporation

59. Petrie A 2018, 'Land and water rights of Traditional Owners in Victoria', Research paper no. 3, Research and Inquiries Unit, Parliamentary Library and Information Service, Department of Parliamentary Services, Parliament of Victoria https://www.parliament.vic.gov.au/publications/research-papers/send/36-research-papers/13877-land-and-water-rights-of-traditional-owners-in-victoria Accessed 16 April 2020.
60. Ibid.
61. Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS) 2020. 'Mabo v Queensland' (No. 2) [1992] HCA 23; (1992) 175 CLR 1 https://jade.io/article/67683 Accessed 6 October 2021.
62. Gunditj Mirring Traditional Owners Aboriginal Corporation 2020, 'Native title across Gunditjmara Country' https://www.gunditjmirring.com/nativetitle Accessed 23 April 2020.

- Gunditj Mirring Traditional Owners Aboriginal Corporation
- Wadawurrung Traditional Owners Aboriginal Corporation.[63]

RAPs are Traditional Owner groups legally recognised under the *Aboriginal Heritage Act*. As the primary guardians, RAPs are responsible for managing and protecting the Aboriginal cultural heritage of a particular area. RAPs are the primary source of advice and knowledge on matters relating to Aboriginal places or objects in their region. Their functions include:

- evaluating cultural heritage management plans
- assessing cultural heritage permit applications
- making decisions about cultural heritage agreements
- providing advice on applications for interim or ongoing protection declarations
- entering into Aboriginal Cultural Heritage Land Management Agreements with public land managers
- nominating Aboriginal intangible heritage to the Victorian Aboriginal Heritage Register and managing intangible heritage agreements.[64]

Under the Aboriginal Heritage Act, intangible heritage is defined as any knowledge of or expression of Aboriginal tradition, other than Aboriginal cultural heritage, and includes oral traditions, performing arts, stories, rituals, festivals, social practices, craft, visual arts, and environmental and ecological knowledge, but does not include anything that is widely known to the public. It also includes any intellectual creation or innovation.

RAPs are Traditional Owner organisations with established administrative and management functions that hold decision-making powers under the Act for the protection and management of Aboriginal cultural heritage in a specified geographic area. RAPs are appointed by the Victorian Aboriginal Heritage Council, an independent statutory body. The Council consists of up to 11 Traditional Owners, who are appointed by the Minister for Aboriginal Affairs. All members are resident in Victoria and have extensive knowledge and relevant experience of Aboriginal cultural heritage in Victoria. The Office of the Victorian Aboriginal Heritage Council provides support to the Victorian Aboriginal Heritage Council. Victoria's RAPs are shown in Figure 9.

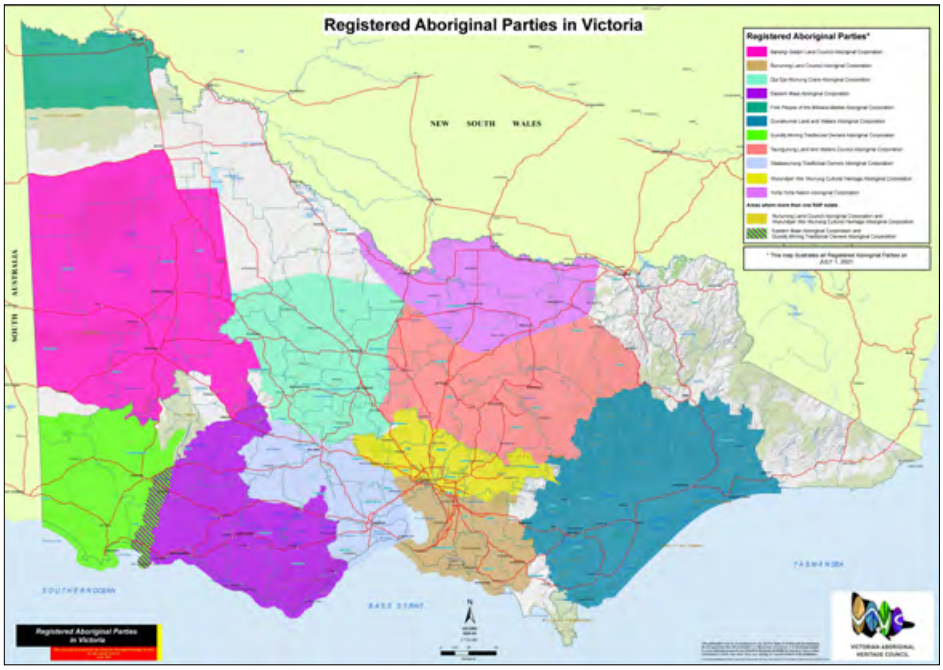


Figure 9: Registered Aboriginal Parties (RAPs) in Victoria as at 1 July 2021.[65]

63. Victorian Aboriginal Heritage Council (VAHC) 2020, 'Victoria's current Registered Aboriginal Parties' https://www.aboriginalheritagecouncil.vic.gov.au/victorias-current-registered-aboriginal-parties Accessed 23 July 2021.
64. Victorian Aboriginal Heritage Council (VAHC) 2021, 'About Registered Aboriginal Parties' https://www.aboriginalheritagecouncil.vic.gov.au/victorias-registered-aboriginal-parties Accessed 23 July 2021.
65. Victorian Aboriginal Heritage Council (VAHC) 2020, 'Victoria's current Registered Aboriginal Parties' https://www.aboriginalheritagecouncil.vic.gov.au/victorias-current-registered-aboriginal-parties Accessed 23 July 2021.

To reiterate, Traditional Owners are formally recognised by the Victorian Government in three ways: through the Native Title Act 1993 (Cth); by way of a recognition and settlement agreement under the Traditional Owner Settlement Act 2010 (Vic); and through appointment as a Registered Aboriginal Party (RAP) under the Aboriginal Heritage Act 2006 (Vic).

Victorian Aboriginal cultural heritage

Aboriginal cultural heritage in Victoria is protected under the Aboriginal Heritage Act 2006 (the Act) and Aboriginal Heritage Regulations 2018. Aboriginal cultural heritage is the knowledge and lore, practices and people, objects and places that are valued, culturally meaningful and connected to identity and Country and that has been passed on from ancestors to future generations.[66] The Act establishes a framework of mechanisms for the management and protection of Aboriginal cultural heritage, including cultural heritage management plans, cultural heritage permits, protection declarations, and Aboriginal Cultural Heritage Land Management Agreements. Aboriginal cultural heritage can be tangible or intangible, and can include secret or sacred objects, ancestral remains, Aboriginal places, knowledge, lore and practices.

Caring for Country

Under the terms and objectives of these legislative mechanisms for ensuring Aboriginal Victorian rights to access, manage and care for Country, several formal approaches support Treaty, self-determination, land justice and economic prosperity. Some of these are discussed below, but this is not a complete list. There are many formal and informal agreements and partnerships between Aboriginal Victorian communities and local government, government statutory bodies and the wider community that are not listed here.

Joint management plans

Joint management refers to a formal partnership between Traditional Owner communities and the Victorian Government that promotes the sharing of knowledge on the management of Crown land, such as national parks or other public parks.[67,68] Joint management is established under the terms of the *Conservation, Forests and Lands Act 1987* (Vic) and the Traditional Owners Settlement Act 2010 (Vic) via a Recognition and Settlement Agreement.

Joint management is formalised via a Traditional Owner Land Management Agreement (TOLMA) by Traditional Owner communities under a form of land title called Aboriginal Title. The TOLMA can include a provision for national parks and other public parks to be returned to Aboriginal ownership while continuing to be managed as a national park or a public park. The TOLMA establishes a process for developing joint management plans on Aboriginal Title lands and involves Traditional Owners working with Parks Victoria and DELWP staff in sharing knowledge to manage these lands.

Joint management plans are endorsed by the Secretary of DELWP and the Victorian Minister for Environment. Endorsed plans also allow for the establishment of Traditional Owner Land Management Boards, to recognise the knowledge and culture of Traditional Owner communities in the joint management of Aboriginal Title lands. Traditional Owner Land Management Board members are appointed by the Minister for Environment, where membership composition is at least 50% Traditional Owner representation, DELWP Secretary's nominee and general members. Membership can range between 7 and 11 people. Joint management also aims to economically benefit the whole Traditional Owner community through the creation of jobs, such as joint manager rangers, and potential commercial partnerships, while supporting reconciliation, land justice and community healing.[69]

Parks Victoria and DELWP will continue to manage the lands on a day-to-day basis and will permanently keep some core management functions.[70] This includes fire management and catchment management including designated water supply catchment areas under the *National Parks Act 1975* (Vic).[71] Traditional Owner Land Management Boards will also play a role in monitoring and supporting compliance with Joint Management Plans.

66. Victorian Aboriginal Heritage Council (VAHC) 2020, 'Aboriginal cultural heritage' https://www.aboriginalheritagecouncil.vic.gov.au/aboriginal-heritage Accessed 16 April 2020.
67. Parks Victoria 2020, 'Managing Country together' https://www.parks.vic.gov.au/managing-country-together Accessed 16 April 2020.
68. Petrie A 2018, 'Land and water rights of Traditional Owners in Victoria', Research paper no. 3, Research and Inquiries Unit, Parliamentary Library and Information Service, Department of Parliamentary Services, Parliament of Victoria https://www.parliament.vic.gov.au/publications/research-papers/send/36-research-papers/13877-land-and-water-rights-of-traditional-owners-in-victoria Accessed 16 April 2020.
69. Parks Victoria 2020, 'Managing Country together' https://www.parks.vic.gov.au/managing-country-together Accessed 16 April 2020.
70. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Land management: joint management' https://www.forestsandreserves.vic.gov.au/land-management/joint-management Accessed 16 April 2020.
71. Ibid.

At the time of writing this report, Victoria had formal agreements with five Traditional Owner communities for joint management of traditional lands under either the Native Title Act 1993 (Cth), Traditional Owner Settlement Act 2010 (Vic) and/or the Aboriginal Heritage Act 2006 (Vic).[72] Formal agreements relevant to the geographic scope of this SMCE 2021 Report include:

- Gunaikurnai Settlement Agreement: established in 2010 – the first agreement under the Traditional Owner Settlement Act.
- Gunditjmara Settlement Agreement: established in 2007 following a consent determination from the High Court of Australia.[73]

Aboriginal Cultural Heritage Land Management Agreements

An Aboriginal Cultural Heritage Land Management Agreement is a voluntary agreement between a RAP and a public land manager[74] It facilitates a proactive, holistic approach to managing and protecting Aboriginal cultural heritage and landscape during ongoing, routine land management activities in a RAP area.[75] These agreements document the approach taken to manage Aboriginal cultural heritage by setting out the results of a cultural heritage assessment and mutually agreed measures on how Aboriginal cultural heritage will be protected and managed during land management activities over a specified time frame.[76] As at June 2021, three RAPs have entered into an Aboriginal Cultural Heritage Land Management Agreement.[77]

Whole of Country Plans

Several Victorian Traditional Owner organisations, including RAPs, are working in partnership with government and non-government organisations to develop Whole of Country Plans, strategies and assessment frameworks that will integrate cultural heritage and spiritual values, self-determination and governance, health and wellbeing, and economic capacity to improve, care and manage the cultural landscape health of Country. Whole of Country Plans are overarching, long-term visions that set out clear goals and priorities, principles of engagement, and measures of success in caring for Country.[78] At the time of this report's publication, there were nine Whole of Country Plans.

Those relevant to the geographic scope of this SMCE 2021 Report include:

- Gunaikurnai Whole-of-Country Plan – Gunaikurnai Land and Waters Aboriginal Corporation
- Budj Bim Master Plan (including UNESCO World Heritage Landscape listing and Indigenous Protected Areas) – Gunditj Mirring Traditional Owners Aboriginal Corporation
- Meerreengeeye ngakeepoorryeeyt Country Plan – Eastern Maar Aboriginal Corporation.

Indigenous Peoples' Protected Areas

Indigenous Peoples' Protected Areas (IPA), also known as Indigenous Peoples' and Community Conserved Territories and Areas, are defined as:

> *clearly defined geographical spaces, within the lands and waters under traditional occupation and use by a given Indigenous people, nation or community, that are voluntarily dedicated and managed, through legal or other effective means including their customary law and institutions, to achieve the long-term conservation of nature with associated ecosystem services, as well as the protection of the inhabiting communities and their culture, livelihoods and cultural creations.*[79]

72. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Agreements with Traditional Owners' https://www.forestsandreserves.vic.gov.au/land-management/what-we-do/agreements-with-traditional-owners Accessed 16 April 2020.
73. Native Title Tribunal 2007, 'The Gunditjmara People's native title determinations 30 March 2007 south-west Victoria' http://www.nntt.gov.au/Information%20Publications/Determination%20brochure%20Gunditjmara%20March%202007.pdf
74. Aboriginal Victoria 2020, 'Cultural heritage management plans, permits, agreements and tests: processes under the Aboriginal Heritage Act 2006 for managing and protecting Aboriginal cultural heritage' https://www.aboriginalvictoria.vic.gov.au/cultural-heritage-management-plans-permits-agreements-and-tests Accessed 16 April 2020.
75. Ibid.
76. Aboriginal Victoria 2020, 'Aboriginal Cultural Heritage Land Management Agreements' https://www.aboriginalvictoria.vic.gov.au/aboriginal-cultural-heritage-land-management-agreements Accessed 23 April 2020.
77. Personal communication: Department of Premier and Cabinet 2021, First Peoples – State Relations Group, Victorian Government, Melbourne.
78. Aboriginal Victoria 2020, 'Victorian Government Aboriginal Affairs report 2019: Culture and Country' https://www.aboriginalvictoria.vic.gov.au/victorian-government-aboriginal-affairs-report-2019/culture-country Accessed 23 April 2020.
79. Stolton S, Shadie P, and Dudley N 2013, 'IUCN WCPA best practice guidance on recognising protected areas and assigning management categories and governance types', Best practice protected area guidelines series no. 21, International Union for Conservation of Nature, Gland, Switzerland https://www.iucn.org/theme/protected-areas/resources/iucn-wcpa-best-practice-guidelines-protected-area-managers-series Accessed 24 September 2021.

IPA rules generally intertwine with cultural and spiritual values. Although some of the protected areas governed by Indigenous peoples and local communities have been in existence for hundreds or even thousands of years, their recognition by national governments and their inclusion in national protected area systems is a much more recent phenomenon.[80] The main distinguishing features of IPAs have to do with the socio-political arrangements that are established between Indigenous peoples and government of lands and resources in Indigenous peoples' lands:

- IPAs are based on the collective rights of the respective Indigenous people, nation or community to lands, territories and resources, under national contexts.
- IPAs are established as protected areas in application of the right of self-determination, exercised mainly through:
    - self-declaration of the protected area by the Indigenous people or nation with collective territorial rights on the area
    - free, prior and informed consent of the people, nation or community with territorial rights on the area, in cases where the designation proposal is originated in government agencies, conservation organisations or other actors.
- IPAs are based on ancestral or traditional occupation.
    - Occupation, use and management are connected to and dependent upon the broader socio-cultural and political structure of a people or nation, which includes their customary law and institutions.
- IPAs are self-governed by Indigenous institutions within their territories and the protected areas contained therein, in application of arrangements established with system-level protected area authorities[81]

In Australia, IPAs have been created at the request or initiative of Indigenous owners, or through joint arrangements with governments and agencies. In such cases, Indigenous land and resource rights, as well as Indigenous government of the land, are important features. In Victoria, RAPs and Traditional Owners are primary guardians responsible for IPAs.

Within the geographic scope of the SMCE 2021 Report, the Gunditj Mirring Traditional Owners Aboriginal Corporation is the guardian for the IPA in the Budj Bim UNESCO World Heritage Landscape.

Marine and coastal public policy context

Victorian, as well as international and national, public policies are of direct relevance to this State of the Marine and Coastal Environment 2021 Report.

Prominent policies are briefly described below, with more detail on the policies and their direct links to environmental condition and management of the marine and coastal environment provided in the indicator assessment narratives in Part 3.

International

When the parties to the UN Convention on Biological Diversity met in 2010 at Aichi, Japan, they committed to the Strategic Plan for Biodiversity 2011–2020. This set five strategic goals and 20 targets for countries to slow and reverse biodiversity loss during the UN Decade on Biodiversity.

The 2030 Agenda for Sustainable Development was adopted by the UN in 2015 and comprises 17 goals with 169 targets.[82] Victoria's progress towards many of the Sustainable Development Goals (SDGs) – notably 'SDG 13 – Climate action', 'SDG 15 – Life below water' and 'SDG 17 – Partnerships for the goals' – are reviewed in Part 2 of the present report.

Indicator 32, Conservation of marine ecosystems in protected areas, contains an analysis of Victoria's extent of marine protected areas against international benchmarks for levels of protection, such as the Aichi targets and the SDGs. Both Aichi Target 11 and SDG Target 14.5 aim for at least 10% of coastal and marine areas to be conserved.

The Ramsar Convention[83] aims to halt the loss of wetlands and conserve those that remain. Victoria has 12 wetland sites on the List of Wetlands of

80. Ibid.
81. Ibid.
82. United Nations Department of Economic and Social Affairs, n.d. 'Sustainable development: The 17 goals' https://sdgs.un.org/goals Accessed 23 September 2021.
83. Ramsar Convention 2014, 'Wetlands of international importance' https://www.ramsar.org/sites-countries/wetlands-of-international-importance Accessed 23 September 2021.

As a signatory to the Ramsar Convention, Australia has committed to wetlands conservation, reserves and education. The first of a series of national action plans was released in 2016, and forms part of Australia's implementation of the four goals and 19 strategies of the Ramsar Strategic Plan 2016–24. Seven thematic sub-chapters in Part 3 of the present report include a focus on the Gippsland Lakes.

National

Several national policies, strategies, plans and laws are relevant to the scope of the present report.

The Commonwealth Department of Agriculture, Water and Environment is responsible for protecting and strengthening Australia's agriculture, water resources, environment and heritage. The relevant ministers administer various national laws, including the *Environment Protection and Biodiversity Conservation Act 1999* .[84] This is Australia's most important piece of environmental legislation and covers environment and heritage protection and biodiversity conservation. Actions that will lead to changes in land use or land management in any state or territory may be subject to its provisions.

The Environment Protection and Biodiversity Conservation Act protects nine 'matters of national environmental significance', including:

- listed threatened species and communities
- listed migratory species
- Ramsar wetlands of international importance
- world heritage properties
- national heritage places.

The National Climate Resilience and Adaptation Strategy 2015[85] follows on from the National Climate Change Adaptation Framework agreed to by the Commonwealth, state and territory governments in 2007. The strategy has as its vision: 'We act together to support prosperity and wellbeing in Australia and beyond by building the resilience of communities, the economy and the environment to a variable and changing climate'.[86] Its four priorities for national engagement are 'Understand and communicate', 'Plan and act', 'Check and reassess' and 'Collaborate and learn'.

Various standards, guidelines and strategies have been developed to mitigate risks associated with shipping and ports. The International Convention for the Control and Management of Ships' Ballast Water and Sediment places obligations on vessels to manage ballast water to reduce the translocation of invasive marine species.[87] Australian commercial shipping standards assist in maintaining vessel safety, thus minimising the risk of potential accidents, such as oil spills.[88] The *Biosecurity Act 2015* (Cth) deals with ballast water and marine pests.[89] The Australian Ballast Water Management Requirements set out the obligations on vessel operators for the management of ballast water and ballast tank sediment when operating in Australian seas.[90]

National guidelines deal with problems such as biofouling (Anti-Fouling and In-water Cleaning Guidelines 2015).[91] To minimise the risks associated with marine pests, the Commonwealth Government, in conjunction with state and territory governments, industry, research organisations and non-government organisations, has released *MarinePestPlan 2018–2023*.[92] The five objectives of the plan are to:

- minimise the risk of marine pest introductions, establishment and spread
- strengthen the national marine pest surveillance system
- enhance Australia's preparedness and response capability for marine pest introductions
- support marine pest biosecurity research and development
- engage stakeholders to better manage marine pest biosecurity.

84. Commonwealth of Australia, *Environment Protection and Biodiversity Conservation Act 1999*, https://www.legislation.gov.au/Series/C2004A00485 Accessed 23 September 2021.
85. Commonwealth of Australia 2015, 'National climate resilience and adaptation strategy', https://www.environment.gov.au/climate-change/adaptation/strategy Accessed 23 September 2021.
86. Ibid.
87. International Maritime Organisation 2004, 'International convention for the control and management of ships' ballast water and sediments. Adoption: 13 February 2004; Entry into force: 8 September 2017' https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Control-and-Management-of-Ships%27-Ballast-Water-and-Sediments-(BWM).aspx Accessed 6 July 2021.
88. Australian Maritime Safety Authority 2021, 'National standard for commercial vessels (NSCV)', Australian Government, Canberra https://www.amsa.gov.au/about/regulations-and-standards/national-standard-commercial-vessels-nscv Accessed 1 July 2021.
89. Commonwealth of Australia 2020, *Biosecurity Act 2015*, no. 61, compilation no. 8 incorporating amendments up to 25 March 2020 https://www.legislation.gov.au/Details/C2020C00127 Accessed 6 July 2021.
90. Department of Agriculture, Water and the Environment 2020, 'Australian ballast water management requirements: Version 8', Australian Government, Canberra.
91. Department of Agriculture, Department of Environment 2015, 'Anti-fouling and in-water cleaning guidelines', Australian Government, Canberra. https://www.agriculture.gov.au/sites/default/files/documents/australian-ballast-water-management-requirements.pdf.
92. Department of Agriculture and Water Resources 2018, 'MarinePestPlan 2018–2023: The national strategic plan for marine pest biosecurity', Australian Government, Canberra, https://www.marinepests.gov.au/what-we-do/publications/marine-pest-plan Accessed 18 November 2021.

National Light Pollution Guidelines for Wildlife were published by the Commonwealth Government in January 2020.[93] In the introduction to these guidelines, natural darkness was described as providing a conservation value in the same way that clean water, air and soil have intrinsic value.

Victorian

Several Victorian Government agencies and organisations are part of the collaborative governance arrangements that influence biodiversity conservation and bushfire management and recovery. They interact with a diverse and complex set of policies, laws, regulations, strategies, plans and monitoring frameworks.

On 1 August 2018 the Marine and Coastal Act 2018 (the Act) came into effect, with the aim of protecting Victoria's marine and coastal environment now and into the future. The Act outlines the following objectives for the planning and management of the marine and coastal environment in Victoria:

- to protect and enhance the marine and coastal environment
- to promote the resilience of marine and coastal ecosystems, communities and assets to climate change
- to respect natural processes in planning for and managing current and future risks to people and assets from coastal hazards and climate change
- to acknowledge Traditional Owner groups' knowledge, rights and aspirations for land and sea Country
- to promote a diversity of experience in the marine and coastal environment
- to promote the ecologically sustainable use and development of the marine and coastal environment and its resources in appropriate areas
- to improve community, user group and industry stewardship and understanding of the marine and coastal environment
- to engage with specified Aboriginal parties, the community, user groups and industry in marine and coastal planning, management and protection
- to build scientific understanding of the marine and coastal environment.

The Act is complemented by Victoria's Marine and Coastal Reforms Final Transition Plan, which lists 45 actions to be taken between 2018 and 2022. Making a statewide marine and coastal policy, which includes a marine spatial planning framework, and also making a statewide marine and coastal strategy, are some of the Transition Plan's most important actions.

The Act requires the Minister to make a marine and coastal policy that:

- sets out policies for planning and managing the marine and coastal environment
- provides guidance to decision-makers in delivering the objectives of the Act
- includes a Marine Spatial Planning Framework to set out steps for achieving integrated and coordinated planning and management of Victoria's marine environment.

The Victorian Government, with guidance from the Victorian Marine and Coastal Council, developed a statewide Marine and Coastal Policy, which was released in March 2020.[94] An important focus of the policy is to manage the health of the marine and coastal environment so that ecosystems, communities and built assets are as resilient as they can be in the face of future change. Change could be from natural hazards, climate change, population growth or, most likely, a combination of these factors. The policy states that a healthy marine and coastal environment will promote resilience for industries and communities that rely on its resources from a liveability and economic perspective.

The Act requires the relevant Victorian Government minister to make a marine and coastal strategy within 12 months of formulating the marine and coastal policy. A draft strategy was released in July 2021, containing six actions:

- Traditional Owners determine how their rights and obligations are embedded into planning and management of the marine and coastal environment.

93. Australian Government Department of the Environment and Energy, and Western Australian Department of Biodiversity, Conservation and Attractions 2020, 'National light pollution guidelines for wildlife: Including marine turtles, seabirds and migratory shorebirds', Commonwealth of Australia. https://www.environment.gov.au/system/files/resources/2eb379de-931b-4547-8bcc-f96c73065f54/files/national-light-pollution-guidelines-wildlife.pdf.
94. Department of Environment, Land Water and Planning (DELWP) 2020, 'Marine and coastal policy', East Melbourne, Victoria. https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0027/456534/Marine-and-Coastal-Policy_Full.pdf

- Improve the condition and connectivity of habitats and respect and care for our marine and coastal areas.
- Support sustainable use and development of the marine and coastal environment.
- Adapt to impacts of climate change.
- Implement integrated planning of the marine environment.
- Identifying resource needs and funding for sustainable marine and coastal management.[95]

The Marine and Coastal Act 2018 (the Act) requires the development of a statewide marine and coastal policy that must include a Marine Spatial Planning Framework which 'establishes a process for achieving integrated and coordinated planning and management of the marine environment'. The Marine Spatial Planning Framework provides an overarching guide for planning, management and decision-making by marine sectors.

A Marine and Coastal Council (effective 1 August 2018) has been tasked with providing independent advice to the government on a range of matters including:

- the development and implementation of statewide policy and strategy (and other plans developed under the Act)
- significant decisions relating to the marine and coastal environment
- matters requiring scientific research.

Environmental Management Plans (EMPs) can be developed under the Marine and Coastal 2018 Act at the discretion of the Minister. Currently there is only one EMP implemented in Victoria. The Act requires an EMP for Port Phillip Bay and five-yearly evaluation. This plan, and any developed in the future for other marine and coastal ecosystems, will align government, industry and community groups on actions to manage future challenges resulting from population growth, urbanisation, and climate change. The monitoring, evaluation, reporting and improvement mechanisms associated with developing and implementing EMPs will be used to inform future State of the Marine and Coastal Environment Reports.

In July 2021, the Environment Protection Act 2017 (Vic) came into effect. It incorporated findings from the Victorian 2016 Inquiry into the EPA.[96] This Act's subordinate legislation includes Environment Protection Regulations and the ERS.[97] The ERS is a new tool which identifies environmental values that Victorians want to achieve and maintain, and enables assessment of those values across Victoria.[98]

Victoria's Climate Change Strategy, released in 2021, is a roadmap to net-zero greenhouse gas emissions and a climate-resilient Victoria by 2050. The initiatives in the Climate Change Strategy will support communities and businesses as they make the changes needed to reduce the effects of climate change and continue to support our economy to grow.[99]

The Invasive Plants and Animals Policy Framework presents the overarching Victorian Government approach to the management of existing and potential invasive species. It incorporates a biosecurity approach and ensures that Victoria maintains a comprehensive planning framework to guide future policy, planning and community activity specific to invasive species. The document sets out a vision for what invasive species management can achieve for Victoria, and a framework for working towards that vision. Response to invasive pests is also part of the State Emergency Management Plan Biosecurity Sub-plan. This describes the integrated approach and shared responsibility between state and Commonwealth governments, agencies, business and the community in responding to biosecurity emergencies, which may be new incursions of invasive plants or animals, or rapid population increases in established pests.[100] Cooperation and coordination between agencies can improve emergency preparedness, including the development and regular review of agreed emergency response arrangements, and ensuring adequate training and capacity.

95. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Draft marine and coastal strategy', Victoria State Government, p. 3 https://engage.vic.gov.au/draft-marine-and-coastal-strategy Accessed 24 September 2021.
96. Environmental Protection Authority Victoria 2021, 'New laws to better protect the environment' https://www.epa.vic.gov.au/about-epa/laws/new-laws Accessed 2 August 2021.
97. Environmental Protection Authority Victoria 2021, 'Subordinate legislation tools to support the new Act' https://www.epa.vic.gov.au/about-epa/laws/new-laws/subordinate-legislation Accessed 2 August 2021.
98. Environmental Protection Authority Victoria 2021, 'The Environment Reference Standard: About the Environment Reference Standard' https://www.epa.vic.gov.au/about-epa/laws/epa-tools-and-powers/environment-reference-standard Accessed 2 August 2021.
99. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Victoria's climate change strategy' https://www.climatechange.vic.gov.au/victorias-climate-change-strategy Accessed 26 May 2021.
100. Emergency Management Victoria 2018, 'State Emergency Response Plan. Biosecurity Sub-Plan', Edition 1.1, p. 11. Note that the State Emergency Response Plan (SERP) has been superseded by the State Emergency Management Plan (SEMP), which incorporates existing sub-plans from the SERP.

Table 2: Victorian legislation and policies relevant to the SMCE 2021 Report.

Theme	Legislation and policies
Water quality and catchment inputs	Environmental Protection Act 2017 Water Act 1989 Melbourne Water 2018, Healthy Waterways Strategy 2018–2028 Port Phillip Bay Environmental Management Plan 2017–2027 Coastcare Victoria Strategy 2020–2025 State Environment Protection Policy (Waters) 2018 State Environment Protection Policy (Waters) Environmental Reference Standards 2021
Litter and pollution	Environmental Protection Act 2017 Environment Protection Regulations 2021 Melbourne Water 2018, Healthy Waterways Strategy 2018–2028 Coastcare Victoria Strategy 2020–2025
Biodiversity	Fisheries Act 1995 Victorian Fisheries Regulations 2009 Environmental Protection Act 2017 Environmental Reference Standards Flora and Fauna Guarantee Act 1988 Port Phillip Bay Environmental Management Plan 2017–2027 Biodiversity 2037 Coastcare Victoria Strategy 2020–2025 Parks Victoria Act 2018, Marine National Parks and Marine Sanctuaries, Marine and Coastal Parks, Marine Parks, Marine Reserves and Managing Country Together
Seafloor integrity and health	Land Act 1958 Biodiversity 2037
Pests and invasive species	Catchment and Land Protection Act 1994 Flora and Fauna Guarantee Act 1988 National Parks Act 1975 Fisheries Act 1995 Sustainable Forests (Timber) Act 2004 State Emergency Management Plan Biosecurity Sub-plan Invasive Plants and Animals Policy Framework

Table 2: Victorian legislation and policies relevant to the SMCE 2021 Report.

Theme	Legislation and policies
Climate and climate change impact	Climate Change Act 2017 Victoria's Climate Change Strategy 2021 Victoria's Draft 30-Year Infrastructure Strategy 2020 Siting and Design Guidelines for Structures on the Victorian Coast, May 2020
Managing coastal hazards and risks	Climate Change Act 2017 Victoria's Climate Change Strategy 2021 Emergency Management Act 2013
Communities	Marine and Coastal Act 2018 Marine and Coastal Policy 2020 Draft Marine and Coastal Strategy 2021 Victoria's Climate Change Strategy 2021 Great Ocean Road and Environs Protection Act 2020 Victorian Planning and Environment Act 1987 Victorian Planning Provisions Planning and Environment Amendment (Distinctive Areas and Landscapes) Act 2018 Aboriginal Heritage Act 2006 Heritage Act 2017 Heritage (Underwater Cultural Heritage) Regulations 2017 Port Management Act 1995 State Emergency Management Plan Biosecurity Sub-plan Fisheries Act 1995 Environmental Protection Act 2017 Siting and Design Guidelines for Structures on the Victorian Coast May 2020
Stewardship and collaborative management	Environmental Protection Act 2017 Catchment and Land Protection Act 1994 Crown Land Reserves Act 1978 Coastal Waters (State Title) Act 1980 Marine and Coastal Act 2018 Marine and Coastal Policy 2020 Draft Marine and Coastal Strategy 2021 Coastcare Victoria Strategy 2020–2025

Part 2A
Spatial analysis

Commissioner *for* Environmental Sustainability Victoria

Spatial analysis

This section[101] focuses on spatial information technology and data coordination for state of the environment reporting. Spatial technologies are divided into eight categories for this analysis, with five categories representing data collection types and three defined as data technologies (Table 3). The opportunities and potential for spatial information technologies are supported by the analysis in Appendix A. This analysis considers in detail each technology's potential to improve marine and coastal reporting now, in the immediate future and in the longer term.

Table 3: Spatial technology and data maturity assessment.

		Current	Emerging	Future
DATA COLLECTIONN TYPES	**Earth observation (EO) and remote sensing**	Satellite passive and active sensors Aerial imagery Airborne light detection and ranging (LiDAR) Mobile LiDAR Ship sonar Video	SmallSats (small spacecraft) and CubeSats (a class of nanosatellite) High-altitude pseudo satellites (HAPS) Analysis-ready data (ARD) Configurable payloads Satellite-as-a-service e.g., Exodus Orbitals Ground-station-as-a-service e.g., Amazon GroundStation or Azure Orbital	Real-time EO Persistent EO HD video from space Sensor miniaturisation and integration New sensors e.g. ultraspectral Space-based edge computing Satellite on board processing
	Smart sensors and the Internet of Things (IoT)	QR Codes, barcodes and radio frequency identification devices Smartphones Telemetry systems Sensor meters and probes Data loggers Smart meters DNA sensors	Real-time 5G mobile IoT Edge computing Explosion of IoT devices Intelligent sensor networks IoT analytics Digital twins Smart cities Mobile phone LiDAR Low Earth orbit communication e.g. SpaceX's Starlink	Smart cars Smart houses Intelligent mobility The Internet of Animals (IoA)
	Remotely piloted vehicle systems	Fixed-wing, single-rotor and multi-rotor Blimps, balloons and kites Boats, submersibles and underwater gliders Optical camera and video payloads Thermal camera payloads Multispectral or hyperspectral camera payloads	Hybrid platforms LiDAR payloads Specialised payloads Obstacle detection and collision avoidance Open real-time kinematic and satellite-based augmentation systems for aviation Automated RPV for sonar seafloor capture	Solar RPV Self-driving autonomous RPV Smart RPV (capture, analyse and act) Smart sensor payloads Onboard optimisation of big data processing
	Global positioning system (GPS) and tracking	Data loggers and passive tracking Data pushers and active tracking Data pullers and transponders Free, open centimetre-level accurate positioning	Integrating IoT connectivity Geofencing Device miniaturisation Precise indoor positioning Release timers Satellite-based augmentation systems and real-time kinematic accurate Global navigation satellite systems (GNSS) and inertial measurement unit (GNSS+IMU) sensor fusion Dead-reckoning techniques	Improved battery life for multi-year lifespan tracking The Internet of (tracked) Animals Precise smartphone GNSS Ubiquitous, low-cost, high-accuracy devices
	Citizen science	Traditional citizen science projects Citizen Science platforms Crowdsourcing Real-time data streams for planning and mapping e.g., Google traffic	New technologies for data collection Citizen science in policymaking Gamification Virtual peers (bots) Machine Learning for citizen science data	Citizen sensing
DATA TECHNOLOGY	**Artificial intelligence (AI) and machine learning**	Predictive analysis Decision support systems Optimisation ML	Artificial Intelligence AI Deep learning Automated feature extraction Real-time predictions Imagery+synthetic aperture radar (Imagery+SAR) ML super sampling	Natural language processing Generative adversarial networks AI robotics & and Artificial Intelligence of Things Event detection from ML (+SAR) Space-based ML and AI
	Big data and analytics including a geographic information system (GIS) mapping	Local storage and computing Distributed processing Data mining Predictive analysis Visualisation GIS analysis for experts Scripting and visual modelling	Cloud storage and computing Hybrid storage (local and cloud) Multi-cloud environments such as BigQuery Open Data Cube Cloud-based supercomputer capability	Space-based edge computing Quantum computing Fast data Actionable data Intelligent modelling (eGIS for non-experts) Self-organising big data optimisation
	Simulation and modelling	Environmental modelling Species predictive modelling (ARI) Atmospheric modelling	Thematic digital twin Environmental modelling + simulation and warning Simulated populations	Ocean avatar Real-time monitoring Understanding blue carbon fluxes

101. The content in this section (and Appendix A) has been adapted from analysis provided by FrontierSI 2021.

There is overlap between categories for two primary reasons: (i) data collection types must be paired with a data technology to process and analyse acquired data, and (ii) the rise of integrated technologies. For example, citizen scientists may use remotely piloted vehicles to capture earth observation data which are then processed by machine learning algorithms to extract useful information.

The following analysis describes the opportunity to apply these technologies to future SMCE reports.

Earth observation and remote sensing

Earth observation (EO) involves acquiring information about the Earth's surface using remote sensing. This began with capturing aerial photographs from a balloon in the 1850s, only two decades after photography was invented. Today there are many types of sensors categorised as passive or active. Passive sensors do not emit radiation, but typically use the sun as the energy source, including multispectral, hyperspectral and microwave radiometry sensors. Active sensors provide their own energy source and include light detection and ranging (LiDAR), synthetic aperture radar (SAR) and radar altimetry sensors. There are also different platforms for these sensors including remotely piloted aircraft (drones), aeroplanes, satellites and ships.

In recent years, satellites have become smaller, promoting reduced build and launch costs, and resulting in the emergence of SmallSats and CubeSats and an exponential increase in space satellites. A focus on improving spatial resolution and obtaining better coverage and faster revisit time aims to provide near real-time, persistent EO monitoring accessible to everyone. With an abundance of satellites in orbit, the collaborative economy is being applied to this industry with satellite-as-a-service, for shared access to single-host, multi-tenant platforms through pay-as-you-go services. EO providers are likely to evolve from data to intelligent information provision. The future of EO will include new sensor types such as greenhouse gas emissions detection, sensor miniaturisation and integration, space-based computing to produce analysis-ready data in space, and real-time persistent monitoring.

See Appendix A for an analysis of EO and remote sensing applications for marine and coastal science.

Smart sensors and the Internet of Things

The Internet of Things (IoT) is a network of interconnected physical objects or things embedded with sensors and software that can collect and transfer data over the internet. Physical objects can be anything from computing devices (e.g. phones), machines (e.g. vehicles), infrastructure (e.g. light poles) to animals or people. IoT helps people live and work smarter by offering smart devices to automate processes and access information from anywhere. Common types of sensors used in IoT include temperature, humidity, pressure, water level, proximity, infrared and optical sensors. Communications technologies for transmitting the data collected by sensors have matured into commercially available solutions over the last few years, including globally standardised low-power wide-area networks such as LoRaWAN and narrowband IoT (NB-IoT).

Although low-power wide-area networks are on the rise, often they do not support remote areas and this is where emerging low Earth orbit communication satellite networks such as SpaceX's Starlink come into play. Other emerging technologies in this area are 5G mobile, which enables real-time IoT, and edge computing, which performs analysis at or close to the location at which data are captured, to improve response times and save bandwidth. The future of IoT will see the development of smart industries and areas such as smart healthcare, smart cities, and the Internet of Animals.

See Appendix A for an analysis of smart sensors and the Internet of Things applications for marine and coastal science.

Remotely piloted vehicle systems

Remotely piloted vehicles (RPVs) were originally used in the military for combat and surveillance, with aerial systems becoming popular as recreational products from 2013. Subsequently, as systems advanced, the commercial use of drones began. The Civil Aviation Safety Authority has regulations for flying aerial RPVs. Consumers can use off-the-shelf RPVs (under 25 kg) for sport and recreation if they follow the safety rules. Two specific regulations limiting enterprise adoption in Australia are that pilots must always keep their RPV in visual line of sight and that operator accreditation or a remote pilot licence is required, depending on the RPV's size.

RPVs are commonly regarded as autonomous aerial vehicles, but there are also water-based RPVs such as boats and submersibles which operate without a human occupant. Different types of RPV platforms are available, including fixed-wing, single-rotor, multi-rotor and hybrid systems. Apart from typical RPV platforms, blimps, balloons and kites are increasingly used for continuous monitoring applications.

Payload refers to an RPV's carrying capacity and the equipment it conveys. Sensor payloads include:

- optical cameras which capture visible light
- thermal cameras to detect heat
- multispectral or hyperspectral cameras which capture visible light, heat and ultraviolet light (hyperspectral cameras able to do so with many more bands of data)
- other specialised instruments such as particle sensors and magnetometers.

Payloads can also be deliveries or collections such as water or soil samples. LiDAR and specialised sensor payloads are starting to emerge as they become small and light enough for an RPV to carry. Depth-sensing cameras that help drones identify objects and avoid collisions have also been a recent development focus. In the future, RPVs will become solar powered, self-driving (rather than remotely piloted) and smart, as they will capture data, perform onboard processing and then act based on the data analysis.

See Appendix A for an analysis of RPV systems applications for marine and coastal science.

Global positioning system and tracking

Global positioning system (GPS) tracking monitors an object's (e.g. car, person, animal or equipment) exact location using GPS or broader global navigation satellite system (GNSS) satellites and tracking devices. There are three main types of GPS trackers:

1. Data loggers or passive trackers simply log the position of the device at regular intervals to their internal memory, which is then downloaded.
2. Data pushers or active trackers are the most common type and push or send their location at regular intervals to a server.
3. Data pullers or transponders are always on and can be queried to acquire the location data as often as required.

Emerging technology in this area includes device miniaturisation, the integration of IoT connectivity, improvements in positioning techniques such as satellite-based augmentation systems and real-time kinematic accuracy, GNSS and IMU sensor fusion and dead-reckoning techniques (calculating position when the GNSS signal is lost). The future of GPS and tracking will see ubiquitous, low-cost, high-accuracy devices with improved battery life to enable multi-year lifespan tracking and contribution to the IoT and IoA.

See Appendix A for an analysis of GPS and tracking applications for marine and coastal science.

Citizen science

Citizen science is scientific research conducted, in whole or in part, by amateur or non-professional scientists which aims to increase scientific knowledge. There are many types of citizen science projects, including bird counts, frog watches and post-bushfire animal monitoring schemes, for marine and terrestrial plants and animals. While citizen science is not new, it has become popular globally over recent decades and is increasingly common and technology enabled. This is due to extended human life spans resulting in more retirees applying their scientific skills and knowledge; scientists and governments recognising the benefits of volunteer engagement; and technological advancement including the proliferation of smartphones which has expedited data collection by citizen scientists. There are now many citizen science platforms available for the community to source projects and activities and contribute data (e.g. the Atlas of Living Australia and iNaturalistAU). Emerging technologies in this field include more accurate positioning for smartphones, contribution to policymaking, and machine learning (ML) for citizen science data. The future of citizen science will be citizen sensing, which will see people using low-cost or self-built sensors to collect data on issues they care about to empower themselves.

See Appendix A for an analysis of citizen science applications for marine and coastal science.

Artificial intelligence and machine learning

Artificial intelligence (AI) is a technique which enable machines, via computer programs, to mimic human behaviour. Machine learning (ML) is a subset of AI which uses statistical methods (or algorithms) in computer programs, allowing machines to improve through iteration and data use. ML facilitates spatial dataset creation via automated feature extraction, that often cannot be created any other way and uses datasets that cannot be leveraged with traditional methods. Although most of an ML process (70–80%) can be automated, considerable upfront investment is needed to produce training data, train an algorithm, review the outputs and perform any manual corrections required.

AI and ML are new and emerging fields along with deep learning, a specific ML approach that makes the computation of multi-layer neural networks feasible. These concepts extend the existing approaches of predictive analysis, decision support and optimisation. The future of AI and ML will see improvements in natural language processing, such as digitising archived documents and generative adversarial networks. These are ML models that allow two neural networks to compete to become more predictively accurate, by creating new data instances resembling existing training data. There will also be AI robotics, Artificial Intelligence of Things, AI and ML on board satellite platforms.

See Appendix A for an analysis of artificial intelligence and machine learning applications for marine and coastal science.

Big data and analytics (including a geographic information system)

As big data comprises EO, remote sensing and IoT data, and analytics includes AI and ML, there is significant overlap between this category and earlier categories. Big data are defined by the three Vs of volume, velocity and variety. So big data are larger (measured in terabytes to zettabytes), faster (real-time or near real-time) and more complex, deriving from many different sources (structured, semi-structured (e.g. digital photo or email) and unstructured (e.g. Twitter stream or video)). Traditional data types are structured and fit in relational databases which can be processed and visualised with desktop GIS and stored locally.

Big data analytics uses advanced technology systems and mathematics on big data to uncover hidden patterns, correlations and other insights. There are four types of big data analytics: descriptive, diagnostic, predictive and prescriptive. The development of open-source frameworks, allowing a network of computers to solve problems, contributed to big data's growth by making it easier and cheaper to work with. The volume of big data is growing exponentially with the rise of IoT and ML and will increasingly be stored and processed in the cloud. Hybrid storage across local and cloud environments and multi-cloud storage environments are emerging, along with cloud-based supercomputer capability.

The future of big data and analytics will see space-based edge computing, quantum computing, fast data processed in real-time streams and actionable data analysed to provide value.

See Appendix A for an analysis of big data and analytics applications for marine and coastal science.

Simulation and modelling

Spatial modelling is a process of spatial analysis that uses mathematical rules and procedures to analyse and visualise spatial data. While modelling is the act of building a model, simulation is the process of using the model to study the behaviour of a system. The objective of spatial modelling and simulation is to study objects or phenomena that occur in the real world, for problem-solving and planning. For example, a flood model could be filled to different flood levels for risk assessment, or a species predictive model could be used to predict the distribution of a species over time for species management.

Models and simulations are an important way to study inaccessible systems, and to complement conventional scientific experiment and observation approaches. Emerging concepts in this area include thematic digital twins (e.g. building information models) and environmental modelling systems combined with simulation and advanced warning (e.g. to predict natural disasters). The future of simulation and modelling may include an ocean avatar (an entire ocean digital twin) and real-time monitoring feeds in simulated environments.

See Appendix A for an analysis of simulation and modelling applications for marine and coastal science.

Future opportunities

The opportunity for future SMCE reporting to adopt more spatial technologies is evident, and these opportunities will continue to increase. Prioritising them and developing an ongoing improvement process will establish Victoria as an authority on SMCE reporting and provide a reporting template that is efficient, effective and informative.

Part 3 of this SMCE 2021 Report relies on a plethora of diverse mapped and measured data to assess an indicator at a point in time. This complex and important activity builds on crucial data created by many different government departments and agencies and demonstrates the potential of data to be 'created once and used many times' adding significant value. This reliance on data from many stakeholders will only increase over time, as will the number of data sources. For SMCE reporting to be repeatable, CES needs assurance that the data will be maintained, interpreted, findable, accessible and interoperable into the future. Collaboration with data owners is essential to support the ongoing maintenance (and potential improvement) of data required for this process.

This report's analysis also finds that with emerging technologies, both the spatial resolution and temporal resolution of data will improve, and data volumes will increase. Over time, the role of SMCE reporting to synthesise these data into insights may become more technically complex, but the opportunity to create information that is better able to represent change over time, at more local levels is an exciting one. Many of the data collection types and technologies discussed above should not be used in isolation as they will be of more value through integrated approaches.

Part 2B
Applying international frameworks

Commissioner *for* Environmental Sustainability Victoria

Science for Sustainable Development (SDG) Framework

The Science for Sustainable Development (SDG) Framework embraces three levels of synthesis:

1. environmental condition reporting
2. assessing interlinkages across the SDG targets
3. tracking progress on selected SDG targets.

Part 3 of this report delivers the evidence base and scientific assessments for the environmental condition report. The following section is a formative method towards achieving our goal of assessing interlinkages and tracking progress against SDG targets in future reports.

Method objectives

Figure 10 is repeated from Part 1A (Figure 6). It represents the program logic (data for decision making) of the proposed Method. The data for the decision-making system described can be applied to any policy domain, but in Figure 10 it is applied to marine and coastal policy.

The logic is designed to deliver the Method's following objectives:

- Deliver a reporting regime that 'operationalises' the SDG framework by anticipating the whole system – representing all 17 goals – in its findings and recommendations.
- Improve our understanding of how elements of the system affect the whole – and how the system affects discrete elements.
- Assess policy coherence – acknowledging strengths and challenging incoherence.
- Provide data for decision-making in a clear and targeted way that anticipates management and policy options that improve coherence.

Figure 10: Data for decision making: applied to the SMCE 2021 Report.

The Method's first four phases will be considered in the following sections. A summary of each is provided below.

Summary of the Method's first four phases to operationalise the SDGs for state of the environment reporting:

Phase 1 Selection of relevant SDG targets proposes a list of SDG targets that are relevant to marine and coastal reporting in the SMCE 2021 Report. This section describes the selection process for a provisional subset of the 169 SDG targets relevant to SoE reporting in Victoria; from that list a marine and coastal subset of 40 is selected.

Phase 2 Evaluating comprehensiveness of indicators assigns indicators from the scientific assessments (Part 3) in the SMCE 2021 Report to the 40 SDG targets identified in Phase 1 of the Method. The assigned indicators were weighted because not all of the indicators that were mapped to a specific target were equally important in assessing that target; critical indicators were given a heavier weighting.

Phase 3 Localisation of the SDGs describes the steps undertaken to understand local priorities through an engagement process with local coastal and land managers and practitioners.

Phase 4 Reporting on SDG target assessments applies the Method to specific SDG targets that were identified in Phase 1 (i.e. those targets selected as being relevant to marine and coastal reporting in Victoria) and assessed in Phase 2 (i.e. those targets evaluated for comprehensiveness of indicators to report progress in a meaningful way). Reporting on the SDG targets in Phase 4 draws on the information and evidence base in Part 3 but with a focus on the system and the telling of interconnected stories to inform holistic policy interventions and management.

Phase 1 Selection of relevant SDG targets

To enable the application of the SDGs as an organising framework for the SoE 2023 report, a method to report on the connectivity and interlinkages of the SDG targets will be required. This method will also identify a subset of the 169 targets to be reported on in the SoE 2023.

Science for Sustainable Development Framework

Phase 1 proposes a list of 40 SDG targets that are relevant to marine and coastal reporting in the SMCE 2021 Report. Central to a method for adopting the SDGs as an operating framework for SoE reporting in Victoria is the selection of targets that are appropriate and relevant to track ecological sustainable development in Victoria.

Considering the need to 'ensure impartiality, openness, transparency and accountability'[102] in the Commissioner's work, it is critical that clear, authorised criteria are established to guide the determination of SDG target relevancy for Victoria. This is important across all scales – national, state (sub-national, in this section), to local (see Phase 3 Localisation of SDGs).

The legislative framework for selecting SDG targets

The Method adopted here animates the approach described by the Science for Sustainable Development Framework and grounds the criteria for SDG target selection in the CES Act, specifically the objectives for ecologically sustainable development (ESD) defined in the CES Act. The strength of anchoring the selection criteria in the ESD definition in the CES Act is that it provides a robust approach to the Method that will embed longevity and consistency to the Method as this work evolves for future reports.

Ecologically sustainable development objectives:

4.2(a) to enhance individual and community well-being and welfare by following a path of economic development that safeguards the welfare of future generations

4.2(b) to provide for equity within and between generations

4.2(c) to protect biological diversity and maintain essential ecological processes and life support systems.[103]

102. Victorian Government, *Commissioner for Environmental Sustainability Act 2003*, s 10,1 (d) https://www.ces.vic.gov.au/sites/default/files/publication-documents/CES%20Act%202003.pdf
103. Ibid., p. 4.

Through this process, an SDG target was 'selected' as aligned with state of environment reporting in Victoria if assessed as being aligned with all three ESD objectives.

Alignment with the SMCE 2021 Report

Further analysis then took place on the selected SDG targets to assess their relevance to marine and coastal reporting in Victoria.

This analysis aligned the SMCE 2021 Report's three objectives, as defined in the Marine and Coastal Act 2018 (Vic), with the subset of targets identified as aligned with SoE reporting.

These legislative objectives are the:

- condition of the marine and coastal environment
- environmental, social and economic benefits of the marine and coastal environment
- threats to the marine and coastal environment.[104]

Through this alignment exercise, 40 targets from the subset of 98 were found to be aligned with at least one marine and coastal objective (Appendix A).

This list of 40 selected targets for SMCE reporting will be the focus of future phases of the methodology: evaluating comprehensiveness (Phase 2 Evaluating comprehensiveness of indicators) and progress reporting on SDG target assessments (Phase 4 Reporting on SDG target assessments) below.

Phase 2 Evaluating comprehensiveness of indicators

Phase 2 assigned indicators from the scientific assessments (Part 3) in the SMCE 2021 Report to each of the 40 SDG targets identified in the marine and coastal subset.

However, assigning or mapping indicators is not sufficient; for even if extensive alignment is demonstrated, it does not necessarily prove that reporting on a specific target is comprehensive. It only identifies that there are many relevant SoE indicators for that specific target.

To address this, Phase 2 weighted the assigned indicators (i.e. critical indicators were given a heavier weighting).

Informed by the suite of marine and coastal indicators that comprise the scientific assessments (Part 3) in this report, a set of criteria were developed to assign indicators to the 40 selected SDG targets. The criteria were:

- Logical validity: the indicators are related to the main intention, focus or scope of the target.
- Statistical adequacy: the indicators selected represent valid and reliable measures.
- Policy relevance: all selected indicators assist decision-makers in formulating policy options.

Significantly, these criteria help select the indicators and evaluate the relative importance of each one in assessing the target, informing the 'weighting' of each indicator for undertaking the assessment (Appendix B).

Assessing comprehensiveness

This process, when conducted on all 40 SDG targets in the marine and coastal subset, also revealed potential gaps in the indicators, and corresponding data, to comprehensively assess that selected target.

Most notable is the need to ensure Traditional Owners' priorities are reflected in the synthesis and evaluation (refer to the Cultural Landscape Health and Management section in Part B).

The 40 selected SDG targets were aligned with the indicators that have been developed for the SMCE 2021 Report (Part 3). On only two occassions were SoE 2018 indicators (targets 2.5 and 15.6) considered to be more appropriate indicators.

A final point of caution is to note that while it is one thing to align indicators with the targets, and assess them for their comprehensiveness, this does not necessarily mean that the data quality and confidence for making assessments based on those indicators is good. In fact, it will often be quite varied. This issue is explored further in progress reporting on SDG target assessments (Phase 4).

104. Marine and Coastal Act 2018 (Vic) https://content.legislation.vic.gov.au/sites/default/files/2020-04/18-26aa003%20authorised.pdf.

Phase 3 Localisation of the SDGs

An ambition of the Science for Sustainable Development Framework is to track Victoria's progress against the selected SDG targets by prototyping and testing the veracity of using localised indicators that are meaningful at a state, regional, precinct or ecosystem scale.[105]

There are two parts to this work – understanding local priorities and determining the scalability of data. Understanding local priorities has been conducted through an engagement process with local coastal and land managers. In May 2021, the Commissioner for Environmental Sustainability (CES), in partnership with the Royal Society of Victoria, joined a workshop with local coastal and land managers from local government authorities, the Department of Environment, Land, Water and Planning (DELWP), catchment management authorities and other agencies, community groups and volunteers. The workshop brought together more than 70 participants to prioritise a subset of indicators from this report. The aim was to agree on a subset of indicators to which all stakeholders could contribute, and which could reasonably enable the participation and collection of data on priority issues, statewide, to help monitor and manage Victoria's coast.

Workshop participants prioritised SMCE indicators on the following criteria:

- indicators that represent issues of significant local importance
- indicators where local authorities, committees of management, and volunteers can make a difference to improve the result
- indicators requiring a response from more than one local agency, management authority, volunteer group or community group to make a difference and improve the result.

Formal partnerships between Traditional Owners and local authorities were included as a pre-prioritised indicator (see Cultural Landscape Health and Management in Part B). This was justified as an indicator because it was produced by the extensive catchment management authority engagement already done to develop the regional catchment strategies across Victoria. The workshop resulted in the addition of two biodiversity indicators: species of conservation concern (SMCE Indicator 19) and coastal invasive plants (SMCE Indicator 39).

105. Commissioner for Environmental Sustainability (CES) 2020, 'Framework for the Victorian State of the Environment (SoE) 2023 Report', p. 14, Melbourne, Victoria https://www.ces.vic.gov.au/sites/default/files/CESV_Framework%20Report%202023_FINAL_WEB_OCT.pdf

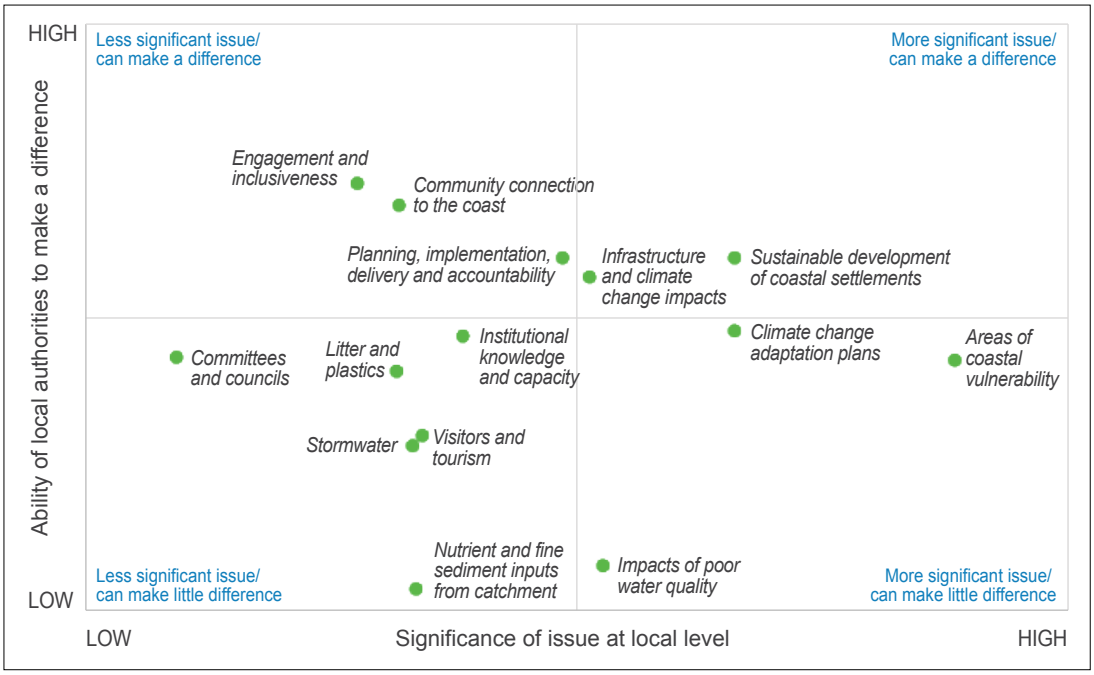


Figure 11: Feedback from stakeholder workshop on relative significance of indicators and ability to influence outcomes at the local level.

The ranking of the remaining indicators by workshop participants was based largely on criteria one and two (above): the significance of the issue represented by the indicator and the degree to which a difference can be made at the local level. While the results are subject to specific interpretation (qualitative responses were collected alongside numerical scoring), it is useful to consider some of the indicators in terms of a quadrant – between the local significance of the issue and the degree of difference that can be made at the local level (Figure 11).

Overall, areas of coastal vulnerability/climate change impacts (SMCE Indicators 45–51) proved to be the most important for those dealing with coastal areas. The consequences of sea-level rise and more frequent storm events are significant for the local coastal environment. Concerns raised by local land and coastal managers include loss of natural habitat and loss of physical infrastructure.

Several indicators relate to pollution, such as the effects of poor water quality, litter and plastics, nutrient and fine sediment inputs from a catchment, and stormwater. The disaggregated way in which these pollution indicators were presented made ranking difficult for some participants and it is likely that this diluted the results.

Participants raised pollution as an issue of concern, so a combined pollution and water quality indicator has been included: inputs from catchment impacting ecosystem health.

Climate change is seen as a significant issue for local authorities and practitioners and one for which they have a moderate ability to make a difference. This assessment of having some, but not a high level of influence in addressing the issue highlights the importance of partnerships between local authorities and other agencies or organisations and communities to improve the ability to address problems in a practical way at the local level.

It is important to note that data and information acquired by local authorities, Traditional Owners, citizen scientists and volunteers will be important, but a greater focus on local reporting must avoid placing a greater burden on these already under-resourced groups. Data from national organisations (ABS, CSIRO, BoM, Geoscience Australia) and state government (DELWP, Parks Victoria and EPA) will continue to be the primary information source. However, these official statistics, while robust, can often be limited in terms of disaggregation at the local scale. The role of local authorities and citizens to address data scalability is an area to be explored.

Eight uniform local indicators were determined as an outcome of a coastal and marine stakeholder workshop:

- formal partnerships between Traditional Owners and local authorities
- species of conservation concern
- invasive coastal plants
- areas of coastal vulnerability
- climate change adaptation plans
- sustainable development of coastal settlements
- climate change impacts on infrastructure
- inputs from catchment impacting ecosystem health.

Phase 4 Reporting on SDG target assessments

In this section, the Method is applied to specific SDG targets that were identified in Phase 1 (i.e. selected as relevant to marine and coastal reporting in Victoria) and assessed in Phase 2 (i.e. evaluated for comprehensiveness of indicators in Part 3 to report progress in a meaningful way).

The work presented in Phase 3 (localisation of the SDGs) is also important in Phase 4 as the prioritisation of issues by local coastal managers influenced the choice of SDG targets (issues) that the Method was applied to in this section (see criteria below).

The narratives for each of the six selected targets in this phase provide additional context for the future priorities proposed, often including practical examples and benefits to marine and coastal management and outcomes for specific priorities.

Future priority 1: Use spatial information and Earth observation to help identify and protect Victoria's marine assets.

Future priority 2: Update Victoria's Marine and Coastal Knowledge Framework to reflect the scientific assessments of this report.[106]

Future priority 3: Develop thresholds to improve future reporting.

Future priority 4: Ensure that the Victorian Government continues to implement existing policies and management plans to benefit the environment.

Future priority 5: Trial different models and ways to represent the complex interlinkages between selected SDG targets, to fully understand the interactions between Victoria's environment, community and economy.

These future priorities support a catchments-to-reefs approach.

Qualitative assessment of SDG Target interlinkages

A systems analysis to the assessments presented in Part 3 has been applied below for six selected SDG targets to help demonstrate the application of the SDGs to frame and contextualise future priorities:

SDG Target 12.4 – By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimise their adverse impacts on human health and the environment

SDG Target 13.2 – Integrate climate change measures into national policies, strategies and planning

SDG Target 14.1 – By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution

SDG Target 15.8 – By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems, and control or eradicate priority species

SDG Target 16.6 – Develop effective, accountable and transparent institutions at all levels

SDG Target 17.14 – Enhance policy coherence for sustainable development.

106. This priority supports the proposed activity of the Marine and Coastal Strategy to support evidence-based marine planning and management by updating Victoria's Marine and Coastal Knowledge Framework (including CoastKit).

The six SDG targets assessed in this section were selected from the 40 SDG targets (Appendix B) aligned with the objectives in the Marine and Coastal Act 2018 (Vic) in Phase 1, based on the following criteria:

- opportunity for storytelling
- data availability (based on comprehensiveness assessment in Phase 2)
- crossover between environmental and social sciences
- alignment with the uniform local indicators (identified in Phase 3)
- ensuring a diversity of SDG goals are represented.

SDG Target 12.4: Achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment.

Weighted SMCE indicators:

02. Toxicants (25%)

05. *Enterococci* bacteria (25%)

08. Total nutrient loads (25%)

09. Total fine sediment loads (25%)

Narrative outline:

- Chemical pollutants and other waste represent a significant threat to marine and coastal ecosystems.
- Management responses in Victoria aim to prevent chemicals and other waste from entering waterways and marine and coastal areas.
- Monitoring provides regular assessment of marine pollutants, although it mostly focuses on Port Phillip Bay and Western Port.
- There is an absence of public reporting available to determine how the nutrient and sediment loads (in Port Phillip Bay) are tracking in relation to the Victorian Government's load targets. Where information is available, the pollutant loads are not categorised by source.
- In Corner Inlet and Nooramunga, it is unclear whether any progress has been made to meeting Water Quality Improvement Plan (WQIP) 2013 targets. Only a limited number of the recommended annual activities in the WQIP 2013 have been reported, which has hindered the tracking of progress on target achievement.
- Although water quality is good at most locations monitored in the Gippsland Lakes catchment, the lower reaches of major rivers, as well as Lake Wellington and Lake Victoria, have only fair or poor water quality.

Link to future priorities

The analysis of this target supports the following future priorities:

Future priority 4: Ensure that the Victorian Government continues to implement existing policies and management plans to benefit the environment.

Future priority 5: Trial different models and ways to represent the complex interlinkages between selected SDG targets, to fully understand the interactions between Victoria's environment, community and economy.

The Port Phillip Bay Environmental Management Plan 2017–2027 and the Corner Inlet [and Nooramunga] Water Quality Improvement Plan (WQIP) 2013 are examples of environmental management authorities developing targets to monitor water quality results. However, no public reporting is available to determine how the nutrient and sediment loads are tracking in relation to the government's load targets.

Interim results from catchment modelling of nutrient and sediment loads from the Port Phillip Bay catchment supplied to the CES for this report suggest a stable trend in annual loads of nutrients and sediments over the period 2016–2019. This is included as part of a broader discussion in the total nutrient loads and total sediment loads indicators in Part 3.

The Port Phillip Bay Environmental Management Plan 2017–2027 includes a priority target that nutrient loads do not exceed current levels. The aim to keep nutrient loads at existing levels recognises that progress has already been made and must be maintained. The first environmental management plan for the bay was released in 2001 and included an objective to reduce the annual nitrogen load to the bay by 1,000 tonnes. The nitrogen load reduction of 1,000 tonnes was achieved through upgrades to the Western Treatment Plant and improved stormwater management in the catchments.

The 2019–20 Annual Report and 2020 Delivery Plan Update (which contributes to regular reporting on the Port Phillip Bay Environmental Management Plan 2017–2027) did not provide estimates of nutrient loads in relation to the specific strategy of 'ensuring nutrient and sediment loads do not exceed current levels and pollutant loads are reduced where practicable'.

Nearly halfway to the 2033 timeline for achieving the targets in the Corner Inlet (and Nooramunga) WQIP 2013, it is unclear if any progress has been made towards meeting those targets. As only a limited number of the recommended annual activities in the WQIP 2013 have been reported, this has hindered the tracking of progress on target achievements. Public reporting is required to aid management responses, engage stakeholders and help them to make a practical contribution. Pollutant loads need to be categorised by source to enable assessment and to track intervention efficacy.

SDG Target 13.2: Integrate climate change measures into national policies, strategies and planning

Weighted SMCE indicators:

45. Areas of coastal vulnerability (20%)
52. Considering climate change risks in land-use planning (20%)
53. Climate change adaptation plans (20%)
54. Nature-based adaptation (20%)
55. Emergency planning and preparedness (10%)
80. Institutional knowledge and capacity (10%)

Narrative outline:

- Addressing climate change requires institutions to have the appropriate skills and knowledge so that innovative solutions can be found for evolving problems.
- Preventative as well as responsive approaches will be necessary in dealing with climate change, highlighting the importance of both strategic planning and operational responsiveness and efficiency.
- There is a critical gap in available knowledge to inform climate change adaptation planning. The combination of the Port Phillip Bay Coastal Hazard Assessment and the proposed statewide hazard maps are expected to aid rigorous and robust reporting of coastal areas' vulnerability in future SMCE reports. It is essential that these resources are delivered on schedule.
- Protecting and restoring coastal blue carbon ecosystems, such as mangroves, tidal marshes and seagrasses, offers opportunities for carbon sequestration and mitigation of greenhouse gas emissions.
- Engagement with the community is a critical component of climate change preparedness which can involve engagement on scientific data and proposed planning responses as well as community involvement to monitor change through citizen science.
- While plans and strategies have been developed at state, regional and local levels, the degree of success in adapting to climate change is unclear and requires the development of effective assessment metrics.

Link to future priorities

The analysis of this target supports all five future priorities.

Protecting and restoring coastal blue carbon ecosystems, such as mangroves, tidal marshes and seagrasses, offers opportunities for carbon sequestration and mitigation of greenhouse gas emissions. A 2019 Australian study analysed the effects of land management practices on blue carbon stocks and greenhouse gas fluxes in coastal ecosystems.[107] Upgraded management of blue carbon ecosystems can also improve fisheries and increase coastal resilience to rising sea levels and storm surges. Further research published in 2019 found that saltmarshes, mangroves and seagrasses in Victoria capture approximately 2% of the carbon that it would be possible to capture by 2050 if coastal wetlands can naturally retreat. According to this research, removing levees now and allowing natural tidal exchange to occur would provide an additional 1.65 million tonnes of carbon sequestration, valued at $67 million using average carbon prices paid via the Australian Emission Reduction Fund when the research was completed in 2019.[108]

Research published in 2019 found that allowing coastal wetlands in Victoria to naturally retreat with sea-level rise could sequester 1.6 million tonnes of carbon by 2050 with a value of $65 million.

There are additional natural climate regulation opportunities, for example kelps can absorb an estimated 20 times more carbon dioxide per hectare than forests on land, supporting diverse marine plants and animals and helping to stabilise coasts by absorbing wave energy and dissipation through wrack (debris) on beaches. The benefits of intertidal marshes building coastal resilience to inundation and erosion can also be significant.

To support a future nature-based adaptation strategy, and maximise the opportunities of blue carbon ecosystems, a greater understanding of the threats to both those ecosystems and adjacent communities is required. This research emphasis should be incorporated into current planning for Victoria's Marine and Coastal Knowledge Framework.

DELWP and CSIRO are working together to complete a coastal hazard assessment for Port Phillip Bay. The findings of the hazard assessment have not yet been released. In July 2021, DELWP released a draft Marine and Coastal Strategy. Activity 4.4 in that strategy is to deliver statewide hazard maps that assist fit-for-purpose coastal hazard risk assessments in the period 2022–2024.

It is critical that this information is produced on schedule to make sure communities have the necessary information to be engaged and contribute to a nature-based adaptation strategy, avoiding the risk of planned top-down approaches that ignore the behavioural and social barriers that limit the effectiveness of adaptation actions.[109] Local consensus will be important – the inclusion of local knowledge and values and the development of metrics and thresholds for climate change adaptation monitoring and assessment that are meaningful at the local scale (Phase 3).

107. Carnell PE, Reeves SE, Nicholson E, Macreadie P, et al. 2019, 'Mapping ocean wealth Australia: The value of coastal wetlands to people and nature', The Nature Conservancy, Melbourne https://www.natureaustralia.org.au/content/dam/tnc/nature/en/documents/australia/MOW_Report_Web.pdf
108. Ibid.
109. Stafford Smith M, Horrocks L, Harvey L and Hamilton C 2011, 'Rethinking adaptation for a 4°C world', *Philosophical Transactions of the Royal Society* A, 369, pp. 196-216 https://royalsocietypublishing.org/doi/full/10.1098/rsta.2010.0277.

SDG Target 14.1: By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution

Weighted SMCE indicators:

05. *Enterococci* bacteria (25%)
06. Regulated point source discharges to marine waters (25%)
08. Total nutrient loads (25%)
10. Coastal acid sulfate soils (5%)
13. Coastal contaminated land (5%)
50. Frequency and impact of fire on marine and coastal ecosystems (15%)

Narrative outline:

- Maintaining high water quality is critical for environmental and human health.
- Sources of pollution have been identified.
- Pollution levels are measured and monitored with the aim of improving pollution management.
- Pollution is largely related to human activities and land use. However, quantitative microbial risk assessment and faecal source tracking show that most faecal contamination in Port Phillip Bay is from birds and dogs rather than human sources.
- There is only limited quantitative analysis available to understand the extent to which regulated discharges adversely affect receiving marine environments.

Link to future priorities

The analysis of this target supports the following future priorities:

Future priority 2: Update Victoria's Marine and Coastal Knowledge Framework to reflect the scientific assessments of this report.

Future priority 3: Develop thresholds to improve future reporting.

Future priority 4: Ensure that the Victorian Government continues to implement existing policies and management plans to benefit the environment.

Future priority 5: Trial different models and ways to represent the complex interlinkages between selected SDG targets, to fully understand the interactions between Victoria's environment, community and economy.

Quantitative microbial risk assessment and faecal source tracking show that most faecal contamination in Port Phillip Bay is from birds and dogs rather than human sources, which means evidence is emerging that the current long-term microbial standards in the Environment Reference Standard are likely to overestimate human health risks.

The EPA has completed a quantitative microbial risk assessment report showing there is a lower health risk than previously anticipated (Water Quality, Part 3). The EPA is working with its partners to better understand water quality and determine if site-specific standards can be developed for Port Phillip Bay beaches. Further research is needed to develop site-specific standards, which would more accurately estimate the risk of illness at specific beaches.

Currently, a quantitative indicator assessment is not viable, to look at data closely, to understand how much (or how little) the regulated discharges adversely affect receiving marine environments.

A need for readily accessible, reliable, national-scale data on Australia's domestic wastewater outfalls prompted the Commonwealth Government in 2015 to commission Clean Ocean Foundation (COF) to develop the National Outfall Database. Working collaboratively with all stakeholders and under the auspices of the National Environmental Science Program, COF has collected and analysed outfall data to produce the National Outfall Database for all of Australia's 186 coastal outfalls.

The indicator narrative in Part 3 is only able to comment on the volumes and nutrient loads discharged to marine waters from regulated point sources, which is comprehensively aggregated and reported by the COF as part of the National Outfall Database.

However, there is limited quantitative analysis available to understand the extent that regulated discharges adversely affect the receiving marine environments. EPA Victoria did not provide data and analysis for this report on the noncompliance of licensed facilities that discharge to marine environments, therefore the extent of noncompliance with licensed discharge limits is unknown.

These actions regarding microbial risk assessment and regulated discharges monitoring would contribute to a catchment-to-reefs focus to drive water quality management, thus improving water quality for Victoria's coastal communities and reducing adverse water quality effects in marine receiving environments, including our valuable marine protected areas (MPAs).

SDG Target 15.8: By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species

Weighted SMCE indicators:

38. Invasive marine species (25%)

39. Coastal invasive plants (25%)

40. Coastal invasive animals (25%)

55. Emergency planning and preparedness (25%)

Narrative outline:

- The effects of invasive species on marine and coastal ecosystems have been identified.
- Such species may be introduced through boating and shipping due to biofouling and ballast discharge.
- Regulation and education are in place to limit the risk of new species being introduced.
- Limits to coordination between pest management agencies lead to a lack of clarity on roles, responsibilities and data custodianship.

Link to future priorities

The analysis of this target supports the following future priorities:

Future priority 2: Update Victoria's Marine and Coastal Knowledge Framework to reflect the scientific assessments of this report.

Future priority 3: Develop thresholds to improve future reporting.

Future priority 4: Ensure that the Victorian Government continues to implement existing policies and management plans to benefit the environment.

Future priority 5: Trial different models and ways to represent the complex interlinkages between selected SDG targets, to fully understand the interactions between Victoria's environment, community and economy.

There is a need to assess resourcing to coordinate marine pest management across agencies. The critical gap is coordinating pest management once the pest becomes established in the state and is no longer an immediate biosecurity issue managed by the Department of Jobs, Precincts and Regions. Formally, DELWP becomes the lead agency in this circumstance but DELWP may not be resourced appropriately, and data are often very limited to support decision-making and interventions. Pest management resourcing and coordination need to respond to the full invasion curve, from prevention and preparedness through to on-ground asset-based management.

This is also true of overabundant native species, such as urchins, particularly outside MPAs where Parks Victoria is not the lead management agency.

In coastal areas, there is an opportunity for government and local management authorities to work closely with active and informed community groups to develop comprehensive, well-resourced control programs, designed to address invasive pest animals and plants on coastal public land and abutting private land (e.g., Marna Banggara (formerly Great Southern Ark) and Otway Eden).

Emerging changes to monitoring and reporting regimes need to be developed with an awareness of these management tensions. Biodiversity 2037 reform metrics such as 'Change in suitable habitat', along with the reform's Strategic Management Prospects, could improve pest management and act as cornerstones for future biodiversity reporting.

SDG Target 16.6: Develop effective, accountable and transparent institutions at all levels

Weighted SMCE indicators:

80. Institutional knowledge and capacity (30%)

81. Engagement and inclusiveness (30%)

82. Delivery and accountability (40%)

Narrative outline:

- Efficacy of institutions involved in environmental management is difficult to measure, but there are examples of management effectiveness evaluations being made.
- The Marine Spatial Planning Framework for Victoria sets out Victoria's approach to marine spatial planning. Framework implementation is being progressed through a statewide assessment to determine marine planning areas and identify priorities for more detailed marine spatial planning. Guidelines on how to conduct marine spatial planning in identified priority areas are also being prepared.
- Independent evaluations by parliamentary inquiries or the Victorian Auditor General can result in institutions involved in environmental protection being held accountable.
- Effective stakeholder engagement and the co-creation of policy improves transparency and decision-making processes for those institutions involved in environmental protection.

Link to future priorities

The analysis of this target supports the following future priorities:

Future priority 1: Use spatial information and Earth observation to help identify and protect Victoria's marine assets.

Future priority 4: Ensure that the Victorian Government continues to implement existing policies and management plans to benefit the environment.

Future priority 5: Trial different models and ways to represent the complex interlinkages between selected SDG targets, to fully understand the interactions between Victoria's environment, community and economy.

Victoria's Marine National Parks cover 5% of the state's marine waters and, except for a few reference sites outside the protected areas, no monitoring occurs beyond the parks' boundaries. As the 20th anniversary of the parks' establishment approaches (June 2022), it is an appropriate time to take stock and potentially apply lessons learned, for the future management of these sanctuaries.

The Marine Spatial Planning Framework for Victoria will consider how the marine environments' uses and activities are spatially organised. It aims to provide a structure for integrated management and, by identifying current or potential conflicts, can deliver an approach to manage these through policies, management interventions and governance arrangements. This framework sets out guidance and a process for achieving integrated and coordinated planning and management of the marine environment. A major difficulty for marine policy is that issues are often addressed on a sectoral or issue-specific basis. Fisheries, shipping, recreational fishing and boating, renewable energy and marine resources are some examples of policy focus. This limits capacity for a holistic view of the marine environment and its management. The Marine Spatial Planning Framework's intent is to support and provide a process for integrated planning and management across sectors.

The delivery of this framework presents an opportunity to demonstrate how spatial information can improve the proposed system of management effectiveness reporting for marine parks in Victoria. It is important that the framework establishes a foundation to:

- aid comprehensive and ongoing scientific monitoring, mapping and investigation of coastal and marine habitats and ecological processes
- conduct a statewide review to identify gaps in the marine national parks and sanctuaries network and to make recommendations for additions to ensure the network is comprehensive, adequate and representative, and meets international targets (5.2 in Marine and Coastal Policy).

The review could conduct or assist an assessment, to understand Victoria's capacity to increase (in area or number) no-take MPAs. This analysis would be timely considering the recent High Ambition Coalition for Nature and People's target to have 30% of the land and marine environment protected by 2030.

This proposal could also be a pilot leading to a broader approach to management effectiveness reporting of Victoria's natural assets – terrestrial, aquatic, coastal and marine.

SDG Target 17.14: Enhance policy coherence for sustainable development

Weighted SMCE indicators:

54. nature-based adaptation (25%)

55. emergency planning and preparedness (25%)

78. planning and implementation (25%)

80. Institutional knowledge and capacity (25%)

Narrative outline:

- Policy coherence can be defined as mutually reinforcing policy actions which lead to an agreed set of outcomes.
- Policy coherence can be conceptualised in terms of action across different policy sectors (horizontal coherence) as well as between different levels of government and the community (vertical coherence).
- There are difficulties to achieving policy coherence where policy and data are misaligned, preventing effective monitoring, assessment or improvement.
- Engagement with local stakeholders can improve policy coherence and policy results.

Link to future priorities

The analysis of this target supports the following future priorities:

Future priority 1: Use spatial information and Earth observation to help identify and protect Victoria's marine assets.

Future priority 4: Ensure that the Victorian Government continues to implement existing policies and management plans to benefit the environment.

Future priority 5: Trial different models and ways to represent the complex interlinkages between selected SDG targets, to fully understand the interactions between Victoria's environment, community and economy.

The challenges of achieving greater policy coherence for environmental sustainability are the increasing complexity of issues facing policy makers and the speed of change.

These dual challenges are inseparable, because complex issues (such as climate change) take time to analyse and address, yet require an urgent and immediate response as the speed of change is unpredictable but often fast (e.g. we know bushfires will be more frequent and severe, but we don't know exactly when and where such events will occur). The need to have effective (and up-to-date) operational responses at the same time as longer-term strategic responses is a problem for policy makers. This also highlights the difficulty of operating in dynamic and changing situations that may require new or innovative responses.

Data, information and knowledge management are at the core of this problem. There are constraints on our existing institutions and processes for gathering and sharing knowledge. In the face of a critical challenge like climate change, we may be collecting and analysing real-time data, but the processes embedded in our institutions may take time to absorb or respond to such data.

As the earlier section in Part 2 on spatial analysis asserted, there are many opportunities to improve decision-making through emerging technologies. However, changing technology also places pressure on the uptake of data in the policy cycle. New data sources and the vast amount of data that can now be captured creates their own problems. The opportunities that emerging spatial technologies provide need to be supported by a bureaucracy which reduces constraint on analytical capacity (i.e., a system that can adopt and employ new data in innovative and constructive ways). The risk of data incoherence is further raised by datasets having differences in terms of purpose, quality, temporal and spatial coverage. The sheer size of some datasets, such as satellite data, requires expertise in data handling, cleaning, and management, even before the data are interrogated for policy purposes.

There are two uses of data in policy delivery: first, it is important for monitoring to ascertain management effectiveness and to inform continuous improvement of policies, strategies and plans; second, it is important for inquiry – to learn more about emerging issues which may require policy responses. These two purposes might require very different data. In this sense, data needs are dynamic and are likely to change over time, which is problematic for time series analysis and can lead to fragmented or stranded datasets which are difficult to use for rigorous environmental reporting.

Future priorities

The SDG Framework 'is ambitious and commits the State of the Environment 2023 report to retrospective and prospective analyses'.[110]

However, this 'narrative' or qualitative approach is only one possible application. There are other (quantitative) models that could be trialled.

Predictive analysis

Predictive analysis will be an important component of this work, to assess the causal interlinkages for decision-making. A range of methods could be used for exploring these interlinkages – qualitative, semiquantitative (matrix/network analysis), quantitative (statistical correlation), and dynamic quantitative (modelling). In this context, it is acknowledged that the SDG targets are not all of one type. Some will inform scientific assessments of the SoE. Others are framed to assist decision-making and prioritisation in relation to environmental issues and systemic challenges and will be applied to directly inform recommendations.

Science for Sustainable Development Framework

Understanding the interlinkages between sustainable development management options leads to better decision-making. Funding of the research outlined below would support a comparative analysis of the multiple benefits and trade-offs inherent in sustainable development decision-making. It could also improve the evidence base, aid predictive analysis and lead to more targeted interventions, when combined with ongoing engagement with practitioners and local authorities about local priorities.

Broadly, there are two approaches to the methods of analysis – the quantitative and modelling approaches.

The quantitative approach aims to establish interlinkages between SDGs and targets by quantitative statistical analysis of the underlying indicators. Historical data are often employed in data mining exercises to understand covariation and correlation across goals and targets, but also across space and time. A quantitative approach would explore interlinkages across the SDGs at local, state and federal scales in Australia. Historical data would be used to explore interlinkages across the SDG system using machine learning approaches.[111]

The modelling approach is consistent with the intention to 'enable strategic, forward-looking analyses and interventions that can accelerate progress towards environmental outcomes'.[112] Allen et al. provide an overview of modelling approaches and their contribution to the SDGs' integrated assessment by reviewing 80 quantitative models that have the potential to support national SDG planning and implementation.[113] The authors assessed these models by applying 10 criteria in their analysis. The main criterion is the identification of a broad integrated systems-based approach, encompassing many SDGs and targets and their interlinkages.

Future priority 5 in this report is to trial different models and ways to represent the complex interlinkages between selected SDG targets, to fully understand the interactions between the environment, community and economy of Victoria.

Sourcing data for this interlinkage work will be difficult, but access to datasets outside the scope of traditional SoE reporting through initiatives such as Digital Twin Victoria will assist and continue to improve. The SDG modelling work proposed would provide the frame, logic and rationale for the innovative program logic presented in this report and, ultimately, enable predictive analysis.

110. Commissioner for Environmental Sustainability (CES) 2020, 'Framework for the Victorian State of the Environment (SoE) 2023 Report', p.17, Melbourne, Victoria https://www.ces.vic.gov.au/sites/default/files/CESV_Framework%20Report%202023_FINAL_WEB_OCT.pdf
111. Asadikia A, Rajabifard A, Kalantari M 2021, 'Systematic prioritisation of SDGs: machine learning approach' *World Development*, 140, 105269 https://doi.org/10.1016/j.worlddev.2020.105269.
112. Commissioner for Environmental Sustainability (CES) 2020, 'Framework for the Victorian State of the Environment (SoE) 2023 report', Melbourne, Victoria https://www.ces.vic.gov.au/sites/default/files/CESV_Framework%20Report%202023_FINAL_WEB_OCT.pdf
113. Allen C, Metternicht G, Weidmann T 2016, 'National pathways to the sustainable development goals (SDGs): A comparative review of scenario modelling tools', *Environmental Science and Policy*, 66, pp. 199–207 https://doi.org/10.1016/j.envsci.2016.09.008.

Environmental–economic accounting

In this report we have broadened the scope of the SMCE analysis required under the legislation, to include both environmental and socioeconomic indicators, and we have explored their interlinkages. Further research is required to fully realise the vision of the Science for Sustainable Development Framework, to:

1. show how the environment and natural capital underpin Victoria's social and economic wellbeing
2. identify trade-offs and areas of tension, and potential co-benefits
3. highlight potential opportunities for collaboration between management sectors in the SDG network (e.g., environment, health, infrastructure)
4. enable predictive analysis to assess the causal interlinkages of specific interventions and inform future recommendations.

The narrative approach adopted in this report is one of a range of methods to be trialled for assessing interlinkages but is limited to qualitative assessment. Semiquantitative (matrix/network analysis), quantitative (statistical correlation), and dynamic quantitative (modelling) approaches will require a targeted research project and an analysis of the applications across all SoE reporting themes.

In this way, the SoE 2023 can be both retrospective (extending the scientific baseline another five years) and prospective. It will measure Victoria's progress on the SDGs, identifying areas in which Victoria is lagging; exploring how economic, social and environmental targets interlink; and showing how recommendations help progress the ecologically sustainable development of Victoria.

Background to environmental–economic accounting in Victoria[114]

Environmental–economic accounting (EEA) gained momentum following the recommendations of the 1992 Rio 'Earth Summit',[115] which recognised the need for more holistic indicators of society's development beyond economic output (i.e. gross domestic product (GDP)) to include broader social and environmental indicators. The intention is to ensure economic and societal prosperity can be sustained into the future by recognising the status of the underlying stock of environmental assets on which the economy and society depend (acknowledging the costs of economy growth such as pollution and habitat loss). It specifically recommended that countries implement environmental–economic accounts at the earliest date.

In response, the United Nations Statistical Division (UNSD) published guidance on integrated environmental–economic accounting (in 1993, 2003, 2012 and 2021) and the latest (2021) version was adopted as the international standard for organising information on the environment and its contribution to economic and other human activity. The UN System of Environmental–Economic Accounting (SEEA) framework is consistent with the international standard of System of National Accounts (i.e. GDP) in order to report on the interactions between the economy and the environment at the national level, most often as 'satellite accounts' to national GDP accounts.

Governments around the world, including Australian Commonwealth, state and territory governments, have begun developing and implementing EEA to inform public policy development. The Commonwealth Government has the National Strategy and Action Plan for a common approach to EEA, which was endorsed by environment ministers in April 2018.

Ecosystem accounts are a type of EEA that take stock of current ecosystem assets – in terms of their extent, location and condition – and quantify and value the flow of ecosystem services that these assets generate for people, who enjoy benefits from them. Figure 12 sets out the ecosystem accounting framework.

114. The content in this section has been provided by DELWP.
115. The recommendations of the UN Conference on Environment and Development in Rio de Janeiro are set out in Agenda 21. This is a non-binding action plan of the United Nations on sustainable development https://sustainabledevelopment.un.org/content/documents/Agenda21.pdf Accessed 1 October 2021.

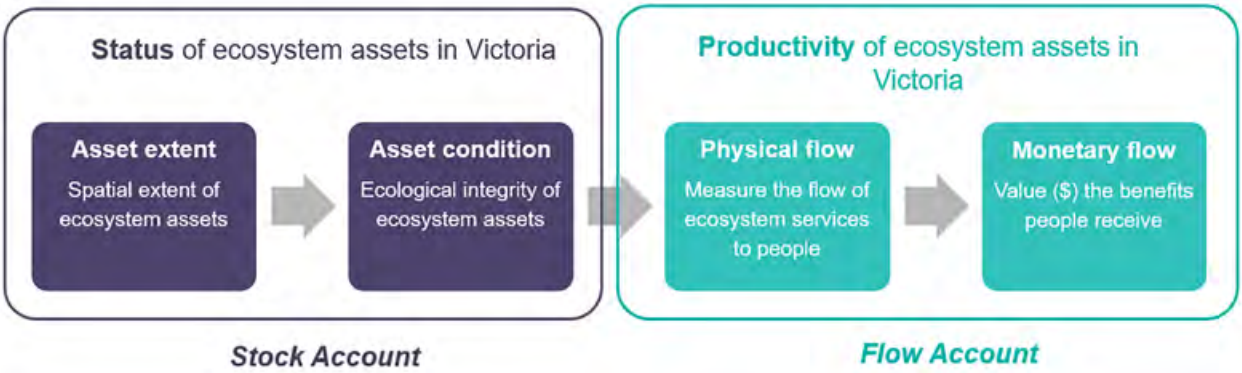


Figure 12: Ecosystem accounting framework.[116]

The interactions between the economy and the environment are reported on in ecosystem accounts by isolating the contribution of the environment to goods and services that are captured in conventional economic (GDP) accounts. However, the accounting framework also extends to include the broader (non-market or public good) values that are supported by the environment (and delivered by government), but which are not captured in GDP accounts. This broader framing of value provides decision-makers with an understanding of the total societal value provided by the natural environment, not just its contribution to supporting tourism, agriculture, fishing and forestry, for example.

Table 4 illustrates the potential structure of a comprehensive and mutually exclusive set of ecosystem accounts for a land area (e.g. an entire country, state or region) where the account reports information on the relationships between ecosystem asset status and productivity in terms of the range of ecosystem services produced (including both 'market' and 'non-market' benefits). Accounts do not necessarily need to cover all cells in this table – an indicative scope is presented for illustrative purposes, with dots representing the ecosystem asset–service relationships that might be considered for an assessment (the actual scope would depend on data availability, resourcing and timing, analytical capability and priorities, for instance).

116. Department of Environment, Land, Water and planning (DELWP) 2021, 'Environmental-economic accounting in Victoria: background to environmental-economic accounting in Victoria', summary for the office of the Commissioner for Environmental Sustainability, Melbourne, Victoria.
117. Ibid.

Table 4: Overview of ecosystem accounting structure.[117]

		Ecosystem assets								
		Alpine	Coastal margins	Farmland	Forest	Freshwater/ Wetland	Grassland	Heath/ Shrubland	Marine	Urban
Provisioning services	Biomass – biofuels	◊	◊	◊	◊	◊			◊	
	Biomass – timber	◊			◊					
	Biomass – food	◊	◊	◊	◊	◊			◊	◊
	Water provision	◊			◊	◊	◊	◊		◊
Regulating services	Air quality regulation	◊			◊		◊	◊		◊
	Coastal protection		◊			◊			◊	
	Flood risk regulation	◊	◊		◊	◊	◊	◊	◊	◊
	Global climate regulation	◊	◊	◊	◊	◊	◊	◊	◊	◊
	Landslide regulation	◊	◊		◊		◊	◊		
	Local climate regulation							◊	◊	◊
	Noise / smell regulation									◊
	Water quality regulation	◊			◊	◊	◊	◊		◊
Cultural servicesa	Aesthetics	◊	◊	◊	◊	◊	◊	◊	◊	◊
	Cultural heritage	◊	◊	◊	◊	◊	◊	◊	◊	◊
	Education and research	◊	◊	◊	◊	◊	◊	◊	◊	◊
	Existence / option value	◊	◊	◊	◊	◊	◊	◊	◊	◊
	Recreation and tourism	◊	◊	◊	◊	◊	◊	◊	◊	◊
	Social cohesion	◊	◊	◊	◊	◊	◊	◊	◊	◊
Bundle	Amenity (liveability)	◊	◊	◊	◊	◊	◊	◊	◊	◊

Ecosystem accounts consist of several linked subaccounts, developed as follows:

Ecosystem asset extent account: this account reports information on the extent (hectares) of environmental assets in the study area. The precise definition or classification of assets is based on an agreed systematic classification or typology of environmental assets (e.g., habitats) in Victoria and Australia from the relevant literature, and includes coastal margins, marine, freshwaters and wetlands, heathland or shrubland, urban, forests, alpine, grassland and farmland.

Ecosystem asset condition account: this account compiles information on a range of metrics which capture the ecological condition and socio-economic characteristics of ecosystem assets in the study area. The specific metrics reported will depend primarily on information availability. Consideration will be given to what is useful from a policy or management perspective, and scientific and economic understanding of the importance of that metric in determining the assets' capacity to support ecosystem services.

Physical account of ecosystem service flows: this account quantifies the physical provision of ecosystem services, over time, based on an agreed systematic classification or typology of ecosystem services from the literature (e.g. the common international classification of ecosystem services).[118] Examples of metrics (for different ecosystem services) include visit numbers (for recreation and tourism), tonnes of carbon sequestered (climate regulation) and kilograms of fish harvested (food provision).

Monetary account of ecosystem service flows: this account values the physical provision of different ecosystem services over time using different economic valuation techniques. For example, people's willingness to pay (a welfare value, based on non-market values) or resource rent based on actual market transactions (exchange values, based on the amount actually paid minus the cost of other (non-natural) capital assets).

Figure 13 and Figure 14 illustrate the type of information captured in the stock and flow accounts for a coastal and marine ecosystem account.

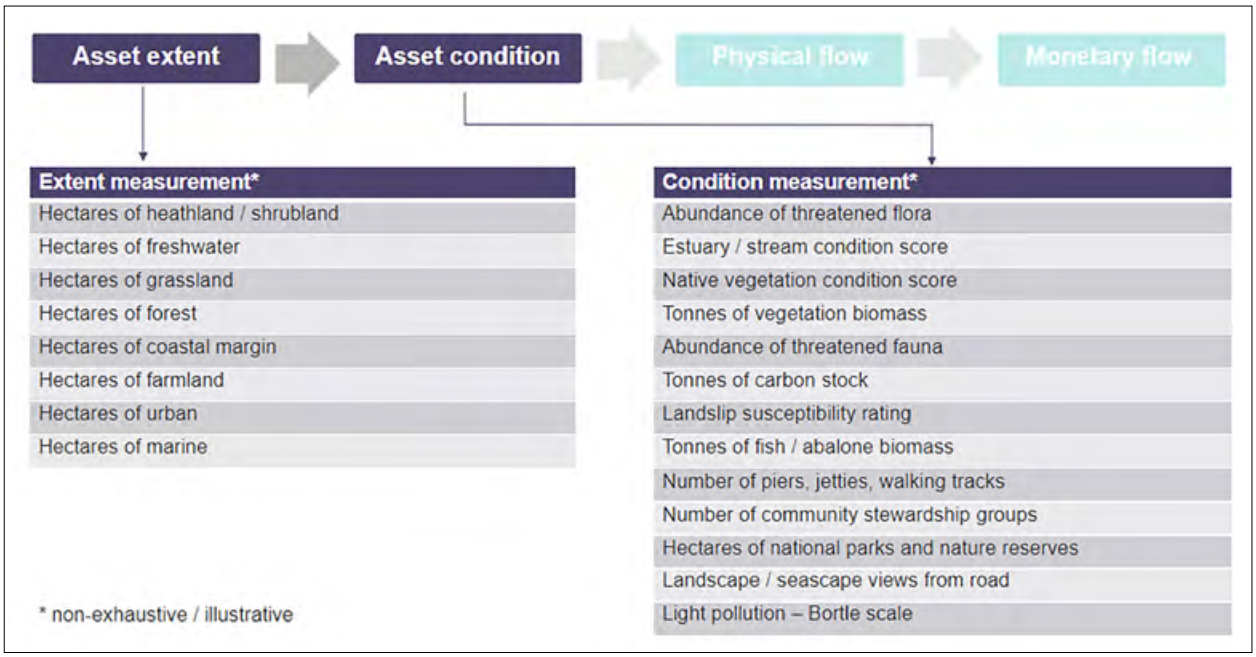
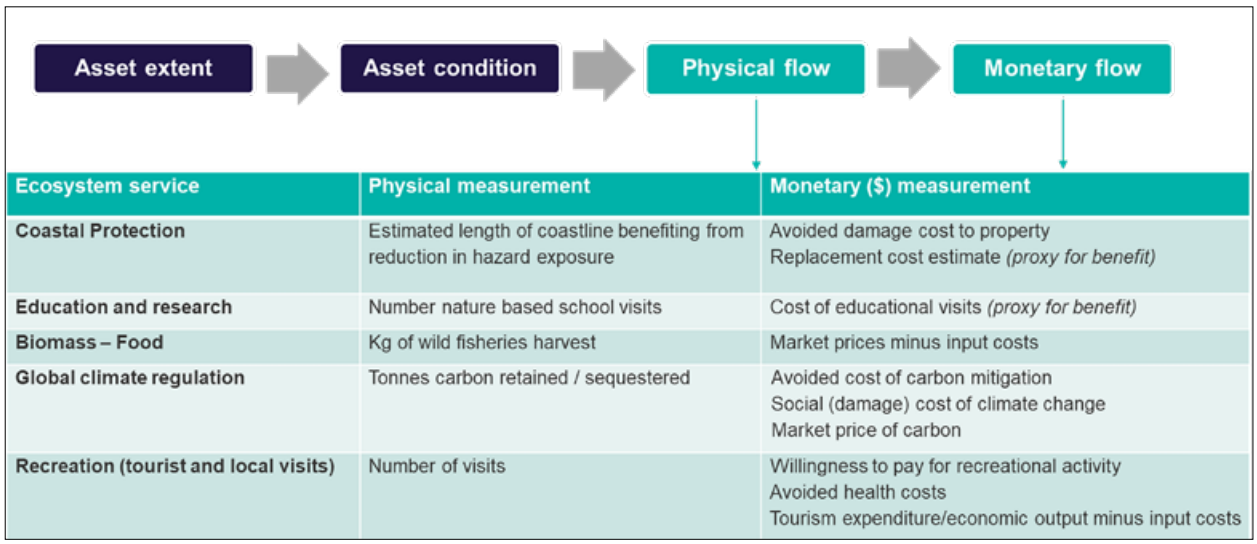


Figure 13: Illustrative stock account (coastal and marine ecosystem account).[119]

118. Haines-Young R and Potschin MB 2018, 'Common international classification of ecosystem services (CICES) v5.1 and guidance on the application of the revised structure', prepared for the European Environment Agency by Fabis Consulting Ltd, Nottingham, UK https://cices.eu/content/uploads/sites/8/2018/01/Guidance-V51-01012018.pdf

119. Department of Environment, Land, Water and planning (DELWP) 2021, 'Environmental–economic accounting in Victoria: Background to environmental–economic accounting in Victoria', summary for the office of the Commissioner for Environmental Sustainability, Melbourne, Victoria.



Ecosystem service	Physical measurement	Monetary ($) measurement
Coastal Protection	Estimated length of coastline benefiting from reduction in hazard exposure	Avoided damage cost to property Replacement cost estimate *(proxy for benefit)*
Education and research	Number nature based school visits	Cost of educational visits *(proxy for benefit)*
Biomass – Food	Kg of wild fisheries harvest	Market prices minus input costs
Global climate regulation	Tonnes carbon retained / sequestered	Avoided cost of carbon mitigation Social (damage) cost of climate change Market price of carbon
Recreation (tourist and local visits)	Number of visits	Willingness to pay for recreational activity Avoided health costs Tourism expenditure/economic output minus input costs

Figure 14: Illustrative flow account (coastal and marine ecosystem account).[120]

Ecosystem accounts are used by governments across the world to understand the value of the environment to society. Incorporating this information into public sector decision-making (e.g. strategic planning, policy and investment appraisals) can support governments to recognise all the costs and benefits associated with interventions – not only the market consequences that are easily quantified or valued.

Ecosystem accounts might also include information that is relevant to inform future policy or ecosystem asset management. This could include details on:

- welfare values (for use in policy appraisal)
- socio-economic characteristics that co-produce benefits from ecosystems
- future or historical changes in ecosystem asset status and productivity
- disservices (e.g. pests, disease and fire)
- negative pressures (e.g. pollution, population growth and climate change)
- positive dependencies (e.g. the removal of impurities from river water by upstream ecosystem filtration)
- expenditures on maintaining, restoring or expanding ecosystem assets
- links to other reporting frameworks (e.g. the UN Sustainable Development Goals)
- income and employment dependencies
- socio-economic distribution of benefits.

Including this broader information means diverging from a sole focus on quantifying and monetising the natural environment's value for the purpose of developing 'satellite accounts' to national GDP accounts. Such a divergence will not preclude this focus, providing the underlying SEEA Framework is adhered to.

Existing ecosystem accounts in Victoria

DELWP is developing accounting applications based on the SEEA Framework to provide better, integrated and more consistent information and analysis on our environmental assets in Victoria: information on which assets have been maintained, restored or destroyed, which are improving or declining in condition, and how the health of these assets affects our wellbeing as a society.

This framework will support government policy, planning and investment decisions affecting the environment. It will also strengthen the ability of local government, business, not-for-profit and community stakeholders to recognise the benefits of protecting and investing in the environment.

120. Ibid.

DELWP's initial ecosystem accounting work (in the early 2010s) was aimed at demonstrating concepts using available information. The more recent program of work has been developed in response to identified policy needs across the department. The existing ecosystem accounts developed for Victoria are a snapshot of ecosystem status and productivity, at a point in time, and have been developed for much of Victoria's land or water area, (Figure 13). One of the snapshot accounts currently under development by DELWP is a baseline account for the Great Ocean Road, including the marine and coastal ecosystems of the Great Ocean Road region.

Figure 15 also shows that DELWP has recently used the information in the 2019 forest ecosystem accounts (for Regional Forest Agreement areas) to assess the effects of the 2019-20 bushfires and the associated social, environmental and economic outcomes. This demonstrates one way that ecosystem accounts can be used to assess the result of pressures on ecosystem assets on societal and economic prosperity.

In addition to developing ecosystem accounts for Victoria, DELWP continues to participate in the development of a common national approach to EEA (led by the Commonwealth Government), which is based on the UN SEEA. This includes senior executive membership of the Interjurisdictional Environmental–Economic Accounting Steering Committee and a leadership role in chairing the interjurisdictional urban ecosystem accounting working group in Australia. This collaborative exchange of concepts, methods and datasets across the public sector in Australia facilitates alignment in EEA practices nationally (as appropriate).

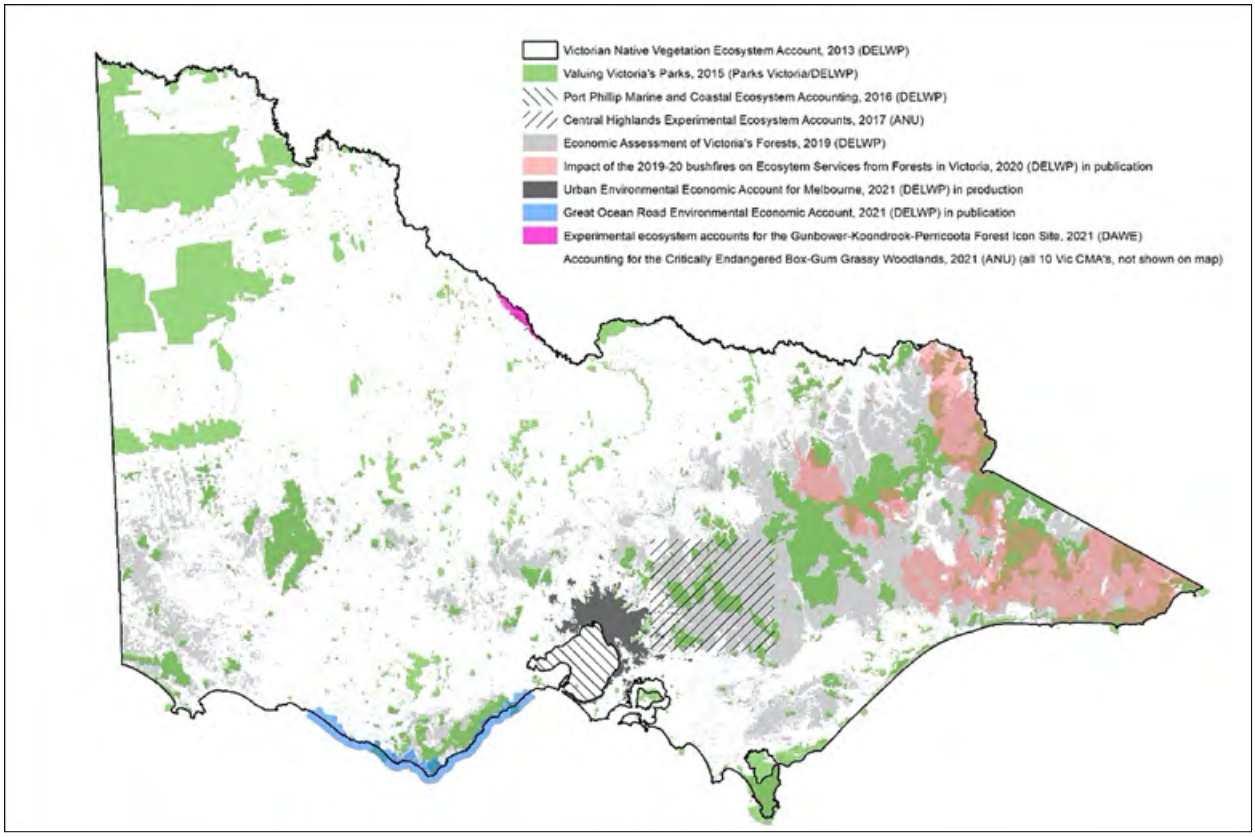


Figure 15: Current coverage and recency of ecosystem accounts in Victoria.[121]

121. Ibid.

Commissioner *for* Environmental Sustainability Victoria

Appendix A

Analysis of spatial information technologies applications for marine and coastal science

Appendix A : Analysis of spatial information technologies applications for marine and coastal science[122]

Spatial technology category	SMCE indicators that this technology currently assists	SMCE indicator that this technology could assist in the next reporting cycle (to 2024)	Examples of this technology being employed internationally
Earth observation (EO) and remote sensing	Saltmarsh Mangroves Seagrass Light pollution Coastal erosion	Algae component of water quality (physio-chemical), the chlorophyll–a component of water quality (estuaries), phytoplankton and plankton Coastal erosion, areas of coastal vulnerability, climate change impact on marine and coastal infrastructure and sea level, and coastal inundation Water clarity component of water quality (physio-chemical), the turbidity component of water quality (estuaries), total fine sediment loads and the sediment components of regulated point source discharges and stormwater Litter and other pollutant components of regulated point source discharges and stormwater, and litter and plastics Saltmarsh | Seagrass | Mangroves Coastal air quality Water temperature	Use Digital Earth Australia (DEA) Sandbox to implement the US method of saltmarsh mapping Use DEA Sandbox to implement synthetic aperture radar (SAR) detection of effluent plumes and detection of macro-plastics from optical data and indices from the literature.
Smart sensors and the Internet of Things (IoT)	Plankton (Integrated Marine Observing System – IMOS) Nitrogen cycle Wave energy (sensors on buoys) Seawater intrusion into coastal aquifers Coastal air quality Rainfall Air temperature Water temperature Sea-level and coastal inundation Ocean acidification	Water quality (physio-chemical), water quality (estuaries), phytoplankton, regulated point source discharges, stormwater, and total fine sediment loads Coastal air quality Phytoplankton and plankton (and many other indicators addressed by the parameters measured) Adverse effects of poor water quality, little penguins, coastal populations (visitors), tourism and recreational boating	In the US, National Oceanic and Atmospheric Administration (NOAA), in partnership with the coastal states, has a National Estuarine Research Reserve System-Wide Monitoring Program which provides real-time water, weather and nutrient data for 29 sites protected for long-term research, ecosystem monitoring, education and coastal stewardship.

122. Victorian Environmental Assessment Council 2019, 'Assessment of the values of Victoria's marine environment', Victorian Government, Melbourne https://www.veac.vic.gov.au/investigations-assessments/previous-assessments/document/getDownload?fid=MjM= Accessed 24 May 2021.

	Opportunities for uptake of other Australian jurisdictions' marine or coastal applications in Victoria	Opportunities to apply the technology (currently used for other purposes in Victoria) to marine and coastal outcomes	Future applications of the technology (beyond 2024)
	DEA provides Sentinel data and the Normalised Difference Chlorophyll Index that can be used in their Sandbox environment Use the DEA Coastlines product to identify areas for detailed investigation of coastal erosion Use the DEA Sandbox to implement a total suspended solid algorithm from the literature Use DEA Sandbox Sentinel-1 SAR and Sentinel-2 time series imagery with the Normalised Difference Vegetation Index indices	ARI and DELWP produce Multi-temporal Land Cover and Native Vegetation Extent data for Victoria (marine and coastal vegetation specific) RMIT University is developing hotspot detection algorithms from Himawari 8 imagery which will be used by DELWP during the fire season and could apply to SMCE Indicator 50 Frequency and impact of fire on marine and coastal ecosystems Potentially apply machine learning techniques such as that used in Sweden and Finland to assess coastal acid sulfate soils	Emerging satellite-as-a-service providers e.g. Exodus Orbitals, ISISPACE and Loft Orbital if specific EO data are required Potentially use reflectance and salinity as methods become more established to measure water nutrients Sentinel-5P data in DEA for coastal air quality The CSIRO and the SmartSat CRC are developing a national water quality monitoring system called AquaWatch. Using sea-surface temperature satellite and salinity data to estimate ocean acidification
	The EPA also has an automated water quality monitoring system on board the Spirit of Tasmania ferry, in partnership with IMOS. The system collects continuous measurements every day while travelling, and measures, salinity, temperature, phytoplankton and turbidity. A new, permanent IMOS National Reference Station could be established in Victoria, as in other Australian states, which would measure a range of parameters for various indicators.	The City of Melbourne recently implemented an automated IoT pedestrian counting system. It helps to monitor and evaluate the effects of pedestrian infrastructure investments, and better understand the environmental impacts and benefits of walking. A similar system could be implemented for the SMCE, with coastal sensor locations at tourist, boating, fishing and penguin hotspots. OysterQual – a project looking at measuring water quality of remote coastal waters for oyster farming site selection SIGWater – IoT connectivity for space monitoring groundwater in South Australia could be redeployed to other applications.	DNA nanosensors can be used to detect environmental pollutants. They are easy to design, cost-effective, and an increasing number of DNA sequences are being devised to detect a wider range of pollutants.

Spatial technology category	SMCE indicators that this technology currently assists	SMCE indicator that this technology could assist in the next reporting cycle (to 2024)	Examples of this technology being employed internationally	
Remotely piloted vehicle (RPV) systems	Coastal erosion	Species of conservation concern, diadromous fish, marine mammals and invasive marine species (and water quality (toxicants) Macroalgae on intertidal reefs	Monitoring macroalgal biodiversity in New Zealand, South-west Atlantic US NOAA uses underwater RPV to collect water samples for analysis of environmental DNA.	
GPS and tracking	Little penguins Marine mammals Litter and plastics	Potentially all fauna indicators with animal tracking programs Potentially all fauna indicators, especially diadromous fish, marine mammals and larger commercially and recreationally important invertebrates, by establishing a permanent IMOS station Potentially all fauna indicators, especially marine and coastal waterbirds, migratory shorebirds and piscivorous birds, by using mini transmitters and saving in Movebank database	In the US, NOAA also has an IOOS Animal Telemetry Network, including real-time tag deployments, satellite telemetry and acoustic telemetry. The ICARUS (International Cooperation for Animal Research Using Space) initiative is an example of this. The initiative has a receiver on the International Space Station which began operational use in March 2021, as well as mini transmitters which weigh only 5 grams. The transmitters have a GPS function and can withstand cold, heat, moisture and dust and can transmit their data by radio for months or years, to the receiver in space. The program is initially targeted at birds, so it could be used for the indicators marine and coastal waterbirds, migratory shorebirds, piscivorous birds.	
Citizen science	Invertebrates on subtidal reefs Subtidal reef fish Marine and coastal waterbirds Migratory shorebirds Piscivorous birds Citizen science	All fauna and flora indicators using data from the Atlas of Living Australia Stormwater, litter and plastics, illegal activities, invasive marine species, invasive coastal plants and invasive coastal animals, using data from Snap Send Solve	There are many databases based on citizen science programs such as MangroveWatch, SeagrassNet, Seagrass-Watch and Phytoplankton Monitoring Network.	

	Opportunities for uptake of other Australian jurisdictions' marine or coastal applications in Victoria	Opportunities to apply the technology (currently used for other purposes in Victoria) to marine and coastal outcomes	Future applications of the technology (beyond 2024)
	The Australian Institute of Marine Science (AIMS) have approximately 10 commercial-grade RPVs which they use for a range of applications such as surveying intertidal reefs, water analysis via aerial sample collection, ocean colour ground truthing to validate satellite data, and algal bloom monitoring.	ARI uses environmental DNA in freshwater and with manual collection; saltwater applications and RPV usage could be considered. Land Use Victoria's Great Ocean Road reality mesh.	RPV imagery and structure from motion or deep learning for important invertebrates or shellfish when methods are established – SMCE Indicators 20: Mobile invertebrates on intertidal reefs, 21: Sessile invertebrates on intertidal reefs and 35: Shellfish reefs.
	Queensland has acoustic telemetry arrays, funded by the Department of Environment and Science, which provide the infrastructure to understand the distribution and movement of important marine species along the east coast of Queensland. Victoria could borrow a receiver and conduct a trial study with the aim of establishing more permanent receivers. This could be complemented by a tagging program potentially including diadromous fish, little penguins, marine mammals and larger commercially and recreationally important invertebrates to contribute to the assessment of these indicators and the IMOS database.	National Livestock Identification System for the supply chain management of meat and dairy products – different types of animal tags are used and electronic tags have transponders with radio frequency identification device numbers for animal identification and tracking. They are not typically GPS tags, although Victoria's On-Farm IoT Trial does include GPS tags.	Probably only reduced size smaller tags, longer battery life and ubiquitous, low-cost, high-accuracy devices enabling the tracking of many more animals
	New South Wales (NSW) CoastSnap beach monitoring There are many databases, including Sea Search, Virtual Reef Diver and Redmap Australia Point Lonsdale Sand Monitoring Program.	Use Strava data to create global heatmaps for SMCE Indicator 75: Community connection to the coast	Citizen sensing which will enable people to use low-cost or self-built sensors for data collection, to learn more about the issues they care about in order to empower themselves

Spatial technology category	SMCE indicators that this technology currently assists	SMCE indicator that this technology could assist in the next reporting cycle (to 2024)	Examples of this technology being employed internationally	
Artificial intelligence (AI) and machine learning (ML)	Marine and coastal infrastructure	Litter and plastics: MARLIT is an open access web app using deep learning, that aids the detection of floating plastics in the sea with RPV and aircraft aerial imagery. For the conservation of coastal ecosystems in protected areas, use Victoria's Land Cover Time series via NatureKit 2.0 Boat counting method using ML and GPS tracking methods	Bird breeding sites counting and mapping in Botswana, West Africa and Turkey US-built models to map concentrations of nitrogen and phosphorus in water bodies across the country in 1994–2018 using random forest classification and an ML algorithm Sweden produced a distribution map of acid sulfate soils along the coast of northern Sweden using ML. The output was a map of surface deposits, vegetation and land-use classification based on satellite data, and a high-resolution digital elevation model based on LiDAR as input data.	
Big data and analytics (including GIS)	Many SMCE indicators across most themes	Areas of coastal vulnerability, coastal erosion, climate change effect on marine and coastal infrastructure and sea level, and coastal inundation: use DEA Coastlines and other products via NationalMap Use of marine and coastal areas: adverse effects of poor water quality, little penguins, coastal populations (visitors), and tourism: obtain People Tracker method to analyse people movement from social-media big data, or investigate and establish an alternative method for using big data (mobile phone or social media) to track visitor populations in an ongoing capacity Frequency and effect of fire on marine and coastal ecosystems: obtain fire data from Spatial Datamart Victoria for spatial analysis (e.g., fire history) Areas of coastal vulnerability, coastal erosion, climate change effect on marine and coastal infrastructure and sea level, and coastal erosion: use the Coastal Hazard Decision Support System when available	Analysis of social big data in South Korea in 2019 and 2020 paper Another example is People Tracker for analysing people movement from social-media–based big data to provide decision support for government authorities. The pilot study was for Fiji using Flickr photos. Other examples include Google mobility analytics and Apple mobility. Fireball International provides an early detection, assessment and mapping system for rapid, effective fire suppression using AI on big data in the form of ground-based, aerial and satellite images.	

	Opportunities for uptake of other Australian jurisdictions' marine or coastal applications in Victoria	Opportunities to apply the technology (currently used for other purposes in Victoria) to marine and coastal outcomes	Future applications of the technology (beyond 2024)
	'Seagrass', a 2019 article describes how IBM used AI for image segmentation of underwater video to identify seagrass in South Australia. The data produced can now be used to predict the health of seagrass and how it will change over time. The NSW Marine Estate Management Authority strategy mentions 'exploring ways of using artificial intelligence to map and monitor habitats and species'. Curtin University and AIMS used deep learning for automated analysis of BRUVS (Baited Remote Underwater Video Stations) fish data which provides a scalable way to analyse video.	ARI and DELWP produce Multi-temporal Land Cover and Native Vegetation Extent data for Victoria. Marine and coastal vegetation specific. FrontierSI's ML project in automatic feature extraction for trees in Victoria could be modified for coastal vegetation.	Develop an ML algorithm for detecting sewerage discharges and implement a system with telemetry, rainfall data and analytics to enable real-time detection of spills – SMCE indicator: Regulated point source discharges and potentially stormwater. Establish an ML research program to investigate opportunities to implement ML algorithms for important indicators, or establish an advisory group to determine the use of AI and ML.
	DEA has a number of products available including DEA Coastlines (which has its own viewer), National Intertidal Digital Elevation Model, Intertidal Extents Model, and High and Low Tide Composites which can be viewed on NationalMap. The DEA also has a Sandbox environment which is a free learning and analysis environment for getting started with DEA and the Open Data Cube (ODC). It has several sample notebooks, such as for chlorophyll monitoring, coastal erosion, intertidal elevation, radar water detection and shipping lane identification, that demonstrate capability and enable big data analytics. The CSIRO also has a platform built on the ODC called Earth Analytics Science and Innovation (EASI) platform.	The Joint Fuel Management Program has an interactive map showing where and when DELWP and PV intend to carry out fire management operations on public land, as well as the fire history for the last five years. Fire history (and many other fire-related datasets) can also be downloaded from the Spatial Datamart Victoria website. These could then be analysed in GIS, along with a time series analysis to assess the frequency and effect of fire on marine and coastal ecosystems indicator.	More online systems to enable people to derive insights from big data, potentially using machine learning, will probably emerge.

Spatial technology category	SMCE indicators that this technology currently assists	SMCE indicator that this technology could assist in the next reporting cycle (to 2024)	Examples of this technology being employed internationally	
Spatial datasets and data portals	Many SMCE indicators across most themes	Many indicators across most themes GoFishVIC App – if de-identified data from this app could be obtained from the Victorian Fisheries Authority, it could be used to assess commercially and recreationally important invertebrates and fish, recreational boating and fishing's contribution to the Victorian economy, and recreational fishing.	Waterbird Population Estimates – an international wetlands database that may support the marine and coastal waterbirds indicator	

	Opportunities for uptake of other Australian jurisdictions' marine or coastal applications in Victoria	Opportunities to apply the technology (currently used for other purposes in Victoria) to marine and coastal outcomes	Future applications of the technology (beyond 2024)
	National Marine Mammal Data Portal – the Department of Agriculture, Water and the Environment (DAWE) provides this database, which is based on mammal sightings (rather than tracking information) and could contribute to Indicator 31: Marine mammals. AusSeabed is a national seabed mapping coordination program providing bathymetry data that could be of use to seafloor integrity and health indicators such as conservation of marine ecosystems in protected areas. Seagrass presence data – TERN Australia's Terrestrial Ecosystem Research Infrastructure has considerable information including this marine data on seagrass presence and absence. Although it dates back to 2005 it may assist with seagrass and other indicators. Seamap Australia – this Australian seabed habitat classification scheme and spatial database could help seafloor integrity and health indicators. CoastAdapt – this National Climate Change Adaptation Research Facility information delivery and decision support framework helps users understand climate change and the responses available to manage the impacts. It may assist climate and climate change impacts indicators.	Merge all the existing Victorian data and portals into one Victorian statewide open data portal for environmental data like the NSW SEED portal	Agricultural property data – The Guardian Australia collated large datasets from every state and territory and created a database of land ownership. Recently, FrontierSI conducted a project to define agricultural property with the intent of creating a dataset in the future. Greening the Greyfields tools are spatial planning tools for revitalising the middle suburbs of Australia and New Zealand. Similar tools could be developed for the coast. Digital Atlas of Australia – planned in the 2021–2022 federal budget, this will be a free interactive platform, allowing access to authoritative national datasets on Australia's geography, people, economy, employment, infrastructure, health, land and the environment.

Spatial technology category	SMCE indicators that this technology currently assists	SMCE indicator that this technology could assist in the next reporting cycle (to 2024)	Examples of this technology being employed internationally	
Simulation and modelling	Total nutrient loads Total fine sediment loads	Stormwater Species of conservation concern Regulated point source discharges Total nutrient loads	International study using numerical model simulations to improve the understanding of micro-plastic distribution and pathways in the marine environment.	

	Opportunities for uptake of other Australian jurisdictions' marine or coastal applications in Victoria	Opportunities to apply the technology (currently used for other purposes in Victoria) to marine and coastal outcomes	Future applications of the technology (beyond 2024)
	Stormwater: the DEA has an Enhanced Normalised Difference Impervious Surfaces Index and an urban change detection notebook that could determine impervious surface area and contribute to stormwater modelling in conjunction with BoM rainfall data. In addition, the eWater Source tool is Australia's National Hydrological Modelling Platform designed for all areas of water management including rainfall-runoff models and water quality analysis based on catchment land-use scenarios. Regulated point source discharges: if the EPA provides point data of discharges for Indicator 06: Regulated point source discharges to marine waters, the flow of pollutants to surrounding areas or the change over time from these point source discharges could be modelled in a GIS. NSW maps outflow events and the effects on habitats. Total nutrient loads: catchment modelling could be done for nitrogen and phosphorous runoff using export coefficients associated with EO land cover or land use. Export coefficients are usually derived from literature and field experiments to determine the rate at which nutrients are lost from each source to the surface drainage network. AIMS' eReefs Visualisation Portal has implemented models for the marine environment (Great Barrier Reef) including a hydrodynamic model, a biogeochemical model of water quality (nutrients and suspended sediment) and key ecological processes (coral, seagrass and plankton).	Use Melbourne Water's stormwater models or industry software MUSIC or Source to generate impervious area and stormwater modelling Use ARI's Habitat distribution models via NatureKit 2.0	The Ocean Data Action Coalition envisages implementing an ocean avatar or ocean digital twin for sustainable ocean management. It has begun building the core of this with the Ocean Data Platform, an open platform that collates and visualises ocean data, but realising the ocean avatar is still a long way off. EcoCommons will provide ecological and environmental modelling tools.

Commissioner *for* Environmental Sustainability Victoria

Appendix B

Comprehensiveness assessment of selected marine and coastal Sustainable Development Goal targets

Appendix B : Comprehensiveness assessment of selected marine and coastal Sustainable Development Goal targets

Goal	Target	Target description	Indicator theme	Aligned SMCE indicator number	Aligned SMCE indicator description	Weighting (%)
2 ZERO HUNGER	2.4	By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality	Theme 8: Communities	68	Aquaculture	30%
			Theme 8: Communities	70	Agriculture	20%
			Theme 1: Water quality and catchment inputs	08	Total nutrient loads	40%
			Theme 6: Climate and climate change impacts	50	Frequency and impact of fire on marine and coastal ecosystems	10%
	2.5	By 2020, maintain the genetic diversity of seeds, cultivated plants, and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the use of genetic resources and associated traditional knowledge, as internationally agreed	n/a	B:21*	Area of management in priority locations	50%
			n/a	Fo:05*	Number of in situ and ex situ conservation efforts for forest-dependent species	50%

*Note: Marked indicators are from State of Environment 2018 Report rather than SMCE 2021 Report

Goal	Target	Target description	Indicator theme	Aligned SMCE indicator number	Aligned SMCE indicator description	Weighting (%)
3 GOOD HEALTH AND WELL-BEING	3.9	By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	Theme 2: Litter and pollution	14	Coastal air quality	40%
			Theme 1: Water quality and catchment inputs	05	*Enterococci* bacteria	40%
			Theme 6: Climate and climate change impacts	50	Frequency and impact of fire on marine and coastal ecosystems	10%
			Theme 2: Litter and pollution	13	Coastal contaminated land	5%
			Theme 1: Water quality and catchment inputs	10	Coastal acid sulfate soils	5%

Goal	Target	Target description	Indicator theme	Aligned SMCE indicator number	Aligned SMCE indicator description	Weighting (%)
6 CLEAN WATER AND SANITATION	6.3	By 2030, improve water quality by reducing pollution, eliminating dumping and minimising release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	Theme 1: Water quality and catchment inputs	02	Toxicants	15%
			Theme 1: Water quality and catchment inputs	05	*Enterococci* bacteria	50%
			Theme 1: Water quality and catchment inputs	06	Regulated point source discharges to marine waters	10%
			Theme 1: Water quality and catchment inputs	07	Stormwater	10%
			Theme 1: Water quality and catchment inputs	10	Coastal acid sulfate soils	15%
	6.6	By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.	Theme 1: Water quality and catchment inputs	03	Water quality (estuaries)	10%
			Theme 3: Biodiversity	18	Wetland and estuary vegetation	20%
			Theme 3: Biodiversity	15	Conservation of coastal ecosystems in protected areas	40%
			Theme 6: Climate and climate change impacts	41	Rainfall	20%
			Theme 6: Climate and climate change impacts	49	Seawater intrusion into coastal aquifers	10%

Goal	Target	Target description	Indicator theme	Aligned SMCE indicator number	Aligned SMCE indicator description	Weighting (%)
8 DECENT WORK AND ECONOMIC GROWTH	8.9	By 2030, devise and implement policies to promote sustainable tourism that create jobs and promote local culture and products	Theme 8: Communities	62	Tourism	60%
			Theme 8: Communities	64	Recreational boating	10%
			Theme 8: Communities	65	Recreational fishing	10%
			Theme 8: Communities	63	Recreational boating and fishing contribution to the Victorian economy	20%
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	9.1	Develop quality, reliable, sustainable and resilient infrastructure, including regional and trans-border infrastructure, to support economic development and human wellbeing, with a focus on affordable and equitable access for all	Theme 6: Climate and climate change impacts	51	Climate change impact on marine and coastal infrastructure	45%
			Theme 8: Communities	66	Shipping and ports	15%
			Theme 6: Climate and climate change impacts	48	Coastal erosion	15%
			Theme 9: Stewardship and collaborative management	80	Institutional knowledge and capacity	25%

Goal	Target	Target description	Indicator theme	Aligned SMCE indicator number	Aligned SMCE indicator description	Weighting (%)
10 REDUCED INEQUALITIES	10.2	By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion, economic or other status	Theme 9: Stewardship and collaborative management	81	Engagement and inclusiveness	60%
			Theme 9: Stewardship and collaborative management	80	Institutional knowledge and capacity	20%
			Theme 8: Communities	62	Tourism	10%
			Theme 8: Communities	71	Built and public benefit infrastructure	10%
11 SUSTAINABLE CITIES AND COMMUNITIES	11.3	By 2030, enhance inclusive and sustainable urbanisation and capacity for participatory, integrated and sustainable human settlement planning and management in all countries	Theme 9: Stewardship and collaborative management	81	Engagement and inclusiveness	35%
			Theme 9: Stewardship and collaborative management	78	Planning and implementation	35%
			Theme 8: Communities	58	Significant landscapes	10%
			Theme 7: Managing coastal hazard risks	52	Considering climate change risks in land-use planning	10%
			Theme 8: Communities	59	Coastal settlements	10%

Goal	Target	Target description	Indicator theme	Aligned SMCE indicator number	Aligned SMCE indicator description	Weighting (%)
11 SUSTAINABLE CITIES AND COMMUNITIES	11.4	Strengthen efforts to protect and safeguard the world's cultural and natural heritage	Theme 8: Communities	60	Cultural heritage	40%
			Theme 3: Biodiversity	15	Conservation of coastal ecosystems in protected areas	30%
			Theme 4: Seafloor integrity and health	32	Conservation of marine ecosystems in protected areas	30%
	11.6	By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management	Theme 8: Communities	59	Coastal settlements	45%
			Theme 2: Litter and pollution	14	Coastal air quality	15%
			Theme 1: Water quality and catchment inputs	06	Regulated point source discharges to marine waters	15%
			Theme 2: Litter and pollution	11	Litter and plastics	15%
			Theme 8: Communities	73	Illegal activities	10%

Goal	Target	Target description	Indicator theme	Aligned SMCE indicator number	Aligned SMCE indicator description	Weighting (%)
11 SUSTAINABLE CITIES AND COMMUNITIES	11.7	By 2030, provide universal access to safe, inclusive and accessible, green and community spaces, in particular for women and children, older people and people with disability	Theme 9: Stewardship and collaborative management	81	Engagement and inclusiveness	40%
			Theme 8: Communities	61	Use of marine and coastal areas	15%
			Theme 9: Stewardship and collaborative management	75	Community connection to the coast	25%
			Theme 9: Stewardship and collaborative management	78	Planning and implementation	20%
	11.a	Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning	Theme 9: Stewardship and collaborative management	78	Planning and implementation	40%
			Theme 8: Communities	58	Significant landscapes	20%
			Theme 8: Communities	59	Coastal settlements	20%
			Theme 6: Climate and climate change impacts	45	Areas of coastal vulnerability	20%

Goal	Target	Target description	Indicator theme	Aligned SMCE indicator number	Aligned SMCE indicator description	Weighting (%)
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	12.2	By 2030, achieve the sustainable management and efficient use of natural resources	Theme 3: Biodiversity	15	Conservation of coastal ecosystems in protected areas	20%
			Theme 4: Seafloor integrity and health	32	Conservation of marine ecosystems in protected areas	20%
			Theme 8: Communities	68	Aquaculture	40%
			Theme 9: Stewardship and collaborative management	80	Institutional knowledge and capacity	20%
	12.4	By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimise their adverse effects on human health and the environment	Theme 2: Litter and pollution	14	Coastal air quality	25%
			Theme 1: Water quality and catchment inputs	05	*Enterococci* bacteria	25%
			Theme 1: Water quality and catchment inputs	08	Total nutrient loads	25%
			Theme 1: Water quality and catchment inputs	02	Toxicants	25%

Goal	Target	Target description	Indicator theme	Aligned SMCE indicator number	Aligned SMCE indicator description	Weighting (%)
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	12.8	By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature	Theme 9: Stewardship and collaborative management	75	Community connection to the coast	20%
			Theme 9: Stewardship and collaborative management	82	Delivery and accountability	40%
			Theme 9: Stewardship and collaborative management	80	Institutional knowledge and capacity	40%
	12.b	Develop and implement tools to monitor sustainable development effects on sustainable tourism that create jobs and promote local culture and products	Theme 8: Communities	62	Tourism	70%
			Theme 8: Communities	60	Cultural heritage	30%

Goal	Target	Target description	Indicator theme	Aligned SMCE indicator number	Aligned SMCE indicator description	Weighting (%)
13 CLIMATE ACTION	13.1	Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	Theme 7: Managing coastal hazard risks	54	Nature-based adaptation	20%
			Theme 6: Climate and climate change impacts	45	Areas of coastal vulnerability	40%
			Theme 6: Climate and climate change impacts	46	Sea-level and coastal inundation	10%
			Theme 7: Managing coastal hazard risks	55	Emergency planning and preparedness	20%
			Theme 8: Communities	56	Population (resident)	10%
	13.2	Integrate climate change measures into national policies, strategies and planning	Theme 7: Managing coastal hazard risks	54	Nature-based adaptation	30%
			Theme 7: Managing coastal hazard risks	52	Considering climate change risks in land-use planning	30%
			Theme 9: Stewardship and collaborative management	80	Institutional knowledge and capacity	10%
			Theme 7: Managing coastal hazard risks	55	Emergency planning and preparedness	15%
			Theme 7: Managing coastal hazard risks	53	Climate change adaptation plans	15%

Goal	Target	Target description	Indicator theme	Aligned SMCE indicator number	Aligned SMCE indicator description	Weighting (%)
13 CLIMATE ACTION	13.3	Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning	Theme 7: Managing coastal hazard risks	55	Emergency planning and preparedness	15%
			Theme 7: Managing coastal hazard risks	53	Climate change adaptation plans	35%
			Theme 9: Stewardship and collaborative management	80	Institutional knowledge and capacity	35%
			Theme 7: Managing coastal hazard risks	52	Considering climate change risks in land-use planning	15%
14 LIFE BELOW WATER	14.1	By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	Theme 1: Water quality and catchment inputs	08	Total nutrient loads	25%
			Theme 1: Water quality and catchment inputs	06	Regulated point source discharges to marine waters	25%
			Theme 6: Climate and climate change impacts	50	Frequency and impact of fire on marine and coastal ecosystems	15%
			Theme 1: Water quality and catchment inputs	05	*Enterococci* bacteria	25%
			Theme 2: Litter and pollution	13	Coastal contaminated land	5%
			Theme 1: Water quality and catchment inputs	10	Coastal acid sulfate soils	5%

Goal	Target	Target description	Indicator theme	Aligned SMCE indicator number	Aligned SMCE indicator description	Weighting (%)
14 LIFE BELOW WATER	14.2	By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse effects, including by strengthening their resilience, and taking action for their restoration to achieve healthy and productive oceans	Theme 3: Biodiversity	15	Conservation of Coastal Ecosystems in Protected Areas	30%
			Theme 4: Seafloor Integrity and Health	32	Conservation of Coastal Ecosystems in Protected Areas	30%
			Theme 8: Communities	68	Aquaculture	10%
			Theme 7: Managing coastal hazard risks	52	Considering climate change risks in land-use planning	15%
			Theme 7: Managing coastal hazard risks	55	Emergency planning and preparedness	15%
	14.3	Minimise and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels	Theme 6: Climate and climate change impacts	44	Ocean acidification	100%
	14.4	By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics	Theme 8: Communities	67	Commercial fishing	40%
			Theme 8: Communities	65	Recreational fishing	40%
			Theme 8: Communities	68	Aquaculture	20%
	14.5	By 2020, conserve at least 10% of coastal and marine areas, consistent with national and international law and based on the best available scientific information	Theme 9: Stewardship and collaborative management	78	Planning and implementation	100%

Goal	Target	Target description	Indicator theme	Aligned SMCE indicator number	Aligned SMCE indicator description	Weighting (%)
14 LIFE BELOW WATER	14.6	By 2020, prohibit certain forms of fisher subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing similar new subsidies, recognising that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organisation fisheries subsidies negotiation	Theme 8: Communities	67	Commercial fishing	30%
			Theme 8: Communities	65	Recreational fishing	30%
			Theme 9: Stewardship and collaborative management	80	Institutional knowledge and capacity	40%
	14.b	Provide access for small-scale artisanal fishers to marine resources and markets	Cultural landscape health and management	To be developed	See note at bottom of table	n/a
15 LIFE ON LAND	15.1	By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements	Theme 3: Biodiversity	18	Wetland and estuary vegetation	10%
			Theme 3: Biodiversity	15	Conservation of coastal ecosystems in protected areas	30%
			Theme 9: Stewardship and collaborative management	75	Community connection to the coast	10%
			Theme 9: Stewardship and collaborative management	74	Stewardship	10%
			Theme 9: Stewardship and collaborative management	82	Delivery and accountability	40%

Note: In Victoria, Target 14.b could focus on working with Traditional Owners in recognition of their relationship with marine and coastal cultural heritage and resources. Existing protections and arrangements for access to, and use of, Country are supported, while recognising that there is ongoing development and adaptation of policy in this regard. The Sea Country partnerships currently underway in Victoria may be a preliminary investigation of this potential. More broadly, all the targets in this table need to be considered in terms of Victorian Traditional Owner aspirations and recognition (see Part 1: Cultural Landscape Health and Management).

Goal	Target	Target description	Indicator theme	Aligned SMCE indicator number	Aligned SMCE indicator description	Weighting (%)
15 LIFE ON LAND	15.5	Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	Theme 3: Biodiversity	15	Conservation of coastal ecosystems in protected areas	30%
			Theme 3: Biodiversity	19	Species of conservation concern	40%
			Theme 4: Seafloor integrity and health	32	Conservation of marine ecosystems in protected areas	30%
	15.6	Promote fair and equitable sharing of the benefits arising from the use of genetic resources and promote appropriate access to such resources, as internationally agreed	n/a	B:21*	Area of management in priority locations	50%
			n/a	Fo:05*	Number of in situ and ex situ conservation efforts for forest dependent species	50%
	15.7	Take urgent action to end poaching and trafficking of protected species of flora and fauna and address both demand and supply of illegal wildlife products	Theme 8: Communities	73	Illegal activities	100%
	15.8	By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species	Theme 7: Managing coastal hazard risks	55	Emergency planning and preparedness	25%
			Theme 5: Pests and invasive species	38	Invasive marine species	25%
			Theme 5: Pests and invasive species	39	Coastal invasive plants	25%
			Theme 5: Pests and invasive species	40	Coastal invasive animals	25%

Goal	Target	Target description	Indicator theme	Aligned SMCE indicator number	Aligned SMCE indicator description	Weighting (%)
15 LIFE ON LAND	15.9	By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts	Theme 7: Managing coastal hazard risks	52	Considering climate change risks in land-use planning	15%
			Theme 8: Communities	58	Significant landscapes	15%
			Theme 8: Communities	59	Coastal settlements	15%
			Theme 9: Stewardship and collaborative management	78	Planning and implementation	55%
	15.a	Mobilise and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems	Theme 9: Stewardship and collaborative management	82	Delivery and accountability	50%
			Theme 9: Stewardship and collaborative management	80	Institutional knowledge and capacity	50%
	15.c	Enhance global support for efforts to combat poaching and trafficking of protected species, including by increasing the capacity of local communities to pursue sustainable livelihood opportunities	Theme 8: Communities	73	Illegal activities	100%

Goal	Target	Target description	Indicator theme	Aligned SMCE indicator number	Aligned SMCE indicator description	Weighting (%)
16 PEACE, JUSTICE AND STRONG INSTITUTIONS	16.6	Develop effective, accountable and transparent institutions at all levels	Theme 9: Stewardship and collaborative management	80	Institutional knowledge and capacity	30%
			Theme 9: Stewardship and collaborative management	82	Delivery and accountability	40%
			Theme 9: Stewardship and collaborative management	81	Engagement and inclusiveness	30%
	16.7	Ensure responsive, inclusive, participatory and representative decision-making at all levels	Theme 9: Stewardship and collaborative management	80	Institutional knowledge and capacity	30%
			Theme 9: Stewardship and collaborative management	82	Delivery and accountability	30%
			Theme 9: Stewardship and collaborative management	81	Engagement and inclusiveness	40%
	16.b	Promote and enforce non-discriminatory laws and policies for sustainable development	Theme 9: Stewardship and collaborative management	81	Engagement and inclusiveness	55%
			Theme 8: Communities	58	Significant landscapes	15%
			Theme 9: Stewardship and collaborative management	82	Delivery and accountability	15%
			Theme 7: Managing coastal hazard risks	54	Nature-based adaptation	15%

Goal	Target	Target description	Indicator theme	Aligned SMCE indicator number	Aligned SMCE indicator description	Weighting (%)
17 PARTNERSHIPS FOR THE GOALS	17.14	Enhance policy coherence for sustainable development	Theme 7: Managing coastal hazard risks	54	Nature-based adaptation	20%
			Theme 9: Stewardship and collaborative management	82	Delivery and accountability	20%
			Theme 7: Managing coastal hazard risks	55	Emergency planning and preparedness	20%
			Theme 9: Stewardship and collaborative management	78	Planning and implementation	20%
			Theme 9: Stewardship and collaborative management	80	Institutional knowledge and capacity	20%

Goal	Target	Target description	Indicator theme	Aligned SMCE indicator number	Aligned SMCE indicator description	Weighting (%)
17 PARTNERSHIPS FOR THE GOALS	17.17	Encourage and promote effective public, public–private and civil society partnerships, building on the experience and resourcing strategies of partnerships	Theme 9: Stewardship and collaborative management	78	Planning and implementation	40%
			Theme 9: Stewardship and collaborative management	75	Community connection to the coast	20%
			Theme 9: Stewardship and collaborative management	77	Citizen science	10%
			Theme 9: Stewardship and collaborative management	81	Engagement and inclusiveness	10%
			Theme 9: Stewardship and collaborative management	82	Delivery and accountability	10%
			Theme 9: Stewardship and collaborative Management	80	Institutional knowledge and capacity	10%

Commissioner *for* Environmental Sustainability Victoria

Appendix C

Indicator summaries by theme

Appendix C

Indicator summaries by theme

This report assesses 82 indicators. These indicators were developed during an extensive and iterative co-creation period with stakeholders in 2020. The indicators fulfil the requirements of the Marine and Coastal Act 2018 (s.37(2)) that an SMCE Report must include the following information:

- the condition of the marine and coastal environment
- the environmental, social and economic benefits of the marine and coastal environment
- the threats to the marine and coastal environment.

This report card summarises the scientific assessments of each indicator, which are provided metrics for each indicator, an overall comment on the assessment, the status, trend and data confidence for each indicator, and the source of the data.

Where appropriate, the corresponding indicator assessments from the State of the Bays 2016 and/or the State of the Environment 2018 reports have been included.

Region

The assessments have been conducted on a statewide and/or regional scale based on the localisation of the impacts associated with each indicator and/or the spatial scale of the evidence supporting the assessment.

Figure 16 shows the spatial extent of marine and coastal reporting by the CES as a timeline from the State of the Bays 2016 Report (Port Phillip Bay and Western Port), to the State of the Marine and Coastal Environment 2021 Report, which includes six marine biounits, and the State of the Marine and Coastal Environment 2024 Report, which is expected to cover Victoria's entire marine and coastal environment. Figure 16 also shows a map of all 26 Victorian marine biounits.

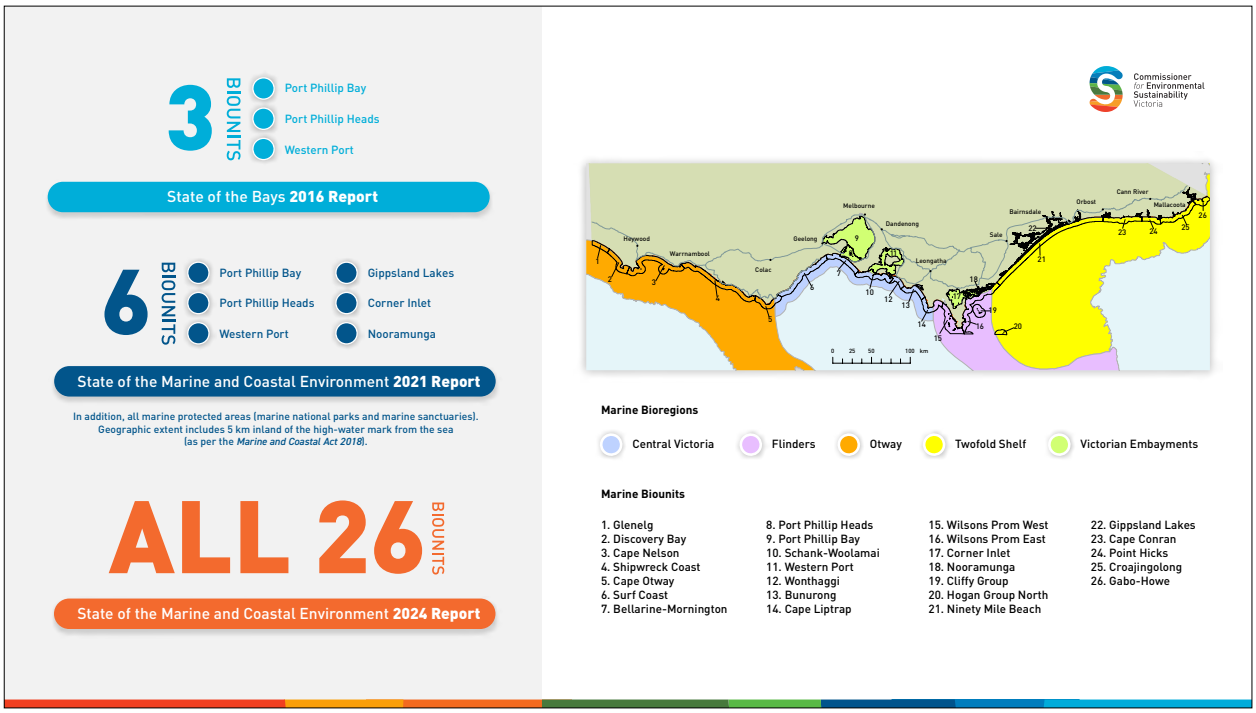


Figure 16: Spatial extent of the SMCE 2021 Report, represented as six Victorian marine biounits.[123]

123. Victorian Environmental Assessment Council 2019, 'Assessment of the values of Victoria's marine environment', Victorian Government, Melbourne https://www.veac.vic.gov.au/investigations-assessments/previous-assessments/document/getDownload?fid=MjM= Accessed 24 May 2021.

Status

The status summary presents an overall analysis of the assessment for each selected indicator. An indicator can be assessed as having a good, fair or poor status (see status thresholds below). Where there is insufficient data, the indicator status is assessed as unknown.

The legend for status in the report card is:

- **Good:** Environmental condition is healthy across Victoria, OR pressure is likely to have negligible impact on environmental condition/human health, OR comprehensive protection of natural ecosystems and biodiversity is evident.
- **Fair:** Environmental condition is neither positive nor negative and may be variable across Victoria, OR pressure is likely to have limited impact on environmental condition/human health, OR moderate protection of natural ecosystems and biodiversity is evident.
- **Poor:** Environmental condition is under significant stress, OR pressure is likely to have significant negative impact on environmental condition/human health, OR inadequate protection of natural ecosystems and biodiversity is evident.
- **Unknown:** Data are insufficient to assess status or trend.
- **N/A (not applicable):** An indicator status assessment has not been made, because this indicator is not relevant for this region or because the assessment of status is inappropriate for the indicator.
- N **Narrative**

Trend

The trend summary presents an overall analysis of the trend assessments for each selected indicator. The trend identifies whether the status of the indicator is deteriorating, improving or remaining stable.

The legend for trend in the report card reads as follows:

- ↗ **Improving**
- → **Stable**
- ↙ **Deteriorating**
- ? **Unclear**
- N/A **N/A Not applicable:** An indicator trend assessment has not been made because this indicator is not relevant for this region, or because the assessment of trend is inappropriate for the indicator.

Data

Data confidence reflects on knowledge gaps and data limitations when assessing the status and trend of the indicator.

The legend for data quality in the report card is:

- **High:** Adequate high-quality evidence and high level of consensus.
- **Moderate:** Limited evidence or limited consensus.
- **Low:** An assessment can be made, but there is only minimal evidence to guide the assessment.
- **Insufficient:**There is negligible evidence (that is, suitable data and/or thresholds) and no status and trend assessments can be made.
- N/A **N/A (not applicable):** An indicator data confidence assessment has not been made, because status and trend assessments have not been made for this indicator.

Theme 1: Water quality and catchment inputs

Indicator 01: Water quality (physicochemical)

Region		2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		Good	→	Good	Fair	→	Good
Western Port		Good	→	Good	Poor	→	Good
Corner Inlet-Nooramunga		Unknown	?	Unknown	Unknown	N/A	Unknown
Gippsland Lakes	Lake King	Good	→	Good	Unknown	N/A	Unknown
	Lake Victoria	Good	→	Good	Unknown	N/A	Unknown
	Lake Wellington	Poor	→	Good	Unknown	N/A	Unknown

Data source:	EPA, Melbourne Water, DELWP
Measures:	Water quality index scores

Comments:

Port Phillip Bay – These assessments are based on the Water Quality Index scores for Port Phillip Bay, which have been rated as good or very good each year since monitoring and reporting began in 2002. Confidence in the status and trend assessments is high because the Water Quality Index is benchmarked against objectives in the Environment Reference Standard (ERS), while there is adequate spatial and temporal monitoring data.

Western Port – These assessments are based on the Water Quality Index scores for Western Port, which have been good each year since monitoring and reporting began in 2000, except in 2017–18 (when water quality in Western Port Bay was rated as fair). Confidence in the status and trend assessments is high because the Water Quality Index is benchmarked against objectives in the ERS, while there is adequate spatial and temporal monitoring data.

The water quality indicator that was assessed as poor for Western Port in the 2018 report has been assessed as good in this report. This is not necessarily a reflection of improved environmental condition; the improved rating for Western Port is mainly because the indicator assessment in 2021 is based on the water quality results solely for Western Port rather than a combination of the marine water quality in Western Port and the water quality in the catchment, as was done for the SoE 2018 Report. The catchment inputs information is provided as a complementary and explanatory narrative for the water quality indicator, with nutrient and sediment loads assessed in separate indicators.

Corner Inlet-Nooramunga – Water quality is not currently routinely measured in the marine environment of the Corner Inlet and Nooramunga biounits. Therefore, the status and trend assessments have been assessed as unknown and unclear, respectively. The evidence to assess this indicator is minimal, therefore an indicator confidence assessment cannot be made. The water quality targets in the Water Quality Improvement Plan (WQIP) for Corner Inlet are likely to be used as thresholds for future assessments.

Gippsland Lakes – These assessments are based on the Water Quality Index scores for Gippsland Lakes. The eastern lakes (Lake King and Lake Victoria) have been rated as good for six of the past seven years, while Lake Wellington has been rated as poor for the past three years, and poor or very poor in seven of the past 10 years. Confidence in the status and trend assessments is high because the Water Quality Index is benchmarked against the environmental quality objectives in the ERS and is available at several sites across the Gippsland Lakes, with monthly time series data available back to 2000.

Indicator 02: Toxicants

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		?			N/A	N/A
Western Port		?	Moderate (status), Low (trend)		N/A	N/A
Corner Inlet-Nooramunga		?			N/A	N/A
Gippsland Lakes		?	Moderate (status), Low (trend)		N/A	N/A

Data source:	EPA, Melbourne Water, academic researchers
Measures:	Assessment against toxicants listed in ERS and the Australian and New Zealand Guidelines for Fresh and Marine Water Quality

Comments:

Port Phillip Bay – There is no routine monitoring of toxicants to enable an assessment against toxicants listed in the ERS and the Australian and New Zealand Guidelines for Fresh and Marine Water Quality.[124] Recent research has focused on the PFAS (per-and polyfluoroalkyl substances) group of manufactured chemicals, with results so far indicating where the greatest concentrations are being found and what the likely sources of contamination are. Because these studies provide point-in-time assessments, the trend is unclear. The status has been rated as fair because the environmental condition is variable, but, based on a limited number of focused studies, is unlikely to be under significant widespread stress. However, confidence in this assessment is low, because there are no Victorian or national PFAS thresholds to base assessments on, although a 2019 study assessed PFAS in estuaries in Port Phillip Bay using the European environment quality standards and found that none of the PFAS observed at estuary sites had concentrations higher than the EU standards.

Western Port – Although a 2013 study concluded that there are some localised areas in the Western Port catchment where toxicants are at levels of concern, toxicant concentrations in Western Port were generally below guideline values and therefore are likely to be a low risk to ecosystem health. Research from 2018 found frequent and widespread contamination by pesticides across the north-east catchments that discharge into Western Port. Pesticides were present in surface waters and sediments in complex mixtures and often at concentrations likely to harm resident flora and fauna. Because these research studies provide point-in-time assessments, the trend is unclear. This contributes to the confidence being rated as low for the trend because, although there is moderate confidence in the status based on research completed in 2013 and 2018, there is no ongoing toxicant assessment program in Western Port. Recent efforts have focused on understanding the major sources to the bay in the catchment.

Corner Inlet-Nooramunga – A risk assessment of toxicant threats in Corner Inlet revealed no medium, high or extreme risk to seagrass. Otherwise, there is no monitoring data to enable status or trend assessments. The absence of toxicant monitoring has been previously identified as a knowledge gap in this region. The evidence to assess this indicator is minimal, therefore an indicator confidence assessment cannot be made.

Gippsland Lakes – Concentrations of nickel, mercury and arsenic exceeding Australian and New Zealand Environment and Conservation Council guideline values for sediment quality were measured in Lake Wellington and Lake Victoria for a 2015–16 study.[125] All other locations had toxicant concentrations within guideline levels. Because this research is a point-in-time assessment, the trend is unclear. This is why confidence is moderate for status but only low for trend.

124. Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand 2000, 'National water quality management strategy, Paper no. 4: Australian and New Zealand guidelines for fresh and marine water quality. Volume 1: The guidelines', https://www.waterquality.gov.au/sites/default/files/documents/anzecc-armcanz-2000-guidelines-vol1.pdf Accessed 19 July 2021.
125. Reeves J and Trewarn A 2016, 'Assessment of heavy metals and other contaminants of the Gippsland Lakes', report commissioned by Department of Environment, Land, Water and Planning, Federation University Australia, Mt Helen, Victoria, http://www.loveourlakes.net.au/wp-content/uploads/2014/01/Gippsland-Lakes-Heavy-Metals-Report.pdf Accessed 23 September 2021.

Indicator 03: Water quality (estuaries)

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		?	High (status) Low (trend)		N/A	N/A
Western Port		?	High (status), Low (trend)		N/A	N/A
Corner Inlet-Nooramunga		?	High (status), Low (trend)		N/A	N/A
Gippsland Lakes		?	High (status), Low (trend)		N/A	N/A
Statewide		?	High (status), Low (trend)		N/A	N/A

Data source:	DELWP
Measures:	The Index of Estuary Condition water quality sub-index

Comments:

Through the 2021 Index of Estuary Condition (IEC) assessments, there is high confidence in the status assessment for estuarine water quality in this indicator. Because this is the first IEC, and IECs are designed as point-in-time assessments, no time series data are available to assess trends.

Port Phillip Bay – As part of the IEC, water quality assessments were completed for 11 estuaries in the Port Phillip catchment region, with two estuaries rated as excellent for water quality, three as good, two as fair, two as poor and two as very poor. The status assessment of fair reflects variable water quality in the estuaries that flow into Port Phillip Bay.

Western Port – As part of the IEC, water quality assessments were completed for nine of the 10 estuaries in the Western Port catchment region, with five estuaries receiving ratings of very poor for water quality, three estuaries as fair and one estuary as good.

Corner Inlet-Nooramunga – As part of the IEC, water quality assessments were completed for 11 estuaries in the West Gippsland catchment region for those estuaries that flow into Corner Inlet and Nooramunga. One estuary was rated as excellent for water quality, two estuaries as good, three as fair, one as poor and four as very poor. The status assessment of fair is due to variable water quality in the estuaries that flow into Corner Inlet and Nooramunga.

Gippsland Lakes – As part of the IEC, water quality assessments were completed for 14 estuaries in the West and East Gippsland catchment regions for those estuaries that flow into the Gippsland Lakes. Two estuaries were rated as excellent for water quality, four estuaries as good, four as fair, one as poor and three as very poor. The status assessment of fair is due to variable water quality in the estuaries that flow into the Gippsland Lakes.

Statewide – Water quality was good or excellent in 54% of the state's estuaries. It was poor or very poor in 25% of them – usually estuaries with catchments that were predominantly urban or agricultural. The status assessment of fair reflects variable water quality across the state, although it should be noted that more estuaries recorded good or excellent water quality than poor or very poor.

Theme 1: Water quality and catchment inputs

Indicator 04: Plankton

Region		2021 status	2021 trend	2021 data	2016 status	2016 trend	2016 data
Port Phillip Bay		Good	→	Good	Good	↗	Good
Western Port		Good	↗	Good	Poor	→	Good
Corner Inlet-Nooramunga		Unknown	?	Unknown	Black	N/A	N/A
Gippsland Lakes	Lake King	Good	↗	Good	Black	N/A	N/A
	Lake Victoria	Good	↗	Good	Black	N/A	N/A
	Lake Wellington	Poor	→	Good	Black	N/A	N/A
Statewide		N	N	N	Black	N/A	N/A

Data source:	EPA, Integrated Marine Observing System (IMOS)
Measures:	Chlorophyll-a (µg/L) | Total phytoplankton (cells/L)

Comments:

Port Phillip Bay – Chlorophyll-a is a commonly used measure of water quality, and concentrations indicate phytoplankton abundance and productivity in aquatic environments. The results show that chlorophyll-a ratings in Port Phillip Bay fluctuated between fair and very good from 2001–02 until 2012–13, but have been very good since then. Confidence in the status and trend assessments is high, because Chlorophyll-a is assessed against the objectives in the ERS, while there is adequate spatial and temporal monitoring data.

Western Port – Chlorophyll-a is a commonly used measure of water quality, and concentrations indicate phytoplankton abundance and productivity in aquatic environments. In Western Port chlorophyll-a was rated as fair to poor from 2000–01 to 2011–12, while it has been rated as good to very good since 2014–15, indicating a good status and improving trend. Confidence in the status and trend assessments is high because chlorophyll-a is assessed against the objectives in the ERS, while there is adequate spatial and temporal monitoring data.

Corner Inlet-Nooramunga – Phytoplankton is not currently routinely measured in the marine environment of the Corner Inlet and Nooramunga biounits. Therefore, the status and trend assessments have been assessed as unknown and unclear, respectively. The evidence to assess this indicator is minimal, therefore an indicator confidence assessment cannot be made.

Gippsland Lakes – Chlorophyll-a is a commonly used measure of water quality, and concentrations indicate phytoplankton abundance and productivity in aquatic environments. The results show chlorophyll-a ratings in Lake Wellington have been poor to very poor since 2007–08, which has been translated to a status assessment of poor and a stable trend that reflects poor to very poor ratings for more than a decade. Chlorophyll-a ratings have been more favourable in the eastern Lakes (Lake Victoria and Lake King), with five of the past six years rated as good for chlorophyll-a. Confidence in the status and trend assessments is high because chlorophyll-a is assessed against the objectives in the ERS, while there is adequate spatial and temporal monitoring data.

Indicator 05: *Enterococci* bacteria

Region	2021 status	2021 trend	2021 data	2016 status	2016 trend	2016 data
Port Phillip Bay	Fair	→	Good	Good	→	Good

Data source:	EPA
Measures:	Number of beaches meeting short-term and long-term standards for primary and secondary contact

Comments:

Port Phillip Bay – The fair status assessment is due to all beaches meeting standards for secondary contact (for example, boating and canoeing) and most meeting standards for primary contact (for example, swimming) during dry weather. However, most beaches do not meet standards for all-weather primary contact. Stormwater pollution is often a key reason why beaches don't meet standards. Water quality has been stable over time for all weather conditions. Confidence in the assessment is high based on the quality of the analytical data used to complete the assessment against standards.

Indicator 06: Regulated point source discharges to marine waters

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	Unknown	?	Unknown	Poor	N/A	N/A
Corner Inlet-Nooramunga	Unknown	?	Unknown	Poor	N/A	N/A
Statewide				Unknown	?	Very poor

Data source:	EPA
Measures:	Volumes and nutrient loads discharged to marine waters from regulated point sources

Comments:

Port Phillip Bay and Corner Inlet-Nooramunga – There is good information available on the volumes and nutrient loads discharged to marine waters from regulated point sources. However, there is limited quantitative analysis available to understand the extent to which regulated discharges affect the receiving marine environments. There is no available analysis of non-compliance of licensed facilities that discharge to marine environments, so the extent of non-compliance with licensed discharge limits is unknown.

Theme 1: Water quality and catchment inputs

Indicator 07: Stormwater

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		?	Moderate (status), Low (trend)		N/A	N/A
Western Port		?	Moderate (status, Low (trend)		N/A	N/A
Corner Inlet-Nooramunga		?			N/A	N/A
Gippsland Lakes		?			N/A	N/A

Data source:	Melbourne Water
Measures:	Directly connected imperviousness, which is the proportion of the impervious surface that is directly connected to a stream through a conventional drainage connection

Comments:

Port Phillip Bay – The status of fair is due to variable stormwater conditions across Port Phillip Bay's catchments. There are very strong regional differences in the overall assessment for the bay. For example, stormwater has only minor effects on stream health in the Werribee catchment, while stream health is being severely affected by stormwater in the Dandenong catchment. Despite the analysis by catchment, there has been no public reporting on whether the Victorian Government's target of limiting nutrient and sediment loads to 2017 levels is being met, so there is only a moderate confidence in the stormwater status assessment. No time series data are available to provide a trend assessment.

Western Port – The status of good is due to Melbourne Water's assessment that stormwater has only minor effects on stream health in Western Port. No time series data are available to provide a trend assessment. Given that there are no data available on the stormwater loads into Western Port, confidence in these assessments is moderate rather than high.

Corner Inlet-Nooramunga – The stormwater impact on marine water quality in Corner Inlet and Nooramunga remains largely unknown. The evidence to assess this indicator is minimal, so an indicator confidence assessment cannot be made.

Gippsland Lakes – There are no available assessments of the contribution of stormwater to pollutant loads entering the Gippsland Lakes. The evidence to assess this indicator is minimal, so an indicator confidence assessment cannot be made.

Indicator 08: Total nutrient loads

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay					N/A	N/A
Western Port			Low (status), Moderate (trend)		N/A	N/A
Corner Inlet-Nooramunga			Moderate (status), Low (trend)		N/A	N/A
Gippsland Lakes					N/A	N/A

Data source:	Melbourne Water, academic researchers
Measures:	Total nitrogen and phosphorus loads (t/yr)

Comments:

Port Phillip Bay – Estimated nutrient loads over 2016–19 are within one quartile of the modelled 2000–19 long-term average, suggesting a stable trend over this time. This preliminary finding is based on interim results from a continuing project, with further work underway to improve confidence in the modelled estimates. Given that the Port Phillip Bay Environmental Management Plan 2017–2027 sets a priority target for nutrient loads to not exceed 2017 levels, the estimated stable trend from 2016–19 indicates good status, but information is insufficient to determine whether annual nitrogen load objectives in the ERS are being met.

Western Port – The evidence currently available suggests that nutrients are not having a significant effect on the Western Port environment. Estimated nutrient loads over 2016–19 are within one quartile of the 2000–19 long-term average, suggesting a stable trend over this time. This preliminary finding is based on interim results from a continuing project, with further work underway to improve confidence in the modelled estimates. Confidence in the status assessment is low because there is no pollutant load target for nutrient loads for Western Port.

Corner Inlet-Nooramunga – Periodic research has shown that high nutrient loads are entering Corner Inlet and that these are linked with infrequent algal bloom occurrences in the Inlet. There is no routine monitoring to assess nutrient loads, so confidence in the status assessment is moderate and the trend is unclear, due to the absence of time series data. The nutrient load targets in the Water Quality Improvement Plan for Corner Inlet are likely to be used as thresholds for future assessments.

Gippsland Lakes – Nutrient loads and flow for the most recent five years of data are within 20% of the long-term median, while total phosphorous loads are regularly not meeting the 100 tonnes per year maximum target in the Environment Reference Standard. This information informs the status rating of fair. The inflow of nitrogen and phosphorus was above the long-term median for the past five years of data (to 2016), indicating a deteriorating trend. The absence of recently analysed data (the most recent data included in the assessment is from 2016) means that confidence is moderate rather than high.

Theme 1: Water quality and catchment inputs

Indicator 09: Total sediment loads

Region		2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay			→			N/A	N/A
Western Port			→			N/A	N/A
Corner Inlet-Nooramunga			?			N/A	N/A
Gippsland Lakes	Lake King		?			N/A	N/A
	Lake Victoria		?			N/A	N/A
	Lake Wellington		?			N/A	N/A

Data source:	Melbourne Water, academic researchers
Measures:	Total suspended solids loads (t/yr)

Comments:

Port Phillip Bay – Estimated sediment loads for 2016–19 are within one quartile of the modelled 2000–19 long-term average, suggesting a stable trend over this time. This preliminary finding is based on interim results from a continuing project, with further work underway to improve confidence in the modelled estimates. Given that the Port Phillip Bay Environmental Management Plan 2017–2027 sets a priority target for sediment loads to not exceed 2017 levels, the estimated stable trend from 2016–19 is indicative of good status. However, information is insufficient to determine whether annual total suspended solids load objectives in the ERS are being met.

Western Port – Estimated sediment loads for 2016–19 are within one quartile of the modelled 2000–19 long-term average, suggesting a stable trend over this time. This preliminary finding is based on interim results from a continuing project, with further work underway to improve confidence in the modelled estimates. The interim results show that total suspended solids loads for Western Port for recent years are estimated to be above the ERS marine pollutant load objective of 28,000 tonnes of total suspended solids per year. Confidence in the status assessment is moderate rather than high because even though the status can be benchmarked against the ERS, the data are from interim results only, as part of a continuing project.

Corner Inlet-Nooramunga – The limited available evidence suggests that sediment loads are not having a significant effect on general marine and coastal habitats in Corner Inlet and Nooramunga. This has led to a status assessment of good, but with only low confidence.

Gippsland Lakes – Recent studies have measured sediment loads to the Gippsland Lakes and determined their major sources. Because these studies are point-in-time assessments, no time series of data exist and the trend is unclear. Status has been rated as poor because water clarity in some parts of the Gippsland Lakes (Lake Wellington) has recently been rated as very poor, and riverine sediment loads probably contribute to this rating, as they can damage seagrass. There are no specific thresholds available for this assessment, so confidence is low.

Indicator 10: Coastal acid sulfate soils

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		?			N/A	N/A
Western Port		?			N/A	N/A
Corner Inlet-Nooramunga		?			N/A	N/A
Gippsland Lakes		?			N/A	N/A

Data source:	Department of Jobs, Precincts and Regions
Measures:	Area of potential coastal acid sulfate soil within 5 km of the high-water mark adjacent to marine biounits

Comments:

Potential acid sulfate soil sites have been mapped along the Victorian coastline. Because this mapping is a point-in-time assessment, the trend is unclear. Because there are no thresholds to guide status and trend assessments and there is no available evidence on the effects of coastal acid sulfate soils, an indicator confidence assessment cannot be made.

Port Phillip Bay – The aggregated area of potential coastal acid sulfate soil sites is 12,000 hectares, which is a significant area of land but not near a complete coverage of the Port Phillip Bay coastline.

Western Port – The aggregated area of potential coastal acid sulfate soil sites is 8,000 hectares, which is a significant area of land but not near a complete coverage of the Western Port coastline.

Corner Inlet-Nooramunga – The aggregated area of potential coastal acid sulfate soil sites is 20,000 hectares, which is a significant area of land but not near a complete coverage of the Corner Inlet and Nooramunga coastline.

Gippsland Lakes – The status has been rated as poor for Lake Wellington and fair for the eastern lakes because the aggregated area of potential coastal acid sulfate soil sites is 43,000 hectares, which is a significant area of land. Coastal areas surrounding the Gippsland Lakes have a greater area of potential coastal acid sulfate soil than the combined potential area along the Port Phillip Bay, Western Port and Corner Inlet and Nooramunga coastlines. The area of potential coastal acid sulfate soil sites is nearly a complete coverage of the Lake Wellington coastline.

Theme 2: Litter and pollution

Indicator 11: Litter and plastics

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		↙			N/A	N/A
Western Port		?			N/A	N/A
Corner Inlet-Nooramunga		?			N/A	N/A
Gippsland Lakes		?			N/A	N/A

Data source:	Port Phillip EcoCentre, Tangaroa Blue Foundation, academic researchers
Measures:	Number of litter items (including plastic and microplastic) in catchment waterways flowing into marine environments

Comments:

Port Phillip Bay – A deteriorating trend is provided with moderate confidence due to the estimated amount of litter increasing in both the Maribyrnong and the Yarra. The status is unknown because, although the number of litter items and microplastics flowing into Port Phillip Bay has been estimated, there is an absence of thresholds that can be used to guide the assessment. The lack of any thresholds based on quantitative analysis of the effects of litter and plastics means that no status assessment can be provided. In other words, we do not know if the current status of litter and plastics is good, fair or poor, but we have moderate confidence that the amount of litter and microplastics is increasing.

Western Port – There are no specific analyses of litter in Western Port, therefore the status and trend have been assessed as unknown and unclear, respectively. Given the relatively smaller urban environment, litter and microplastics are likely to pose a lesser risk in Western Port than in Port Phillip Bay, where more studies have been completed.

Corner Inlet-Nooramunga, Gippsland Lakes – No litter and plastic pollution data are available for Corner Inlet and Nooramunga or the Gippsland Lakes. Given the relatively smaller urban environment of these regions, litter and microplastics are likely to pose a lesser risk than in Port Phillip Bay, where more studies have been completed.

Theme 2: Litter and pollution

Indicator 12: Light pollution

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		?			N/A	N/A
Western Port		?			N/A	N/A
Corner Inlet-Nooramunga		?			N/A	N/A
Gippsland Lakes		?			N/A	N/A
Statewide					?	

Data source:	https://www.lightpollutionmap.info/, academic researchers
Measures:	Artificial light at night measured as radiance (Watts per square cm)

Comments:

There is insufficient information to provide status and trend assessments for this indicator. The evidence to assess this indicator is minimal, therefore an indicator confidence assessment cannot be made.

Theme 2: Litter and pollution

Indicator 13: Coastal contaminated land

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	Fair	?	Poor	Not assessed	N/A	N/A
Western Port	Good	?	Poor	Not assessed	N/A	N/A
Corner Inlet-Nooramunga	Good	?	Poor	Not assessed	N/A	N/A
Gippsland Lakes	Good	?	Poor	Not assessed	N/A	N/A
Statewide				Not assessed	?	Fair

Data source:	EPA
Measures:	Numbers of contaminated and potentially contaminated land locations within 5 km of the coastline for various datasets published on Victoria Unearthed

Comments:

Because information available via Victoria Unearthed is point-in-time spatial data, the trend is unclear. Confidence for this assessment is low because, although the quality of the data is good, there are no thresholds available to guide the status assessments.

Port Phillip Bay – The status assessment of fair is based on there being several sites within 5 km of the Port Phillip Bay coastline that are known to be contaminated or that are the location of current activity involving a relatively high risk of contamination. Examples of contamination include the groundwater contamination that has been identified beneath Fishermans Bend. The status assessment is a subjective interpretation that moderate protection of natural ecosystems and biodiversity is evident due to the management of the Priority Sites Register, with the relatively large number of contaminated sites along the Port Phillip Bay coastline relative to other Victorian coastal regions indicating that coastal contaminated land is exerting moderate pressure on environmental condition and human health.

Western Port – The status assessment of good is based on there being only a few sites within 5 km of the Western Port coastline that are known to be contaminated or that are the location of current activity involving a relatively high risk of contamination. The status assessment is a subjective interpretation that there is a reasonably small number of contaminated sites along the Western Port coastline, indicating that coastal contaminated land is generally exerting minimal pressure on environmental condition and human health in this region.

Corner Inlet-Nooramunga – The status assessment of good is based on there being only a few sites within 5 km of the Corner Inlet and Nooramunga coastline that are known to be contaminated or that are the location of current activity involving a relatively high risk of contamination. The status assessment is a subjective interpretation that there is a reasonably small number of contaminated sites along the Corner Inlet and Nooramunga coastline, indicating that coastal contaminated land is generally exerting minimal pressure on environmental condition and human health in this region.

Gippsland Lakes – The status assessment of good is based on there being only a few sites within 5 km of the Gippsland Lakes coastline that are known to be contaminated or that are the location of current activity involving a relatively high risk of contamination. The status assessment is a subjective interpretation that there is a reasonably small number of contaminated sites along the Gippsland Lakes coastline, indicating that coastal contaminated land is generally exerting minimal pressure on environmental condition and human health in this region.

Theme 2: Litter and pollution

Indicator 14: Coastal air quality

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	(ozone, nitrogen dioxide, carbon monoxide, sulfur dioxide) (fine particle pollution)	→	(near shipping terminals) (elsewhere)	●	N/A	N/A
Western Port	●	?	●	●	N/A	N/A
Corner Inlet-Nooramunga	●	?	●	●	N/A	N/A
Gippsland Lakes	(fine particle pollution during bushfire periods) (all other times)	?	(fine particulate pollution during bushfire periods) (all other times)	●	N/A	N/A

Data source:	EPA, academic researchers
Measures:	Number of exceedences of air quality standards

Comments:

Port Phillip Bay – The status assessments are based on the compliance of air quality at Victorian air quality monitoring stations with the National Environment Protection (Ambient Air Quality) Measure. Focused research on air quality near shipping terminals using lower-quality air monitoring sensors provides evidence of high concentrations of fine particle pollution near Station Pier resulting in poor air quality with a moderate confidence.

Western Port, Corner Inlet-Nooramunga – EPA does not currently measure air quality along the Western Port, Corner Inlet or Nooramunga coastlines.

Gippsland Lakes – The status assessments are based on the compliance of air quality at Victorian air quality monitoring stations with the National Environment Protection (Ambient Air Quality) Measure. Air quality monitoring does not routinely occur along the Gippsland Lakes coastline, with recent monitoring only conducted as part of the emergency management response to significant amounts of bushfire smoke in the region.

Theme 3: Biodiversity

Indicator 15: Conservation of coastal ecosystems in protected areas

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide	Fair	?	Poor	Fair	→	Fair

Data source:	Parks Victoria
Measures:	Percentage of the land within 5 km of the high-water mark managed as national and state parks or as coastal reserves Conservation status of ecological vegetation classes Area of ecological vegetation classes within 5 km of the high-water mark

Comments:

Statewide – This is a broad indicator that covers a range of coastal ecosystems and conservation efforts. A variety of protection is given to coastal ecological vegetation classes; some classes have been more affected by changing coastal land use. The status of fair is due to a range of national parks and other conservation areas having generally good coverage (that is, extending along approximately 70% of the Victorian coastline), countered by there being some data limitations for threatened and invasive species, while some ecological vegetation classes could be given greater protection. There is no evidence to support a trend assessment. Due to the lack of an existing overarching threshold for conservation of coastal ecosystems, confidence in this status assessment is low.

Indicator 16: Saltmarsh

Region		2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		Fair	→	Fair	Fair	→	Fair
Western Port		Good	→	Fair	Good	↙	Fair
Corner Inlet-Nooramunga	Corner Inlet	Fair	→	Fair	Unknown	N/A	N/A
	Nooramunga	Fair	→	Fair	Unknown	N/A	N/A
	Nooramunga islands	Good	→	Fair	Unknown	N/A	N/A
Gippsland Lakes		Fair	?	Fair	Good	?	Poor

Data source:	Academic researchers, DELWP
Measures:	Extent of saltmarsh | Change in saltmarsh extent since European settlement

Comments:

Port Phillip Bay – Although there have been significant losses of saltmarsh cover since European settlement, approximately half of the saltmarsh cover remains today. The limit of acceptable change (LAC) for saltmarsh in the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site is that total saltmarsh extent will not decline below 900 hectares. This is being met. Limited information on saltmarsh condition suggests that most saltmarsh communities were 'healthy or near-stressed'. The status of fair is based on a balance of the significant losses of saltmarsh cover since European settlement, with the LAC for saltmarsh being met in the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site, where more than half of the saltmarsh communities are not under significant stress. Confidence in the assessments is moderate rather than high, because the most recent assessments of saltmarsh extent and condition are from 2011.

Western Port – There has been minimal loss of saltmarsh cover since European settlement, with approximately 90% of the saltmarsh cover remaining in 2012. The LAC for saltmarsh in the Western Port Ramsar site is that total saltmarsh extent will not decline below 900 hectares. This is being met. Based on this, the status for this indicator has been assessed as good.

Corner Inlet-Nooramunga – The status for Corner Inlet has been rated as fair because, although more than half of the saltmarsh cover has been lost since European settlement, the LAC for saltmarsh in the Corner Inlet Ramsar site is that total saltmarsh extent will not decline below 2,775 hectares, which is being met. Nooramunga's status is fair because the saltmarsh losses have been less extensive (20%), while the saltmarsh area around the Nooramunga islands is rated as good and estimated to be 6% greater now than in the pre-1750s period.

Gippsland Lakes – There has been some loss of saltmarsh cover since European settlement, with approximately 65–100% of the saltmarsh cover remaining in 2012, the losses occurring variably across the lakes. The LAC for saltmarsh in the Gippsland Lakes Ramsar site is that the total mapped area of salt flat, saltpan and salt meadow habitat at Lake Reeve Reserve extent will not decline below 2,517 hectares. This is being met, with the most recent assessment, completed in 2021, estimating that there is more than 5,000 hectares of saltmarsh habitat in the Ramsar site. The status of fair is based on variable losses of saltmarsh cover since European settlement, but the LAC for saltmarsh is being met in the Gippsland Lakes Ramsar site.

Theme 3: Biodiversity

Indicator 17: Mangroves

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	Good	?	Medium	Poor	N/A	N/A
Western Port	Good	↗	Medium	Good	?	Good
Corner Inlet-Nooramunga	Good	→	Medium	Medium	?	Good

Data source:	Academic researchers, DELWP
Measures:	Extent of mangroves | Change in mangrove extent since European settlement

Comments:

Port Phillip Bay – There are currently 52 hectares of mangroves in the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site, which meets the LAC for mangroves in the Ramsar site. This is reflected in a status of good. There is no pre-European settlement baseline data for comparison. Therefore, the trend is unclear. Confidence in the assessments is moderate rather than high, because the most recent assessments of mangrove extent and condition are from 2011.

Western Port – There has been minimal loss of mangrove habitat in Western Port since European settlement, with approximately 90% of the mangrove habitat remaining in 2012. This assessment was used to inform an estimate of 1,700 hectares of mangrove extent in the Western Port Ramsar site, which meets the LAC for mangroves in the Ramsar site to remain above 900 hectares. This is reflected in a status of good, while the trend is rated as improving based on advice from DELWP that the mangrove extent in the Western Port Ramsar site has increased by 40% since 1982. Confidence in the assessments is rated as moderate rather than high because the most recent assessments of mangrove extent and condition are nearly a decade old.

Corner Inlet-Nooramunga – There has been minimal loss of mangrove habitat since European settlement, with approximately 80% of the mangrove habitat in Corner Inlet and Nooramunga remaining in 2012. Corner Inlet and Nooramunga have the most extensive stands of mangrove along Victoria's coast. Based on this information, the status for this indicator has been assessed as good. The LAC for mangroves in the Corner Inlet Ramsar site is that total mangrove extent will not decline below 1,600 hectares. This is being met, with the most recent assessment estimating that there are more than 3,800 hectares of saltmarsh in the Ramsar site.

Indicator 18: Wetland and estuarine vegetation

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	Yellow	?	Green	Black	N/A	N/A
Western Port	Green	?	Yellow	Black	N/A	N/A
Corner Inlet-Nooramunga	Yellow	?	Green	Black	N/A	N/A
Gippsland Lakes	Green (estuarine flora) Yellow (wetland habitat extent) Red (condition of paperbark-dominated wetlands)	?	Green (estuarine flora) Yellow (wetland habitat extent, condition of paperbark-dominated wetlands)	Black	N/A	N/A
Statewide	Green	?	Green	Black	N/A	N/A

Data source:	Academic researchers, DELWP
Measures:	The Index of Estuary Condition flora sub-index

Comments:

Port Phillip Bay – Through the 2021 Index of Estuary Condition (IEC) assessments, there is high confidence in the status assessment for estuarine flora in this indicator. As part of the IEC, flora assessments for nine of the 11 estuaries in the Port Phillip catchment region were completed, with two estuaries rated as good for flora, five as fair and two as poor.

Western Port – As part of the IEC, flora assessments for eight of the 10 estuaries in the Western Port catchment region were completed, with two estuaries rated as excellent for flora, four as good and two as fair. Through the 2021 IEC assessments, only two estuaries were rated on both fringing and submerged vegetation, with the six estuaries receiving the best ratings not assessed for submerged vegetation. Because of this, there is moderate, rather than high, confidence in the status assessment for estuarine flora in this indicator.

Corner Inlet-Nooramunga – Through the 2021 IEC assessments, there is high confidence in the status assessment for estuarine flora in this indicator. As part of the IEC, flora assessments for 11 estuaries were completed in the West Gippsland catchment region for those estuaries that flow into Corner Inlet and Nooramunga. One estuary was rated as excellent for flora, three as good, six as fair, and one rated poor.

Gippsland Lakes – Even though many of the paperbark-dominated wetlands of the Gippsland Lakes are in poor ecological condition, the LAC for freshwater wetland habitat extent was assessed as being met in 2021, while the LAC for brackish wetland habitat extent is likely to be met. Through the 2021 IEC assessments, there is high confidence in the status assessment for estuarine flora in this indicator. As part of the IEC, flora assessments for 14 estuaries were completed in the West and East Gippsland catchment regions for those estuaries that flow into the Gippsland Lakes. Three estuaries were rated as excellent for flora, seven estuaries were rated as good, two as fair, with two rated poor.

Statewide – As part of the IEC, flora assessments for 100 estuaries across Victoria were completed. Half of the state's estuaries had flora in excellent or good condition, and only 11% had flora in poor condition. No estuaries had flora in very poor condition.

Theme 3: Biodiversity

Indicator 19: Species of conservation concern

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		?			N/A	N/A
Western Port		?			N/A	N/A
Corner Inlet-Nooramunga		?			N/A	N/A
Gippsland Lakes		?			N/A	N/A
Statewide		?			N/A	N/A

Data source:	Victorian Biodiversity Atlas
Measures:	Victorian Biodiversity Atlas

Comments:

The data analysed and reported for this indicator provides information on the number of species of conservation concern. The status and trend assessments are unknown and unclear, respectively, because no information is available to ascertain how these species are being tracked and managed, and no trend data are available to assess how these species are tracking over time.

Indicator 20: Mobile invertebrates on intertidal reefs

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		→			?	
Other marine protected areas		→			→	

Data source:	Parks Victoria
Measures:	Parks Victoria control charts

Comments:

Port Phillip Bay – The status assessment of good is based on the available information provided as part of Parks Victoria's long-term Intertidal Reef Monitoring Program. No reports have been published since 2014, with the only subsequent information contributing to this status assessment being draft control charts from 2018. Due to the lack of recent evidence, confidence in the status and trend assessments is low. Parks Victoria is progressing monitoring and assessment, with a technical report in preparation for the Port Phillip Heads Marine National Park, which is likely to fill knowledge gaps and increase confidence in this indicator assessment in future SMCE Reports.

Other marine protected areas – The status assessment of good is based on the available information provided as part of Parks Victoria's long-term Intertidal Reef Monitoring Program. That program ceased in 2014, with the only subsequent information contributing to this status assessment being draft control charts from 2018. Due to the lack of recent evidence, confidence in the status and trend assessments is low. Parks Victoria is progressing monitoring and assessment, with plans to publish technical reports in the next couple of years for Port Phillip Heads, Wilsons Promontory, Cape Howe and Discovery Bay marine national parks, which will fill intertidal reef knowledge gaps in marine protected areas and increase confidence in this indicator assessment in future SMCE Reports.

Indicator 21: Sessile invertebrates on intertidal reefs

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay					N/A	N/A
Other marine protected areas						

Data source:	Parks Victoria
Measures:	Parks Victoria control charts

Comments:

Port Phillip Bay – The status assessment of good is based on the available information provided as part of Parks Victoria's long-term Intertidal Reef Monitoring Program. No reports have been published since 2014, with the only subsequent information contributing to this status assessment being draft control charts from 2018. Due to the lack of recent evidence, confidence in the status and trend assessments is low. Parks Victoria is progressing monitoring and assessment, with a technical report in preparation for the Port Phillip Heads Marine National Park, which is likely to fill knowledge gaps and increase confidence in this indicator assessment in future SMCE Reports.

Other marine protected areas – The status assessment of good is based on the available information provided as part of Parks Victoria's long-term Intertidal Reef Monitoring Program. That program ceased in 2014, with the only subsequent information contributing to this status assessment being draft control charts from 2018. Due to the lack of recent evidence, confidence in the status and trend assessments is low. Parks Victoria is progressing monitoring and assessment, with plans to publish technical reports in the next couple of years for Port Phillip Heads, Wilsons Promontory, Cape Howe and Discovery Bay marine national parks, which will fill intertidal reef knowledge gaps in marine protected areas and increase confidence in this indicator assessment in future SMCE Reports.

Theme 3: Biodiversity

Indicator 22: Invertebrates on subtidal reefs

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	Fair	↗ (north) → (south)	Fair	Fair	↙ (north) → (south)	Good
Other marine protected areas	Good	?	Fair	Fair	?	Good

Data source:	Parks Victoria, Reel Life Surveys
Measures:	Parks Victoria control charts | The number of mobile macroinvertebrate species recorded on individual Reef Life Surveys (species per 50 m^2)

Comments:

Port Phillip Bay – The status assessment of fair is based on the available information provided as part of Parks Victoria's long-term Subtidal Reef Monitoring Program, and the (more recent) Reef Life Survey. The Reef Life Survey data shows that the trend over the past decade is an increasing number of species in the Port Phillip Bay's north, with fluctuations in the south but a generally stable underlying trend.

Other marine protected areas – The status assessment of good is based on the available information from Parks Victoria's long-term Subtidal Reef Monitoring Program, the more recent Reef Life Survey, and the 2020 Technical Report for Point Addis Marine National Park. Parks Victoria draft control charts assessed mobile megafaunal invertebrates as good in 12 of the parks, fair in one and unknown in one. The Reef Life Survey data shows that the trend over the past decade is an increasing number of species in Port Phillip Bay's north, with variability in the south. Broadly though, across Victoria's marine protected areas, the trend is unclear.

Indicator 23: Commercially and recreationally important invertebrates

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	(commercial scallop, short-spined sea urchin)	(commercial scallop, short-spined sea urchin)	(commercial scallop, short-spined sea urchin)		N/A	N/A
Statewide	(southern calamari, Maori octopus) (southern rock lobster) (blacklip abalone) (pipi, greenlip abalone)	(southern calamari, Maori octopus, southern rock lobster) (blacklip abalone) (pipi, greenlip abalone)	(southern calamari, southern rock lobster) (Maori octopus, blacklip abalone) (pipi, greenlip abalone)		N/A	N/A

Data source:	Victorian Fisheries Authority (VFA)
Measures:	Landings (tonnes) | Catch per unit of effort (fish per angler hour) Recruitment (using fishery independent sampling of recruits and or pre-recruits) Percentage of fishers satisfied with their fishing experience

Comments:

Port Phillip Bay (commercial scallop) – As time progresses, the effect of natural variation in scallop abundance on dive fishery will become apparent. At present, given the very minimal landings of commercial scallops, it is highly unlikely that the Port Phillip Bay commercial scallop dive fishery is causing recruitment impairment, and thus the stock can be considered as sustainable in accordance with the Status of Australian Fish Stocks classification, which translates to a good status and stable trend for this report.

Port Phillip Bay (short-spined sea urchin) – There is no information to suggest that the stock is in any danger of depletion. Based on the available evidence, stock of the short-spined sea urchin in Port Phillip Bay is sustainable in accordance with the Status of Australian Fish Stocks classification, which translates to a good status and stable trend for this report.

Statewide (southern calamari) – There is no evidence to suggest recruitment impairment and, in the context of this species' biology and the relatively low level of fishing pressure, the stock is expected to remain sustainable into the future.

Statewide (Maori octopus) – There is minimal reason to believe that this species is at risk of depletion under current fishing practices. This implies that stocks of Maori octopus in Victoria are sustainable.

Statewide (pipi) – Based on the available information, the current status of Victoria's pipi stock is uncertain.

Statewide (southern rock lobster) – The southern Australian stock is sustainable, but Victorian catch per unit effort (CPUE) is at very low levels, and the abundance of undersize lobsters is at or near record lows in the western and eastern zones of the Victorian fishery. Balancing this information, the status is fair with a stable trend.

Statewide (blacklip abalone) – Based on the two fisheries management units with the largest catches in Victoria both being classified as having depleting stocks, the status of this indicator has been assessed as poor, with a deteriorating trend.

Statewide (greenlip abalone) – There is insufficient information available to classify status.

Theme 3: Biodiversity

Indicator 24: Commercially and recreationally important fish

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	(snapper, King George whiting) (southern sand flathead)	(King George whiting) (snapper, southern sand flathead)	(snapper, King George whiting) (southern sand flathead)		N/A	N/A
Western Port	(snapper, King George whiting)	(King George whiting) (snapper)	(snapper) (King George whiting)		N/A	N/A
Corner Inlet-Nooramunga	(King George whiting, rock flathead)	(King George whiting) (rock flathead)	(King George whiting, rock flathead)		N/A	N/A
Gippsland Lakes	(black bream, dusky flathead)	(dusky flathead) (black bream)	(black bream, dusky flathead)		N/A	N/A
Statewide	(bluethroat, purple wrasse)	(bluethroat, purple wrasse)	(bluethroat, purple wrasse)		?	

Data source:	VFA, academic researchers
Measures:	Landings (tonnes) | Catch per unit of effort (fish per angler hour) Recruitment (using fishery independent sampling of recruits and or pre-recruits) Percentage of fishers satisfied with their fishing experience

Comments:

Port Phillip Bay (snapper) – The recreational fishery for adult snapper in Port Phillip Bay is considered sustainable at its current level, appearing to have stabilised since 2014. Commercial fishing pressure has reduced substantially in recent years, while record snapper spawning in the region during 2018 is likely to result in a snapper population boom in Port Phillip Bay during 2022 and 2023.

Port Phillip Bay (King George whiting) – The recent strong post-larval recruitment is expected to drive a strong increase in catch per unit of effort (CPUE) over the next few years, so the stock should remain sustainable.

Port Phillip Bay (southern sand flathead) – The evidence suggests that the stock has now stabilised at a lower biomass under a lower recruitment regime, and that recruitment has been sufficient to balance natural and fishing mortality at this lower level.

Western Port (snapper) – There is a declining trend in the recreational fishery for adult snapper in Western Port. Recent strong recruitment is expected to reverse any declining biomass trends and drive a rebuilding of adult biomass and improved fishery performance over the next five to 10 years.

Western Port (King George whiting) – There is only limited data for King George whiting in Western Port. A slight decline in recreational fishing CPUE was measured during the 2010s, but recent strong post-larval recruitment is expected to drive a rapid increase in CPUE over the next few years, so the stock should remain sustainable.

Corner Inlet-Nooramunga (King George whiting) – The likelihood of recent strong post-larval recruitment based on sampling in Port Phillip Bay is expected to support an increasing CPUE for King George whiting in Corner Inlet over the next few years, so the stock should remain sustainable.

Corner Inlet-Nooramunga (rock flathead) – In recent years a greater commercial effort is being made to catch rock flathead, and this is resulting in a greater catch. However, a decreasing CPUE shows that rock flathead is becoming more difficult to catch in Corner Inlet and Nooramunga. If this combination continues, a further deterioration of rock flathead in Corner Inlet and Nooramunga is expected.

Gippsland Lakes (black bream) – Due to the recent CPUE data for both commercial and recreational fishers trending near the reference period minimums, and uncertainty in how recruitment replenishes the adult stock, the Gippsland Lakes, black bream stock was assessed as depleting in the VFA's most recent stock assessment report (published in 2020). This analysis has been translated into status and trend assessments of poor and deteriorating, respectively, in this report.

Gippsland Lakes (dusky flathead) – Current levels of fishing pressure on dusky flathead are well below historic highs, yet the CPUE has remained below average in recent years. Based on this, Gippsland Lakes dusky flathead stock was described as depleting in the Status of Key Victorian Fish Stocks report published by the VFA in 2020. This analysis has been translated into status and trend assessments of poor and stable, respectively, in this report.

Statewide (bluethroat and purple wrasse) – The current harvest and effort appear to present a low risk for the stock becoming recruitment overfished at a statewide scale, bearing in mind a depleting trend in the east, which was occurring before licence transferability. Statewide, fishing for blue throat and purple wrasse appears to be sustainable.

Indicator 25: Subtidal reef fish

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	(north) (south)	(north) (south)		(north) (south)	(north) (south)	(north) (south)
Other marine protected areas						

Data source:	Parks Victoria, Reef Life Surveys, ReefWatch
Measures:	Parks Victoria control charts | The number of mobile macroinvertebrate species recorded on individual Reef Life Surveys (species per 50 m^2) | Fish species sightings and abundances

Comments:

Port Phillip Bay – The data shows a pattern of fewer fish species in the north of the bay and more in the south, particularly around the entrance to the bay. During the past decade, there has been a decline in the number of fish species in the north and a slight increase in the number of species in southern Port Phillip Bay.

Other marine protected areas – Parks Victoria's integrated dataset and control charts show that the condition of large mobile fish (including sharks and rays) on subtidal reefs in marine national parks and sanctuaries beyond Port Phillip Bay was assessed as good in 14 parks, fair in one and unknown in one. Confidence is moderate rather than high because the data in some marine protected areas are now several years out of date, although monitoring and assessment programs are underway to provide contemporary data and analysis, which will be incorporated into future SMCE Reports. Advances in use of baited remote underwater videos are enabling the monitoring of time series fish assemblages for the entire depth range of marine national parks.

Indicator 26: Diadromous fish

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	N	N	N	●	N/A	N/A
Western Port	N	N	N	●	N/A	N/A
Gippsland Lakes	N	N	N	●	N/A	N/A
Statewide	●	?	●	●	N/A	N/A

Data source:	Academic researchers, DELWP, Melbourne Water
Measures:	Ramsar site limits of acceptable change assessments for Australian grayling

Comments:

Statewide – There is no routine monitoring or assessment of diadromous fish in Victoria, so status and trend assessments cannot be made for this indicator. However, the narrative highlights research that has been done to understand migration habits and enable waterway managers to increase delivery of environmental water and thereby improve immigration by diadromous fishes in Victorian coastal rivers.

Port Phillip Bay, Western Port and Gippsland Lakes – DELWP has advised that the limits of acceptable change (LACs) for the Australian grayling (*Protroctes maraena*) in the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site, the Western Port Ramsar site and the Gippsland Lakes Ramsar site were all assessed as being met during the most recent LAC assessments (in 2020).

Indicator 27: Marine and coastal waterbirds

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	Fair	→	Fair	Unknown	?	Poor
Western Port	Fair	↙	Good	Fair	↙	Good
Corner Inlet-Nooramunga	Fair	→	Fair	Not applicable	N/A	N/A
Gippsland Lakes	Fair	?	Fair	Fair	Species-dependent	Good

Data source:	BirdLife Australia, academic researchers, DELWP, Melbourne Water
Measures:	Waterbird abundance, breeding and diversity

Comments:

Port Phillip Bay – The LAC assessments from 2020 show that LACs for waterbird abundance and diversity were being met in the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site. The most recent LAC assessment for waterbird breeding took place in 2016 and there was insufficient data to assess this LAC. For threatened waterbird species, the most recent LAC assessment took place in 2020, and the LAC was met for all species except the lesser sand plover (*Charadrius mongolus*). Data from 2019–20 show record numbers of many types of waterbirds near the Western Treatment Plant. The status rating is fair rather than good because the 2020 count of the straw-necked ibis (*Threskiornis spinicollis*) was the lowest since 2017, while the LAC for the lesser sand plover was not met.

Western Port – Population trends were determined for 39 of the 85 observed waterbird species (excluding seabirds). Populations of 22 of the 39 species declined between 1973 and 2015, 15 remained stable (despite fluctuations and some changes in distribution), and two have increased. This indicator assessment summarises these results, with an overall trend assessment of deteriorating because populations of the majority of waterbird species have declined. The status has been rated as fair because waterbirds are still present in significant numbers in Western Port, which is noted as an important habitat for waterbirds.

Corner Inlet-Nooramunga – The LAC assessments from 2020 show that LACs for waterbird abundance and threatened species were being met in the Corner Inlet Ramsar site for non-migratory birds. There was insufficient information to assess the LAC for waterbird breeding, which has resulted in a confidence assessment of moderate.

Gippsland Lakes – The LAC assessments from 2021 show that the LAC for waterbird abundance is being met, while there was insufficient information to assess the LAC for waterbird breeding. This is reflected in a fair status and moderate confidence.

Theme 3: Biodiversity

Indicator 28: Migratory shorebirds

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay						
Western Port					N/A	N/A
Corner Inlet-Nooramunga						
Gippsland Lakes		?			N/A	N/A

Data source:	BirdLife Australia, academic researchers, DELWP, Melbourne Water
Measures:	Migratory shorebird abundance and breeding

Comments:

Port Phillip Bay – The numbers of red-necked stint (C*alidris ruficollis*), curlew sandpipers (*Calidris ferruginea*) and sharp-tailed sandpipers (Calidris acuminate) are declining in line with populations throughout the world over the past 20 years. The status is rated as fair because there are still significant numbers of migratory shorebirds stopping at sites along Port Phillip Bay (for example, more than 10,000 sharp-tailed sandpipers were counted near the Western Treatment Plant in 2019–20), while a 2020 assessment found LACs for key migratory shorebird species were being met in the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site.

Western Port – Declines have been observed in several species of trans-equatorial migratory shorebirds that visit Western Port. The status has been rated as fair because migratory shorebirds are still present in significant numbers in Western Port, which is noted as an important habitat for waterbirds.

Corner Inlet-Nooramunga – A review of 30 years of data (1981–2011) for migratory shorebird numbers in Corner Inlet and Nooramunga revealed a 23% decline in the combined numbers of all species. Despite the deteriorating trend, the status has been rated as fair because the combined population is still estimated to be approximately 25,000–30,000.

Gippsland Lakes – The LAC assessments from 2021 show that the LAC for waterbird abundance is being met for the red-necked stint and sharp-tailed sandpiper. Both species have been recorded multiple times in the past five years (2017–2021).

Indicator 29: Piscivorous (fish-eating) birds

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	Good	→	Good	Poor	N/A	N/A
Western Port	Good	↙	Good	Good	↙	Good
Corner Inlet-Nooramunga	Good	↗	Good	Good	↗	Good

Data source:	BirdLife Australia, academic researchers, DELWP, Melbourne Water
Measures:	Piscivorous bird abundance and diversity

Comments:

Port Phillip Bay – The status is rated as good, because Mud Island supports very large numbers of fish-eating waterbirds, mainly of petrels and gulls. A 2020 assessment found that LACs were being met for piscivorous species in the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site.

Western Port – Research shows that Western Port's populations of terns, cormorants and the Australian pelican (*Pelecanus conspicillatus*) decreased between 1974 and 2012. Although the data quality to support these assessments is good, confidence in these assessments is only rated as moderate. This is because there are no clear criteria and thresholds to assess the status, and the most recent data are now nearly a decade old.

Corner Inlet-Nooramunga – A study completed in 2015 analysed data from 1987 to 2012. The researchers found increasing population trends for terns, cormorants and the Australian pelican at west Corner Inlet. The results of this study are the basis of the status and trend assessments of good and improving, respectively.

Indicator 30: Little penguins

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	Good	↗	Good	Good	→	Good
Western Port	Good	↗	Good	Good	→	Good

Data source:	Earthcare St Kilda, Phillip Island Nature Parks
Measures:	Estimated population size, number of unique penguins tracked, number of chicks microchipped

Comments:

Port Phillip Bay – Little penguin numbers at St Kilda Harbour breakwater have grown to an estimated 1,400 since they were first observed in the 1960s. Based on this, the status has been rated as good and the trend as improving, although confidence is only moderate because there is no routine monitoring of the population and there are no existing thresholds available to guide the assessment.

Western Port (Bass Coast Shire) – Extensive conservation work since the 1980s has resulted in an increase in little penguin numbers from 12,000 in the mid-1980s to an estimated 32,000 in 2021. Based on this the status has been rated as good. The trend is improving based on unpublished surveys available for trend analysis across recent years.

Theme 3: Biodiversity

Indicator 31: Marine mammals

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	(dolphins)	(dolphins)	(dolphins)		N/A	N/A
Western Port	(dolphins, seals)	(dolphins) (seals)	(seals) (dolphins)		N/A	N/A
Gippsland Lakes	(dolphins)	(dolphins)	(dolphins)		N/A	N/A

Data source:	Dolphin Research Institute, Marine Mammal Foundation, Phillip Island Nature Parks, academic researchers
Measures:	Marine mammal population estimates

Comments:

Port Phillip Bay (dolphins) – There is contention about the species of dolphins residing in Port Phillip Bay, but there is strong agreement that there is a stable population of more than 100. Although this might seem small, it is likely to have been reasonably stable for a long time (since the 1960s), which is why the status is rated as fair rather than poor.

Western Port (dolphins) – The Dolphin Research Institute estimates that Western Port has a resident population of 20 dolphins. There is no evidence to suggest a decline of these numbers over the past three decades. The very small population size means that the consequences of significant mortality events can be proportionally significant on the dolphin population in Western Port, so the status has been rated as poor to reflect this vulnerability.

Western Port (seals) – There are an estimated 20,000 to 30,000 Australian fur seals in the Seal Rocks colony at the western entrance to Western Port, including bulls, seals and pups. Phillip Island Nature Parks and collaborators have identified statistically significant declining trends in pup numbers since 2007 at Seal Rocks.

Gippsland Lakes (dolphins) – There has been a relatively stable population of between 60 and 100 dolphins living in the Gippsland Lakes, although a significant mortality event and skin infections for the resident dolphins in 2020 have been linked with the 2019–20 bushfires, which is reflected in a deteriorating trend assessment. The small population means the consequences of significant mortality events can be proportionally significant on the dolphin population in the lakes, so the status has been rated as poor to reflect this vulnerability.

Indicator 32: Conservation of marine ecosystems in protected areas

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Other marine protected areas				(Victoria's five marine bioregions)	(seals)	(seals)
Gippsland Lakes						

Data source:	Parks Victoria
Measures:	Percentage of Victoria's state waters that are protected | Percentage of Victoria's marine protected areas that are no-take zones where removing animals and plants is banned | Percentage of marine parks reported to be in good condition

Comments:

This is a broad indicator that covers a range of marine protected areas and conservation efforts. In total, Victoria's marine protected areas cover 106,106 hectares or 10.4% of state waters. Based on 10.4% of all Victoria's marine coastal waters being covered by marine protected areas, Victoria does satisfy an international target for at least 10% marine protected area coverage. However, only 5.2% of Victoria's state waters are no-take zones where removing animals and plants is banned – Victoria has the second-lowest proportion of no-take areas of any Australian state or territory.

Parks Victoria reports that the condition of natural values is good or very good in 93% of marine parks.

Based on this broad range of evidence, with Victoria's marine protected areas generally in good condition and meeting the international target to conserve at least 10% of coastal and marine areas, but with a smaller spatial coverage of no-take zones relative to most other Australian jurisdictions, the status of this indicator is rated as fair. The trend is rated as stable, because the area protected in marine parks has remained unchanged since 2002, while the condition of marine protected areas remains generally good.

Theme 4: Seafloor integrity and health

Indicator 33: Nitrogen cycle

Region		2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		Good	→	Adequate	Good	→	Good
Western Port		Good	→	Poor	Poor	?	Poor
Gippsland Lakes	Lake King	Good	→	Adequate	Unknown	N/A	N/A
	Lake Victoria	Poor	→	Adequate	Unknown	N/A	N/A
	Lake Wellington	Poor	→	Adequate	Unknown	N/A	N/A

Data source:	DELWP, Melbourne Water, academic researchers
Measures:	Denitrification efficiency | The ratio of nitrogen fixation to denitrification Dissolved inorganic nitrogen concentrations

Comments:

Port Phillip Bay – The denitrification efficiency (DE) process generally maintains nutrients in Port Phillip Bay at an optimal level for biodiversity. No event since 1994 has been large enough to reduce DE for more than a month. A status assessment of good has been made on the basis that a threshold of DE lower than 60% in Port Phillip Bay (40% for Hobsons Bay) indicates that the denitrification process is disrupted. Confidence in the assessment is only moderate, because no data since 2014 are available.

Western Port – In most parts of Western Port, the ratio of nitrogen fixation to denitrification is high (that is, nitrogen fixation is more common than denitrification). Low denitrification indicates that the water column is starved of nutrients because the vegetation is processing it. This ratio is inverted in less-vegetated areas of Western Port (that is, denitrification is higher than nitrogen fixation). There is only a small number of research studies that have investigated this, so confidence in the status assessment is low.

Gippsland Lakes – These status and trend ratings for the Gippsland Lakes are based on dissolved inorganic nitrogen concentration assessments using thresholds derived from the framework established in the Australian and New Zealand Water Quality Guidelines. Dissolved inorganic nitrogen concentrations in Lake King are rated as good, but in Lakes Victoria and Wellington were above the threshold for all five years from 2010 to 2015. Although there is a pattern of increased concentrations in high rainfall years, there are no sustained trends.

Indicator 34: Seagrass

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	Fair	?	Poor	Good	↗	Fair
Western Port	Poor	↗	Fair	Unassessed	?	Fair
Corner Inlet-Nooramunga	Fair	↗	Fair	Fair	↙	Fair
Gippsland Lakes	Fair	?	Fair	Fair	?	Fair
Other marine protected areas	Fair	→	Fair			

Data source:	Academic researchers, Melbourne Water
Measures:	Seagrass extent Seagrass condition (includes a range of variables such as shoot length, density and biomass, along with epiphyte cover, epifauna, water temperature and light)

Comments:

Port Phillip Bay – During the last major drought (1997–2009), Port Phillip Bay lost considerable areas of seagrass. There is insufficient information to measure the extent of recovery, if any, since the drought ended in 2010. The LAC for seagrass in the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site is that total seagrass extent will not decline below 1,500 hectares for a period of greater than 20 continuous years. This is being met, although most of the data used to make this assessment are now more than 20 years old. The condition of seagrass in Port Phillip Bay is good but based on only four years of data (2008–11). This information on seagrass extent and condition has been combined into a status assessment of fair. Due to the short time series and lack of recent data from the past decade, the trend is unclear and confidence in the assessment is low.

Western Port – In the mid-1970s to early 1980s extensive loss (up to 75%) of intertidal seagrasses was observed. Seagrass recovery has been observed since then, although coverage is still less than during the 1970s. The LAC for seagrass in the Western Port Ramsar site is that total seagrass extent will not decline below 5,400 hectares. This is being met. Even though the LAC for seagrass is being met, because of the documented and extensive historical seagrass losses and the lack of a major recovery in recent years, the status has been rated as poor, but the trend is improving.

Corner Inlet-Nooramunga – Despite a long history of slow seagrass decline in Corner Inlet, where seagrass extent had declined on average by 0.5 km^2 per year between 1965 and 2013, the cover of seagrass appears to have stabilised between 2013 and 2018, and then increased between 2018 and 2020. Based on this information, the status has been assessed as fair and the trend as improving.

Gippsland Lakes – The LAC for seagrass in the Gippsland Lakes Ramsar site is being met for one of the two components of the LAC, with the other unable to be assessed. No trend can be determined for seagrass in the Gippsland Lakes, as there are only two points in time upon which extent and condition can be compared. Seagrass extent can be highly variable. The decline from 1997 to 2016 does not provide any indication of variability over time or tell us whether seagrass extent expanded and contracted several times over that period or is on a trajectory of decline.

Other marine protected areas – Parks Victoria data show a 9% decline in seagrass extent in marine protected areas over a three-year period from 2015. The change in seagrass extent is variable across Victoria's marine protected areas and is small enough in magnitude for the trend to be rated as stable. For example, there have been increases during the past decade in Corner Inlet and Nooramunga Marine and Coastal Parks, while there has been a decrease of *Amphibolis antartica* seagrass extent in the Port Phillip Heads Marine National Park from a high of 12% cover in 2003 to a low of 4% in 2019. The most recent estimate is that there is 18,287 hectares of seagrass habitat in Victorian Marine Protected Areas.

Theme 4: Seafloor integrity and health

Indicator 35: Shellfish reefs

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		↗			N/A	N/A
Western Port		→			N/A	N/A
Corner Inlet-Nooramunga		→			N/A	N/A
Gippsland Lakes		→			N/A	N/A

Data source:	Academic researchers
Measures:	Extent of shellfish reefs

Comments:

Port Phillip Bay – Historically, there were large areas of blue mussel (*Mytilus edulis galloprovincialis*) and native flat oyster (*Ostrea angasi*) reefs in Port Phillip Bay. While flat oysters and blue mussel can still be found throughout Port Phillip Bay, there are currently no known areas of extensive mussel or flat oyster reefs on the bay sediments. The trend has been rated as improving because of a current restoration project that has built 5.5 hectares of shellfish reef in Port Phillip Bay since 2015. The confidence is rated as moderate rather than high because it is unknown whether the conditions that support the continuing enhancement and maintenance of these oyster reefs are improving.

Western Port – Historically, there were large areas of native flat oyster reefs in Western Port. Anecdotal evidence reported as part of a 2016 research project indicates that sporadic oyster harvesting has not occurred since the mid-20th century, suggesting that the extent of native flat oyster reefs is now minimal. However, the lack of recent quantitative analysis means that confidence in this indicator assessment is low.

Corner Inlet-Nooramunga – The past distribution of native flat oyster in Corner Inlet and Nooramunga is estimated to be almost the entire enclosed waterway and some sandy stretches on the open coast. The species is still present in many locations in Corner Inlet and Nooramunga but consists mainly of isolated clumps or individuals and no longer forms a continuous reef matrix.

Gippsland Lakes – Large mussel reefs can still be found in the entrance region of the Gippsland Lakes, which is why the status is fair despite the extent of shellfish reefs having declined in the 20th century. No significant changes to shellfish reefs have been noted this century, so the trend has been assessed as stable.

Indicator 36: Macroalgae on intertidal reefs

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	Good	→	Fair	Good	→	Good
Other marine protected areas	Fair	?	Fair	Good	→	Good

Data source:	Parks Victoria
Measures:	Parks Victoria's control charts for the condition of brown algae communities on intertidal reefs

Comments:

Port Phillip Bay – The status assessment of good is based on information provided as part of Parks Victoria's long-term Intertidal Reef Monitoring Program. No reports have been published since 2014, but Parks Victoria advises that monitoring and assessment are continuing and the most recent findings are consistent with those previously published – an updated technical report is in preparation by Parks Victoria.

Other marine protected areas – The status assessment of fair is based on information provided as part of Parks Victoria's long-term Intertidal Reef Monitoring Program to 2014, draft control charts from 2018, and a 2020 publication focusing on Point Addis Marine National Park. The absence of regular published reporting for many marine protected areas is reflected in an unclear trend and a confidence assessment of moderate rather than high.

Theme 4: Seafloor integrity and health

Indicator 37: Macroalgae-dominated subtidal reefs

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	(Port Phillip Heads Marine National Park) (Ricketts Point Marine Sanctuary) (Point Cooke and Jawbone marine sanctuaries)	→		(north) (south)	? (north) ↙ (south)	(north) (south)
Other marine protected areas		?			?	
Data source:	Parks Victoria					
Measures:	Parks Victoria control charts					

Comments:

Port Phillip Bay – A range of evidence from research studies and Parks Victoria's long-term Subtidal Reef Monitoring Program shows that the condition and extent of macroalgae on subtidal reefs in Port Phillip Bay is poor for Point Cooke and Jawbone marine sanctuaries, fair for Ricketts Point Marine Sanctuary, and good for Port Phillip Heads Marine National Park. The recent trend is stable, although it is worth noting that there was a significant deterioration in kelp loss during the early 2000s in association with the millennium drought.

Other marine protected areas – The status assessment of fair is based on the available information provided as part of Parks Victoria's long-term Subtidal Reef Monitoring Program to 2014, draft control charts from 2018, and a 2020 publication focusing on Point Addis. The absence of regular published reporting for many marine protected areas is reflected in a confidence assessment of moderate rather than high. Parks Victoria is progressing monitoring and assessment, with plans to publish technical reports in the next couple of years for Port Phillip Heads, Wilsons Promontory, Cape Howe and Discovery Bay marine national parks, which will help fill gaps in knowledge on intertidal reefs in marine protected areas and increase confidence in this indicator assessment in future SMCE Reports.

Theme 5: Pests and invasive species

Indicator 38: Invasive marine species

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	🔴	↙	🟡	🔴	↙	🟡
Western Port	🟡	↙	🟡	⚫	N/A	N/A
Corner Inlet-Nooramunga	🟢	↙	🟡	⚫	N/A	N/A
Gippsland Lakes	🟡	↙	🟡	⚫	N/A	N/A
Other marine protected areas	🟡	?	🟡	⚫	N/A	N/A

Data source:	Department of Jobs, Precincts and Regions
Measures:	Number of invasive marine species | Change in the number of marine species Abundance of invasive marine species | Impact of invasive marine species

Comments:

Port Phillip Bay – There are now more than 160 invasive marine species in Port Phillip Bay. The damage caused by some of these is significant, notably the northern Pacific seastar (*Asterias amurensis*), which has been shown to cause changes in fish populations in Port Phillip Bay. New invasive species continue to arrive, most recently the Asian shore crab (*Hemigrapsus sanguineus*), first detected at Mount Martha in late 2020.

Western Port – The status assessment of fair reflects the presence of several invasive marine species in Western Port, although the size and number of infestations are significantly lower than in Port Phillip Bay.

Corner Inlet-Nooramunga – The status assessment of good reflects that Corner Inlet has remained relatively free of invasive marine species. The deteriorating trend is based on *Undaria pinnatifida*, a kelp also known as wakame, being observed in the region since 2018.

Gippsland Lakes – The status assessment of fair reflects research published in 2016 which determined that the Gippsland Lakes' risk profile for invasive marine species is lower than that of many other major ports along the Australian coast. The deteriorating trend is based on the arrival of the northern Pacific seastar and the Pacific oyster (*Magallana gigas*), with both species being observed in the lakes in recent years.

Other marine protected areas – The status assessment of fair reflects research highlighting the risks that invasive marine species pose to marine protected areas. For example, wakame is an introduced kelp that was first detected in 1996 near Point Wilson and has progressively become established in all three of Port Phillip Bay's marine sanctuaries (Point Cooke, Jawbone and Ricketts Point) and Portsea Hole in the Port Phillip Heads Marine National Park. Not enough information is available to determine the trend. Confidence in the status and trend indicator assessments is rated as moderate.

Theme 5: Pests and invasive species

Indicator 39: Coastal invasive plants

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		?			N/A	N/A

Data source:	DELWP, Department of Jobs, Precincts and Regions, Parks Victoria
Measures:	Area of treatment works to control weeds on land within 5 km of the Victorian coastline The impact of weeds | Threat of transformer weeds | Benefit minus cost of weed control Number of locations where invasive plants have been detected within 5 km of the Victorian coastline

Comments:

Statewide – Only limited time series data exist to track the impact of coastal invasive plants over time. The status of fair is due to varying impacts of invasive plants along the Victorian coastline.

Indicator 40: Coastal invasive animals

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		?			N/A	N/A

Data source:	Statewide (SW)
Measures:	Area of treatment works to control cats, deer, foxes, goats, pigs and rabbits within 5 km of the Victorian coastline | The impact of pest animals | Benefit minus cost of fox control Number of locations where invasive animals have been detected within 5 km of the Victorian coastline

Comments:

Statewide – Only limited time series data exist to track the impact of coastal invasive animals over time. The status of fair is due to varying impacts of invasive animals along the Victorian coastline.

Indicator 41: Rainfall

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	Fair	↙	Fair	Black	N/A	N/A
Western Port	Fair	→	Fair	Black	N/A	N/A
Corner Inlet-Nooramunga	Fair	↙	Fair	Black	N/A	N/A
Gippsland Lakes	Fair	↙	Fair	Black	N/A	N/A
Statewide				Fair	↙	Good

Data source:	BoM, CSIRO, DELWP
Measures:	Rolling 10-year average of annual rainfall | Rolling 10-year average of cool-season (April to October) rainfall | Percentage change in rainfall from 1980–99 to 2000–19

Comments:

Confidence in the status and trend assessments is rated as moderate rather than high because even though the data quality on rainfall is good, understanding of the impacts of rainfall on coastal settlements is constantly evolving.

Port Phillip Bay, Corner Inlet-Nooramunga, Gippsland Lakes – The status and trend assessments of fair and deteriorating respectively reflect the fluctuating pressure being exerted on the water resources and agricultural sectors by wetter years interspersing a predominantly drying climate. Greater reduction in rainfall during the cool seasons is particularly important, given the harm this can cause to streamflows and the reduced reliability for water storage filling seasons.

Western Port – The status and trend assessments of fair and stable respectively reflect the fluctuating pressure being exerted on the water resources and agricultural sectors by wetter and drier years.

Theme 6: Climate and climate change impacts

Indicator 42: Air temperature

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	Fair	↙	Fair	Poor	N/A	N/A
Western Port	Fair	↙	Fair	Poor	N/A	N/A
Corner Inlet-Nooramunga	Fair	↙	Fair	Poor	N/A	N/A
Gippsland Lakes	Fair	↙	Fair	Poor	N/A	N/A
Statewide	N	N	N	Fair	↙	Good

Data source:	BoM, CSIRO, DELWP
Measures:	Rolling 10-year average of annual mean maximum temperature | Rolling 10-year average of summer mean maximum temperature | Temperature change (average daily maximum temperature in °C) per decade from the 1980s to the 2010s | Number of days when the daily maximum temperature exceeds 35°C

Comments:

Confidence in the status and trend assessments is rated as moderate rather than high because, even though the data quality on temperature is good, knowledge on the impacts of increasing temperatures is constantly evolving.

Port Phillip Bay – The status and trend assessments of fair and deteriorating respectively reflect the increasing pressure being exerted on human health, biodiversity and coastal infrastructure. Melbourne was 0.96°C warmer in the 2010s than in the 1990s, highlighting the rapid rate of recent warming.

Western Port – The status and trend assessments of fair and deteriorating respectively reflect the increasing pressure being exerted on human health, biodiversity and coastal infrastructure. Temperature measurements made at coastal settlements along Western Port show that temperatures have increased by approximately 1°C from the 1990s to the 2010s, highlighting the rapid rate of recent warming.

Corner Inlet-Nooramunga – The status and trend assessments of fair and deteriorating respectively reflect the increasing pressure being exerted on human health, biodiversity and coastal infrastructure. Wilsons Promontory was 0.8°C warmer in the 2010s than in the 1990s, highlighting the rapid rate of recent warming.

Gippsland Lakes – The status and trend assessments of fair and deteriorating respectively reflect the increasing pressure being exerted on human health, biodiversity and coastal infrastructure. The rolling 10-year average temperature has increased significantly at East Sale, by 1.14°C, from the 1950s to the 2010s, with the rate of increase being most pronounced during the past 20 years. The 2010s were 0.74°C warmer than the 1990s, highlighting the rapid rate of recent warming.

Theme 6: Climate and climate change impacts

Indicator 43: Water temperature

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide						

Data source:	BoM, CSIRO, DELWP
Measures:	Trends in sea-surface temperatures (°C per decade)

Comments:

Statewide – The increasing frequency of marine heatwaves around Australia in recent years has permanently harmed marine ecosystem health, marine habitats and species. These harms include depleting kelp forests and sea grasses, a poleward shift in some marine species, and increased occurrence of disease. This information is the basis of the status and trend assessments of poor and deteriorating, respectively.

Indicator 44: Ocean acidification

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide			Low (status), High (trend)		N/A	N/A

Data source:	BoM, CSIRO, DELWP
Measures:	Change in pH of surface waters

Comments:

Ocean surface waters around Australia have increased in acidity by more than 30% from the 1880s to the 2010s. The increase in acidity has become mare rapid in recent decades. There are limited studies on the effects of ocean acidification around Victoria, so the status is rated fair, but with low confidence. There is high confidence in the trend assessment.

Theme 6: Climate and climate change impacts

Indicator 45: Areas of coastal vulnerability

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	●	?	●	●	N/A	N/A
Western Port	●	?	●	●	N/A	N/A
Corner Inlet-Nooramunga	●	↙	●	●	N/A	N/A
Gippsland Lakes	●	↙	●	●	N/A	N/A
Statewide	N	N	N	●	N/A	N/A

Data source:	DELWP, academic researchers
Measures:	This indicator is designed to describe the types of hazards, report on where these hazards are, and how much area they cover.

Comments:

Port Phillip Bay – There is currently not enough published information to provide status and trend assessments for this indicator.

Western Port – The most recent comprehensive assessment of coastal inundation and erosion hazards for Western Port occurred in 2014. A range of hazards were identified, but the spatial extent of the area of coastal vulnerability is unknown.

Corner Inlet-Nooramunga – Modelling predicts that Corner Inlet will be affected extensively by climate change, with the effects worsening over time. A range of hazards were identified, but the spatial extent of the area of coastal vulnerability is unknown, so confidence in the status and trend assessments is only rated as moderate.

Gippsland Lakes – The most recent comprehensive assessment of coastal inundation and erosion hazards for the Gippsland Lakes occurred in 2014. A range of hazards was identified, but the spatial extent of the area of coastal vulnerability is unknown. The findings converged on increasing effects, which is reflected in a deteriorating trend. The status has been rated as fair due to there currently being damage associated with coastal risks such as inundation and erosion, but these are still relatively infrequent. For example, there is currently a 10% chance each year that Lakes Entrance will be subjected to inundation during a flood event.

Indicator 46: Sea-level and coastal inundation

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	Fair	↙	Good	Poor	N/A	N/A
Western Port	Fair	↙	Good	Poor	N/A	N/A
Corner Inlet-Nooramunga	Fair	?	Fair	Poor	N/A	N/A
Gippsland Lakes	Fair	?	Fair	Poor	N/A	N/A
Statewide	Fair	↙	Good	Fair	↙	Good

Data source:	BoM
Measures:	Annual mean sea level | Annual maximum sea level

Comments:

Port Phillip Bay, Western Port – The status and trend assessments of fair and deteriorating respectively reflect the increasing pressure being exerted on human coastal settlements and infrastructure.

Corner Inlet-Nooramunga – The status assessment of fair reflects the pressure being exerted on human coastal settlements and infrastructure. Confidence in the assessments is moderate rather than high, because the time series of tidal gauge data covers less than two decades and has many gaps.

Gippsland Lakes – The status assessment of fair reflects the pressure being exerted on human coastal settlements and infrastructure. Confidence in the assessments is moderate rather than high, because the time series of tidal gauge data covers only the last 12 years.

Statewide – Future rises in sea level are projected with high confidence. Sea levels are expected to rise by approximately 12 cm at various places along Victoria's coastline by 2030, with a rise of approximately 40 cm projected by 2070. The status and trend assessments of fair and deteriorating respectively reflect the increasing pressure being exerted on human coastal settlements and infrastructure.

Theme 6: Climate and climate change impacts

Indicator 47: Wave climate

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		?			N/A	N/A
Statewide		?			N/A	N/A

Data source:	Academic researchers
Measures:	Percentage of load on structures from meteorological and oceanographic forcing (that is, the combined wind, wave and climate conditions)

Comments:

Port Phillip Bay – A recent study of Port Phillip Bay's wave climate deepened the understanding of its characteristics and effects. Extreme sea levels are often not associated with large extreme wave events in Port Phillip Bay, while meteorological and oceanographic forcing (that is, the combined wind, wave and climate conditions) is a major cause of damage to marine and coastal infrastructure – this combination of various wave climate parameters produces approximately 70% of loads on structures. Because the research used for this indicator assessment is more of a characterisation of current wave climate rather than an analysis of the effects of a changing wave climate due to climate change, the status has been rated as unknown, and the trend is unclear.

Statewide – A recent study of Victoria's wave climate deepened the understanding of its characteristics. Despite this research, Victoria's relatively high-wave-energy coastline is a major gap in Australia's knowledge of the open coast wave climate of Australia, due to a lack of permanent wave buoys. There has been no statewide analysis of the effects of Victoria's wave climate, with the published research focusing on the significant effects that are estimated to occur at a global scale. Confidence in this indicator is rated as low, because of the lack of local studies and data.

Indicator 48: Coastal erosion

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	Fair	?	Fair	Not assessed	N/A	N/A
Western Port	Fair	↙	Fair	Not assessed	N/A	N/A
Corner Inlet-Nooramunga	Fair	↙	Fair	Not assessed	N/A	N/A
Gippsland Lakes	Poor	↙	Fair	Not assessed	N/A	N/A
Statewide	Fair	?	Fair	Not assessed	N/A	N/A

Data source:	DELWP
Measures:	Area of coast defined as an erosion hotspot (that is, where there has been a landward shift in shoreline position between 1986 and 2017 at a rate greater than 0.5 m per year) Area of coastline defined as highly or very highly vulnerable to erosion

Comments:

Port Phillip Bay – The results of a 2017 erosion vulnerability assessment have been used to guide the status assessment for this indicator. Thirty-one percent of Port Phillip Bay's coastline has a very high or high vulnerability to coastal erosion, which is reflected in a status assessment of fair for this indicator. Because this mapping is a point-in-time assessment, the trend is unclear.

Western Port – Two studies in recent years have measured the Lang Lang coastline (at the head of Western Port) as eroding, on average, by approximately 30 cm per year, while coastal bank erosion has also been estimated to be responsible for one-third of the sediment delivered to Western Port annually. The results of a 2017 erosion vulnerability assessment have also been used to guide the status assessment for this indicator: 27% of Western Port's coastline has a very high or high vulnerability to coastal erosion. This information is reflected in a status assessment of fair for this indicator, with a deteriorating trend.

Corner Inlet-Nooramunga – The results of a 2017 erosion vulnerability assessment have been used to guide the status assessment for this indicator. Thirty-four percent of Corner Inlet and Nooramunga's coastline has a very high or high vulnerability to coastal erosion, which is reflected in a status assessment of fair. Because this mapping is a point-in-time assessment, the trend is unclear.

Gippsland Lakes – The results of a 2017 erosion vulnerability assessment have been used to guide the status assessment for this indicator. More than 100 kilometres of the Gippsland coastline is rated as having a very high vulnerability to coastal erosion. This means that more than one-quarter of the entire Victorian coastline most at risk of erosion is located along the Gippsland Lakes, which is reflected in a status assessment of poor. Because this mapping is a point-in-time assessment, the trend is unclear.

Statewide – Researchers have estimated that erosion hotspots (defined as showing a landward shift in shoreline position between 1986 and 2017 at a rate greater than 0.5 m per year) extend over 76.6 km of the coastline, equivalent to approximately 6.2% of the Victorian coast. Because this mapping is a point-in-time assessment, the trend is unclear.

Theme 6: Climate and climate change impacts

Indicator 49: Seawater intrusion into coastal aquifers

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		?			N/A	N/A

Data source:	Academic researchers
Measures:	Vulnerability ratings for seawater intrusion into coastal aquifers

Comments:

Statewide – There is insufficient information to provide status and trend assessments for this indicator. The evidence to assess this indicator is minimal, therefore an indicator confidence assessment cannot be made.

Indicator 50: Frequency and impact of fire on marine and coastal ecosystems

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Gippsland Lakes		?			N/A	N/A

Data source:	Academic researchers
Measures:	Change in water quality, algal bloom frequency and nutrient loads before, during and after significant fire activity

Comments:

Gippsland Lakes – The status assessment of fair is due to the Gippsland Lakes water quality being temporarily adversely affected by the large bushfires in the 2019–20 fire season. Previous fires in 2003 and 2006–07 were linked with algal blooms. No data on the frequency and impact of fires along the Gippsland Lakes coastline are available to ascertain a trend.

Theme 6: Climate and climate change impacts

Indicator 51: Climate change impact on marine and coastal infrastructure

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	●	?	●	●	N/A	N/A
Western Port	●	↙	●	●	N/A	N/A
Gippsland Lakes	●	↙	●	●	N/A	N/A
Statewide	●	↙	●	●	N/A	N/A

Data source:	DELWP, AURIN (Australian Urban Research Infrastructure Network)
Measures:	Number and proportion of buildings expected to be inundated by 2100 under a high-emissions scenario with an expected sea-level rise of 82 cm and a one-in-100-year storm tide, by coastal local government area Total capital improved value of properties vulnerable to flooding

Comments:

Port Phillip Bay – DELWP and CSIRO are collaborating on a coastal hazard assessment for Port Phillip Bay. This assessment will enable impact assessments and projections for inundation (flooding), groundwater change, and erosion.

Western Port – A significant number of coastal infrastructure assets, valued in the billions of dollars, are at risk from climate change. For example, based on flood mapping information available in 2008, an estimated 18,000 properties with a total capital improved value of almost $2 billion are vulnerable to flooding.[126] The effects of climate change are expected to dramatically increase the likelihood of this flood risk, with projections suggesting that a current one-in-100-year storm surge could become a one-in-one to one-in-four-year storm surge by 2070.

Gippsland Lakes – A range of recent studies highlights significant likelihood of impact from climate change on coastal infrastructure, including properties, the road network and utilities (for example, powerlines) along the Gippsland Lakes coastline. The studies do not provide quantitative estimates of the extent of the impact and the economic value of the vulnerable infrastructure, so confidence in the status and trend assessments is low.

Statewide – The status and trend assessments are based on analysis of the Victorian Coastal Inundation digital dataset; Microsoft's Australia Building Footprints dataset; and the research synthesis and commentary provided in Infrastructure Victoria's Draft 30-Year Infrastructure Strategy, which was released in December 2020.

There has been no statewide quantitative analysis of the risks to, and impacts on, Victoria's marine and coastal infrastructure from climate change, so confidence in this indicator's status and trend assessments is low. However, the examples provided in the indicator narrative all suggest a poor status and an unclear trend, although there is expected to be a deteriorating trend in the future as the effects of climate change are projected to increase.

126. Kinrade P and Preston B 2008, 'Impacts of climate change on settlements in the Western Port region: people, property and places. Final report', Australian Government Department of Climate Change, and Department of Sustainability and Environment, Victoria.

Theme 7: Managing coastal hazard risks

Indicator 52: Considering climate change risks in land-use planning

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		?			?	

Data source:	DELWP
Measures:	Percentage of Victorian coastal councils assessed as having Advanced or Intermediate consideration of climate change in land-use planning

Comments:

Statewide – The status assessment of fair reflects data from 2018 that shows 70% of the 22 Victorian coastal councils were assessed as having Advanced or Intermediate consideration of climate change in land-use planning. Because this mapping is a point-in-time assessment, the trend is unclear. As climate change risks regularly evolve, it is possible that coastal councils have advanced their consideration of climate change in land-use planning since 2018, so confidence in the indicator assessment is only rated as moderate.

Indicator 53: Climate change adaptation plans

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		↗			N/A	N/A

Data source:	catchment management authorities
Measures:	Number of catchment management authorities that have developed and are implementing climate change adaptation plans or strategies

Comments:

Statewide – The status assessment of fair reflects the fact that considerable work is being done to adapt to climate change based on the best scientific information. For example, all 10 catchment management authorities across Victoria have developed and are implementing climate change adaptation plans or strategies based on the latest climate change projections by the CSIRO and formulated in conjunction with Australia's principal research organisations. The trend is improving because more guidance material to enable organisations to develop climate change adaptation plans has been published during recent years. The low confidence rating reflects the fact that only a minimal amount of evidence is available to assess the development and implementation of climate change adaptation plans.

Theme 7: Managing coastal hazard risks

Indicator 54: Nature-based adaptation

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		?			N/A	N/A

Data source:	DELWP
Measures:	Soil carbon stocks (tonnes of organic carbon per hectare) in saltmarsh, mangrove and seagrass ecosystems mapped across Victoria Potential carbon sequestration gains from 2020 to 2100 by restoring coastal wetlands in areas inundated by levee breaching and sea-level rise Economic benefit of carbon sequestration

Comments:

The status assessment of poor reflects research published during 2019 which found that saltmarshes, mangroves and seagrasses in Victoria are currently capturing approximately 2% of the carbon that would be possible to be captured by 2050 if coastal wetlands can naturally retreat. Because this research is a point-in-time assessment, the trend is unclear.

Indicator 55: Emergency planning and preparedness

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		↗			N/A	N/A

Data source:	Emergency Management Victoria
Measures:	As per the Emergency Management Act 2013, the State Emergency Management Plan contains provisions for the mitigation of, response to and recovery from emergencies, and specifies the roles and responsibilities of agencies in managing emergencies.

Comments:

The status assessment of good reflects the existence of the State Emergency Management Plan, which sets out arrangements for integrated, coordinated and comprehensive emergency management at the state level. The trend is assessed as improving due to anecdotal evidence of the maturation of the Victorian Government's improving capability and capacity to plan, prepare and respond to emergencies, with incident air monitoring cited as an example.

Theme 8: Communities

Indicator 56: Population (resident)

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide	N	N			N/A	N/A

Data source:	ABS, DELWP
Measures:	Resident coastal population growth rate by town/suburb/Statistical Areas Level 2 Projected coastal population growth rate by Statistical Areas Level 2

Comments:

Resident population growth remains high in specific locations along the Victorian coast.

Land-use planning policies have channelled most of this growth into designated locations.

There are detailed and rigorous data available on population growth, and government is able to make projections of future growth.

Although a vast amount of data about resident populations is collected, the nature and scale of its environmental impacts will depend on many other factors, such as peoples' values and behaviour, the use of infrastructure and technology to minimise impact, and the planning regimes that influence where people can settle. For this reason, a formal assessment of this indicator has not been undertaken. Instead, a narrative outlines the patterns of population change along the Victorian coast and the implications of this for environmental management.

Indicator 57: Population (visitors)

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide	N	N			N/A	N/A

Data source:	DELWP Planning, Business Victoria, Phillip Island Nature Parks
Measures:	Estimates of peak population Tourist visitor numbers Visitor numbers and coastal visitor management strategies – Phillip Island

Comments:

Problems such as overcrowding and congestion are often related to visitor rather than resident populations.

In many areas, data on visitor populations are poorer than for resident populations.

Land-use planning is less effective for visitor populations; this creates issues of people management rather than settlement planning.

The impact of population on the environment is not linear – it is dependent on behaviour, technology and the regulatory environment.

The COVID-19 pandemic has severely disrupted international travel, which will cause short-term to medium-term reductions in international visitor numbers to major coastal attractions such as Phillip Island and the Great Ocean Road. However, the majority of visitors to these destinations are domestic.

Domestic travel restrictions have also affected regional visitation rates in the short term.

Data on visitor populations is not as robust as that collected for resident populations. The mobility of visitors makes such measurement inherently difficult. Even where data are available, the nature and scale of environmental impacts will depend on many other factors, such as peoples' values and behaviour and the management regimes and infrastructure which are in place to minimise impact. For this reason, an assessment of this indicator has not been undertaken. Instead, a narrative outlines the nature and scale of visitor populations along the Victorian coast and the implications of this for environmental management.

Theme 8: Communities

Indicator 58: Significant landscapes

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		→			N/A	N/A

Data source:	DELWP Planning
Measures:	Number of permits for dwellings or other buildings in areas covered by a Special Landscape Overlay Number of planning Declarations of Distinctive Areas and Landscapes Number of approvals for statements of planning policy for Distinctive Areas and Landscapes

Comments:

Victorian land-use planning legislation is improving protection, through Declarations of Distinctive Areas and Landscapes.

Planning permit data are able to provide quantitative assessments of how many planning permits are being issued for residential development in areas subject to a Special Landscape Overlay. However, it cannot show the degree to which qualitative aspects of building design are improving or diminishing landscape quality.

The trend assessment reflects that, on balance, planning controls are being strengthened to protect important landscapes, but we have no monitoring systems in place to determine whether the end results protect the qualities of significant landscapes.

Indicator 59: Coastal settlements

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide	N	N			N/A	N/A

Data source:	ABS, Agriculture Victoria, DELWP Planning
Measures:	Building approvals | Land-use change Vegetation removal | Development outside urban boundaries

Comments:

Settlements generally represent an urbanisation of land use and associated infrastructure such as roads and pathways.

This process represents a significant change in land use, potentially reducing natural habitat and introducing impervious surfaces. There may also be a significant change in landscape amenity as built form replaces, or is incorporated into, natural environments.

The rezoning of land from rural to urban uses could be tracked using amendments data. However, the dataset is difficult to use for monitoring, because it was established to streamline amendment processes rather than as an analytical tool. Further work would be needed to enable the dataset to be used to track changes in urban and rural land use.

Although information on the growth of settlements in Victoria is available, it is not possible to make an overall assessment of status and trend for this indicator. While some people will view urbanisation as fundamentally damaging to the environment, the provision of housing is a basic element of human wellbeing, and the availability of affordable housing a matter of social and environmental justice. Future assessment of this type of indicator might therefore focus on the degree to which built form is meeting environmental standards.

Theme 8: Communities

Indicator 60: Cultural heritage

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide					N/A	N/A

Data source:	First Peoples – State Relations Group, Heritage Victoria
Measures:	Number of items included on Aboriginal Cultural Heritage Register Number of cultural heritage management plans Number of coastal heritage items/sites included on the Victorian Heritage Register Value of investment ($) through the Living Heritage program for coastal heritage Number of registered coastal heritage sites under threat from natural hazards

Comments:

Legislative protection is given to a range of cultural heritage for both Aboriginal and non-Aboriginal Victorians, on land and in marine environments.

Data are available on the number of items registered as having cultural significance, subject to certain restrictions in the case of Aboriginal cultural heritage.

While a variety of data are available, constraints in undertaking non-standard analyses of Heritage Victoria data (e.g., using the data in geographical information systems) limit its potential use.

Although cultural heritage can be assessed quantitatively (number of sites), it is important to monitor the qualitative status of sites and the degree to which investment is supporting their preservation and protection.

Indicator 61: Use of marine and coastal areas

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		?			N/A	N/A

Data source:	DELWP (Ipsos), Parks Victoria
Measures:	Activities undertaken while visiting the Victorian coast Value of the coast

Comments:

The assessment of this indicator is based on the social and economic benefits derived from the use of marine and coastal areas, rather than on environmental impact (which is explored in other sections).

Victorian coastal areas are used by a range of people for a variety of purposes. Many of these activities bring health benefits and support economic activity in coastal communities.

Appropriate management of people and their activities can minimise environmental harm. This is of particular importance as populations (resident or visitor) grow.

Survey-based data do not always lend themselves to time-series analysis. Hence assessment of trend has not been undertaken for this indicator.

Theme 8: Communities

Indicator 62: Tourism

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide					N/A	N/A

Data source:	Business Victoria 2020, Parks Victoria, Tourism Victoria
Measures:	Visitor numbers and total spend for selected Victorian tourism regions Number of visitors to coastal and marine parks Annual number of tourists visiting significant coastal tourist attractions

Comments:

Tourism is supported through government policy and is seen as a valuable source of jobs and revenue for Victorian coastal communities.

At present there appear to be limited links between tourism growth policies and visitor management or environmental management strategies. This has the potential to lead to management conflict and lack of policy coherence.

Although data are available, they tend to be geographically broad and survey-based, which makes detailed assessment of tourist impact very difficult.

Environmental certification schemes do not yet enable comprehensive assessment of tourism operators' environmental credentials.

The COVID-19 pandemic has severely disrupted international travel, which will cause short-term to medium-term reductions in international visitor numbers to major coastal attractions such as Phillip Island and the Great Ocean Road. However, the majority of visitors to these destinations are domestic.

Domestic travel restrictions have also affected regional visitation rates in the short term.

Indicator 63: Recreational boating and fishing contribution to the Victorian economy

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide					N/A	N/A

Data source:	Better Boating Victoria, VFA
Measures:	Recreational boating and fishing contribution to the Victorian economy Revenue from licence fees

Comments:

The assessment of this indicator is based on the economic and social benefits derived from these marine and coastal activities, rather than on environmental impact (which is explored in other sections).

Recreational boating and fishing are supported through government policy, and are seen as a valuable source of jobs and revenue for the Victorian economy.

Recreational boating and fishing are also recognised as benefiting human health by providing a relaxing activity that improves mental and social health.

COVID-19 restrictions have led to a decline in the number of licences issued, and subsequent revenue from recreational fishing and boating. While this has led to a deteriorating trend assessment, it is likely to improve once travel restrictions are eased.

Theme 8: Communities

Indicator 64: Recreational boating

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		→			N/A	N/A

Data source:	Victorian Fisheries Authority, Better Boating Victoria, academic researchers
Measures:	Participation in recreational boating | Number of boat licence holders

Comments:

Licensing arrangements enable generally good data on the scale and nature of boating, although the effects of boating on specific habitats and geographical areas are more elusive.

Despite COVID-19 restrictions having affected activities such as recreational fishing and boating, this is not reflected in the number of registered vessels or the number of people with current boating licences. In fact, both have increased over the past year. This suggests that activity will recover quickly once travel restrictions are eased.

Indicator 65: Recreational fishing

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		?			N/A	N/A

Data source:	VFA, academic researchers
Measures:	Number of recreational fishers | Hours spent in recreational fishing Quantity of fish caught through recreational fishing | Environmental impacts of recreational fishing Preferred species | Fish restocking programs (quantity)

Comments:

Increasingly, there are programs aiming to foster responsible fisher behaviour that improves environmental outcomes. These range from legislative, regulatory and compliance measures through to citizen science programs involving anglers in environmental research.

Although some data on recreational fishing are available, there remain gaps in our understanding of its scale and consequences. This is partly due to the dispersed nature of the activity and a reliance on survey-based data.

Lack of data means that we cannot assess the overall consequences of recreational fishing on fish stocks and ecological wellbeing.

Indicator 66: Shipping and ports

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide					N/A	N/A

Data source:	Bureau of Infrastructure and Transport Research Economics; Department of Infrastructure, Transport, Regional Development and Communications; Port of Melbourne, Gippsland Ports, Department of Agriculture, Water and the Environment
Measures:	Volume of shipping | Value of shipping Stormwater and ballast discharge | Number of spills and pollution events Introduction of pest species through ballast and biofouling | Channel dredging

Comments:

Shipping continues to be an important part of Victoria's transport system, and the associated trade flows make a positive contribution to the Victorian economy.

Some of the risks associated with shipping, for example oil spills, are events of low probability but high consequence. It is therefore difficult to use past data to determine the likelihood of future events. However, the potential for major harm from such events requires effective regulation and emergency response systems. Victoria has both of these, but diligence is still required to maintain readiness for unexpected events.

The increase in environmental reporting and use of the UN SDGs by port authorities is a positive development, although it is too early to have a long enough time series of data to determine trends for environmental effects.

Introduction of pest species remains a significant threat that could undermine environmental quality.

Indicator 67: Commercial fishing

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide					N/A	N/A

Data source:	ABS, Fisheries Research and Development Corporation, VFA, academic researchers
Measures:	Value of commercial fishing production | Quantity of commercial fishing production Employment in fishing-related industries | Cetacean entanglements

Comments:

Commercial fishing (for both domestic consumption and export) continues to be an important part of the Victorian economy.

Commercial fishing relies on healthy marine and coastal environments. Regulatory and management regimes aim to balance resource demand with environmental health.

Although Victoria's fisheries management systems are more effective than those of many other parts of the world, there are still some threats, such as overfishing, illegal and unreported fishing, introduction of pests, bycatch, and entanglements.

Theme 8: Communities

Indicator 68: Aquaculture

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide					N/A	N/A

Data source:	Fisheries Research and Development Corporation, Agriculture Victoria
Measures:	Value of aquaculture production | Quantity of aquaculture production

Comments:

Aquaculture is an increasingly important source of seafood in Victoria, for both the domestic and export markets.

Abalone and blue mussels are the main species farmed in Victorian coastal waters. Guidelines and protocols are in place for these and other aquaculture species, along with regulation and licensing systems to help prevent the spread of invasive marine species in the aquaculture industry. Monitoring of aquaculture farms is also undertaken by the EPA.

Disease is a potential threat to the industry. In 2021 the marine area near Portland was formally closed for a time, to prevent the spread of abalone viral ganglioneuritis. The process of closure and restriction suggests that management regimes are responsive to such threats. However, costs to the aquaculture industry and to others affected by such closures (commercial and recreational fishers, divers) can be high.

As some farms grow much larger, there may be an increasing risk in relation to biosecurity and pollution. Countering this, however, is a concurrent improvement in biosecurity technology and management regimes.

Indicator 69: Resources and energy generation

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide					N/A	N/A

Data source:	Department of the Environment and Energy, DELWP, Department of Jobs, Precincts and Regions, academic researchers
Measures:	Offshore oil production in Victoria | Gas production in Victoria Electricity (MW) generated from renewable marine sources (wave, tidal, offshore wind)

Comments:

Generation of wind and solar energy has been increasing in recent years and more projects are planned as Victoria makes the transition to low-carbon sources of energy.

Oil, gas and coal production still contribute to Victoria's energy sector and export markets.

Victoria does not have any operating offshore wind generation, although three proposals are being considered.

Some sources, such as wave, tidal and geothermal energy, have been the subject of trials and research projects, but none has yet emerged as a major contender in Victoria's energy-production market.

Although hydrogen power is not yet contributing to Victoria's energy generation, a pilot project currently in train aims to produce and transport liquid hydrogen from the Latrobe Valley, through the Port of Hastings, to Japan.

Global initiatives towards decarbonisation are likely to place pressure on Victoria's fossil fuel use in the coming decade, requiring a more rapid transition to renewable energy sources.

Theme 8: Communities

Indicator 70: Agriculture

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide					N/A	N/A

Data source:	Agriculture Victoria, DELWP Planning, Melbourne Water
Measures:	Agricultural runoff – contaminants reaching marine and coastal ecosystems (nutrients/toxins) Change in land use from agricultural to residential and urban land uses Loss of agricultural land

Comments:

Agriculture is a major land use that provides economic benefits and food for the wider community. Agriculture can be done in a sustainable way: farmers can be stewards of their land by maintaining or improving soils, vegetation and other environmental features.

Agriculture presents environmental risks, such as the water runoff with high nutrient loads from fertiliser or toxins from agricultural chemicals like pesticides. Limiting contaminated runoff is the focus of a number of policy initiatives that focus on recycling high-nutrient water and managing the application of chemicals.

Although research in the Western Port catchment has shown that the largest proportion of fine sediment load in catchment runoff is from grazing and cropping, this reflects the fact that grazing and cropping comprise a high proportion of catchment land use. In contrast, urban uses, though occupying smaller land area, have greater consequences for runoff.

Changes to agricultural land use can be measured using land-use data. This is providing a basis for protecting high-quality agricultural land through land-use planning in areas where agricultural land is under threat from urban and residential uses.

Indicator 71: Built and public benefit infrastructure

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide					N/A	N/A

Data source:	DELWP Coastal Programs, Victorian Auditor-General's Office
Measures:	Number of assets in coastal areas Built assets at risk of climate change (sea-level rise) impacts

Comments:

The condition of coastal assets and infrastructure is currently undergoing review. It is therefore difficult to fully assess their status.

Siting and design guidelines have been developed for coastal infrastructure which is likely to strengthen the resilience of any new construction. However, given the legacy of built assets currently sited along the coast, it is evident that climate change presents a clear threat to coastal and marine infrastructure through rising seas levels and more extreme weather events.

The trend assessment of stable recognises that although assets have been recently reviewed with a view to improving their condition, there is a clear threat to many of these assets due to climate change. Thus, levels of improvement are likely to be balanced by the loss or degradation of some coastal infrastructure in coming decades.

Theme 8: Communities

Indicator 72: Recreational boating infrastructure

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide					N/A	N/A

Data source:	Better Boating Victoria, DELWP, VEAC
Measures:	Boating infrastructure upgrades | Boating infrastructure with proximity to marine and coastal assets Climate change impacts on boating infrastructure

Comments:

With the establishment of the Better Boating Fund, there is a funding mechanism to enable upgrading of boating facilities along the Victorian Coast.

Investment is being undertaken to improve boating infrastructure across Victoria. Over time, the effectiveness of this program will be able to be tracked.

In some cases, the location of boat ramps is in proximity to significant protected areas (for example, RAMSAR sites or national parks) and this requires heightened attention being given to the management issues.

Nevertheless, coastal boating infrastructure remains under threat from climate change due to sea-level rise and increasing frequency of severe weather events. This is now being taken into consideration in new proposals dealing with boating infrastructure.

Government policy is encouraging expansion of boating and fishing. The impact of this increase will require mitigation efforts to minimise negative environmental, social or cultural impacts.

Indicator 73: Illegal activities

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide					N/A	N/A

Data source:	EPA, Maritime Safety Victoria, VFA, DELWP, Office of the Conservation Regulator
Measures:	Number of boating infringements | Number of fishing infringements Number of environmental infringements | Point source discharges – non-compliance

Comments:

Illegal activities affecting marine and coastal environments fall within the responsibility of many different agencies depending on whether they relate to fishing, boating, or environmental damage. It is therefore difficult to gain an overall picture of compliance or environmental impact even where data are available.

While good data are available for some illegal activities (for example for boating and fishing infringements) other compliance data are affected by when and where compliance activities are undertaken. Hence, they may provide an incomplete picture of the character and prevalence of illegal activities.

An important factor in achieving compliance is the role of engagement and education. Parks Victoria found that rules affecting marine national parks and sanctuaries are not always understood by visitors. This finding suggests the need for further communication and engagement with users to explain, not only the existence of these rules, but the purpose behind them.

Theme 9: Stewardship and collaborative management

Indicator 74: Stewardship

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		?			N/A	N/A

Data source:	DELWP
Measures:	Marine and Coastal Stewardship Index (comprising: environmental objectives, effort, outcome, accountability and adaptive management)

Comments:

Many policies and on-ground activities represent actions of stewardship however measurement protocols have been limited to date.

Although defining and measuring stewardship is difficult there has been recent progress through the development of a stewardship index by DELWP.

Although it is too early to measure trends using this index, benchmark data are starting to be collected for Port Phillip Bay programs and this should provide a model for future data collection and indicator assessment.

At a more disaggregated level, stewardship activities can also be assessed through measures provided for Indicator 76: Community connection to the coast, Indicator 77: Volunteering, and Indicator 78: Citizen science.

Indicator 75: Community connection to the coast

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		→			N/A	N/A

Data source:	Ipsos Marine and Coastal Community Attitudes and Behaviour Report, VFA Creel Surveys
Measures:	Values held in relation to marine and coastal environment; Reasons for involvement in coastal activities like fishing

Comments:

Surveys provide clear evidence that many Victorians value marine and coastal areas. This suggests a strong sense of connection with such environments.

Australia has long had coastal environments as part of its cultural heritage – both for Indigenous and non-Indigenous Australians.

One challenge this raises is how to maintain important cultural aspects of the ocean or beach experience while protecting coastal and marine environments from being 'loved to death'.

Theme 9: Stewardship and collaborative management

Indicator 76: Volunteering

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide					N/A	N/A

Data source:	ABS, DELWP, Parks Victoria
Measures:	Participation

Comments:

There are many committed volunteer groups that contribute to protecting, conserving and improving marine and coastal environments.

However, less than 6% of Australians who volunteer are involved in environmental activities. There is an opportunity to draw from the broader community to increase the number of environmental volunteers.

Maintaining and attracting volunteers is challenging in the modern era due to competing demands on peoples' time and changing lifestyles and expectations.

Indicator 77: Citizen science

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide					N/A	N/A

Data source:	DELWP, Parks Victoria, VFA, VNPA, Tangaroa Blue Foundation, Estuary Watch, RedMap, Atlas of Living Australia.
Measures:	Citizen science participation | Citizen science coastal programs.

Comments:

Citizen scientists have been involved in marine and coastal programs, even during COVID-19 lockdowns when virtual projects enabled seal counts (via webcam) and other activities to continue.

While there can be challenges in ensuring scientific rigour, there are models available such as ReefWatch (with photo identification of species required) Sea Search (with supervision from park rangers and photo identification of species) or Redmap (with expert coordinators) which provide examples of how rigour can be achieved and maintained.

Nevertheless, ensuring rigorous citizen science is not costless and funding is required to support coordination, equipment, communications and web platforms to be maintained.

Current development of a citizen science framework for Victoria is a promising development that can help address some of these requirements and challenges in order to expand citizen science activities.

Theme 9: Stewardship and collaborative management

Indicator 78: Planning and implementation

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide	N	N	N	●	N/A	N/A

Data source:	VEAC, GeoScience Australia, DELWP
Measures:	Effectiveness of marine and coastal plans and policies

Comments:

Policy frameworks affecting marine and coastal planning may operate at international, national or state levels. Those involved in local marine and coastal management may be from local government, CMAs, not-for-profit entities and. This makes a single assessment of 'planning and implementation' unrealistic. This section therefore takes a narrative approach to explore Victoria's marine and coastal planning regimes and implementation strategies.

In the past, Victoria's marine and coastal planning and policy arrangements have been criticised for being overly complex and multi-layered, thus limiting policy coherence.

The introduction of the Marine and Coastal Act 2018 and the subsequent Marine and Coastal Policy 2020 have helped to streamline and clarify aspects of coastal policy. The identification and documentation of various legislation and policies relevant to Victoria's marine and coastal environments has provided a level of coherence.

Victoria's first Marine Spatial Planning Framework is currently being developed as part of the Marine and Coastal Policy 2020. This is intended to provide overarching guidance and a process for achieving integrated and coordinated planning and management of the marine environment.

Inventories and assessments by the Victorian Environmental Assessment Council have also contributed to valuable benchmark data from which planning and implementation can be undertaken.

However, marine and coastal planning remains a somewhat crowded and contested space suggesting that ongoing monitoring and assessment will be important to maintain the benefits of recent work. In particular, the effectiveness of recent initiatives will be important to evaluate over time so that a process of continuous improvement and sustained clarity and coherence can be achieved.

One way of assessing the effectiveness of policies is through community surveys such as those done by Parks Victoria for the system of marine parks which they manage. The parks are perceived by a majority of Victorians as successful. Importantly, this success is evident across a number of environmental, social and economic criteria, suggesting that sustainability objectives which aim to balance the interests of different users while protecting the environment are being achieved.

Theme 9: Stewardship and collaborative management

Indicator 79: Committees and councils

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide	N	N	N	●	N/A	N/A

Data source:	VEAC, VAGO, DELWP
Measures:	Area managed by coastal CoMs | Effectiveness of coastal CoMs

Comments:

Policy frameworks affecting marine and coastal planning may operate at international, national or state levels. Those involved in local marine and coastal management may be from local government, catchment management authorities, not-for-profit entities and. This makes a single assessment of 'planning and implementation' unrealistic. This section therefore takes a narrative approach to explore Victoria's marine and coastal planning regimes and implementation strategies.

In the past, Victoria's marine and coastal planning and policy arrangements have been criticised for being overly complex and multi-layered, thus limiting policy coherence.

The introduction of the Marine and Coastal Act 2018 and the subsequent Marine and Coastal Policy 2020 have helped to streamline and clarify aspects of coastal policy. The identification and documentation of various legislation and policies relevant to Victoria's marine and coastal environments has provided a level of coherence.

Victoria's first Marine Spatial Planning Framework is currently being developed as part of the Marine and Coastal Policy 2020. This is intended to provide overarching guidance and a process for achieving integrated and coordinated planning and management of the marine environment.

Inventories and assessments by the Victorian Environmental Assessment Council have also contributed to valuable benchmark data from which planning and implementation can be undertaken.

However, marine and coastal planning remains a somewhat crowded and contested space suggesting that ongoing monitoring and assessment will be important to maintain the benefits of recent work. In particular, the effectiveness of recent initiatives will be important to evaluate over time so that a process of continuous improvement and sustained clarity and coherence can be achieved.

One way of assessing the effectiveness of policies is through community surveys such as those done by Parks Victoria for the system of marine parks which they manage. The parks are perceived by a majority of Victorians as successful. Importantly, this success is evident across a number of environmental, social and economic criteria, suggesting that sustainability objectives which aim to balance the interests of different users while protecting the environment are being achieved.

Theme 9: Stewardship and collaborative management

Indicator 80: Institutional knowledge and capacity

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		?			N/A	N/A

Data source:	N/A
Measures:	Number of applied scientists employed by marine and coastal management agencies Government funding for marine and coastal research or monitoring projects in Victoria

Comments:

Knowledge and capacity are acknowledged as critical for effective environmental policy.

Following findings from the State of the Bays 2016 Report, Victoria has put in place the MACKF to support the knowledge needs of planning for Victoria's marine and coastal areas. One outcome has been CoastKit – an online system for marine and coastal spatial data. While the development of data systems for marine and coastal management is welcome, analysis of what the data tell us and the degree to which such intelligence is being used in decision-making is still unclear and unable to be fully assessed yet.

At the aggregate level, a meaningful assessment of institutional knowledge and capacity is unrealistic because of the large number, variety and complexity of institutions which have responsibilities for marine and coastal management.

Measures which aim to capture educational qualifications or skill levels within organisations are not suitable for judging the qualitative aspects of how such knowledge and skills are being applied.

Although assumptions about the positive role of funding on institutional capacity make intuitive sense, there are issues in trying to measure this quantitatively. This is partly because of the complexity of unravelling public funding streams but also because of causal ambiguities in assessing capacity. Qualitative approaches may prove more reliable for future assessments.

Theme 9: Stewardship and collaborative management

Indicator 81: Engagement and inclusiveness

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide	N	N	N	●	N/A	N/A

Data source:	Engage Victoria
Measures:	Engagement processes undertaken for marine and coastal policies | Environmental justice

Comments:

Engagement processes are increasingly documented as part of policy development. Evaluation of engagement processes is sometimes undertaken and can provide a good basis for continuous improvement.

Different parts of government and different professions may take a different approach to engagement and this can make a single assessment of engagement processes difficult.

Because engagement processes are undertaken by different agencies for many different policies affecting marine and coastal planning, a single assessment of 'engagement and inclusiveness' is unrealistic. This section therefore takes a narrative approach to explore engagement and inclusiveness more broadly.

The impacts of environmental degradation may disproportionally affect certain groups within society (such as the elderly or the poor) and may also have varying spatial outcomes. The impacts of climate change along Victoria's coastline may be similar in terms of physical effects but coastal communities vary greatly in their capacity to respond. Environmental policies themselves may have disproportionate effects across different populations, for example, transition to a low-carbon economy can mean increased energy prices which has a greater impact on those with low incomes.

Theme 9: Stewardship and collaborative management

Indicator 82: Delivery and accountability

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		↗			N/A	N/A

Data source:	Parks Victoria, Victorian Auditor-General's Office
Measures:	Effectiveness of delivery

Comments:

Delivery and accountability are essential for any policy or program. Although delivery is often reported through corporate annual reporting processes, the evaluation of policy effectiveness is more difficult to determine.

Policy effectiveness has been assessed by Parks Victoria, based on the expert judgement of land managers. While such assessment might be criticised for being subject to subjective bias of individuals, or institutional pressures for favourable judgements, it nevertheless provides valuable insights that are generally unavailable.

Victoria has a number of systems to ensure accountability for government performance and spending. Government inquiries such as the Review of the Environmental Protection Authority are one example. The Victorian Auditor-General's Office also reviews the effectiveness of government activity and spending on behalf of the Victorian community.

The existence of these systems of accountability has led to an assessment of good for this indicator, while the improving trend reflects departments' efforts to develop monitoring and evaluation systems that also report on policy effectiveness.

Commissioner *for* Environmental Sustainability Victoria

Appendix D

References

Appendix D

Abernethy K, Barclay K, McIlgorm A, Gilmour P, McClean N, Davey J 2020, 'Victoria's fisheries and aquaculture: economic and social contributions', Fisheries Research and Development Corporation (FRDC) 2017-092, University of Technology Sydney, Sydney https://www.frdc.com.au/Archived-Reports/FRDC%20Projects/2017-092-DLD.pdf

Aboriginal Victoria 2020, 'Aboriginal cultural heritage land management agreements' https://www.aboriginalvictoria.vic.gov.au/aboriginal-cultural-heritage-land-management-agreements Accessed 23 April 2020.

Aboriginal Victoria 2020, 'Cultural heritage management plans, permits, agreements and tests: processes under the Aboriginal Heritage Act 2006 for managing and protecting Aboriginal cultural heritage' https://www.aboriginalvictoria.vic.gov.au/cultural-heritage-management-plans-permits-agreements-and-tests Accessed 16 April 2020.

Aboriginal Victoria 2020, 'Victorian Government Aboriginal affairs report 2019: culture and Country' https://www.aboriginalvictoria.vic.gov.au/victorian-government-aboriginal-affairs-report-2019/culture-country Accessed 23 April 2020.

Aboriginal Victoria 2020, 'Vi*ctorian Government Aboriginal affairs report 2020'*, Victorian Government, Melbourne, p. 96 https://www.firstpeoplesrelations.vic.gov.au/victorian-government-aboriginal-affairs-report-2020 Accessed 6 October 2021.

Allen C, Metternicht G, Weidmann T 2016, 'National pathways to the sustainable development goals (SDGs): A comparative review of scenario modelling tools', *Environmental Science and Policy,* 66, pp. 199-207 https://doi.org/10.1016/j.envsci.2016.09.008.

ANTaR Victoria 2020, 'Local Nations: Language groups' https://antarvictoria.org.au/local-nations Accessed 16 April 2020.

Atie Asadikia, Abbas Rajabifard, Mohsen Kalantari 2021, 'Systematic prioritisation of SDGs: machine learning approach' *World Development,* 140, 105269 https://doi.org/10.1016/j.worlddev.2020.105269.

Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand 2000, 'National water quality management strategy, Paper no. 4: Australian and New Zealand guidelines for fresh and marine water quality. Volume 1: The guidelines'. https://www.waterquality.gov.au/sites/default/files/documents/anzecc-armcanz-2000-guidelines-vol1.pdf Accessed 19 July 2021.

Australian Bureau of Statistics (ABS), 'Regional population growth', cat. 3218.0.

Australian Government Department of the Environment and Energy, and Western Australian Department of Biodiversity, Conservation and Attractions 2020, 'National light pollution guidelines for wildlife: Including marine turtles, seabirds and migratory shorebirds', Commonwealth of Australia. https://www.environment.gov.au/system/files/resources/2eb379de-931b-4547-8bcc-f96c73065f54/files/national-light-pollution-guidelines-wildlife.pdf.

Australian Government Inspector-General of Biosecurity 2019, 'Pest and disease interceptions and incursions in Australia', p. 53, Mascot, NSW https://www.igb.gov.au/sites/default/files/documents/qid52819_igb_interceptions_and_incursions_report_-_final.docx Accessed 8 October 2021.

Australian Human Rights Commission 2019, 'Right to self-determination' https://www.humanrights.gov.au/our-work/rights-and-freedoms/right-self-determination Accessed 28 May 2019.

Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS) 2020. 'Mabo v Queensland' (No. 2) [1992] HCA 23; (1992) 175 CLR 1 https://jade.io/article/67683 Accessed 6 October 2021.

Australian Maritime Safety Authority 2021, 'National standard for commercial vessels (NSCV)', Australian Government, Canberra https://www.amsa.gov.au/about/regulations-and-standards/national-standard-commercial-vessels-nscv Accessed 1 July 2021.

Butler CL, Lucieer VL, Wotherspoon SJ, Johnson CR 2020, 'Multi-decadal decline in cover of giant kelp *Macrocystis pyrifera* at the southern limit of its Australian range', *Marine Ecology Progress Series*, 653, pp. 1–18 https://doi.org/10.3354/meps13510

Carnell PE, Reeves SE, Nicholson E, Macreadie P, Ierodiaconou D, Young M, Kelvin J, Janes H, Navarro A, Fitzsimons J, Gillies CL 2019, 'Mapping ocean wealth Australia: the value of coastal wetlands to people and nature', The Nature Conservancy, Melbourne https://www.natureaustralia.org.au/content/dam/tnc/nature/en/documents/australia/MOW_Report_Web.pdf

Charko F, Blake N, Seymore A, Johnstone C et al. 2020, 'Clean bay blueprint: Microplastics in Melbourne', Port Phillip EcoCentre, Melbourne https://ecocentre.com/sites/default/files/images/Documents/Programs/Baykeeper/EcoCentre_CleanBayBlueprint_FinalEdits%20(2).pdf.

Clarkson C, Jacobs Z, Marwick B, Fullagar R, Wallis L, Smith M, Roberts R, Hayes E, Lowe K, Carah X, Florin S, McNeil J, Cox D, Arnold L, Hua Q, Huntley J, Brand H, Manne T, Fairbairn A, Shulmeister J, Lyle L, Salinas M, Page M, Connell K, Park G, Norman K, Murphy T and Pardoe C 2017, 'Human occupation of northern Australia by 65,000 years ago', *Nature*, 547, pp. 306–310, https://doi.org/10.1038/nature22968.

Commissioner for Environmental Sustainability Victoria, 'State of the Bays 2016', Victoria State Government https://www.ces.vic.gov.au/sotb

Commissioner for Environmental Sustainability (CES) 2020, 'Framework for the Victorian State of the Environment (SoE) 2023 report' Melbourne, Victoria https://www.ces.vic.gov.au/publications-library/framework-victorian-state-environment-2023-report

Commissioner for Environmental Sustainability (CES) 2020, 'State of the Environment 2018 Government Response', pp. 19-21, Melbourne, Victoria https://www.environment.vic.gov.au/__data/assets/pdf_file/0017/504008/Victorian-Government-response-to-the-State-of-the-Environment-2018-report.pdf

Commissioner for Environmental Sustainability (CES), 'State of the Bays 2016', Victorian Government, Melbourne https://www.ces.vic.gov.au/sotb

Commissioner for Environmental Sustainability Victoria (CES) 2018, 'Victorian State of the Environment 2018 report', Victoria State Government, Melbourne https://www.ces.vic.gov.au/reports/state-environment-2018 Accessed 23 September 2021.

Commonwealth of Australia 2015, 'National climate resilience and adaptation strategy', https://www.environment.gov.au/climate-change/adaptation/strategy Accessed 23 September 2021.

Commonwealth of Australia 2020, Biosecurity Act 2015, no. 61, compilation no. 8 incorporating amendments up to 25 March 2020 https://www.legislation.gov.au/Details/C2020C00127 Accessed 6 July 2021.

Commonwealth of Australia, Environment Protection and Biodiversity Conservation Act 1999 https://www.legislation.gov.au/Series/C2004A00485 Accessed 23 September 2021.

Department of Agriculture and Water Resources 2018, 'MarinePestPlan 2018–2023: The national strategic plan for marine pest biosecurity', Australian Government, Canberra, https://www.marinepests.gov.au/what-we-do/publications/marine-pest-plan.

Department of Agriculture, Department of Environment 2015, 'Anti-fouling and in-water cleaning guidelines', Australian Government, Canberra, https://www.agriculture.gov.au/sites/default/files/sitecollectiondocuments/animal-plant/pests-diseases/marine-pests/antifouling-consultation/antifouling-guidelines.pdf.

Department of Agriculture, Water and the Environment 2020, 'Australian ballast water management requirements: Version 8', Australian Government, Canberra, https://www.agriculture.gov.au/sites/default/files/documents/australian-ballast-water-management-requirements.pdf.

Department of Environment, Land Water and Planning (DELWP) 2020, 'Marine and coastal policy', East Melbourne, Victoria, https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0027/456534/Marine-and-Coastal-Policy_Full.pdf.

Department of Environment, Land, Water and Planning (DELWP) 2017, 'Port Phillip Bay environmental management plan 2017–2027 supporting document', East Melbourne, Victoria.

Department of Environment, Land, Water and Planning (DELWP) 2017, 'Western Port Ramsar site management plan', East Melbourne, Victoria.

Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria unearthed', East Melbourne, Victoria

Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019', East Melbourne, Victoria.

Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria in future 2019: population projections 2016 to 2056', East Melbourne, Victoria.

Department of Environment, Land, Water and Planning (DELWP) 2019, 'Coastcare Victoria strategy 2020–2025: have your say on our draft Coastcare Victoria Strategy', Victorian Government, Melbourne https://engage.vic.gov.au/coastcare-victoria-strategy-2020-2025 Accessed 24 February 2021.

Department of Environment, Land, Water and Planning (DELWP) 2020, 'Wind energy projects. As at 08/10/20' https://www.planning.vic.gov.au/permits-and-applications/specific-permit-topics/wind-energy-facilities/wind-energy-projects-planning?_ga=2.189197033.318809511.1602653626-245237306.1598233448 Accessed 14 October 2020.

Department of Environment, Land, Water and Planning (DELWP) 2020, 'Annual report 2020', Victorian Government, Melbourne, p. 52 https://www.delwp.vic.gov.au/__data/assets/pdf_file/0025/494134/Annual-Report-2019-20-3.pdf

Department of Environment, Land, Water and Planning (DELWP) 2020, 'Annual report 2019', Victorian Government, Melbourne, p. 42 https://www.delwp.vic.gov.au/__data/assets/pdf_file/0032/438188/DELWP-Annual-Report-2018-19-web.pdf

Department of Environment, Land, Water and Planning (DELWP) 2020, 'Land management: joint management' https://www.forestsandreserves.vic.gov.au/land-management/joint-management Accessed 16 April 2020.

Department of Environment, Land, Water and Planning (DELWP) 2020, 'Agreements with Traditional Owners' https://www.forestsandreserves.vic.gov.au/land-management/what-we-do/agreements-with-traditional-owners Accessed 16 April 2020.

Department of Environment, Land, Water and Planning (DELWP) 2021, 'Port Phillip Bay environmental management plan 2017-2027. 2019-2020 annual report and 2020 delivery plan update', East Melbourne, Victoria.

Department of Environment, Land, Water and Planning (DELWP) 2021, 'Draft marine and coastal strategy', Victoria State Government https://engage.vic.gov.au/draft-marine-and-coastal-strategy Accessed 24 September 2021.

Department of Environment, Land, Water and Planning (DELWP) 2021, 'Victoria's climate change strategy' https://www.climatechange.vic.gov.au/victorias-climate-change-strategy Accessed 26 May 2021.

Department of Environment, Land, Water and Planning (DELWP) 2021, 'Marine and coastal knowledge framework' https://www.marineandcoasts.vic.gov.au/coastal-programs/marine-and-coastal-knowledge-framework Accessed 7 October 2021.

Emergency Management Victoria 2018, 'State emergency response plan. Biosecurity sub-plan', edition 1.1, Victorian Government, Melbourne.

Environmental Protection Authority Victoria 2021, 'New laws to better protect the environment' https://www.epa.vic.gov.au/about-epa/laws/new-laws Accessed 2 August 2021.

Environmental Protection Authority Victoria 2021, 'Subordinate legislation tools to support the new Act' https://www.epa.vic.gov.au/about-epa/laws/new-laws/subordinate-legislation Accessed 2 August 2021.

Environmental Protection Authority Victoria 2021, 'The environment reference standard: about the environment reference standard' https://www.epa.vic.gov.au/about-epa/laws/epa-tools-and-powers/environment-reference-standard Accessed 2 August 2021.

Ernst & Young, for Better Boating Victoria and Victorian Fisheries Authority 2020, 'The economic value of recreational fishing and boating in Victoria: Final report', p. 7 https://vfa.vic.gov.au/__data/assets/pdf_file/0003/629256/The-economic-value-of-recreational-boating-in-Victoria-2020-Ernst-and-Young-Report.pdf.

Gunditj Mirring Traditional Owners Aboriginal Corporation 2020, 'Native Title across Gunditjmara Country' https://www.gunditjmirring.com/nativetitle Accessed 23 April 2020.

Ierodiaconou D, Wines S, Carnell P, Tinkler P, Allan B, Carey J, Young M, Howe S, Pocklington J 2020, 'An enhanced signs of healthy parks monitoring program for Victoria's marine national parks and marine sanctuaries: Point Addis marine national park', Parks Victoria technical series no. 114, Melbourne, Victoria.

Intergovernmental Panel on Climate Change (IPCC) 2021, 'Climate Change 2021: the physical science basis, contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, report prepared by V Masson-Delmotte, P Zhai, A Pirani, SL Connors, C Péan, S Berger, N Caud, Y Chen, L Goldfarb, MI Gomis, M Huang, K Leitzell, E Lonnoy, JBR Matthews, TK Maycock, T Waterfield, O Yelekçi, R Yu, and B Zhou (eds.), Cambridge University Press https://www.ipcc.ch/report/ar6/wg1/ Accessed 5 October 2021.

International Maritime Organisation 2004, 'International convention for the control and management of ships' ballast water and sediments. Adoption: 13 February 2004; Entry into force: 8 September 2017' https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Control-and-Management-of-Ships%27-Ballast-Water-and-Sediments-(BWM).aspx Accessed 6 July 2021.

Ipsos 2018, 'Wave 5 Marine and Coastal Community Attitudes and Behaviour Report', prepared for the Victorian Marine and Coastal Council (VMaCC), Parks Victoria and Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria, https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0029/438329/Final-Report-Wave-5-Victorian-Marine-and-Coastal-Attitudes-Research.pdf

Kinrade P and Preston B 2008, 'Impacts of climate change on settlements in the Western Port region: people, property and places. Final report', Australian Government Department of Climate Change, and Department of Sustainability and Environment, Victoria.

Konlechner TM, Kennedy DM, O'Grady JJ, Leach C, Ranasinghe R, Carvalho RC and Ierodiaconou D 2020, 'Mapping spatial variability in shoreline change hotspots from satellite data; a case study in southeast Australia', *Estuarine, Coastal and Shelf Science*, 246, 107018 https://dx.doi.org/10.1016/j.ecss.2020.107018

Melbourne Water 2018, 'Co-designed catchment program for the Werribee catchment region: working together for healthy waterways', https://healthywaterways.com.au/sites/default/files/2021-03/HWS-werribee-co-designed-catchment-program.pdf

Melbourne Water 2018, 'Healthy waterways strategy 2018' https://www.melbournewater.com.au/media/6976/download Accessed 22 February 2021.

Melbourne Water and CSIRO 2021, 'Westernport catchment planning tool' https://www.flowmatters.com.au/viz/#/mw-cpt?_page=0 Accessed 20 July 2021.

Native Title Tribunal 2007, 'The Gunditjmara People's native title determinations 30 March 2007 south-west Victoria' http://www.nntt.gov.au/Information%20Publications/Determination%20brochure%20Gunditjmara%20March%202007.pdf

North East Catchment Management Authority 2021, 'Monitoring and reporting' https://northcentral.rcs.vic.gov.au/this-strategy/monitoring-and-reporting/ Accessed 7 October 2021.

Pacific Hydro 2020, 'Codrington wind farm' https://www.pacifichydro.com.au/projects/operations/codrington-wind-farm/ Accessed 14 October 2020.

Parks Victoria 2005, 'Corner Inlet Marine National Park management plan'.

Parks Victoria 2020, 'Managing Country together' https://www.parks.vic.gov.au/managing-country-together Accessed 16 April 2020.

Parry G, Heislers S and Werner G 2004, 'Changes in distribution and abundance of *Asterias amurensis* in Port Phillip Bay 1999–2003', Department of Primary Industries technical report, Victoria, DOI10.13140/2.1.4058.4484

Petrie A 2018, 'Land and water rights of Traditional Owners in Victoria', Research paper no. 3, Research and Inquiries Unit, Parliamentary Library and Information Service, Department of Parliamentary Services, Parliament of Victoria https://www.parliament.vic.gov.au/publications/research-papers/send/36-research-papers/13877-land-and-water-rights-of-traditional-owners-in-victoria Accessed 16 April 2020.

Ramsar Convention 2014, 'Wetlands of international importance' https://www.ramsar.org/sites-countries/wetlands-of-international-importance Accessed 23 September 2021.

Reeves J and Trewarn A 2016, 'Assessment of heavy metals and other contaminants of the Gippsland Lakes', report commissioned by Department of Environment, Land, Water and Planning, Federation University Australia, Mt Helen, Victoria, http://www.loveourlakes.net.au/wp-content/uploads/2014/01/Gippsland-Lakes-Heavy-Metals-Report.pdf Accessed 23 September 2021.

Smale DA, Wernberg T, Oliver ECJ, Thomsen M, Harvey BP, Straub SC, Burrows MT, Alexander LV, Benthuysen JA, Donat MG, Feng M, Hobday AJ, Holbrook NJ, Perkins-Kirkpatrick SE, Scannell HA, Gupta AS, Payne BL and Moore PJ 2019, 'Marine heatwaves threaten global biodiversity and the provision of ecosystem services', *Nature Climate Change*, 9, pp. 306–312 https://doi.org/10.1038/s41558-019-0412-1

Spatial Vision 2017, 'Victorian coastal hazard assessment 2017 technical report 1', Melbourne, Victoria, https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0021/122709/VCHA2017_R1_Victorian_Coastal_Hazard_Assessment_2017_Final_R1.compressed.pdf

Stafford Smith M, Horrocks L, Harvey L and Hamilton C 2011, 'Rethinking adaptation for a 4°C world', Philosophical Transactions of the Royal Society A, 369, pp. 196-216 https://royalsocietypublishing.org/doi/full/10.1098/rsta.2010.0277

Stolton S, Shadie P, and Dudley N 2013, 'IUCN WCPA best practice guidance on recognising protected areas and assigning management categories and governance types', Best practice protected area guidelines series no. 21, International Union for Conservation of Nature, Gland, Switzerland https://www.iucn.org/theme/protected-areas/resources/iucn-wcpa-best-practice-guidelines-protected-area-managers-series Accessed 24 September 2021.

Thurstan R, Brittain Z, Jones D, Cameron E, Dearnaley J and Bellgrove A 2018, 'Aboriginal uses of seaweeds in temperate Australia: an archival assessment', *Journal of Applied Phycology*, 30, pp. 1821–1832, https://doi.org/10.1007/s10811-017-1384-z

United Nations Conference on Environment and Development (UNCED) 1992, 'Agenda 21', Rio de Janerio, Brazil https://sustainabledevelopment.un.org/content/documents/Agenda21.pdf

United Nations Department of Economic and Social Affairs, 'Sustainable development: The 17 goals' https://sdgs.un.org/goals Accessed 23 September 2021.

Victorian Aboriginal Corporation for Languages (VACL) 2020, Map: 'Aboriginal languages of Victoria' https://vacl.org.au/home Accessed 16 April 2020.

Victorian Aboriginal Heritage Council (VAHC) 2020, 'Aboriginal cultural heritage' https://www.aboriginalheritagecouncil.vic.gov.au/aboriginal-heritage Accessed 16 April 2020.

Victorian Aboriginal Heritage Council (VAHC) 2020, 'Victoria's current Registered Aboriginal Parties' https://www.aboriginalheritagecouncil.vic.gov.au/victorias-current-registered-aboriginal-parties Accessed 23 July 2021.

Victorian Aboriginal Heritage Council (VAHC) 2021, 'About Registered Aboriginal Parties' https://www.aboriginalheritagecouncil.vic.gov.au/victorias-registered-aboriginal-parties Accessed 23 July 2021.

Victorian Environmental Assessment Council 2019, 'Assessment of the values of Victoria's marine environment', Victorian Government, Melbourne https://www.veac.vic.gov.au/investigations-assessments/previous-assessments/document/getDownload?fid=MjM= Accessed 24 May 2021.

Victorian Government 2020, 'Victorian Government response to the State of the Environment 2018 Report', https://www.environment.vic.gov.au/reports/state-of-the-environment-report-response Accessed 26 August 2021.

Victorian Government, *Commissioner for Environmental Sustainability Act 2003,* no. 15 of 2003 https://www.ces.vic.gov.au/sites/default/files/publication-documents/CES%20Act%202003.pdf

Victorian Government, Marine and Coastal Act 2018, no. 26 of 2018, authorised version incorporating amendments as at 1 July 2021 https://content.legislation.vic.gov.au/sites/default/files/2021-06/18-26aa005%20authorised.pdf Accessed 6 July 2021.

West Gippsland Catchment Management Authority (WGCMA) 2013, 'Corner Inlet water quality improvement plan 2013', Traralgon, Victoria.

Authorised by the Commissioner for Environmental Sustainability

Level 36, 2 Lonsdale Street
Melbourne, Victoria 3000

Accessibility

If you would like to receive this publication in an alternative format, please telephone the Commissioner for Environmental Sustainability office on 136186, email info.ces@ces.vic.gov.au or call 03 9948 2846, or via the National Relay Service on 133 677 www.relayservice.com.au. This document is also available on the internet at www.ces.vic.gov.au.

Disclaimer

This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

For further information contact:

Commissioner for Environmental Sustainability
Level 36, 2 Lonsdale Street
Melbourne Victoria 3000

Email: info.ces@ces.vic.gov.au
www.ces.vic.gov.au

ISBN (print): 978-0-6485069-5-9

ISBN (online): 978-0-6485069-7-3

Published by the Commissioner
for Environmental Sustainability,
Victoria, 2021

Level 36, 2 Lonsdale Street
Melbourne Victoria 3000

info.ces@ces.vic.gov.au
www.ces.vic.gov.au

Commissioner *for* Environmental Sustainability Victoria

VICTORIA State Government

RECYCLED CONTENT FOREST MANAGEMENT MANUFACTURED CARBON NEUTRAL ENVIRONMENTAL MANAGEMENT SYSTEMS BLEACHING PROCESS

Commissioner *for* Environmental Sustainability Victoria

State of the Marine and Coastal Environment 2021 Report
Part 3 Scientific Assessments

VICTORIA State Government

Wedge-tailed eagle (*Aquila audax*)
© Parks Victoria

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

Commissioner *for* Environmental Sustainability Victoria

Traditional Owners

The Commissioner for Environmental Sustainability proudly acknowledges Victoria's Aboriginal community and their rich culture and pays respect to their Elders past and present. We acknowledge Aboriginal people as Australia's first peoples and as the Traditional Owners and custodians of the land and water on which we rely. We recognise and value the ongoing contribution of Aboriginal people and communities to Victorian life, and how this enriches us. We embrace the spirit of reconciliation, working towards the equality of outcomes and ensuring an equal voice.

Contents

Contents

Contents

Contents

Tables

Tables

Tables

Figures

Figures

Figures

Figures

Figures

Figures

Abbreviations

ABS ..... Australian Bureau of Statistics
ACHRIS ..... Aboriginal Cultural Heritage Register and Information System
ACORN-SAT ..... Australian Climate Observations Reference Network – Surface Air Temperature
AMDI ..... Australian Marine Debris Initiative
ANZECC ..... Australian and New Zealand Environment and Conservation Council
APVMA ..... Australian Pesticides and Veterinary Medicines Authority
ARMCANZ ..... Agriculture and Resource Management Council of Australia and New Zealand
AusCPR ..... Australian Continuous Plankton Recorder
AVG ..... Abalone Viral Ganglioneuritis
BBV ..... Better Boating Victoria
BOM ..... Bureau of Meteorology
BRUVs ..... Baited Remote Underwater Videos
CaLP Act ..... Catchment and Land Protection Act 1994
CBD ..... Convention on Biological Diversity's
CES ..... Commissioner for Environmental Sustainability
CICSMP ..... Corner Inlet Community Seagrass Monitoring Project
CIN ..... Corner Inlet-Nooramunga
CMA ..... Catchment Management Authority
COF ..... Clean Ocean Foundation
CoM ..... Committee of Management
CPUE ..... Catch Per Unit of Effort
CSIRO ..... Commonwealth Scientific and Industrial Research Organisation
DAL ..... Distinctive Area and Landscape
DCI ..... Directly Connected Imperviousness
DE ..... Denitrification Efficiency
DELWP ..... Department of Environment, Water, Planning and Environment
DIN ..... Dissolved inorganic nitrogen
DIP ..... Dissolved inorganic phosphorus
DJPR ..... Department of Jobs, Precincts and Regions
DO ..... Dissolved oxygen
DRI ..... Dolphin Research Institute
EIP ..... Environment Improvement Program
EMP ..... Environmental Management Plan
EPA ..... Environment Protection Authority
EPBC Act ..... Environment Protection and Biodiversity Conservation Act 1999
ERF ..... Emission Reduction Fund
ERS ..... Environment Reference Standard
EVC ..... Ecological Vegetation Class

Abbreviations

EWMA ..... Exponentially Weighted Moving Average
FFG Act ..... Flora and Fauna Guarantee Act 1988
FRDC ..... Fisheries Research and Development Corporation
FTE ..... Full-Time Equivalent
GAM ..... Generalised Additive Model
GDP ..... Gross Domestic Product
GIS ..... Geographical Information System
GL ..... Gippsland Lakes
GQRUZ ..... Groundwater Quality Restricted Use Zones
HESC ..... Hydrogen Energy Supply Chain
IEC ..... Index of Estuary Condition
IMO ..... International Maritime Organisation
IMOS ..... Integrated Marine Observing System
IPCC ..... Intergovernmental Panel on Climate Change
IRMP ..... Intertidal Reef Monitoring Program
IWM ..... Integrated Water Management
LAC ..... Limit of Acceptable Change
LAT ..... Lowest Astronomical Tide
LGA ..... Local Government Area
LiDAR ..... Light Detecting and Ranging
LML ..... Legal Minimum Length
LPS ..... Localised Planning Statements
MCSI ..... Marine and Coastal Stewardship Index
MERI ..... Monitoring, Evaluation, Reporting and Improvement
MPA ..... Marine protected area
MSV ..... Maritime Safety Victoria
NCRIS ..... National Collaborative Research Infrastructure Strategy
NLI ..... National Litter Index
NOAA ..... National Oceanic and Atmospheric Administration
NOD ..... National Outfall Database
NRMA ..... Natural Resource Management Authority
NRS ..... National Reference Station
OCR ..... Office of the Conservation Regulator
OCS ..... Offshore Constitutional Settlement
PFAS ..... Per-and polyfluoroalkyl substances
PFHxS ..... Perfluorohexane sulfonate
PFOA ..... Perfluorooctanoic acid
PFOS ..... Perfluorooctane sulfonate

Abbreviations

PPARS ..... Planning Permit Activity Reporting System
PPB ..... Port Phillip Bay
PPBEMP ..... Port Phillip Bay Environmental Management Plan
PPBES ..... Port Phillip Bay Environmental Study
PSR ..... Priority Sites Register
PWC ..... Personal Water Crafts
QMRA ..... Quantitative Microbial Risk Assessment
RAP ..... Registered Aboriginal Party
RASPs ..... Regional and Strategic Partnerships
RCP ..... Representative Concentration Pathway
Redmap ..... Range Extension Database and Mapping Project
REEF ..... Reef Ecosystem Evaluation Framework
SA1 ..... Statistical Area level 1
SA2 ..... Statistical Area level 2
SAFS ..... Status of Australian Fish Stocks
SDGs ..... Sustainable Development Goals
SEEA ..... United Nations System of Environmental-Economic Accounting
SEMP ..... State Emergency Management Plan
SEPP WOV ..... State Environment Protection Policy (Waters of Victoria)
SEPP ..... State Environment Protection Policy
SLO ..... Significant Landscape Overlay
SMP ..... Strategic Management Prospects
SoE ..... State of Environment
SotB ..... State of the Bays
SRMP ..... Subtidal Reef Monitoring Program
SST ..... Sea Surface Temperature
SVI ..... Sustainable Visitation Index
SWIFFT ..... State Wide Integrated Flora and Fauna Teams
TACC ..... Total Allowable Commercial Catch
TP ..... Total Phosphorus
TSS ..... Total Suspended Solids
UAVs ..... Unmanned Aerial Vehicles
UN ..... United Nations
UVC ..... Underwater Visual Census
VAGO ..... Victorian Auditor General's Office
VCMP ..... Victorian Coastal Monitoring Program
VEAC ..... Victorian Environmental Assessment Council
VEC ..... Victorian Electoral Commission

Abbreviations

VEFMAP ..... Victorian Environmental Flows Monitoring and Assessment Program
VFA ..... Victorian Fisheries Authority
VIIRS ..... Visible Infrared Imaging Radiometer Suite
VMaCC ..... Victorian Marine and Coastal Council
VPF ..... Victorian Preparedness Framework
VPPs ..... Victorian Planning Provisions
WP ..... Western Port
WQI ..... Water Quality Index
WQIP ..... Water Quality Improvement Plan
WSUD ..... Water Sensitive Urban Design
WTP ..... Western Treatment Plant

The colour keys for the assessments are as follows:

Key to status

Good | Fair | Poor | Unknown | Narrative but not assessed | Not assessed and no narrative

Key to trend

Improving | Stable | Deteriorating | Unclear

Key to data

High | Moderate | Low | Unknown | Not Applicable

Theme 1
Water Quality and Catchment Inputs

Commissioner *for* Environmental Sustainability Victoria

Ornate cowfish (*Aracana ornata*), Flinders Pier, Western Port

Theme 1: Water Quality and Catchment Inputs

Background

Poor water quality in marine environments adversely impacts marine ecosystems and human recreational usage. Regular water quality monitoring occurs in Port Phillip Bay, Western Port and the Gippsland Lakes. The Water Quality Index scores for:

- Port Phillip Bay have been rated as good or very good each year since monitoring and reporting began in 2002.
- Western Port have been rated as good for each year except for 2017 (when water quality in Western Port was rated as fair) since monitoring and reporting began in 2000.
- the eastern Gippsland Lakes (that is, Lake King and Lake Victoria) have been rated as good for six of the past seven years, while Lake Wellington has been rated as poor for the past three years and poor or very poor in seven of the past ten years.

EPA Victoria provides daily forecasts on the suitability of more than 30 Port Phillip Bay beaches for swimming and other recreational uses each day during the warmer months when there is a higher recreational usage of Port Phillip Bay. EPA's beach report program detects infrequent breaches of the short-term recreational water quality objectives, while all beaches have met long-term standards for secondary contact (for example, boating and canoeing) and most beaches have met long-term standards for primary contact (for example, swimming) during dry weather. However, most beaches do not meet standards for all weather primary contact. Stormwater pollution is often a key reason for beaches not meeting standards.

The impacts of poor water quality in Western Port are apparent in the effect on seagrass extent. Seagrass extent is strongly correlated with light availability in Western Port. Thus, turbidity caused by sediment loads and variation in water depth plays a major role in seagrass decline or growth. Five of the nine estuaries flowing into Western Port and assessed for water quality in the 2021 Index of Estuary Condition received a rating of very poor, with elevated turbidity noted as a key water quality issue for the estuaries that flow into Western Port.

Water quality in the Gippsland Lakes is generally categorised by divergent ratings for the eastern Lakes (that is, Lake King and Lake Victoria) that are often rated as good and Lake Wellington to the west that has a higher frequency of poor water quality. Lake Wellington is a sink for sediments, nutrients and contaminants. Wind and waves within the shallow waters of the lake can re-suspend sediments and nutrients, with algal blooms often developing because of the high availability of nutrients. Catchment works have focused on reducing sediment and nutrient loads being transported to Lake Wellington. This has included riparian protection and revegetation, wetland restoration, bed and bank stabilisation, and on-farm nutrient use and effluent loss reduction.

Water quality is not currently routinely measured in the marine environment of the Corner Inlet and Nooramunga biounits.

There are variable stormwater impacts across Port Phillip Bay's catchments. Only minor impacts to stream health are occurring from stormwater in the Werribee catchment, while stream health is being severely impacted from stormwater in the Dandenong catchment. It is important to note that urban development presents challenges to waterways as catchment imperviousness expands.[1]

Stormwater condition for Western Port was rated as high (on a scale from very high to very low) in Melbourne Water's Healthy Waterway Strategy 2018-28 that was published in 2018. This rating of high reflects an assessment that only minor impacts to stream health are occurring from stormwater. Much of Western Port's catchment is rural or forested, however existing urban areas of the growth corridor rate lower. For example, the Mornington Peninsula North-Eastern and Western Creeks Sub-catchments both rated as having low stormwater condition.[2]

1. Melbourne Water 2018, 'Healthy waterways strategy 2018', Melbourne, Victoria.
2. Melbourne Water 2018, 'Co-designed catchment program for the Werribee catchment region'.

As reported by Parks Victoria in 2005, about 30 stormwater and agricultural drains discharge into Corner Inlet, however the impact of urban stormwater drains is largely unknown because of the lack of information on water quality and quantity. Similarly, there are no available assessments of the contribution of stormwater to pollutant loads entering the Gippsland Lakes.

The Port Phillip Bay Environmental Management Plan 2017-2027 and the Corner Inlet and Nooramunga Water Quality Improvement Plan 2013 are examples of authorities developing targets to monitor water quality outcomes. However, no public reporting is available to determine how the nutrient and sediment loads are tracking in relation to the load targets.

The 2019-20 Annual Report and Delivery Plan Update (which contributes to regular reporting on the Port Phillip Bay Environmental Management Plan 2017-2027) did not include estimates of nutrient loads in relation to the specific strategy of 'ensuring nutrient and sediment loads do not exceed current levels and pollutant loads are reduced where practicable'.

Similarly, nearly halfway to the 2033 timeline for achieving the targets in the Corner Inlet and Nooramunga WQIP 2013, it is unclear whether any progress has been made toward meeting those targets. Only a limited number of the recommended annual activities within the WQIP 2013 have been reported, which has hindered the tracking of progress on achieving the targets.

The Water Quality and Catchment Inputs chapter highlights the importance of the interconnected nature of our coastal communities and marine environment. The Port Phillip Bay Environmental Management Plan provides a strategic approach to water quality management and consideration should be given to whether similar plans are appropriate elsewhere in Victoria to establish a 'catchment to reefs' approach to water quality management.

Comparison with insights from State of the Bays 2016 Report and the State of the Environment 2018 Report

Generally, water quality within Port Phillip Bay and Western Port has remained consistently good during the recent years since the State of the Bays (SotB) 2016 Report and SoE 2018 Report were published. Apart from algae and water clarity in Western Port, water quality in Port Phillip Bay and Western Port was assessed as good or fair in the SotB 2016 Report. These water quality parameters have been assessed as good in this report.

In the SoE 2018, there was a single indicator encompassing water quality within marine environments and water quality in the catchments. This indictor was rated as poor for Western Port and fair for Port Phillip Bay. This report separates assessment of water quality in marine environments from water quality in the catchments, enabling the generally good surface water quality in Port Phillip Bay and Western Port to be more clearly understood and reported.

The catchment inputs information provided in this report is disaggregated into discrete indicators (that is, regulated point source discharges to marine waters, stormwater, total nutrient loads and total sediment loads indicators). Reporting separate indicator assessments for these focused catchment inputs indicators represents a progression in the Commissioner's marine and coastal reporting, enabling water quality stressors and the scale of their impacts to be individually understood. These focused catchment inputs indicator assessments can be used to prioritise resource allocation to research and management interventions. Regulated point source discharges to marine waters remains a knowledge gap in 2021 as it was in previous reports.

Theme 1: Water Quality and Catchment Inputs

Indicator 01: Water quality (physicochemical)

Region		2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		Good	→	Good	Fair	→	Good
Western Port		Good	→	Good	Poor	→	Good
Corner Inlet-Nooramunga		Unknown	?	Unknown	Very poor	N/A	Unknown
Gippsland Lakes	Lake King	Good	→	Good	Very poor	N/A	Unknown
	Lake Victoria	Good	→	Good	Very poor	N/A	Unknown
	Lake Wellington	Poor	→	Good	Very poor	N/A	Unknown

Data source:	EPA, Melbourne Water, DELWP
Measures:	Water quality index scores

Why this indicator?

Water quality affects the distribution and abundance of marine aquatic plants and animals and a range of biogeochemical and ecological processes. Maintaining good water quality is also important for public health, recreational users of coastal waterways and the overall amenity of the coast.

This indicator provides a high-level summary of physical and chemical water quality parameters that are routinely monitored across Port Phillip Bay, Western Port and Gippsland Lakes. Water quality affects the distribution and abundance of marine aquatic plants and animals and a range of biogeochemical and ecological processes. Maintaining good water quality is also important for public health, recreational users of coastal waterways and the overall amenity of the coast. Human activities such as urban, industrial and agricultural development can significantly affect coastal water quality, which can lead to negative ecological outcomes and poor coastal amenity. Projected changes in sea level, sea surface temperature and flow regimes of coastal rivers due to climate change are also likely to significantly alter water quality characteristics along the Victorian coastline.

Water quality is identified as a key issue and risk in the Marine and Coastal Policy 2020, while the Water for Victoria strategic plan for managing Victoria's water resources identified water quality as being increasingly threatened by a changing climate.[3,4]

EPA Victoria summarises the latest environmental water quality in Port Phillip Bay, Western Port and the Gippsland Lakes and their catchments in an annual report card.[5] These report cards encompass water quality monitoring completed by EPA, Melbourne Water and DELWP.

In the report cards, key indicators of water quality are assessed against Victorian environmental quality objectives for relevant indicators in the Environment Reference Standard (ERS).[6] These are combined to calculate an overall water quality index score (WQI) out of 10, corresponding to a rating of very poor to very good.

3. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Marine and coastal policy', East Melbourne, Victoria.
4. Department of Environment, Land, Water and Planning (DELWP) 2016, 'Water for Victoria – water plan', East Melbourne, Victoria.
5. EPA Victoria, 'Report card', Carlton, Victoria https://www.epa.vic.gov.au/for-community/monitoring-your-environment/monitoring-victorias-water-quality/report-card Accessed 12 July 2021.
6. State Government of Victoria 2021, 'Environment Reference Standard (Environment Protection Act 2017)'

Theme 1: Water Quality and Catchment Inputs

The water quality parameters assessed in bay and lake sites include:

- algae (chlorophyll-a)
- dissolved oxygen
- metals (where data are available)
- nutrients (total nitrogen – Port Phillip Bay and Western Port; total phosphorous – Gippsland Lakes)
- salinity (not at the estuarine Eastern Lakes)
- water clarity.[7,8]

For this report, the report card ratings have been compared with the equivalent SMCE Report status ratings.

WQI scores are calculated based on attainment of environmental quality objectives for relevant indicators in the ERS. The State Environment Protection Policy (SEPP) (Waters) was released in 2018 and preceded the ERS; the water quality objectives in the ERS are based on the environmental quality objectives that were included in SEPP (Waters). During 2019, EPA Victoria published a document summarising how the environmental quality objectives for SEPP (Waters) were developed.[9]

In the bays and lakes, water quality was mostly very good or good for areas able to mix with the open ocean. Water quality was generally worse in rivers that transport pollution from urban and industrial areas.

The assessments for this indicator are based on the water quality results measured in marine water bodies, embayments and coastal lagoons, rather than water quality results from the catchment. Results for catchment water quality are presented as an explanatory narrative to complement the marine water quality narratives and assessments.

Table 1: Water quality index (WQI) scoring categories for the report card and for this report.

Water quality index score	Report card rating	Description of waterway	State of the Marine and Coastal Environment status rating
8-10	Very good	High quality waterways generally not impacted by pollution	Good
7-8	Good	Meets Victorian water quality objectives	Good
5-6	Fair	Some evidence of stress	Fair
3-4	Poor	Under considerable stress	Poor
0-2	Very poor	Under severe stress	Poor

7. EPA Victoria, 'Marine monitoring', Carlton, Victoria https://www.epa.vic.gov.au/for-community/monitoring-your-environment/monitoring-victorias-water-quality/marine-monitoring Accessed 17 July 2021.
8. EPA Victoria 2020, 'Report card 2019-20', Carlton, Victoria https://www.epa.vic.gov.au/about-epa/publications/1923 Accessed 17 May 2021.
9. EPA Victoria 2019, 'Development of environmental quality indicators and objectives for SEPP (Waters)', Carlton, Victoria.

Theme 1: Water Quality and Catchment Inputs

Indicator 02: Toxicants

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		?			N/A	N/A
Western Port		?	Moderate (status), Low (trend)		N/A	N/A
Corner Inlet-Nooramunga		?			N/A	N/A
Gippsland Lakes		?	Moderate (status), Low (trend)		N/A	N/A

Data source:	EPA, Melbourne Water, academic researchers
Measures:	Assessment against toxicants listed in ERS and the Australian and New Zealand Guidelines for Fresh and Marine Water Quality

Why this indicator?

Toxicants are chemical pollutants that have toxic effects on biota. These include both organic and inorganic toxicants. Metals (for example, lead and cadmium) are inorganic toxicants that pose significant risk to the health of coastal waterways.

Toxicants are chemical pollutants that have toxic effects on biota. These include both organic and inorganic toxicants. Metals (for example, lead and cadmium) are inorganic toxicants that pose significant risks to the health of coastal waterways such as rivers, estuaries, wetlands, embayments.

Organic toxicants include organochlorines, flame-retardants (for example, per- and polyfluoroalkyl substances that are more commonly known as PFAS), endocrine disrupting chemicals, and biocides. Despite the known adverse impacts of organic toxicants on aquatic ecosystems, research and routine monitoring of organic toxicants across Victoria has been limited. The monitoring and research effort has predominantly focused on Port Phillip Bay and Western Port.

While no routine monitoring of toxicants occurs in Port Phillip Bay and Western Port, there have been extensive studies of the presence and environmental impact of toxicants in Victorian streams and wetlands. These studies are summarised in the indicator assessments, with this indicator encompassing toxicants in sediments and the water column.

Indicator 03: Water quality (estuaries)

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		?	High (status) Low (trend)		N/A	N/A
Western Port		?	High (status) Low (trend)		N/A	N/A
Corner Inlet-Nooramunga		?	High (status) Low (trend)		N/A	N/A
Gippsland Lakes		?	High (status) Low (trend)		N/A	N/A
Statewide		?	High (status) Low (trend)		N/A	N/A

Data source:	DELWP
Measures:	The Index of Estuary Condition water quality sub-index

Why this indicator?

Water quality affects the distribution and abundance of marine aquatic plants and animals and a range of biogeochemical and ecological processes. Maintaining good water quality is also important for public health, recreational users of coastal waterways and the overall amenity of the coast.

This indicator assessment is based on the Index of Estuary Condition (IEC).[10]

The Index of Estuary Condition (IEC) provides a consistent condition assessment method that can be applied state-wide. There are five themes that make up the Index: fauna, flora, water quality, physical form and hydrology. Each theme contains multiple measures and standard methods have been developed for these.[11]

The IEC assessment program aims to:

- report on the condition of estuaries across Victoria
- assist the prioritisation of management investment among estuaries
- provide a baseline for assessing long-term and large-magnitude changes in resource condition.

The IEC Water Quality sub-index is based on two metrics: turbidity (a signal of sediment inputs from the catchment), and chlorophyll-a concentration (a proxy for primary productivity in the water column and a signal of nutrient pollution). Elevated sediments and nutrients in the water column of estuaries can alter the production of benthic plants (for example, seagrasses and macroalgae) and disrupt food webs with flow-on effects for estuarine fauna.

The regional water quality (estuaries) indicator assessments in this report contain counts of the number of estuaries for each rating from very good to very poor. Analysis of this indicator in future State of the Marine and Coastal Environment reports could incorporate a more sophisticated measure that blends the IEC Water Quality sub-index with estuary size and gives a greater weighting to the larger estuaries when providing regional status and trend assessments.

10. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Index of estuary condition', East Melbourne, Victoria.
11. Ibid.

Theme 1: Water Quality and Catchment Inputs

Indicator 04: Plankton

Region		2021 status	2021 trend	2021 data	2016 status	2016 trend	2016 data
Port Phillip Bay		Good	→	Good	Good	↗	Good
Western Port		Good	↗	Good	Poor	→	Good
Corner Inlet-Nooramunga		Unknown	?	Unknown	Black	N/A	N/A
Gippsland Lakes	Lake King	Good	↗	Good	Black	N/A	N/A
	Lake Victoria	Good	↗	Good	Black	N/A	N/A
	Lake Wellington	Poor	→	Good	Black	N/A	N/A

Data source:	EPA Victoria, Integrated Marine Observing System (IMOS)
Measures:	Chlorophyll-a (µg/L) | Total phytoplankton (cells/L)

Why this indicator?

Plankton are an extremely important part of the marine and coastal environment because of their role in food chains and oxygen production. Without plankton, the Earth would be warmer and devoid of large fish and charismatic animals.

Plankton are the millions of plants and animals that drift around our oceans. The word plankton derives from the Greek planktos meaning 'to drift'. Plankton are an extremely important part of the marine and coastal environment because of their role in food chains and oxygen production. Without plankton, the Earth would be warmer and devoid of large fish and charismatic animals.

There are two types of plankton, distinguished by the way they obtain energy: phytoplankton and zooplankton. Phytoplankton make food by converting energy from the sun, a process called photosynthesis. Most food chains in the sea start with phytoplankton. Zooplankton drift in the water and some can move large distances up and down in the water column to avoid predators and to graze on phytoplankton. Zooplankton can be numerous in marine and coastal environments and are an important food for many animals from filter feeding sponges and bivalves, through to the largest of animals, the blue whale.[12]

Typical of estuarine and coastal waters, the phytoplankton community of Victoria's bays and inlets are dominated by diatoms and dinoflagellates.[13] The composition of phytoplankton communities and abundance of species is informative about the health of the bays. As part of the process called photosynthesis, phytoplankton use light energy from the sun to transform carbon dioxide and elements such as nitrogen and phosphorous into organic matter and oxygen.

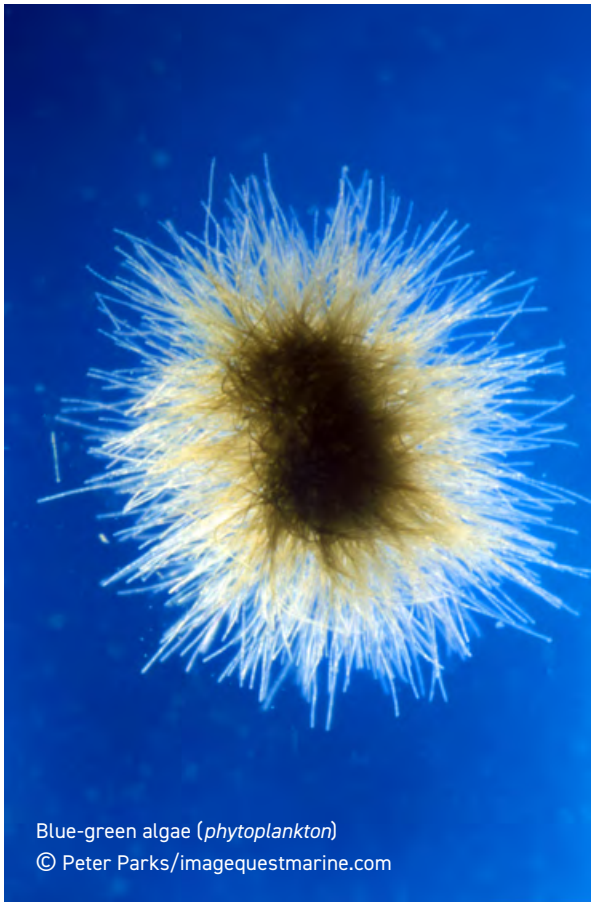
Phytoplankton is linked with the nitrogen cycle that is critical for maintaining the health and viability of marine ecosystems. Nitrogen provides the fuel for phytoplankton growth; therefore an appropriate amount of phytoplankton is an indicator of a healthy marine ecosystem.

12. Department of Primary Industries (DPI) 2010, 'Open water', Melbourne, Victoria.
13. Diatoms and Dinoflagellates are two of the common groups of phytoplankton species found in the marine waters near Victoria's coastline.

Phytoplankton biomass is also inferred from the concentration of chlorophyll-a in the water column. Chlorophyll-a is a green pigment found in plants. It absorbs sunlight and converts it to sugar during photosynthesis. Higher than normal concentrations typically indicate poor water quality, usually when high nutrient concentrations maintain high algal production. It is natural for chlorophyll-a concentrations to fluctuate over time; they are often highest after rain, particularly if the rain flushes nutrients into the water from the catchments on land during the warmer, sunnier months of the year. Harmful algal blooms pose a risk to a range of ecosystem services and uses of marine environments. Under certain conditions, harmful algal blooms can also occur in coastal waterways which can have negative ecological impacts and present a public health risk.

Data on phytoplankton and zooplankton community composition is critical for assessing lower trophic level and ecosystem responses to environmental change, and plankton are well established indicators for estuarine, coastal and oceanic systems.[14]

The Integrated Marine Observing System (IMOS) is a national ocean observing system measuring the physical, chemical and biological environment. Plankton observations within IMOS are available for the open coastline and provided by the Australian Continuous Plankton Recorder survey (AusCPR) and the National Reference Stations (NRS) program.[15] The IMOS NRS network does not contain any reference stations along the Victorian coastline, which makes Victoria the only state or territory without a reference station.



Blue-green algae (*phytoplankton*)
© Peter Parks/imagequestmarine.com

Terebellid worm larva (zooplankton)
© Peter Parks/imagequestmarine.com

14. Eriksen R, Davies C, Bonham P, Coman F, Edgar S McEnnulty F, McLeod D, Miller M, Rochester W, Slotwinski A, Tonks M, Uribe-Palomino J, Richardson A, 2019, 'Australia's long-term plankton observations: the integrated marine observing system national reference station network', *Frontiers in Marine Science*, 6(161) DOI:10.3389/fmars.2019.00161.
15. Richardson A, Eriksen R, Rochester W 2015, 'Plankton 2015: state of Australia's oceans', CSIRO Report, Canberra, Australia.

Theme 1: Water Quality and Catchment Inputs

Indicator 05: *Enterococci* bacteria

Region	2021 status	2021 trend	2021 data	2016 status	2016 trend	2016 data
Port Phillip Bay						

Data source:	EPA
Measures:	Number of beaches meeting short-term and long-term standards for primary and secondary contact

Why this indicator?

Poor water quality in marine environments adversely impacts marine ecosystems and human recreational usage. *Enterococci* is a bacterial indicator of microbial water quality. It is used to indicate the presence of faecal pollution that drains into the marine environment through stormwater drains and river outlets. The concentration of *enterococci* in marine environments generally increases after significant rainfall events, indicating an increase of microorganisms causing organisms (that is, pathogens) of faecal origin which can lead to gastroenteritis and skin irritations. Children, the elderly, and people with vulnerable immune systems that recreationally use water (for example, to swim in) when it is contaminated by these pathogens are at the highest risk of getting ill.

Poor water quality in marine environments adversely impacts marine ecosystems and human recreational usage.

Enterococci is a bacterial indicator of microbial water quality. It is used to indicate the presence of faecal pollution that drains into the marine environment through stormwater drains and river outlets. The concentration of *enterococci* in marine environments generally increases after significant rainfall events, indicating an increase of microorganisms causing organisms (that is, pathogens) of faecal origin which can lead to gastroenteritis and skin irritations. Children, the elderly, and people with vulnerable immune systems that recreationally use water (for example, to swim in) when it is contaminated by these pathogens are at the highest risk of getting ill.

EPA Victoria's beach reporting season runs from the December 1 until the Labour Day public holiday in early March. The Beach Report program samples *enterococci* each week at 36 Port Phillip Bay beaches. Weekly sampling results are assessed against short-term standards outlined in the ERS.[16] If standards are exceeded, warnings are issued to the community via EPA's website, social media channels and through an opt-in text message service. Warnings reduce the community's short-term exposure to microbial levels that may result in higher risk of illness. Beach Report also provides twice daily forecasts for swimming and other recreational uses and is the primary advice on swimming provided to the community during warmer months when there is a higher recreational usage of Port Phillip Bay.

For reporting against long-term microbial water quality standards, summer *enterococci* data has been used from Beach Report.

Beach Report has three main objectives:

- provide information about beach water quality during the summer so the community can make informed decisions about primary (for example, swimming) and secondary (for example, boating and canoeing) contact recreation
- identify trends in recreational water quality
- strategically improve recreational water quality.

16. State Government of Victoria 2021, 'Environment Reference Standard (Environment Protection Act 2017)'.

Indicator 06: Regulated point source discharges to marine waters

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		?			N/A	N/A
Corner Inlet-Nooramunga		?			N/A	N/A
Statewide					?	

Data source:	EPA Victoria
Measures:	Volumes and nutrient loads discharged to marine waters from regulated point sources

Why this indicator?

Oceans are used as receiving waters for treated sewage effluent and other wastewater from industrial processes. The assumption is that with rapid dilution in the receiving waters, contaminants in the wastewater are at a low enough concentrations to have no toxic effect on marine plants and animals. The discharges of waste from 19 outfalls, including the Eastern and Western treatment plants, are regularly monitored by the agencies responsible for them to ensure compliance with licence conditions.

Oceans are used as receiving waters for treated sewage effluent and other wastewater from industrial processes. The assumption is that with rapid dilution in the receiving waters, contaminants in the wastewater are at a low enough concentrations to have no toxic effect on marine plants and animals.[17]

The discharges of waste from 19 outfalls,[18] including the Eastern and Western treatment plants, are regularly monitored by the agencies responsible for them to ensure compliance with licence conditions, including data collection outside the mixing zones to establish background readings. Each outfall is licensed by EPA Victoria and must satisfy several licence conditions, with outfall operators submitting an annual performance statement each year.[19]

A need for readily accessible, reliable, national-scale data on Australia's domestic wastewater outfalls prompted the federal government in 2015 to commission Clean Ocean Foundation (COF) to develop the National Outfall Database (NOD). Working collaboratively with all stakeholders and under the auspices of the National Environmental Science Program, COF has collected and analysed outfall data to produce the NOD for all of Australia's 186 coastal outfalls.[20]

EPA Victoria was unable to provide aggregated information on breaches of licence conditions from outfall sites across Victoria, therefore the data analysed and reported by COF have been used to inform the regional narratives for this indicator. The data limitations for this indicator are consistent with those reported in the corresponding indicator (Indicator MC:19 point source discharges to marine waters) in the State of Environment 2018 Report.

17. Victorian Environmental Assessment Council (VEAC) 2019, 'Assessment of the values of Victoria's marine environment', Melbourne, Victoria.
18. Gemmill J, Rohmana QA, Fischer A, Blackwell B and Cumming J 2019, 'National outfall database: prospectus report 2019, report to the National Environmental Science Program', Marine Biodiversity Hub, Clean Ocean Foundation.
19. Victorian Environmental Assessment Council (VEAC) 2019, 'Assessment of the values of Victoria's marine environment', Melbourne, Victoria.
20. Gemmill J, Fischer A, Rohmana QA 2021, 'Towards a national outfall standard and guidelines for reporting wastewater treatment plant outfall data', report to the National Environmental Science Program, Marine Biodiversity Hub, Clean Ocean Foundation and University of Tasmania.

Theme 1: Water Quality and Catchment Inputs

Indicator 07: Stormwater

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		?	Moderate (status), Low (trend)		N/A	N/A
Western Port		?	Moderate (status, Low (trend)		N/A	N/A
Corner Inlet-Nooramunga		?			N/A	N/A
Gippsland Lakes		?			N/A	N/A

Data source:	Melbourne Water
Measures:	Directly connected imperviousness, which is the proportion of the impervious surface that is directly connected to a stream through a conventional drainage connection

Why this indicator?

Stormwater has a direct impact upon the health of coastal waterways. As stormwater drains, it carries pollutants with it like litter, sediment and oil. These are a major cause of pollution in our rivers, creeks, lakes and bays.

Stormwater is water that runs off surfaces into drains. Stormwater has a direct impact upon the health of coastal waterways. As stormwater drains, it carries pollutants with it like litter, sediment and oil. These are a major cause of pollution in our rivers, creeks, lakes and bays. Most of the time it is everyday activities that cause urban stormwater pollution, not major spills or industrial accidents.[21]

Sediments, litter and other pollutants discharged from stormwater outlets and coastal outfalls can severely impact water quality, with implications for marine life as well as the health of people engaged in water-based recreational activities. Regular monitoring can detect changes requiring management and planning responses.

Nearly all stormwater ends up in a receiving water body (for example, a bay, lake or the open sea).[22] For example, in Melbourne, rainfall flushes stormwater into Port Phillip Bay, making it less safe for swimming.

Unlike sewage, stormwater usually enters Victorian waterways untreated. At the end of the pipe system there are options for treating stormwater. For example, with pollutant traps that remove gross pollutants such as litter, or with water sensitive urban design, assets such as constructed stormwater wetlands. But in most cases, it flows from our streets and gutters into our creeks, rivers and the ocean.[23]

Recognising that existing drainage infrastructure has not been optimally mitigating the impacts from stormwater, an Improving Stormwater Management Advisory Committee was established in April 2018. The Committee was tasked with providing independent advice to the Victorian Minister for Planning on planning and development controls for improving stormwater management and strengthening the links between water management and urban planning.[24]

21. EPA Victoria, 'About stormwater', Carlton, Victoria https://www.epa.vic.gov.au/for-community/environmental-information/water/stormwater/about-stormwater Accessed 19 February 2021.
22. Department of Environment, Land, Water and Planning (DELWP) 2018, 'Improving stormwater management advisory committee: final report', East Melbourne, Victoria.
23. EPA Victoria, 'About stormwater', Carlton, Victoria https://www.epa.vic.gov.au/for-community/environmental-information/water/stormwater/about-stormwater Accessed 19 February 2021.
24. Department of Environment, Land, Water and Planning (DELWP), 'Improving stormwater management', East Melbourne, Victoria https://www.water.vic.gov.au/liveable/stormwater Accessed 19 February 2021.

The Improving Stormwater Management Advisory Committee reported that conventional drainage engineering is not good for waterways because it directs large volumes of stormwater into drains, carrying litter and other pollutants into waterways. Many waterway values were also noted to have been lost to drainage engineering and land management activities.[25]

Population growth and urban development will influence the volume of stormwater entering Victoria's receiving water bodies in the future.

Based on the advice provided by the Improving Stormwater Management Advisory Committee, planning reforms came into effect during October 2018, including:

- New arrangements under the Victoria Planning Provisions (VPPs) to expand the current best practice stormwater management requirements. The broader arrangements encompass commercial subdivisions and developments, industrial subdivisions and developments, public use developments, and residential multi dwelling subdivisions and developments.
- A new integrated water management clause in the State Planning Policy Framework to embed integrated water management objectives and strategies into urban land-use planning.

To support these reforms DELWP has delivered information and training sessions, and has developed checklists, guidance and an online resource portal to support development applicants and planning assessors.

As Victoria's population grows, there is a need for stormwater management policy reform including changes to the VPPs, clearer accountabilities for stormwater managers and clearer specifications of what is expected of land and infrastructure managers (for example, water corporations, local governments, VicRoads and industrial and commercial businesses).[26]

Management of urban stormwater runoff

Reducing the total volume of urban stormwater run-off and improving the quality of run-off entering waterways are two key stormwater management priorities. A diversity of strategies can help reduce the total volume, contaminant and gross pollutant loads of urban stormwater runoff. These strategies can be nested across scales from site or individual property level to the whole of catchment scale.

At-the-site or property level Water Sensitive Urban Design (WSUD) principles can be applied to increase water re-use, short term storage and soil infiltration. WSUD integrates water cycle management into urban planning and design, aiming to create urban environments that allow the water cycle to function as it would naturally. This reduces the impact of development on the water cycle.[27]

Many different types of WSUD are used to reduce the volume of stormwater and pollution that enters our waterways. In highly urbanised settings, rainwater tanks for re-use, sub-pavement filtration systems and green roofs are options for 'at source treatment'. At the development scale, features that promote water infiltration and short-term retention are being utilised. Such features include, artificial wetlands, damns and ponds designed to decrease the magnitude of run-off events and promote soil infiltration.

Urban stormwater can be considered as a resource and urban stormwater harvesting schemes vary in specific characteristics. These schemes harvest, treat and distribute stormwater for re-use. Most schemes are currently used, predominantly in Melbourne, to supply water for sporting grounds, parks and gardens.

Seven key challenges to waterways were identified in Melbourne Water's Healthy Waterways Strategy for 2018-2028. Stormwater was one of two key challenges, along with climate change, described as being of a magnitude that cannot be ignored.[28]

25. Department of Environment, Land, Water and Planning (DELWP) 2018, 'Improving stormwater management advisory committee: final report', East Melbourne, Victoria.
26. Department of Environment, Land, Water and Planning (DELWP), 'Improving stormwater management', East Melbourne, Victoria https://www.water.vic.gov.au/liveable/stormwater Accessed 19 February 2021.
27. City of Melbourne, 'What is water sensitive urban design?' http://urbanwater.melbourne.vic.gov.au/melbournes-water-story/water-sensitive-urban-design-wsud/ Accessed 4 May 2021.
28. Melbourne Water 2018, 'Healthy waterways strategy 2018-2028' https://healthywaterways.com.au/waterway-conditions/stormwater Accessed 22 July 2021.

Theme 1: Water Quality and Catchment Inputs

The planning and implementation of policies and projects to improve stormwater management is a feature of water management in Victoria's coastal catchments, however there are still considerable knowledge gaps quantifying the impact of these management and engineering initiatives on environmental condition.

For Port Phillip Bay and Western Port, the indicator assessments are based on the stormwater condition metric that was developed and used by Melbourne Water as part of the Healthy Waterways Strategy.[29]

Stormwater condition is assessed in terms of Directly Connected Imperviousness (DCI), which is the proportion of the impervious surface that is directly connected to a stream through a conventional drainage connection. As this indicator evolves in future State of the Marine and Coastal Environment reports, it should also provide info on the effect of stormwater changing flow regimes and peak flow impacts.

Table 2: Stormwater condition metrics for rivers.[30]

Rating	Explanation
Very high	DCI <0.5% minimal or no threat from stormwater
High	DCI 0.5-2% minor impacts to stream health from stormwater
Moderate	DCI 2-5% stream health is impacted
Low	DCI 5-10% stream health is significantly impacted from stormwater
Very low	DCI >10% stream health is severely impacted from stormwater

29. Ibid.
30. Ibid.

Indicator 08: Total nutrient loads

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	Good	→	Good	Data gap	N/A	N/A
Western Port	Good	→	Low (status). Moderate (trend)	Data gap	N/A	N/A
Corner Inlet-Nooramunga	Good	?	Moderate (status). Low (trend)	Data gap	N/A	N/A
Gippsland Lakes	Good	↙	Good	Data gap	N/A	N/A

Data source:	Melbourne Water, academic researchers
Measures:	Total nitrogen and phosphorus loads (t/yr)

Why this indicator?

Nutrients such as nitrogen and phosphorus are necessary for ecological functioning in coastal waters. However, excessive levels of nutrients can greatly modify aquatic plants, and subsequently general water quality, by promoting the growth of organisms like blue-green algae at the expense of other species. This in turn can affect the entire food chain.

Nutrients such as nitrogen and phosphorus are necessary for ecological functioning in coastal waters. However, excessive levels of nutrients can greatly modify aquatic plants, and subsequently general water quality, by promoting the growth of organisms like blue-green algae at the expense of other species. This in turn can affect the entire food chain.

Rural and urban land use activities like housing development and farming have led to broad scale and significant increases in the nutrient loads from the catchments.

Catchment loads are typically estimated using modelling approaches, supported by routine monitoring of nutrient concentrations and flow (see the physicochemical water quality indicator for information on nutrient concentrations). Reducing total nutrient loads to coastal waterways remains a key objective of many integrated catchment planning efforts across Victoria.

Theme 1: Water Quality and Catchment Inputs

Indicator 09: Total sediment loads

Region		2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay			→			N/A	N/A
Western Port			→			N/A	N/A
Corner Inlet-Nooramunga			?			N/A	N/A
Gippsland Lakes	Lake King		?			N/A	N/A
	Lake Victoria		?			N/A	N/A
	Lake Wellington		?			N/A	N/A

Data source:	Melbourne Water, academic researchers
Measures:	Total suspended solids loads (t/yr)

Why this indicator?

Higher loads of sediments can reduce the amount of light available for seagrass growth, while they also carry toxicants into the marine environment. Sediment toxicants can affect fish and invertebrates in inshore areas, as well as marine mammals and waterbirds (through the food chain).

The Yarra River - which flows through a large catchment containing the natural environment and areas for urban, industrial and agricultural uses - discharges 14,000 tonnes of sediment into the bay annually, along with 650 tonnes of nutrients in fertiliser, litter, heavy metals and bacteria.[31] In coastal areas beyond the Port Phillip Bay catchment, agricultural uses influence water quality by causing nutrient and sediment pollution that threatens estuaries and coastal ecosystems.

For example, in Corner Inlet there are strong connections across catchment nutrients and sediments, algal blooms, reduced light-penetration and seagrass decline, which impact the inlet's commercial and recreational fisheries. The link is the first strong evidence that the activities in the catchment are contributing to habitat loss and productivity costs to the fishery.[32]

Most sediments received by coastal waterways are delivered in short pulses associated with high rainfall and run-off events. During flood conditions sediments can be mobilised from hillslopes, gullies and channel banks and transported downstream rapidly.

31. Department of Sustainability and Environment (DSE) 2012, 'A cleaner Yarra River and Port Phillip Bay – a plan of action', Melbourne, Victoria.
32. Ford J, Barclay K and Day R 2016, 'Using local knowledge to understand and manage ecosystem-related decline in fisheries productivity', Fisheries Research and Development Corporation (FRDC) final project report, no. 2013-021, Melbourne, Victoria.

Indicator 10: Coastal acid sulfate soils

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		?			N/A	N/A
Western Port		?			N/A	N/A
Corner Inlet-Nooramunga		?			N/A	N/A
Gippsland Lakes		?			N/A	N/A

Data source:	Department of Jobs, Precincts and Regions
Measures:	Area of potential coastal acid sulfate soil within 5 km of the high-water mark adjacent to marine biounits

Why this indicator?

Coastal acid sulfate soils occur naturally along many parts of Victoria's coastal zone and, if left undisturbed, are largely benign. However, if disturbed (that is, water drains from the soil and air enters), they can react with oxygen and produce sulfuric acid. This can be detrimental to the environment with impacts that include acidification of water and soil, de-oxygenation of water, poor water quality, dissolution of soil, rock and concrete, and corrosion of metals.

Coastal acid sulfate soils occur naturally along many parts of Victoria's coastal zone and, if left undisturbed, are largely benign. However, if disturbed and resulting in water draining from the soil and air entering, they can react with oxygen and produce sulfuric acid. This can be detrimental to the environment with impacts that include acidification of water and soil, de-oxygenation of water, poor water quality, dissolution of soil, rock and concrete, and corrosion of metals. Sometimes impacts can be extreme (for example, resulting in fish kills).[33]

This indicator is designed to incorporate an assessment of the acid sulfate extent as well as the potential for impact along the Victorian coastline. The map below (Figure 1) shows an example of coastal acid sulfate soil distribution mapping that was completed in 2010 by the Victorian Government. Future analysis and research should investigate the location of potential coastal acid sulfate soils with respect to areas of significant natural values (for example, Ramsar sites and other coastal wetlands). This would enable future State of the Marine and Coastal Environment reports to have status and trend assessments for this indicator that are more robust, with consideration to the location of potential coastal acid sulfate soils and their links with natural systems rather than just a measure of coastal acid sulfate soils area.

33. Department of Jobs, Precincts and Regions (DJPR), 'Coastal acid sulfate soils', Melbourne, Victoria http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/soil_acid_sulfate_soils Accessed 22 July 2020.

Theme 1: Water Quality and Catchment Inputs

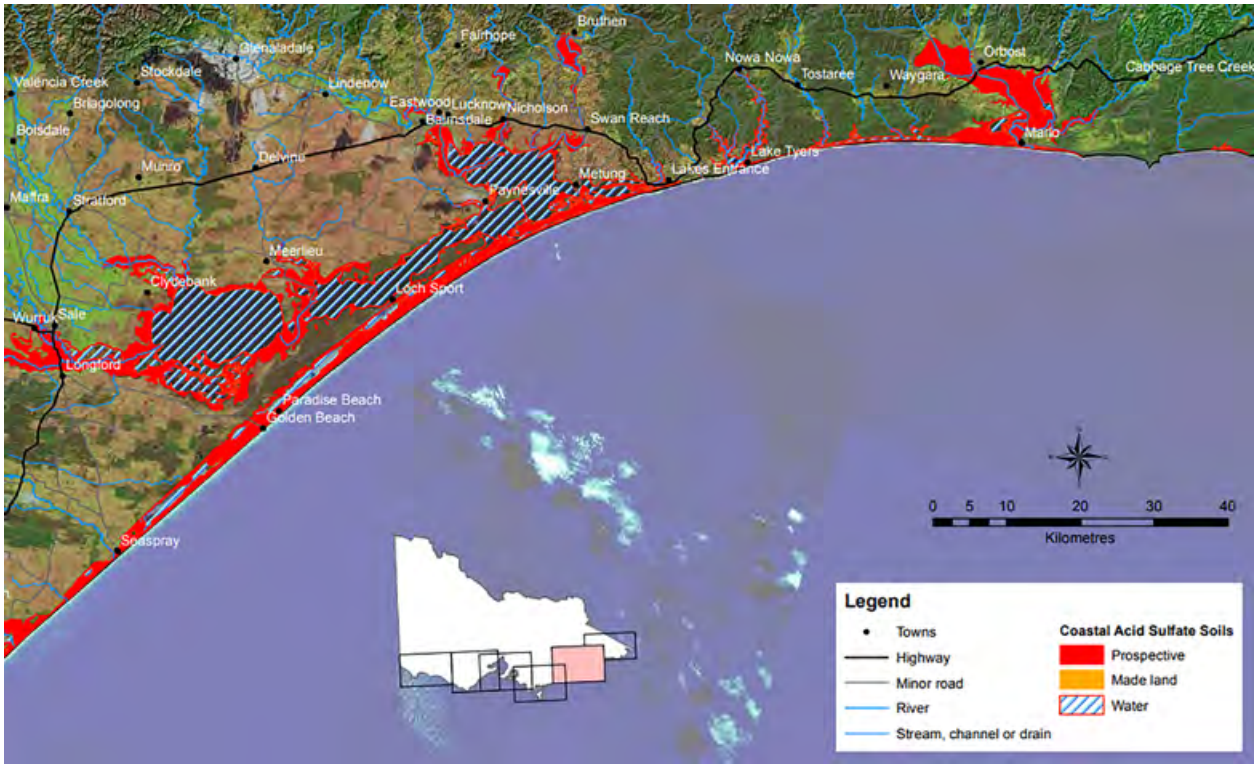


Figure 1: Coastal acid sulfate soils distribution for the Gippsland Lakes.[34]

Port Phillip Bay

PPB 01: Water quality (physicochemical)

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	●	→	●
Justification for assessment ratings:	These assessments are based on the Water Quality Index scores for Port Phillip Bay, which have been rated as good or very good each year since monitoring and reporting began in 2002. The confidence in the status and trend assessments is high because the Water Quality Index is benchmarked against objectives in the Environment Reference Standard (ERS), while there is adequate spatial and temporal monitoring data.		

Port Phillip Bay's annual water quality ratings have been good to very good during the past two decades despite being fed by a highly urbanised catchment. Port Phillip Bay is surrounded by densely populated urban areas, including Melbourne (a population of 4.936 million) and Geelong (a population of 253,000). Water quality during 2019-20 was rated as good in the Maribyrnong catchment, fair for Werribee, poor for Mornington and the Yarra, and very poor for the Dandenong catchment.

Despite the pressures from some of these catchments, Port Phillip Bay is well-mixed due to being reasonably shallow and covering a large surface area, which allow winds and currents to mix the water column. This mixing has helped mitigate the pollutant inputs from the catchment and contributed to water quality in Port Phillip Bay being rated as good or very good each year since monitoring and reporting began in 2002 (Figure 2) on the following page.

34. Department of Jobs, Precincts and Regions (DJPR), 'Coastal acid sulfate soils distribution - Map 5 for the Gippsland Lakes of Victoria' Melbourne, Victoria.

It is noteworthy that water quality in Port Phillip Bay has been rated as good or very good for this length of time because it demonstrates the Bay's water quality is generally resilient to a range of weather conditions, including both wet years and drought conditions. An example of this resilience to climatic variability was shown during 2019-20, which was a period with above average rainfall in areas of the Port Phillip catchment.

High rainfall events led to increased surface and stormwater run-off, which led to increased loads of nutrients, sediments and toxicants entering the Bay, so it is encouraging to note good water quality was still recorded in the Bay. Further discussion on the impact of rainfall on recreational water quality is provided in Indicator 05: *Enterococci* bacteria.

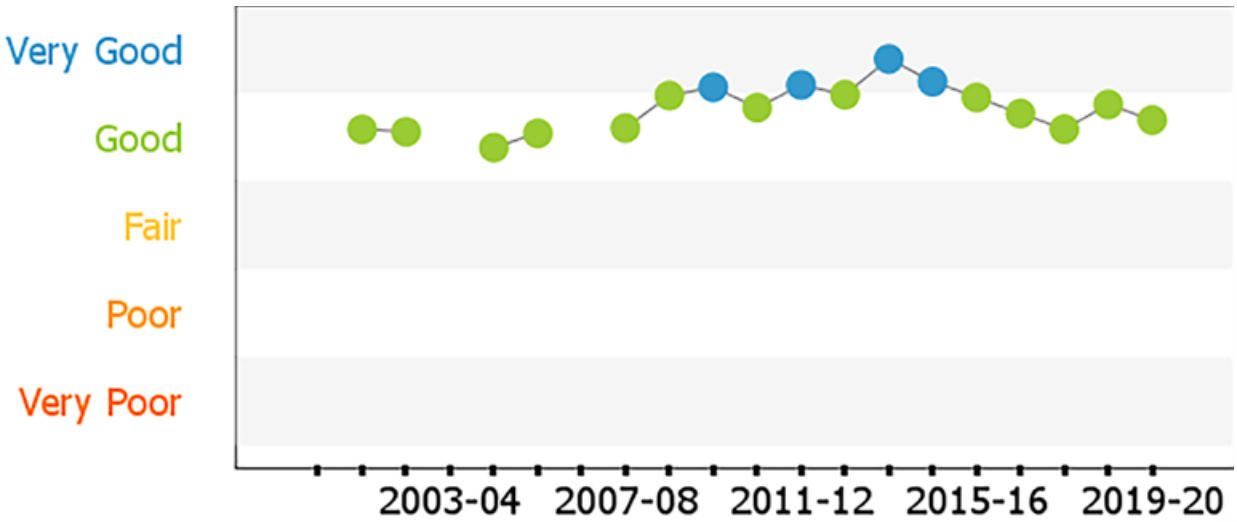


Figure 2: Historical Water Quality Index scores for Port Phillip Bay.[35]

The Report Card for Port Phillip Bay and catchment is calculated using data collected by Melbourne Water and EPA. Melbourne Water monitors water quality at more than 100 sites in the catchment and EPA Victoria monitors water quality at six sites in the bay.[36] Both EPA and Melbourne Water monitor similar parameters, including: dissolved oxygen, metals, nutrients and salinity.

35. EPA Victoria 2020, 'Report card 2019-20', Carlton, Victoria https://www.epa.vic.gov.au/about-epa/publications/1923 Accessed 17 May 2021.
36. Ibid.

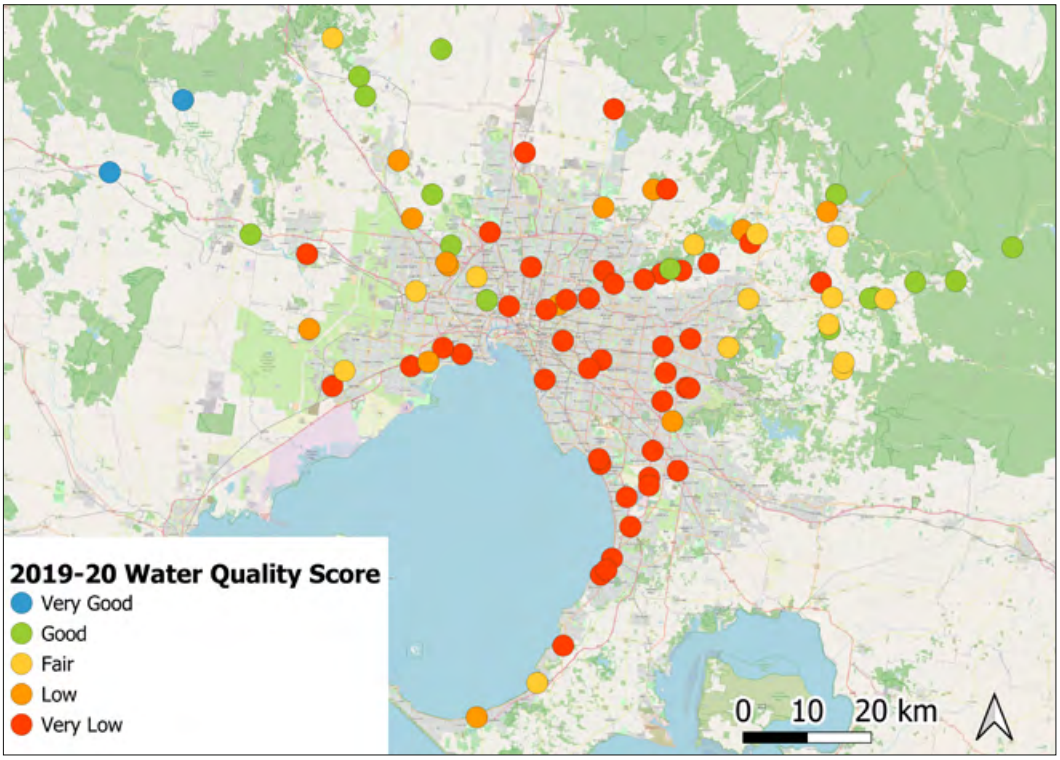


Figure 3: Locations and Water Quality Index scores from monitoring sites in the Port Phillip Bay catchments for 2019-20.[37]

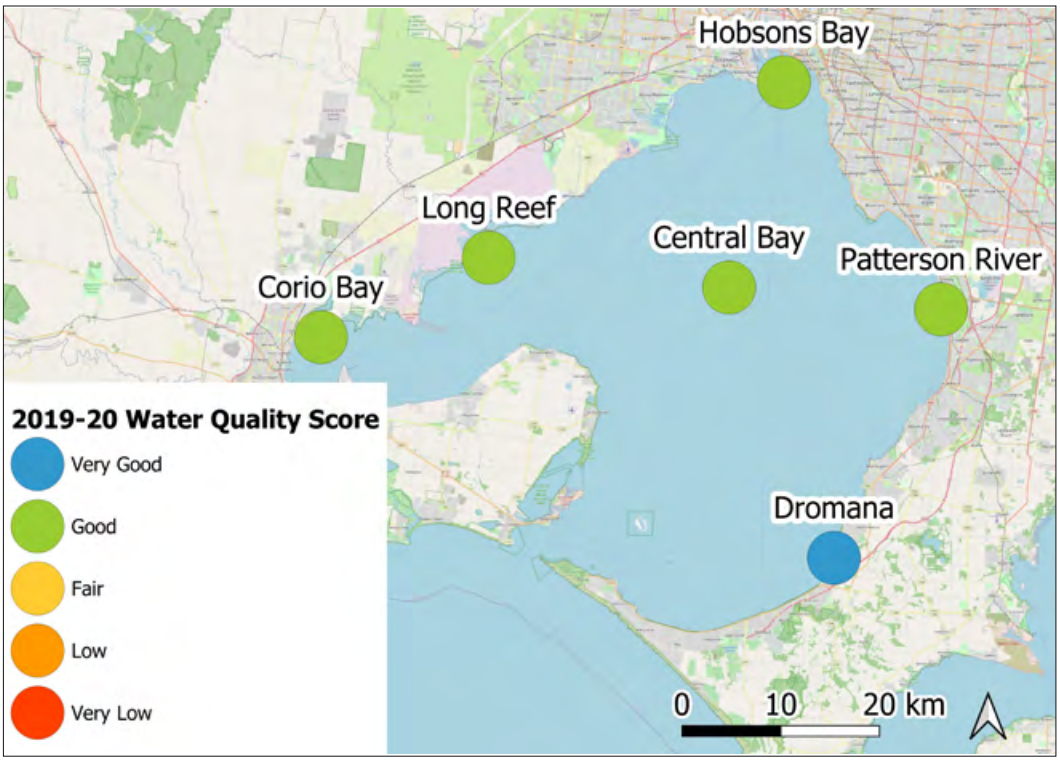


Figure 4: Locations and Water Quality Index scores from marine monitoring sites in Port Phillip Bay for 2019-20.[38]

37. Ibid.
38. Ibid.

Theme 1: Water Quality and Catchment Inputs

Conditions in Port Phillip Bay have remained relatively consistent since 2002, with overall water quality fluctuating between good to very good. Riverine inputs, particularly nutrients such as nitrogen and phosphorus, can have a strong influence on water quality in the northern part of the bay. However, good water quality is maintained in the Bay as the catchment inputs mix with oceanic waters from Bass Strait, while there is a natural recycling of nutrients in the sediments.[39]

For each of the five years from 2015–16 to 2019–20, overall water quality in Port Phillip Bay and its catchment has been rated as good. During 2019–20, water quality varied from very good in areas of the bay and upper reaches of the catchment, to very poor in highly urbanised waterways. This was similar to previous years.[40]

A summary of the results, and local effects that occur, is provided below for the sites where EPA Victoria monitors water quality in Port Phillip Bay.

Dromana typically has very good water quality. This is because the southern area of Port Phillip Bay is well flushed with water from Bass Strait due to regular tidal exchange, and minimal impacts from rivers and urban run-off.[41]

The Central Bay area, including Patterson River, typically has good water quality. Water quality can decline during periods of very high rainfall. Following rain, increased flows from the Werribee and Yarra Rivers transport high levels of nutrients and sediments to the northern and eastern parts of the bay. This stimulates algal growth and reduces light clarity.[42]

Corio Bay, Long Reef and Hobsons Bay typically has good water quality, with the influence of river flows, run-off and stormwater that carry pollutants (for example, nutrients, sediments and heavy metals), preventing a rating of very good.[43]

The Yarra, Maribyrnong and Werribee Rivers are major river systems that originate in the forested hills and mountains, then flow through rural properties, townships and urban areas to the bay. The Bay is connected to Bass Strait by a narrow entrance. Waters in the south of the bay mix well with ocean waters, while riverine inputs highly influence the waters in the north and west.[44]

The WQI ratings show that average water quality in the Werribee and Maribyrnong Rivers has been improving from very poor in Werribee and poor in Maribyrnong in the early 2000s to now being consistently rated as fair in Werribee and good in Maribyrnong. Local community groups such as the Werribee River Association have played an important role to highlight water quality issues, support the monitoring and assessment and reduce the litter and pollution load.[45,46,47]

Whist the surface water quality ratings have been good to very good for Port Phillip Bay, the sub-catchment water quality scores have generally been very poor to fair (with the exception of some recent years of good water quality in the Maribyrnong River) – this is important in the context of the impacts to the benthic biotopes (that is, marine habitats) in the intertidal zone and nearshore waters off sub-catchments such as Werribee where there are eutrophic drift algae impacting habitats and biodiversity.[48]

39. Ibid.
40. Ibid.
41. Ibid.
42. Ibid.
43. Ibid.
44. EPA Victoria 2020, 'Report card 2019-20', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/1923 Accessed 17 May 2021.
45. Werribee River Association 2018, 'Our Werribee River – a water quality analysis report'.
46. Sharley D, Marshall S, Mackintosh T, Coombes L, Forrester J 2020, 'Reducing stormwater pollution in the Werribee catchment: Sources, impacts and solution, Werribee River Association'.
47. Werribee River Association 2015, 'The Werribee River – a stream of litter'.
48. Wong WW, Greening C, Shelley G, Lappan R, Leung PM, Kessler A, Winfrey B, Poh SC, and Cook P 2021, 'Effects of drift algae accumulation and nitrate loading on nitrogen cycling in a eutrophic coastal sediment', *Science of The Total Environment*, 790, 2021.

Theme 1: Water Quality and Catchment Inputs

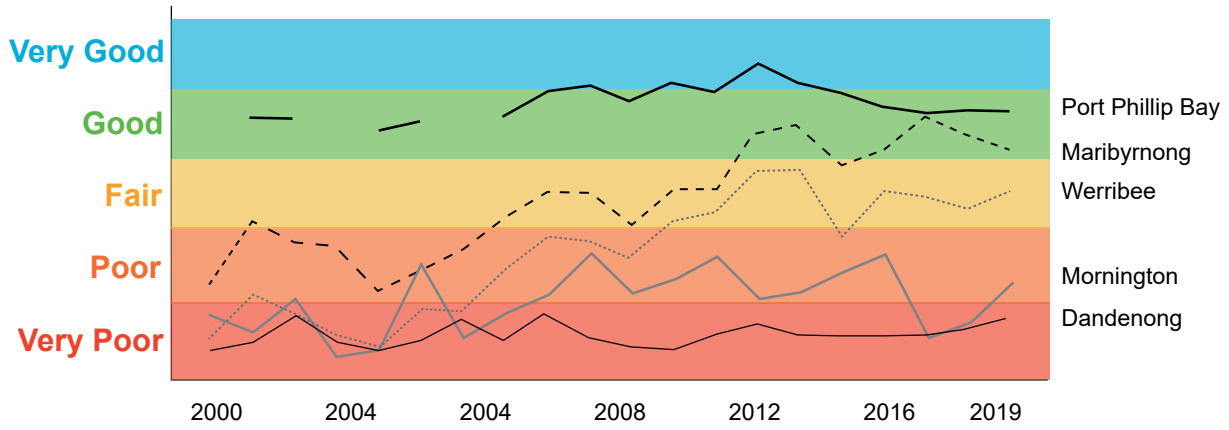


Figure 5: Historical Water Quality Index scores for Port Phillip Bay's catchments.[49]

PPB 02: Toxicants

Region	2021 status	2021 trend	2021 data
Port Phillip Bay		?	
Justification for assessment ratings:	There is no routine monitoring of toxicants to enable an assessment against toxicants listed in the Environment Reference Standard and the Australian and New Zealand Guidelines for Fresh and Marine Water Quality.[50] Recent research has focused on the PFAS (per-and polyfluoroalkyl substances) group of manufactured chemicals, with results so far indicating where the greatest concentrations are being found and what the likely sources of contamination are. Because these research studies provide 'point-in-time' assessments, the trend is unclear. The status has been rated as fair because the environmental condition is variable but, based on a limited number of focused studies, is unlikely to be under significant widespread stress. However, the confidence in this assessment is rated as low because there are no Victorian or National PFAS thresholds to base assessments on, although a 2019 study assessed PFAS in estuaries in Port Phillip Bay using the European Environment Quality Standards and found none of the PFAS observed at estuary sites had concentrations higher than the European Union standards.		

The Port Phillip Bay Environmental Management Plan 2017-2027 contained assessments of the pressures and stressors for Port Phillip Bay. Toxicants was rated as a stressor with a 'very high' level of concern.[51]

A synthesis of toxicant research that was completed during 2016 and used to inform the Port Phillip Bay Environmental Management Plan, found that many gaps still exist regarding the presence of different toxicants and their effects on Bay values.[52]

The synthesis concluded that toxicants, such as metals and organochlorine pesticides, were generally below guideline levels. However, increased levels were found in a few localised areas, including Hobsons and Corio Bays and where the Mordialloc and Kananook Creeks discharge into the Bay.[53,54]

49. Data provided by EPA Victoria 2021.
50. Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000, 'Australian and New Zealand guidelines for fresh and marine water quality'.
51. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Port Phillip Bay environmental management plan 2017-2027', East Melbourne, Victoria.
52. Barbee N, Longmore A, Townsend K, Pettigrove V and Swearer S 2016, 'Technical knowledge synthesis for nutrient cycling, marine pests and pollutants in Port Phillip Bay: informing the development of the new Port Phillip Bay environmental management plan', Centre for Aquatic Pollution Identification and Management (CAPIM) technical report no. 60, University of Melbourne, Parkville, Victoria.
53. Ibid.
54. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Port Phillip Bay environmental management plan 2017-2027', East Melbourne, Victoria.

Contaminants of emerging concern include endocrine-disrupting compounds, pharmaceuticals, flame retardants, pesticides (other than organochlorines), and microplastics. These pollutants have not been monitored in the Bay in a systematic way, and in many instances their impacts on Bay values have not been well characterised. The prevalence and impact of these toxicants in Port Phillip Bay is an emerging research field addressing the knowledge gap of these contaminants in the Bay.

Urban runoff from Melbourne, particularly from industrial areas, is a major source of heavy metals such as zinc, copper and petroleum hydrocarbons.[55] This effect increases with more urbanisation.[56] The heavy metals accumulate in sediments and become toxic to benthic organisms.[57,58]

The synthetic pyrethroid pesticide bifenthrin is another urban runoff contaminant that is present throughout Melbourne's urban water bodies,[59] often at concentrations toxic to aquatic invertebrates.[60] It also accumulates in sediments and is quite persistent.

Surveys of Port Phillip Bay are required to determine the concentrations of these contaminants. Ecotoxicological testing of surface water and sediment would confirm whether there is evidence of toxicity. This is the only way of measuring the overall condition and exposure of the ecosystems to any toxicants that are present.

PFAS (per-and polyfluoroalkyl substances) are a group of manufactured chemicals. There are more than 4,000 types of PFAS, including perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA) and perfluorohexane sulfonate (PFHxS).[61] Many products contain PFAS, including carpets, clothes and non-stick cookware.[62]

A 2019 study into PFAS in Port Phillip Bay's estuaries screened 19 PFAS and assessed potential risk using the European environment quality standards as there are no Australian marine water quality trigger values for PFAS.[63] None of the PFAS observed at estuary sites had concentrations higher than the European Union standards, which suggests none of the PFAS screened would have posed an acute risk to organisms in the estuarine waters at the time of sampling. However, the detection of these PFAS in Victorian estuaries highlights this is not just an issue for more densely populated countries in the northern hemisphere, but also potentially of concern in Australia. And, in that context, the study concluded that more sampling campaigns in Port Philip Bay are of paramount importance to assess the potential risk posed by these compounds to aquatic ecosystems.

55. Sharley DJ, Sharp SM, Marshall S, Jeppe K and Pettigrove VJ 2017, 'Linking urban land use to pollutants in constructed wetlands: implications for stormwater and urban planning', *Landscape and Urban Planning*, 162, pp. 80-91.
56. Sharley DJ, Sharp SM, Bourgues S and Pettigrove VJ 2016, 'Detecting long-term temporal trends in sediment-bound trace metals from urbanised catchments', *Environmental Pollution*, 2016, 219, pp. 705-713.
57. Marshall S, Pettigrove V, Carew M and Hoffmann A 2010, 'Isolating the impact of sediment toxicity in urban streams', *Environmental Pollution*, 158, pp. 1716–1725.
58. Pettigrove VJ and Hoffmann A 2005, 'A field-based microcosm method to assess the effects of polluted urban sediments on aquatic macroinvertebrates', *Environmental Toxicology and Chemistry*, 24, pp. 170–180.
59. Marshall S, Sharley DJ, Jeppe K, Sharp SM, Rose G and Pettigrove VJ 2016, 'Potentially toxic concentrations of synthetic pyrethroids associated with low density residential land use', *Frontiers in Environmental Science*, 4(75), DOI:10.3389/fenvs.2016.00075.
60. Jeppe KJ, Kellar CR, Marshall S, Colombo V, Sinclair GM, Pettigrove VJ 2017, 'Bifenthrin causes toxicity in urban stormwater wetlands: field and laboratory assessment using Austrochiltonia (Amphipoda)', *Environmental Toxicology and Chemistry*, 51(12), pp. 7254-7262.
61. EPA Victoria, 'About PFAS', Carlton, Victoria https://www.epa.vic.gov.au/for-community/environmental-information/pfas Accessed 10 March 2021.
62. Ibid.
63. Allinson M, Yamashita N, Taniyasu S, Yamazaki E, Allinson G 2019, 'Occurrence of perfluoroalkyl substances in selected Victorian rivers and estuaries: an historical snapshot', *Heliyon*, 5(9), e02472.

Theme 1: Water Quality and Catchment Inputs

PPB 03: Water quality (estuaries)

Region	2021 status	2021 trend	2021 data
Port Phillip Bay		?	High (status) Low (trend)
Justification for assessment ratings:	Through the 2021 Index of Estuary Condition (IEC) assessments, there is high confidence in the status assessment for estuarine water quality in this indicator. As part of the IEC, water quality assessments for 11 estuaries in the Port Phillip catchment region were completed, with two estuaries receiving ratings of excellent for water quality, three estuaries rated as good, two as fair, two as poor and two as very poor. The status assessment of fair is reflective of variable water quality in the estuaries that flow into Port Phillip Bay. As this is the first Index of Estuary Condition, and IECs are designed to be point-in-time assessments, no time series data are available to assess trends.		

Table 3 shows the IEC Water Quality results for estuaries in the Port Phillip Catchment Region.[64] Two estuaries received ratings of excellent for water quality, three estuaries were rated as good, two as fair, two as poor, while two estuaries were rated as very poor. As this is the first Index of Estuary Condition, and IECs are designed to be point-in-time assessments, no time series data are available to assess trends.

Water Quality was assessed as excellent in the Yarra River, where monitoring was undertaken at the Princess Bridge.

It is worth noting that water quality monitoring for the IEC aimed to assess Water Quality under base flow conditions, therefore monitoring during or immediately after rainfall events was avoided. High rainfall and surface runoff events can deliver substantial amounts of nutrients and sediments into estuaries, including the Yarra River estuary.[65]

Four of the eleven estuaries in the region had poor or very poor Water Quality, with high turbidity and chlorophyll-a levels, indicating elevated sediment and nutrient inputs to estuaries, respectively.[66]

Table 3: IEC results for estuarine water quality within the Port Phillip catchment region; range 1–10 (1=poorest condition, 10=best condition).[67]

Estuary	Water Quality	Condition Class
Little River	4	Poor
Werribee River	2	Very poor
Skeleton River	6	Fair
Laverton Creek	10	Excellent
Kororoit Creek	3	Very poor
Yarra River	10	Excellent
Elwood Canal	4	Poor
Mordialloc Creek	8	Good
Patterson River	9	Good
Kananook Creek	9	Good
Balcombe Creek	7	Fair

64. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Index of estuary condition', East Melbourne, Victoria.
65. Ibid.
66. Ibid.
67. Ibid.

PPB 04: Plankton

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	●	→	●
Justification for assessment ratings:	Chlorophyll-a is a commonly used measure of water quality, and concentrations indicate phytoplankton abundance and productivity in aquatic environments. The results show chlorophyll-a ratings in Port Phillip Bay fluctuated between fair and very good from 2001-02 until 2012-13 but have been rated as very good since then. The confidence in the status and trend assessments is high because chlorophyll-a is assessed against the objectives in the Environment Reference Standard (ERS), while there is adequate spatial and temporal monitoring data.		

With significant catchment discharges to the bay (predominantly in the north), and relatively slow flushing rates, Port Phillip Bay can experience periods of enhanced plankton productivity (that is, blooms). Some plankton bloom types can be harmful to aquatic life and human health, for example the bloom detected in Hobsons Bay during January 2020.[68]

EPA Victoria has been monitoring chlorophyll-a monthly since 1990. Chlorophyll-a is a commonly used measure of water quality, and concentrations indicate phytoplankton abundance and productivity in aquatic environments. The results show chlorophyll-a ratings fluctuated between fair and very good from 2001-02 until 2012-13 but have been rated as very good since then.

Figure 6: Chlorophyll-a water quality rating in Port Phillip Bay.[69]

68. Department of Environment, Land, Water and Planning (DELWP), 'Marine algal bloom detected in Hobsons Bay', East Melbourne, Victoria https://www.marineandcoasts.vic.gov.au/media-releases/marine-algal-bloom-detected-in-hobsons-bay Accessed 12 July 2021.
69. Image supplied by EPA Victoria.

To monitor long-term trends on phytoplankton species and abundance, EPA Victoria has collected monthly samples from at least six sites across Port Phillip Bay since 2008 as part of its marine fixed sites sampling program (see Figure 4). The sampling sites are spread around Port Phillip Bay to provide data in all hydrodynamic and biological zones - from the quiet Corio Bay to the nutrient loads of the Western Treatment Plant and Yarra River, and the strong currents over the Sands at Queenscliff.[70]

The phytoplankton dataset encompasses changes in climate as 2008-2009 covers the last years of the millennium drought, a wetter period (2010–2011) and a return to dry conditions before another wetter year (2020).

Increases in phytoplankton biomass have been linked to rainfall and run-off events.[71] For example, high phytoplankton counts in December 2009 were recorded following a significant rainfall event in November 2009. Such increases in phytoplankton biomass typically occur during spring or early summer as warming sea temperature and excess nutrients (for example, Nitrogen) stimulate phytoplankton productivity. Blooms typically occur during calm periods in the absence of winds and waves which can break-up blooms. Over the 2008–16 period, fewer than 10% of the samples collected had concerning levels of phytoplankton. Phytoplankton are generally greater:

- during wetter years
- close to freshwater inputs associated with nutrients
- in the north of the bay
- during the spring and summer months when temperature and light availability are optimal for growth.

In Port Phillip Bay, the Western Treatment Plant at Werribee and the Yarra River are the largest sources of nutrients and freshwater.[72] Salinity and nutrient levels associated with these inputs influence the phytoplankton community.[73] Diatoms are predominant during periods of moderate river flows, whereas other flagellates (for example, *Plagioselmis prolonga* and *Helmiselmis spp.*) prefer lower flows. Copepods, the preferred zooplankton food of larval snapper (*Chrysophrys auratus*), thrive on abundant diatoms.[74] In this way, the recruitment of snapper and sand flathead, key recreational fishing species', depends on nutrient and freshwater flows into Port Phillip Bay.[75,76] Further information on snapper recruitment is provided in Indicator 24: Commercially and recreationally important fish.

The 3-dimensional Nutrient-Phytoplankton-Zooplankton model Bubbles has been shown to provide close predictions of nutrients and planktonic productivity.[77] When calibrated against field data over a full year in Port Phillip Bay, Victoria, Australia, the model proved to be uniquely able to predict the concentration of the 12 most abundant phytoplankton, down to individual species and when aggregated to diatoms, flagellates and totals.[78] The model has also been successfully applied to explain inter-annual variations in snapper recruitment in Port Phillip Bay and to the controlling effects of diatoms on important zooplankton species.[79,80]

This indicator also links to Indicator 33: Nitrogen cycle, as the denitrification process in Port Phillip Bay plays an important role to maintain nitrogen at a suitable level for biodiversity. Nitrogen provides the fuel for phytoplankton growth therefore phytoplankton is an indicator of a healthy marine ecosystem.

70. Black KP, Jenkins GP 2020, 'Model bubbles validation', technical report no. 2020-6, School of *BioSciences*, University of Melbourne and Sanctuary Beach Pte. Ltd.
71. Commissioner for Environmental Sustainability (CES) 2016, 'State of the Bays 2016', Melbourne, Victoria.
72. Victorian Environmental Assessment Council (VEAC) 2019, 'Assessment of the values of Victoria's marine environment', Melbourne, Victoria.
73. Ibid.
74. Murphy H, Jenkins G, Hamer P and Swearer S 2011, 'Interannual variation in larval survival of snapper (Chrosophrys auratus, Sparidae) is linked to diet breadth and prey availability', *Canadian Journal of Fisheries and Aquatic Sciences*, 69, pp. 1340-1351.
75. Longmore A 2014, 'Spatial and temporal scales of key ecological processes in marine protected areas', Fisheries Victoria science report series no. 4.
76. Hirst A, Rees C, Hamer P, Conron S and Kemp J 2014, 'The decline of sand flathead stocks in Port Phillip Bay: magnitude, causes and future prospects', Fisheries Victoria Recreational Fishing Grant Program Research Report, Queenscliff, Victoria.
77. Black KP, Longmore AR and Jenkins GP 2019, 'Model bubbles refinements and calibration', technical report no. 2019-2, School of *BioSciences*, University of Melbourne and Sanctuary Beach Pte. Ltd.
78. Black KP, Jenkins GP 2020, 'Model bubbles validation', technical report no. 2020-6, School of *BioSciences*, University of Melbourne and Sanctuary Beach Pte. Ltd.
79. Black KP, Longmore AR, Hamer PA, Lee R, Swearer SE and Jenkins GP 2016, 'Linking nutrient inputs, phytoplankton composition, zooplankton dynamics and the recruitment of pink snapper, *Chrysophrys auratus, in a temperate bay', Estuarine, Coastal and Shelf Science*, 183, pp. 150-162.
80. Jenkins GP and Black KP 2019, 'Contrasting impact of diatoms on dominant calanoid and cyclopoid copepods in a temperate bay', *Estuarine, Coastal and Shelf Science*, 217, pp. 211-217.

PPB 05: *Enterococci* bacteria

Region	2021 status	2021 trend	2021 data
Port Phillip Bay			
Justification for assessment ratings:	The fair status assessment is due to all beaches meeting standards for secondary contact (for example, boating and canoeing) and most meeting standards for primary contact (for example, swimming) during dry weather. However, most beaches do not meet standards for all weather primary contact. Stormwater pollution is often a key reason when beaches don't meet standards. Water quality has been stable over time for all weather conditions. The confidence in the assessment is high based on the quality of the analytical data used to complete the assessment against standards.abundance and productivity in aquatic environments. The results show chlorophyll-a ratings in Port Phillip Bay fluctuated between fair and very good from 2001-02 until 2012-13 but have been rated as very good since then. The confidence in the status and trend assessments is high because chlorophyll-a is assessed against the objectives in the Environment Reference Standard (ERS), while there is adequate spatial and temporal monitoring data.		

Updated standards for water-based recreation

The Victorian Government released the ERS in 2021.[81] This updated legislation carried forward standards from the SEPP (Waters) that came into effect in 2018. SEPP (Waters) contained several changes from the previous legislation, which was the SEPP (Waters of Victoria). These changes in 2018 included more stringent short-and long-term standards for microbial water quality. These standards are based on National Health and Medical Research Council guidelines, which are derived from an epidemiological study linking microbial water quality to human health outcomes.

The stricter standards for long-term water quality management have resulted in fewer beaches in Port Phillip Bay meeting long-term standards for microbial water quality. This is a considerable change for the Beach Report, where most beaches have previously met long-term standards under the previous policy, SEPP (Waters of Victoria).

The use of long-term standards for condition reporting requires five years of sampling data, and a sanitary inspection for each beach (that is, a risk assessment of faecal sources). To meet these standards, no more than 5% of samples can exceed microbial levels that could cause an outbreak of illness (>200 *enterococci* per 100 ML). As a result, even a small number of high microbial results over a five-year period can result in a site not meeting long-term standards.

Despite long-term standards often not being met, beaches are generally suitable for swimming during the summer season (outside of periods of rainfall), with most water quality samples meeting the short-term standards.

Long-term recreational water quality

The ERS provides long-term recreational water quality standards that link the concentration of *enterococci* detected in the water to the risk of illness associated with recreational contact with the water.[82] The purpose of the long-term standards is to better understand potential health risks and inform the long-term management of faecal contamination causing the risk. The long-term standards enable an assessment of long-term condition and trends in water quality.

As part of the long-term assessment, beaches are graded on five years of water quality data and a sanitary survey that identifies the potential sources of contamination and the likelihood of these sources impacting water quality.[83]

81. State Government of Victoria 2021, 'Environment Reference Standard (Environment Protection Act 2017)'.
82. Ibid.
83. All grades in this report are provisional, either due to minimum data required not being available for microbial assessment categories, or sanitary surveys that EPA still requires to be externally reviewed.

A grade of good or fair indicates that a beach is generally suitable for primary contact recreation for the five-year reporting period. A grade of poor indicates that a beach may be more susceptible to faecal contamination and less likely to be suitable for primary contact recreation for the five-year reporting period. The water quality data and sanitary survey data are also used to assess the suitability of secondary contact recreation.

For primary contact recreation, 'All Weather' and 'Dry Weather' grades are provided for beaches:

'All Weather' grades use water quality data from dry conditions and wet conditions, including samples taken during and after rain. They provide information on how contamination from run-off and stormwater may impact water quality.

'Dry Weather' grades use water quality data from dry conditions when there has not been recent stormwater run-off to Port Phillip Bay. They provide information about water quality when people are most likely to engage in water-based recreational activity.

Eleven beaches did not meet long-term standards for primary contact recreation during 'Dry Weather' for the period from 2016-17 to 2020-21. Targeted sampling conducted at these beaches suggests a relatively low health risk from microbial levels during dry weather. The sampling found low levels of faecal contamination mostly linked to faecal sources from animals such as birds and dogs, rather than human faecal sources. These types of faeces pose less of a human health risk.

Twenty-four beaches did not meet long-term standards for primary contact recreation during 'All Weather'. Stormwater pollution after rain has the biggest influence on long-term microbial water quality for primary contact recreation. High microbial levels in stormwater pollution can increase the risk of illness during swimming. EPA Victoria recommends avoiding swimming after rain.

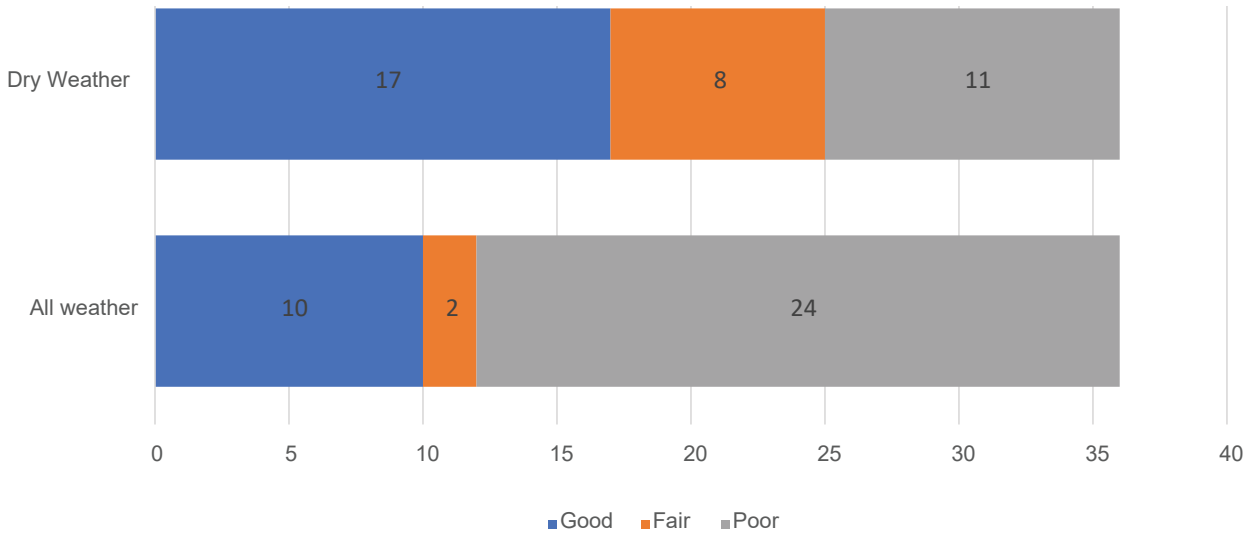


Figure 7: Long term microbial water quality for primary contact recreation at all 36 Port Phillip Bay beaches for the current five-year period (2016-2017 to 2020-2021 summers), according to 'all weather' and 'dry weather' conditions.[84]

84. Data supplied by EPA Victoria.

Despite long-term standards often not being met, beaches were suitable for swimming during most summer days (outside of periods of rainfall) of 2016-17 to 2020-21, with most water quality samples meeting the short-term standards. Beaches not meeting long-term standards still had microbial water quality suitable for swimming on most days during those summers. In the infrequent cases when water quality was unsuitable for primary contact, sampling shows water quality generally returned to suitable levels the next day.

All 36 Port Phillip Bay beaches included in the assessment met long-term standards for secondary contact recreation for the 2016-17 to 2020-21 reporting period.

The number of beaches meeting long-term recreational water quality standards (that is, receiving a good or fair grade) for 'All Weather' has been variable over time. This is most likely due to changing rainfall patterns at individual beaches.

There has been an increase in the number of beaches meeting long-term recreational water quality standards for 'Dry Weather' over time. This improvement in 'Dry Weather' grades over time may be due to things such as:

- improved drain and sewer infrastructure, to remove drains and risk of dry weather flows, or prevent sewer leaks
- better management of dry weather faecal sources in the beach catchments or foreshore (for example, animals and septic tanks)

The ERS allows site-specific standards to be developed where there has been a study to determine the likely health risk from local faecal sources.[85] Current standards in the ERS are based on criteria from overseas, which are not always comparable to conditions in Port Phillip Bay. Local studies can also be used to target interventions to manage faecal contamination sources.

In 2017-18, EPA Victoria conducted a study using Quantitative Microbial Risk Assessment (QMRA) at Altona, Elwood and Frankston beaches to better understand health risks from swimming. QMRA is an evidence-based approach to assess the microbial safety of water. This makes it a useful tool for informing water quality management, reporting and communication.

In 2019-20, EPA Victoria also conducted faecal source tracking at 14 beaches in Port Phillip Bay. The EPA did this to better understand what types of faeces cause high microbial levels. The QMRA and faecal source tracking showed that most faecal contamination in Port Phillip Bay is from birds and dogs rather than human sources, which means that the current long-term microbial standards in the ERS are likely to overestimate health risks. EPA Victoria is working with its partners to better understand water quality and determine if site-specific standards can be developed for Port Phillip Bay beaches. Site specific standards would better estimate the risk of illness at specific beaches.

Beach Report summer reporting

EPA's Beach Report program provides water quality information during the summer so the community can make informed decisions about primary contact recreation (for example, swimming) and secondary contact recreation (for example, boating and canoeing) activities. The program issues twice-daily water quality forecasts for 36 beaches in Port Phillip Bay between 1 December to Labour Day weekend in March. Water quality forecasts range from 'good – suitable for swimming' to 'poor – not suitable for swimming'.

EPA Victoria assesses microbial water quality against the short-term standards outlined in the ERS.[86] The purpose of this assessment is to reduce the community's short-term exposure to microbial levels that could cause illness. EPA Victoria assesses weekly Beach Report water monitoring results against these standards to:

- issue swim advisories to the community if monitoring results detect high microbial levels that pose a risk to human health. EPA Victoria communicates this information to the community on its website, via Twitter, and to subscribers of the Beach Report SMS alerts.
- report recreational water quality annually through an end of summer technical report published on EPA's website.

85. State Government of Victoria 2021, 'Environment Reference Standard (Environment Protection Act 2017)'.

Theme 1: Water Quality and Catchment Inputs

During the 2019-20 season, water sampling results showed that water quality met standards for 94% of samples taken for Beach Report.[87]

EPA Victoria's forecasting provides predictions of good, fair or poor water quality based on meteorological data, primarily rainfall. These forecasts are accessible to any prospective recreational user of Melbourne's beaches and are provided daily to more than 10,000 subscribers to the Beach Report SMS service and over 8,000 Twitter followers. During the summer season of 2019-20, there was an increase in forecasts of fair and poor water quality compared with the 2018-19 summer, mostly due to an increase in the amount of rainfall. Beach Report forecasting provided accurate advice to community for the recreational use of Port Phillip Bay beaches 88% of the time. Inaccurate forecasts (for example, predicting good water quality when microbial levels were high) were largely due to high microbial sampling values from unexpected pollution incidents, and the considerable rainfall of the summer leading to larger magnitude, and longer duration, stormwater inputs to the Bay.[88]

Snorkelling in Port Phillip Bay
© Parks Victoria

86. Ibid.
87. EPA Victoria, 'Beach report and Yarra watch season 2019-2020 summary', Carlton, Victoria https://www.epa.vic.gov.au/for-community/summer-water-quality/beach-report-and-yarra-watch-season-2019-2020-summary Accessed 12 March 2021.
88. EPA Victoria 2020, 'Beach report and Yarra watch results, 2019–20', Carlton, Victoria.

PPB 06: Regulated point source discharges to marine waters

Region	2021 status	2021 trend	2021 data
Port Phillip Bay		?	
Justification for assessment ratings:	There is good information available on the volumes and nutrient loads discharged to marine waters from regulated point sources. However, there is limited quantitative analysis available to understand the extent that regulated discharges impact the receiving marine environments. There is also no available analysis of non-compliance of licenced facilities that discharge to marine environments, therefore the extent of non-compliance with licenced discharge limits is unknown.		

The largest wastewater discharge in Victoria, comes from Melbourne Water's Western Treatment Plant located at Werribee. The plant, which has been operating since the late 1890s, discharges about 420 megalitres per day of treated effluent to Port Phillip Bay through a series of drains at the shoreline.[89] Along with the discharges at Werribee, there is a second outfall site in Port Phillip Bay, which is at Altona - again in the north-western area of the bay.

Increased nutrient loads to coastal waters increase the risk of more frequent and intense algal blooms. Water quality modelling for Port Phillip Bay has shown that when nitrogen loads from the Western Treatment Plant move clockwise around the bay and combine with stormwater from the Yarra River and other major drains, algal blooms can occur in Hobsons Bay and along the eastern beaches.[90]

The nitrogen and phosphorous loads from the two Port Phillip Bay outfall sites are summarised in Table 4.

Table 4: Coastal outfalls nutrient loads and rankings. A ranking of 1 represents the greatest nutrient load.[91]

Outfall	Total nutrient load for 2017-18 (kg)	Ranking among Victorian coastal outfalls	Ranking among Australian coastal outfalls
Werribee (Western Treatment Plant)	7,988,464	1st of 17	3rd of 140
Altona	57,375	7th of 17	45th of 140

This indicator narrative is only able to provide commentary of the volumes and nutrient loads discharged to marine waters from regulated point sources, which is comprehensively aggregated and reported by the Clean Ocean Foundation as part of the National Outfall Database.

However, there is only limited quantitative analysis available to understand the extent that regulated discharges impact the receiving marine environments. EPA Victoria did not provide data and analysis of non-compliance of licenced facilities that discharge to marine environments, therefore the extent of non-compliance with licenced discharge limits is unknown.

A detailed analysis on the waterbird populations at the Western Treatment Plant is provided in the Port Phillip Bay Marine and coastal waterbirds indicator (Indicator PPB 27).

89. Victorian Environmental Assessment Council (VEAC) 2019, 'Assessment of the values of Victoria's marine environment', Melbourne, Victoria.
90. Ibid.
91. Gemmill J, Rohmana QA, Fischer A, Blackwell B and Cumming J 2019, 'National outfall database: prospectus report 2019. Report to the National Environmental Science Program', Marine Biodiversity Hub, Clean Ocean Foundation.

PPB 07: Stormwater

Region	2021 status	2021 trend	2021 data
Port Phillip Bay		?	Moderate (status), Low (trend)
Justification for assessment ratings:	The status of fair is due to the variable stormwater conditions across Port Phillip Bay's catchments. There are very strong regional differences within the overall assessment for the bay. For example, only minor impacts to stream health are occurring from stormwater in the Werribee catchment, while stream health is being severely impacted from stormwater in the Dandenong catchment. Despite the analysis by catchment, there has been no public reporting assessing whether the Victorian Government's target of ensuring that nutrient and sediment loads do not exceed the 2017 levels is being met, therefore there is only a moderate confidence in the stormwater status assessment. No time series data are available to provide a trend assessment.		

Stormwater is one of the most significant issues impacting the environmental condition of Port Phillip Bay. It has been an enduring issue and there have been many projects, plans and policies implemented to try and limit the adverse impact of stormwater on the environment. Local planning in the Port Phillip Bay catchment is an area where significant investment has been made with:

- the implementation of a stormwater offset service for new developments that cannot meet best practice stormwater management
- $20 million provided to councils to prepare and implement municipal stormwater strategies, including construction of raingardens, wetlands and other projects.[92]

Too much stormwater damages and degrades urban waterways. If Melbourne was to develop out to its Urban Growth Boundary using conventional drainage-engineering approaches, one estimate is that over 900 km of streams would be degraded.[93]

To maintain Port Phillip Bay's generally good to very good water quality, the nitrogen input must remain at current levels. By 2051, the total nitrogen load from urban areas into the bay is projected to be about 40% more than it was in 2011.[94] In the Port Phillip Bay Environmental Management Plan 2017–2027, the government committed to ensuring that nutrient and sediment loads do not exceed the 2017 levels and that pollutant loads are reduced where practicable.[95] No public reporting is available to determine how the nutrient and sediment loads are tracking in relation to the government's load targets. Interim results from catchment modelling of nutrient and sediment loads from the Port Phillip Bay catchment supplied to the Commissioner of Environment Sustainability suggest a stable trend in annual loads of nutrients and sediments over the period 2016–2019. This is included as part of a broader discussion in Indicator 08: Total nutrient loads and Indicator 09: Total sediment loads.

The 2019-20 Annual Report and Delivery Plan Update as part of the Port Phillip Bay Environmental Management Plan 2017 included several references to activities being implemented to limit stormwater impacts to the Bay. These included:

- Reviewing the institutional arrangements governing the accountabilities for urban stormwater and flood-risk management (for example, DELWP will clarify local government's stormwater management functions work with councils, Melbourne Water and the Victorian Planning Authority to determine appropriate funding sources for managing and maintaining stormwater infrastructure).
- Improving the maintenance and performance of on-site wastewater systems (for example, South East Water's Septic Tank Management Program).

Remediating stormwater outfalls (for example,

92. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Port Phillip Bay environmental management plan 2017-2027', East Melbourne, Victoria.
93. Department of Environment, Land, Water and Planning (DELWP) 2018, 'Improving stormwater management advisory committee: final report', East Melbourne, Victoria.
94. Ibid.
95. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Port Phillip Bay environmental management plan 2017-2027', East Melbourne, Victoria.

establishing a filtration system using local indigenous plant species and Water Sensitive Landscaping to improve the operation of an existing outfall drain at Blairgowrie. The project will improve the quality of water through removing heavy metals, nutrients and silt prior to discharge into Port Phillip Bay).[96]

Stormwater condition for the four Port Phillip Bay catchments (that is, Werribee, Maribyrnong, Yarra and Dandenong) were rated on a scale from very high to very low in Melbourne Water's Healthy Waterway Strategy 2018-28 that was published in 2018. Stormwater condition is assessed in terms of Directly Connected Imperviousness (DCI), which is the proportion of the impervious surface that is directly connected to a stream through a conventional drainage connection. Werribee's stormwater condition was rated as high, with Maribyrnong and Yarra rated as Moderate and Dandenong as very poor. The rating of high indicates that only minor impacts to stream health are occurring from stormwater, while the rating of very low indicates that stream health is being severely impacted from stormwater. The Healthy Waterway Strategy sets a target for Stormwater Condition to remain high until 2028 for all catchments except Dandenong, which has a target to improve from very low to low.[97] It is important to note that urban development presents challenges to waterways as catchment imperviousness expands.[98] Stream health is generally highly affected in parts of the catchment where there has been a significant amount of urban development. For example, while the Werribee major catchment as a whole is in high condition, the stormwater condition scores vary at a sub-catchment level, with Kororoit Creek and Cherry Creek both rated as having very low stormwater condition.[99]

The significant adverse impacts of stormwater on water quality in the Dandenong catchment are discussed in the Dandenong Strategic Directions Statement that was published by DELWP in 2018.[100] Within that Statement, it was noted that most waterways in urban areas of the Dandenong catchment were in poor condition and showed concentrations of nutrients and metals due to runoff from nearby roads and industrial areas. Many small creeks and waterways within the Dandenong catchment have been straightened or concrete lined, contributing to decreased water quality and loss of stream habitats in the region.[101]

As part of the focus on stormwater in the Healthy Waterways Strategy, the 2019-20 Report Card tracks the progress of two stormwater-related indicators in the Strategy. The report card concludes that progress to meet a stormwater harvest target from new developments is on track for Port Phillip Bay catchments, while a target focused on stormwater infiltration from new developments is significantly off track.[102] As noted in the report card, there is no evidence of planning or construction of assets designed to infiltrate stormwater for the Werribee, Yarra and Westernport catchments, which is why the target has been to be significantly off-track.[103]

96. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Port Phillip Bay environmental management plan 2017-2027. 2019-2020 annual report and 2020 delivery plan update', East Melbourne, Victoria.
97. Melbourne Water 2018, 'Healthy waterways strategy 2018', Melbourne, Victoria.
98. Ibid.
99. Melbourne Water 2018, 'Co-designed catchment program for the Werribee catchment region'.
100. Department of Environment, Land, Water and Planning (DELWP) 2018, 'Dandenong strategic directions statement 2018', East Melbourne, Victoria.
101. Ibid.
102. Melbourne Water, 'Waterways report card', https://healthywaterways.com.au/report-card?suld=PPW&tabId=river& Accessed 5 May 2021.
103. Ibid.

Theme 1: Water Quality and Catchment Inputs

PPB 08: Total nutrient loads

Region	2021 status	2021 trend	2021 data
Port Phillip Bay			
Justification for assessment ratings:	Estimated nutrient loads over the period 2016-19 are within one quartile of the modelled 2000-19 long-term average, suggesting a stable trend over this time. This preliminary finding is based on interim results from an ongoing project, with further work currently underway to improve confidence in the modelled estimates. Given the Port Phillip Bay Environmental Management Plan 2017-2027 contains a priority target that nutrient loads do not exceed 2017 levels, the estimated stable trend from 2016-2019 is indicative of good status, however information is insufficient to determine whether annual nitrogen load objectives in the ERS are being met.assessment for estuarine water quality in this indicator. As part of the IEC, water quality assessments for 11 estuaries in the Port Phillip catchment region were completed, with two estuaries receiving ratings of excellent for water quality, three estuaries rated as good, two as fair, two as poor and two as very poor. The status assessment of fair is reflective of variable water quality in the estuaries that flow into Port Phillip Bay. As this is the first Index of Estuary Condition, and IECs are designed to be point-in-time assessments, no time series data are available to assess trends.		

The nutrients nitrogen and phosphorus are essential building blocks for plant and animal growth. The amount of nitrogen that comes into Port Phillip Bay controls how much plant growth can occur. The Bay is considered to be nitrogen limited because the amount of phosphorus available in the Bay is in excess of the amount needed for plant growth. When there is too much nitrogen the system is considered to be eutrophic, which results in excessive algal growth and persistent algal blooms.[104] Because of these relationships, this indicator strongly connects to water quality in the catchment, which is discussed in Indicator 01: Water quality (physicochemical).

In Port Phillip Bay, nutrient loads are a combination of catchment inputs (for example, stormwater) and nitrogen loads discharged from the Western Treatment Plant.[105]

The Port Phillip Bay Environmental Management Plan 2017-2027 contains a priority target that nutrient loads do not exceed current levels. The desire to maintain nutrient loads at current levels recognises that progress has already been made and those gains need to be kept – the first Environmental Management Plan for the Bay was released in 2001 and included an objective to reduce the annual nitrogen load to the Bay by 1,000 tonnes. The nitrogen load reduction of 1,000 tonnes was achieved through upgrades to the Western Treatment Plant and improved stormwater management in the catchments.[106]

The 2019-20 Annual Report and Delivery Plan Update (which contributes to regular reporting on the Port Phillip Bay Environmental Management Plan 2017-2027) did not provide any estimates of nutrient loads in relation to the specific strategy of 'ensuring nutrient and sediment loads do not exceed current levels and pollutant loads are reduced where practicable'. Three priority actions were listed in the Plan to achieve the strategy and the 2019-20 Annual Report included examples of these activities, which overlap with those previously detailed in Indicator 07: Stormwater.

In addition to the priority target in the Port Phillip Bay Environmental Management Plan 2017-2027, the ERS includes annual objectives for pollutant loads to Port Phillip Bay of: total nitrogen from surrounding waterways (1,500 to 2,200 tonnes), nitrogen from the Western Treatment Plant (3,100 tonnes based on a rolling 3 year average), total nitrogen from the Yarra and Maribyrnong Rivers (contribution of total nitrogen load not to exceed 70% of total annual average load from all surrounding waterways).

104. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Port Phillip Bay environmental management plan 2017–2027 supporting document', East Melbourne, Victoria.
105. Parry G and Hirst A 2016, 'Decadal decline in demersal fish biomass coincident with a prolonged drought and the introduction of an exotic starfish', *Marine Ecology Progress Series*, 544, pp. 37-52.
106. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Port Phillip Bay environmental management plan 2017-2027', East Melbourne, Victoria.

Interim results from catchment modelling of nutrient loads from the Port Phillip Bay catchment suggest a stable trend in annual loads of nutrients over the period 2016–2019.[107] Further work is currently being undertaken by Melbourne Water to improve the accuracy of estimates of nutrient loads to Port Phillip Bay from the catchments, including the installation of a network of automated water sampling equipment to enable more targeted water quality sampling during rainfall events. Melbourne Water has commissioned Monash University to undertake a research project to develop sampling protocols that will fully realise the potential of this new automated water sampling equipment to improve the confidence in estimated loads to Port Phillip Bay.

A current Melbourne University project is quantifying nutrient sources in the west of the Bay by partnering with community groups and government bodies to take water samples and comparing these to determine the amount of nitrogen in the water and its sources. It will also determine the effect of these nutrients on drift algae production and the cost-benefit of harvesting algae to manage excess nitrogen.[108]

The Bay naturally processes more than 5,000 tonnes of nitrogen per year from catchment runoff and treated wastewater discharge, thus preventing the eutrophication that leads to algal blooms, anoxia and other negative effects.[109] This ecosystem service is potentially worth $11 billion, based on a replacement cost of $2,250 per tonne, when compared to managing the nitrogen in the catchment through the construction of wetlands or new wastewater treatment plants.[110]

Obtaining direct evidence of ecological effects from increased nitrogen is complex. For example, nutrient loads in the north of the Bay are thought to be affecting the diversity and condition of rocky reefs, leading to 'urchin barrens'.[111] Conversely, reduced inputs of nitrogen during the 1998-2010 drought coincided with observed declines in seagrass beds and reduced fish recruitment.[112] As noted in the Port Phillip Bay Environmental Management Plan 2017-2027 Supporting Document, maintaining the Bay's ecological function is not as simple as removing all nitrogen loads, but rather obtaining a balance that sustains productivity and avoids eutrophic conditions.[113]

107. Melbourne Water (unpublished report) 2021, 'Interim report on modelled annual loads to Port Phillip Bay and Western Port'.
108. Department of Environment, Land, Water and Planning (DELWP), 'Managing nitrogen loads in Port Phillip Bay: towards better water quality (3060)', East Melbourne, Victoria https://www.marineandcoasts.vic.gov.au/grants/port-phillip-bay-fund/managing-nitrogen-loads-in-port-phillip-bay-towards-better-water-quality Accessed 22 February 2021.
109. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Port Phillip Bay environmental management plan 2017–2027 supporting document', East Melbourne, Victoria.
110. Marsden Jacob Associates 2014, 'Valuing the water services provided by Victoria's parks', report prepared for Parks Victoria.
111. Carnell PE and Keough MJ 2014, 'Spatially variable synergistic effects of disturbance and additional nutrients on kelp recruitment and recovery', *Oecologia*, 175(1), pp. 409-416.
112. Parry G and Hirst A 2016, 'Decadal decline in demersal fish biomass coincident with a prolonged drought and the introduction of an exotic starfish', *Marine Ecology Progress Series*, 544, pp. 37-52.
113. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Port Phillip Bay environmental management plan 2017–2027 supporting document', East Melbourne, Victoria.

Theme 1: Water Quality and Catchment Inputs

PPB 09: Total sediment loads

Region	2021 status	2021 trend	2021 data
Port Phillip Bay			
Justification for assessment ratings:	Estimated sediment loads over the period 2016-19 are within one quartile of the modelled 2000-19 long-term average, suggesting a stable trend over this time. This preliminary finding is based on interim results from an ongoing project, with further work currently underway to improve confidence in the modelled estimates. Given the Port Phillip Bay Environmental Management Plan 2017-2027 contains a priority target that sediment loads do not exceed 2017 levels, the estimated stable trend from 2016-2019 is indicative of good status. However, information is insufficient to determine whether annual total suspended solids load objectives in the ERS are being met.		

Sediment erosion and transport within waterways is an important natural process. However, excessive sediment inputs into coastal waterways can lead to poor water quality conditions and negative ecological outcomes, including smothering of benthic habitats (for example, seagrass and other filter feeders). Suspended sediments may also transport and disperse toxicants in coastal waterways. Catchment sediment loads are estimates of the total quantity of sediment delivered to the end of the catchment on an annual basis. Managing sediment loads is a key strategy to prevent the ecological degradation of coastal waterways and near-shore habitats.

The Port Phillip Bay Environmental Management Plan 2017-2027 contains a priority target that sediment loads do not exceed current levels. The 2019-20 Annual Report and Delivery Plan Update as part of the Port Phillip Bay Environmental Management Plan 2017-2027 did not provide any estimates of sediment loads in relation to the specific strategy of 'ensuring nutrient and sediment loads do not exceed current levels and pollutant loads are reduced where practicable'. Three priority actions were listed in the Plan to achieve the strategy and the 2019-20 Report included examples of these activities, which overlap with those previously detailed in Indicator 07: Stormwater.

In addition to the priority target in the Port Phillip Bay Environmental Management Plan 2017-2027, the ERS includes annual objectives for pollutant loads to Port Phillip Bay of: Total Suspended Solids (TSS) from surrounding waterways (60,000 to 70,000 tonnes), TSS from the Yarra and Maribyrnong Rivers (contribution of TSS load not to exceed 70% of annual average load from all surrounding waterways).

Interim results from catchment modelling of sediment loads from the Port Phillip Bay catchment suggest a stable trend in annual loads of sediment over the period 2016–2019.[114] Further work is currently being undertaken by Melbourne Water to improve the accuracy of estimates of sediment loads to Port Phillip Bay from the catchment, including the installation of a network of automated water sampling equipment to enable targeted water quality sampling during rainfall events. Melbourne Water has commissioned Monash University to undertake a research project to develop sampling protocols that will fully realise the potential of this new automated water sampling equipment to improve the confidence in estimated loads to Port Phillip Bay.

114. Melbourne Water (unpublished report) 2021, 'Interim report on modelled annual loads to Port Phillip Bay and Western Port'.

PPB 10: Coastal acid sulfate soils

Region	2021 status	2021 trend	2021 data
Port Phillip Bay		?	

Justification for assessment ratings:	Potential coastal acid sulfate soil sites have been mapped along the Port Phillip Bay coastline. The status has been rated as unknown as there is a lack of published analysis on the impacts to the Port Phillip Bay and surrounding coastal areas. The aggregated area of potential coastal acid sulfate soil sites is 12,000 hectares, which is a significant area of land but not approaching a complete coverage of the Port Phillip Bay coastline. There are no thresholds to guide status and trend assessments and there is no available evidence on the impact of coastal acid sulfate soils, so an indicator confidence assessment cannot be made.

Victorian coastal lands that have the potential to contain coastal acid sulfate soil were mapped during 2011 and the results for Port Phillip Bay are presented here.

Approximately 12,000 hectares of land along the Port Phillip Bay coastline was designated as prospective land (that is, land whose geomorphology indicates that there is a potential or prospect of encountering sulfidic material or sulfuric material).

Figure 8 shows the prospective land along the Port Phillip Bay coastline, with a majority of the potential coastal acid sulfate soil locations estimated to be in coastal regions from Werribee to the Port Phillip Heads.

115. Centre for eResearch and Digital Innovation, 'Soil health knowledge base' https://www.ccmaknowledgebase.vic.gov.au/soilhealth/soils_map.php?visible=true&restore_map=true&layer_id=258# Accessed 17 May 2021.

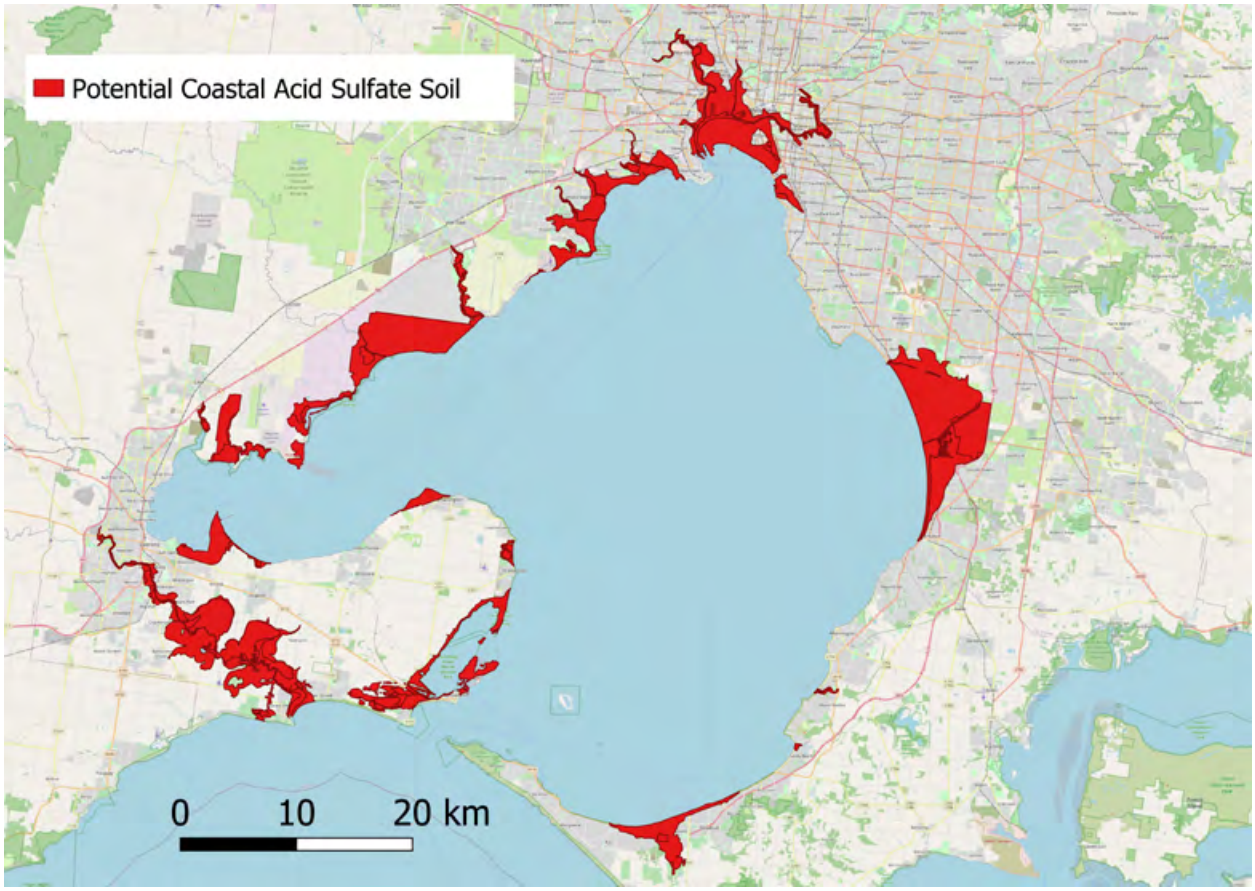


Figure 8: Potential coastal acid sulfate soil sites along the Port Phillip Bay coastline.[115]

Western Port

WP 01: Water quality (physicochemical)

Region	2021 status	2021 trend	2021 data
Western Port	●	→	●
Justification for assessment ratings:	These assessments are based on the Water Quality Index scores for Western Port, which have been rated as good for each year except for 2017-18 (when water quality in Western Port Bay was rated as fair) since monitoring and reporting began in 2000. The confidence in the status and trend assessments is high because the Water Quality Index is benchmarked against objectives in the Environment Reference Standard (ERS), while there is adequate spatial and temporal monitoring data.		

Western Port is a well-flushed, semi-enclosed bay, with two large islands (Phillip Island and French Island) that constrain water flow. The catchment is largely rural (70%), with state reserves (20%) in the upper catchment, and a fast-growing urban growth corridor.[116] The population of the Western Port catchment is expected to double over the next 20 years, with significant densification predicted for many suburbs across the region, particularly those surrounding Pakenham, Cranbourne and Beaconsfield.[117] Large population increases are also anticipated in the suburbs of Frankston, Warragul and the Casey - Clyde area.[118] This considerable population growth and development raises numerous challenges for the region's built and natural water systems over the coming years.[119]

Waterways in the catchment flow through areas that have been highly modified to support rural and green wedge land use. The northern and eastern areas of the bay are mostly intertidal mudflats dominated by catchment inflows from the Bunyip, Lang Lang and Bass Rivers. Tidal exchange with Bass Strait highly influences the western and southern areas.[120]

The Report Card for Western Port and its catchment is calculated using data from Melbourne Water and EPA. In 2019–20, water quality varied from good in areas of the upper catchment and the bay, to very poor in highly urbanised or intensive agricultural areas.[121]

Water quality in the bay has been consistently rated as good in each year of monitoring since 2000-01, except for 2017-18, which was rated fair. The relative deterioration in water quality during 2017-18 was due to a very poor rating of water clarity.

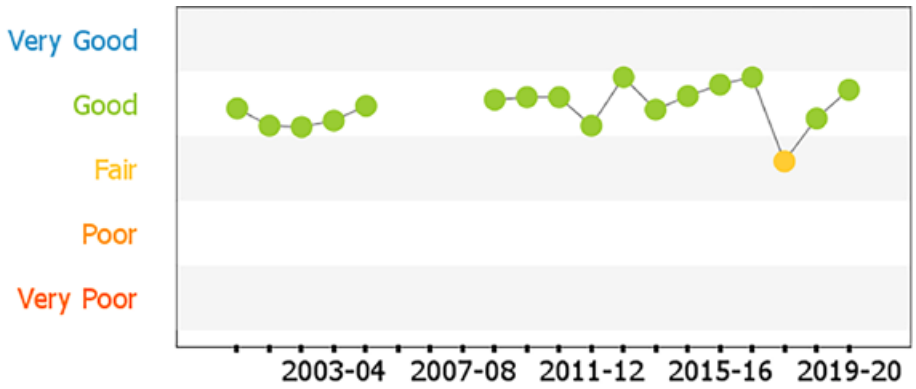


Figure 9: Historical Water Quality Index scores for Western Port Bay.[122]

116. EPA Victoria 2020, 'Report card 2019-20', Carlton, Victoria https://www.epa.vic.gov.au/about-epa/publications/1923 Accessed 17 May 2021.
117. Department of Environment, Land, Water and Planning (DELWP) 2018, 'Western Port strategic directions statement September 2018', East Melbourne, Victoria.
118. Ibid.
119. Ibid.
120. EPA Victoria 2020, 'Report card 2019-20', Carlton, Victoria https://www.epa.vic.gov.au/about-epa/publications/1923 Accessed 17 May 2021.
121. Ibid.
122. Ibid.

Theme 1: Water Quality and Catchment Inputs

Much like the story for Port Phillip Bay, the quality of water entering Western Port from the lower catchment is frequently rated as poor to very poor. For example, water quality was rated as very poor at all four of Melbourne Water's inland sites near the western coastline of Western Port for 2019-20 (Figure 10). Despite the polluted nature of some waterways flowing into the western side of the Bay, EPA's monitoring in the bay near Hastings observed water of very good quality, indicating that the bay's natural processes, including the regular flushing and mixing with oceanic waters from Bass Strait, are effective at diluting the pollution. Nonetheless, the altered drainage regimes and intensive land uses in the lower catchment present significant challenges for maintaining water quality in the rivers and streams that flow into the bay.

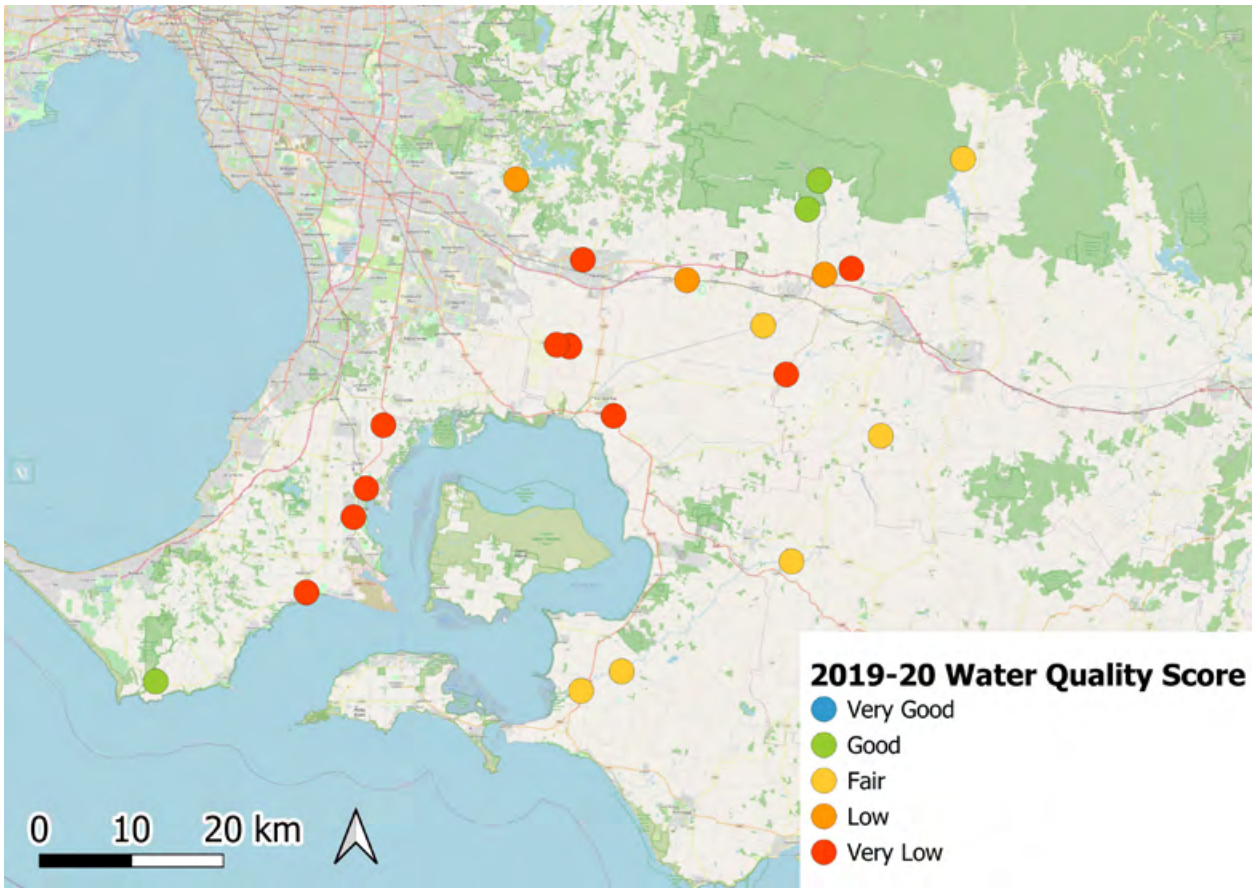


Figure 10: Locations and Water Quality Index scores for monitoring sites in the Western Port catchment for 2019–20.[123]

123. Ibid.

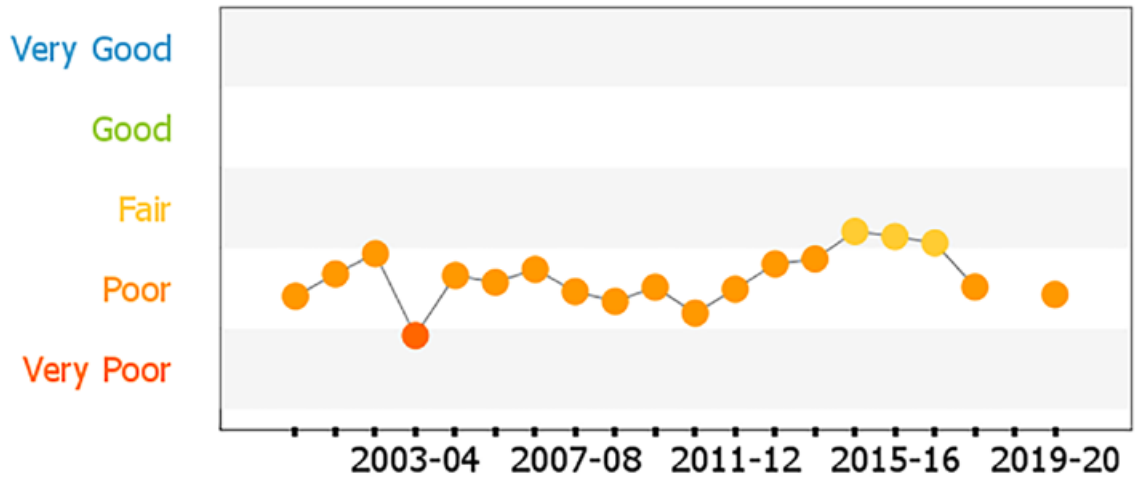


Figure 11: Historical Water Quality Index scores for the Western Port catchment.[124]

Figure 12: Locations and Water Quality Index scores for monitoring sites in Western Port Bay for 2019-20.[125]

124. Ibid.
125. Ibid.

Theme 1: Water Quality and Catchment Inputs

Water quality in the eastern side of Western Port, monitored near Corinella, was rated as fair for 2019-20 (Figure 12) due to high levels of sediment pollution. This was the same rating as the previous year. The high levels of suspended sediment are caused by a combination of high coastal erosion in the north-east of the bay, deposition of fine sediments from the catchment, and the re-suspension of sediment within Western Port.[126] Currents and waves re-suspend sediments, and deposit them on the north and north-eastern tidal flats during calm conditions.

Residual clockwise flow around French Island controls water clarity and sediment distribution through much of the eastern side of the bay. Large amounts of the sediments from the catchments that flow into the north-east of the bay are transported clockwise into the eastern arm near Corinella, where there is substantial deposition. In addition to clockwise circulation of suspended sediment, local increases from activities in the catchment are likely, particularly where drains and streams enter the bay.[127]

French Island National Park
© Parks Victoria

126. Ibid.
127. Melbourne Water 2018, 'Understanding the Western Port environment: a summary of research findings from the Western Port environment research program 2011-2017 and priorities for future research', Melbourne, Victoria.

Theme 1: Water Quality and Catchment Inputs

WP 02: Toxicants

Region	2021 status	2021 trend	2021 data
Western Port		?	Moderate (status) Low (trend)
Justification for assessment ratings:	Although the results of a 2013 study concluded that there are some localised areas in the Western Port catchment where toxicants are at levels of concern, toxicant concentrations in Western Port were generally below guideline values and therefore are likely to be a low risk to ecosystem health. Research from 2018 found frequent and widespread contamination by pesticides across the north-east catchments which discharge into Western Port. Pesticides were present in surface waters and sediments in complex mixtures and often at concentrations likely to impact on resident flora and fauna. Because these research studies provide 'point-in-time' assessments, the trend is unclear. This contributes to the confidence being rated as low for the trend because, although there is moderate confidence in the status based on research completed during 2013 and 2018, there is no ongoing toxicant assessment program in Western Port. Recent efforts have been focussing on understanding the major sources to the bay within the catchment.		

Toxicants in Western Port have been measured below guideline values and therefore are likely to be a low risk to ecosystem health. However, the results of a 2013 study concluded there are some localised areas in the Western Port catchment where toxicants are at levels of concern.[128]

Melbourne Water's 2018 Report Understanding the Western Port Environment 2018 summarised research findings from the Western Port Environment Research Program from 2011 to 2017 and stated that levels of toxicants including heavy metals and hydrocarbons are a low risk to the Western Port environment. The Report noted that pesticides including fungicides, herbicides and insecticides pose a moderate risk to flora and fauna, particularly within the freshwater reaches and estuaries, but also within the bay near the mouths of rivers and creeks.[129]

Storm events appear to increase the risk of exposure to pesticides, with increased rainfall linked to increased pesticide occurrence and concentrations in the catchments.[130] This is linked to the Climate and Climate Change Impacts chapter of this report where this is commentary on extreme rainfall events that are expected to become more intense on average through the rest of the 21st century. These projections of a future climate with more intense storms increase the risks associated pesticides contaminating Western Port's catchment and bay.

Pesticides are primarily associated with agricultural, rather than urban, areas and these pollutants are having biological impacts (for example, mortality and elevated biomarker responses in invertebrates, inhibition of algal growth and inhibited functional stream health).[131] This links to Indicator 70: Agriculture, in the Communities chapter of this Report.

A 2018 study found frequent and widespread contamination by pesticides across the north-east catchments which discharge into Western Port.[132] Pesticides were present in surface waters and sediments in complex mixtures and often at concentrations likely to impact on resident flora and fauna. Herbicides and fungicides are the most frequently detected pesticide groups, also occurring at the highest concentrations.

128. Sharp S, Myers J, Pettigrove V 2013, 'An assessment of sediment toxicants in Western Port and major tributaries', CAPIM technical report no. 27.
129. Melbourne Water 2018, 'Understanding the Western Port environment 2018'.
130. Ibid.
131. Ibid.
132. Myers, JH, Sharp S, Long S, Kellar C and Pettigrove V 2018, 'Final report Western Port toxicant study stage 4: assessment of pesticide risks in catchments of north-eastern Western Port', Aquatic Pollution Prevention Partnership, technical report no. 2, RMIT University, Victoria, Australia.

Key pesticides detected, based on frequency of occurrence and concentration, included:

- herbicides (Diuron, Simazine, Atrazine, Metolachlor)
- fungicides (Tebuconazole, Iprodione)
- insecticides (Bifenthrin, Pirimicarb).[133]

As part of that 2018 study, periods of poor water quality (for example, low dissolved oxygen and elevated turbidity) and elevated nutrients were also detected across the sites creating a multiple stressor environment. Sources of pesticides and nutrients are likely to include both agricultural and non-agricultural applications in the catchments, with further investigation needed to determine these. Catchments presenting the greatest risks to aquatic health, based on pesticide levels and detections, nutrient concentrations and poor water quality were Yallock Cut, Deep Creek, Drain One and Lower Gum Scrub Creeks. It was recommended that sources of pesticides and nutrients in these systems be further investigated and research into the transport pathways and persistence of the key pesticides be completed to determine and assess appropriate management actions to reduce inputs.[134]

For both mangroves and seagrasses, laboratory studies have determined that Diuron was the most toxic herbicide followed by Prometryn and Simazine. These herbicides are used in agricultural settings to control weeds. The results suggest potential for toxicity to seagrasses and mangrove seedlings from exposure to a single herbicide, however monitoring data shows that these plants may be exposed to as many as 22 different herbicides at one time.[135] Experimental results for seagrasses and mangroves indicate that current guideline values for individual herbicides may not be effective in protecting these habitats because they do not consider the potential impacts of pesticide mixtures.[136]

Penguins are excellent indicators of regional pollution; they have a wide geographic distribution within the limits of the Southern Hemisphere and have well-defined foraging habitats. Research published in 2020 collected baseline information on persistent organic pollutants (POPs) in resident little penguins (*Eudyptula minor*) from Phillip Island and migratory short-tailed shearwaters (*Ardenna tenuirostris*) from Fisher Island, Tasmania.[137] The results from this study established a much-needed baseline for POP contamination of both legacy and novel contaminants in two Australian seabird species, successfully filling gaps in knowledge for POP contamination in species local to the Southern Hemisphere. At the same time, this study also highlighted the lack of spatial and temporal studies concerning organic contaminants in this region. The presence of novel flame retardant hexabromobenzene is indicative of changing global regulations as legacy polybrominated diphenyl ether use is phased out.[138]

133. Ibid.
134. Ibid.
135. Melbourne Water 2018, 'Understanding the Western Port environment 2018'.
136. Ibid.
137. Lewis PJ, McGrath TJ, Chiaradia A, McMahon CR, Emmerson L, Allinson G and Shimeta J 2020, 'A baseline for POPs contamination in Australian seabirds: little penguins vs. short-tailed shearwaters', *Marine Pollution Bulletin,* 159, DOI:10.1016/j.marpolbul.2020.111488.
138. Ibid.

Theme 1: Water Quality and Catchment Inputs

WP 03: Water quality (estuaries)			
Region	**2021 status**	**2021 trend**	**2021 data**
Western Port		?	High (status) Low (trend)
Justification for assessment ratings:	Through the 2021 Index of Estuary Condition (IEC) assessments, there is high confidence in the status assessment for estuarine water quality in this indicator. As part of the Index of Estuary Condition, water quality assessments for 9 of the 10 estuaries in the Western Port catchment region were completed, with five estuaries receiving ratings of very poor for water quality, three estuaries were rated as fair and one estuary was rated as good. As this is the first Index of Estuary Condition, and IECs are designed to be point-in-time assessments, no time series data are available to assess trends.		

Table 5 shows the IEC water quality results for estuaries in the Western Port Catchment Region.[139] Five estuaries received a rating of very poor for water quality, three estuaries were rated as fair and one estuary was rated as good, while one estuary was not assessed.

As this is the first IEC, and IECs are designed to be point-in-time assessments, no time series data are available to assess trends.

Elevated turbidity was noted as a water quality issue for the estuaries that flow into Western Port.

Table 5: IEC results for estuarine flora within the Western Port catchment region; range 1 – 10 (1 poorest condition, 10 best condition). NA = not assessed.[140]

Estuary	Water Quality	Condition Class
Merricks Creek	2	Very poor
Warringine Creek	3	Very poor
Watsons Creek	1	Very poor
Cardinia Creek	7	Fair
Deep Creek	6	Fair
Bunyip River	8	Good
Yallock Drain	2	Very poor
Lang Lang River	7	Fair
Bass River	2	Very poor
Saltwater Creek	NA	

139. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Index of estuary condition', East Melbourne, Victoria.
140. Ibid.

WP 04: Plankton

Region	2021 status	2021 trend	2021 data
Western Port			
Justification for assessment ratings:	Chlorophyll-a is a commonly used measure of water quality, and concentrations indicate phytoplankton abundance and productivity in aquatic environments. The chlorophyll-a results for Western Port show that chlorophyll-a was rated as fair to poor in Western Port from 2000-01 until 2011-12, while it has been rated as good to very good since 2014-15, indicating a good status and improving trend. The confidence in the status and trend assessments is high because chlorophyll-a is assessed against the objectives in the Environment Reference Standard (ERS), while there is adequate spatial and temporal monitoring data.		

Microscopic single-celled organisms (that is, phytoplankton) inhabit the water column in Western Port. They are joined by small animals that drift passively with the currents (that is, zooplankton), and larger, passively drifting animals such as jellyfish. The phytoplankton are important indicators of environmental impacts such as elevated nutrients.

The characteristics and effects of plankton in Western Port were summarised in Melbourne Water's 2011 synthesis report Understanding the Western Port Environment.[141] The more recent 2018 report of the same title made only peripheral mentions to plankton, so the 2011 report is referred to for this indicator.

The Understanding the Western Port Environment report highlights the strong positive correlation between suspended solids and chlorophyll-a.[142] It is suggested that high concentrations of suspended solids may make more sediment-bound nutrients available for plankton to grow, and the shading effect may be limited by the shallowness of the bay.[143]

The role of plankton in fish lifecycles is also discussed in Melbourne Water's report. Some organisms move between different habitats at different stages of their life-cycles. This is most common when species arrive from the plankton into one habitat, which has the requirements for tiny juveniles, but then move to different locations as they get larger. In Western Port, examples include species such as King George whiting and snapper, which spawn elsewhere, recruit into specific habitats or locations such as seagrass, and move to deeper water later in life.[144]

Phytoplankton as an indicator of ecosystem health is relatively less important in Western Port when compared with Port Phillip Bay. Western Port is a 'biophysically' dominated system that is governed by shore morphology, wave dynamics, wind and light. As a result, it contains both benthic vegetation (for example, seagrass) and microphytobenthos, which have a high demand for nitrogen. Further, nutrients do not pose the same level of risk in Western Port as they do in Port Phillip Bay because Western Port is a highly-flushed system with a shorter residence time of the water. That is, the nutrients that enter the bay as runoff from the catchments are spread across the large surface area of Western Port.

Phytoplankton is assessed via EPA's routine measurements of chlorophyll-a that are made throughout its marine fixed-sites network (Figure 13). The chlorophyll-a results for Western Port show that chlorophyll-a was rated as fair to poor from 2000-01 until 2011-12, while it has been rated as good to very good since 2014-15.

141. Melbourne Water 2011, 'Understanding the Western Port environment – a summary of current knowledge and priorities for future research'.
142. Ibid.
143. EPA Victoria 2011, 'Western Port condition report – 2009'.
144. Melbourne Water 2011, 'Understanding the Western Port environment – a summary of current knowledge and priorities for future research'.

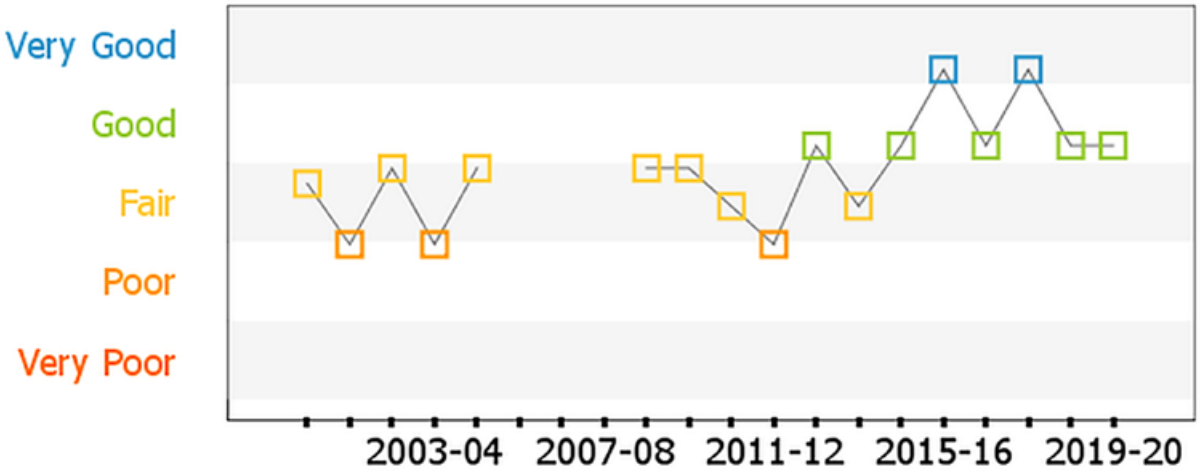


Figure 13: Chlorophyll-a Water Quality Index ratings for Western Port Bay.[145]

WP 05: *Enterococci* bacteria

Region	2021 status	2021 trend	2021 data
Western Port	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. EPA Victoria's microbial water quality monitoring occurs at beaches along Port Phillip Bay.		

WP 06: Regulated point source discharges to marine waters

Region	2021 status	2021 trend	2021 data
Western Port	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. There is an ocean outfall at Phillip Island. However, the discharge is to Bass Strait rather than Western Port so it not suitable for inclusion as part of a Western Port regulated point source discharge to marine waters assessment.		

145. Image supplied by EPA Victoria.

WP 07: Stormwater

Region	2021 status	2021 trend	2021 data
Western Port	●	?	Moderate (status), Low (trend)
Justification for assessment ratings:	The status of good is due to Melbourne Water's assessment that only minor impacts to stream health in Western Port are occurring from stormwater. No time series data are available to provide a trend assessment. Given there is no data available on the stormwater loads into Western Port, the confidence in these assessments is rated as moderate rather than high.		

Stormwater condition for Western Port was rated as high (on a scale from very high to very low) in Melbourne Water's Healthy Waterway Strategy 2018-28 that was published during 2018. This rating of high reflects an assessment that only minor impacts to stream health are occurring from stormwater. The Healthy Waterway Strategy 2018-28 sets a target for stormwater condition to remain high until 2028, although the current trajectory is for the rating to drop to moderate if current policies and effort continue.[146] This projected reduction in stormwater condition for 2028 is based on increasing population growth and urban development in the region. Stormwater condition is assessed in terms of Directly Connected Imperviousness (DCI), which is the proportion of the impervious surface that is directly connected to a stream through a conventional drainage connection.[147] It is important to note that urban development presents challenges to waterways as catchment imperviousness expands.[148] Stream health is generally highly affected in parts of the catchment where there has been a significant amount of urban development. Much of Western Port's catchment is rural or forested, which influences the overall stormwater condition rating of high, however existing urban areas of the growth corridor rate lower for stormwater condition. For example, while the Western Port major catchment as a whole is in 'high' condition, the stormwater condition scores vary at a sub-catchment level, with the Mornington Peninsula north-eastern and Western Creeks sub-catchments both rated as having low stormwater condition.[149]

Stormwater infrastructure assets need to effectively manage stormwater and wastewater from residential development to minimise community flood hazards and deliver improved environmental, commercial and social benefits to the Western Port catchment.[150] The need for water sensitive urban design in the Western Port catchment is becoming increasingly important as the catchment becomes more urbanised. As noted in the 2018 Western Port Strategic Directions Statement, the Western Port integrated water management forum area has an estimated population of more than 250,000 people and is predicted to double by 2040.[151]

Stormwater harvesting is an emerging focus area in the Western Port catchment. A notable example is in the Pakenham Region, where the practicality of harvesting stormwater to be treated at the Pakenham Water Recycling Plant to use as a source for Class A recycled water for local towns is being assessed. This project has the potential to divert approximately 700 ML per year of stormwater which would otherwise discharge into waterways and ultimately to Western Port.[152]

146. Melbourne Water 2018, 'Healthy waterways strategy 2018', Melbourne, Victoria.
147. Ibid.
148. Ibid.
149. Melbourne Water 2018, 'Co-designed catchment program for the Werribee catchment region'.
150. Department of Environment, Land, Water and Planning (DELWP) 2018, 'Western Port strategic directions statement September 2018', East Melbourne, Victoria.
151. Ibid.
152. Ibid.

Further progress with stormwater harvesting is likely to be made in the growth area of Casey and surrounding neighbourhoods along Melbourne's eastern fringe. Based on the current urban growth boundary, this catchment will require around 11.8 GL of stormwater to be harvested each year, with a further 4.4 GL to be infiltrated per year by 2028. Diverting this quantity of stormwater is expected to minimise the proportion of the impervious surfaces that directly connect to a stream through a conventional drainage connection. If stormwater harvesting initiatives are successful, it will mean headwater streams in these growth areas are retained as features in the landscape for environmental and social benefits.[153]

Despite the focus on stormwater in the Healthy Waterways Strategy, the 2019-20 Report Card that tracks the progress of two stormwater indicators in that Strategy concludes progress to meet stormwater targets is off track. The details for these indicators are:

- Stormwater harvest from new urban development is slightly off track, with 225 ML per year harvested, which is only 11% of the target of 1970 ML per year required by 2028.
- Stormwater infiltrate from new development is significantly off track, with 0 ML per year of infiltrate recorded for 2019-20, constituting no progress towards a target of 713 ML per year required by 2028.[154]

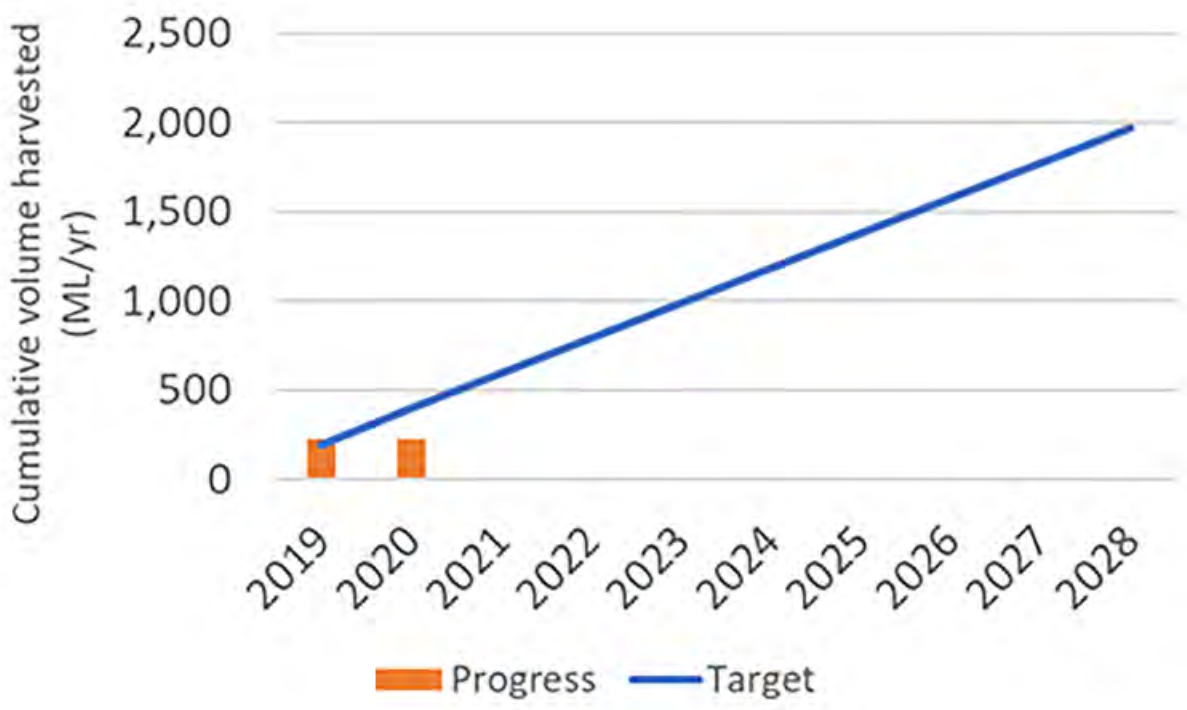


Figure 14: Progress towards 'stormwater from new urban development' target in the Healthy Waterways Strategy.[155]

153. Melbourne Water 2018, 'Healthy waterways strategy 2018', Melbourne, Victoria.
154. Melbourne Water, 'Waterways report card' https://healthywaterways.com.au/report-card?suld=PPW&tabId=river& Accessed 14 March 2021.
155. Ibid.

WP 08: Total nutrient loads

Region	2021 status	2021 trend	2021 data
Western Port			Low (status) Moderate (trend)
Justification for assessment ratings:	The evidence currently available suggests that nutrients are not having a significant impact on the Western Port environment. Estimated nutrient loads over the period 2016-19 period are within one quartile of the 2000-19 long-term average, suggesting a stable trend over this time. This preliminary finding is based on interim results from an ongoing project, with further work currently underway to improve confidence in the modelled estimates. The confidence in the status assessment is rated as low because there is no pollutant load target for nutrient loads for Western Port.		

Interim results from catchment modelling of nutrient loads from the Western Port catchment suggest a stable trend in annual loads of nutrients over the period 2016–2019.[156] Further work is currently being undertaken by Melbourne Water to improve the accuracy of estimates of nutrient loads to Western Port, including through the installation of a network of automated water sampling equipment to enable targeted water quality sampling during rainfall events. Melbourne Water has commissioned Monash University to undertake a research project to develop sampling protocols that will fully realise the potential of this new automated water sampling equipment to improve the confidence in estimated loads to Western Port.

In 2018, a Melbourne Water led research collaboration found that nutrient loads to Western Port were not posing a significant risk to seagrass cover on a bay-wide scale, although the report noted there may have been some localised problem areas.[157]

In Western Port, interactive effects of sediment and nutrient loads on major primary producers are highly likely, including feedbacks via sediment stabilisation and nutrient transformation. Understanding the interactive effects and feedbacks will assist the prioritisation of management actions to reduce sediment and nutrient loads. Initial modelling work has been commissioned by Melbourne Water to determine the relative contribution of urban areas to catchment sediment and nutrient loads including during construction. Quantifying the contributions of urban development relative to runoff from existing urban and agricultural areas will help inform management priorities and future stormwater management targets.[158]

156. Melbourne Water (unpublished report) 2021, 'Interim report on modelled annual loads to Port Phillip Bay and Western Port'.
157. Melbourne Water 2018, 'Understanding the Western Port environment 2018'.
158. Ibid.

WP 09: Total sediment loads

Region	2021 status	2021 trend	2021 data
Western Port			
Justification for assessment ratings:	Estimated sediment loads over the period 2016-19 period are within one quartile of the modelled 2000-19 long-term average, suggesting a stable trend over this time. This preliminary finding is based on interim results from an ongoing project, with further work currently underway to improve confidence in the modelled estimates. The interim results show that total suspended solids (TSS) loads for Western Port for recent years are estimated to be above the ERS marine pollutant load objective for TSS of 28,000 tonnes per year. The confidence in the status assessment is rated as moderate rather than high because even though the status can be benchmarked against the ERS, the data are only from interim results as part of an ongoing project.		

Interim results from catchment modelling of sediment loads from the Western Port catchment suggest a stable trend in annual loads of sediment over the period 2016–2019.[159] The interim results show that total suspended solids (TSS) loads for Western Port for recent years are estimated to be above the ERS marine pollutant load objective for TSS of 28,000 tonnes per year.[160] Further work is currently being undertaken by Melbourne Water to improve the accuracy of estimates of sediment loads to Western Port including through the installation of a network of automated water sampling equipment to enable targeted water quality sampling during rainfall events. Melbourne Water has commissioned Monash University to undertake a research project to develop sampling protocols that will fully realise the potential of this new automated water sampling equipment to improve the confidence in estimated loads to Western Port.

A study completed in 2013 found that Western Port had lost a third of its seagrass cover since the late 1970s.[161] This has been hypothesised to be linked to both a deterioration in water quality, via an increase in sediment inflows and suspended particles that cause an accompanying drop in light availability, and eutrophication associated with excessive nutrients.[162] A CSIRO study for Melbourne Water estimated that 32% of the sediment was sourced from the erosion of a nine-kilometre stretch of shoreline in the bay's north-eastern corner between the mouth of the Yallock Creek and the Lang Lang caravan park.[163]

The State Environment Protection Policy (Waters), which came into effect in 2018 and preceded the ERS, included a target aimed at reducing the amount of fine sediment within the waters of the bay, with the goal of improving water clarity. A publication detailing the development of environmental quality indicators and objectives for State Environment Protection Policy (Waters) reported that high levels of sediment within Western Port are due to past high sediment loads entering Western Port from the catchment and the associated loss of seagrasses, which have a stabilising effect on sediments. The loss of seagrasses means that fine sediments are more readily re-suspended by waves and currents which reduces light available for seagrass growth and survival. In turn, reduced light availability causes further seagrass loss and further sediment re-suspension.[164]

The documentation associated with the State Environment Protection Policy (Waters) also stated that improvements in water clarity are likely to take time to achieve, and modelling indicates that the time required to see meaningful changes in the levels of in-bay sediments from Western Port is approximately 20 years.[165]

159. Melbourne Water (unpublished report) 2021, 'Interim report on modelled annual loads to Port Phillip Bay and Western Port'.
160. State Government of Victoria 2021, 'Environment Reference Standard (Environment Protection Act 2017)'.
161. Holland D, Cook P, Mac Nally R, Thomson J, Womersley B, Ball D, Longmore A, Keough M, Lee R, Martinez G, Greer D 2013, 'Preliminary assessment of water quality requirements of seagrasses in Western Port', report prepared for Melbourne Water, December 2013.
162. Ibid.
163. Wilkinson S, Anstee J, Joehnk K, Karim F, Lorenz Z, Glover M and Coleman R 2016, 'Western Port sediment supply, seagrass interactions and remote sensing', Report to Melbourne Water Corporation, CSIRO, Melbourne, Australia.
164. EPA Victoria 2019, 'Development of indicators and objectives for SEPP (Waters)', Carlton, Victoria.
165. Ibid.

However, such a target will be important for reducing the accumulation of sediments available for re-suspension over the long term, which will improve the amount of light in the water column and therefore help to improve seagrass growth. Note that pollutant load targets in State Environment Protection Policy (Waters) have been adopted as objectives in the ERS.

The load targets had to be achieved by a specified date in State Environment Protection Policy (Waters) and included obligatory actions for waterway managers to achieve that target. Because the ERS imposes no obligations, load objectives now consist only of the indicator and associated load objective.[166]

WP 10: Coastal acid sulfate soils

Region	2021 status	2021 trend	2021 data
Western Port		?	
Justification for assessment ratings:	Potential coastal acid sulfate soil sites have been mapped along the Western Port coastline. The status has been rated as unknown as there is a lack of published analysis on the impacts to Western Port and surrounding coastal areas. The aggregated area of potential coastal acid sulfate soil sites is 8,000 hectares, which is a significant area of land but not approaching a complete coverage of the Western Port coastline. Because this mapping is a 'point-in-time' assessment, the trend is unclear. There are no thresholds to guide status and trend assessments and there is no available evidence on the impact of coastal acid sulfate soils, so an indicator confidence assessment cannot be made.		

Victorian coastal lands that have the potential to contain coastal acid sulfate soil were mapped during 2011 and the results for Western Port are presented here.

Approximately 8,000 hectares of land along the Western Port coastline was designated as prospective land (that is, land whose geomorphology indicates that there is a potential or prospect of encountering sulfidic material or sulfuric material).

Figure 15 shows the prospective land along the Western Port coastline, with a majority of the potential coastal acid sulfate soil locations estimated to be in northern coastal regions of Western Port, such as Tooradin.

Figure 15: Potential coastal acid sulfate soil sites along the Western Port coastline.[167]

166. EPA Victoria 2021, 'Guide to the environment reference standard', Carlton, Victoria.
167. Centre for eResearch and Digital Innovation, 'Soil health knowledge base' https://www.ccmaknowledgebase.vic.gov.au/soilhealth/soils_map.php?visible=true&restore_map=true&layer_id=258# Accessed 17 May 2021.

Corner Inlet and Nooramunga

CIN 01: Water quality (physicochemical)

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga		?	
Justification for assessment ratings:	Water quality is not currently routinely measured in the marine environment of the Corner Inlet and Nooramunga biounits. Therefore, the status and trend assessments have been assessed as unknown and unclear, respectively. The evidence to assess this indicator is minimal, therefore an indicator confidence assessment cannot be made. The water quality targets in the Water Quality Improvement Plan for Corner Inlet are likely to be used as thresholds for future assessments.		

The main efforts being made to improve and maintain water quality in Corner Inlet relate to reducing the pollutant load entering the marine environment from the catchment. The rationale is that by limiting the pollution entering the marine environment, the water quality in the Corner Inlet and Nooramunga marine biounits will be maintained and improved. The West Gippsland Catchment Management Authority published a Water Quality Improvement Plan (WQIP) for Corner Inlet in 2013.[168] Modelling undertaken in the development of the WQIP assessed contributions of major land use categories to the overall end-of-catchment loads to Corner Inlet and Nooramunga and quantified the management actions and land use changes required to achieve nutrient and sediment load targets. These actions were then assessed by their technical feasibility, cost effectiveness and socio-political impact and were evaluated by an expert scientific panel.[169]

The WQIP contained the following three targets for both Corner Inlet and Nooramunga:

- Corner Inlet catchments, at least 15% total nitrogen, 15% total phosphorus, 10% total suspended sediment reduction by 2033.
- Nooramunga catchments, at least 10% total nitrogen 10%, total phosphorus, 5% total suspended sediment reduction by 2033.[170]

Nearly halfway to the 2033 timeline for achieving the targets in the 2013 WQIP, it is unclear whether any progress has been made toward meeting those targets, although a monitoring and modelling framework is being designed currently to enable the quantification of progress towards load targets in the future. However, a substantial amount of work has been completed or is underway to achieve the targets. For example, the West Gippsland CMA has been working with farmers that have rivers and creeks on their property to for more than 20 years. This work has recently involved fencing off and revegetating waterways. Focussing on the hotspot catchments in the WQIP, 80% of the Agnes River and 70% of the Franklin River have now been fenced to exclude stock and revegetated to control erosion and create habitat.[171]

168. West Gippsland Catchment Management Authority (WGCMA) 2013, 'Corner Inlet water quality improvement plan 2013', Traralgon, Victoria.
169. EPA Victoria 2019, 'Development of environmental quality indicators and objectives for SEPP (Waters)', Carlton, Victoria.
170. West Gippsland Catchment Management Authority (WGCMA) 2013, 'Corner Inlet water quality improvement plan 2013', Traralgon, Victoria.
171. West Gippsland Catchment Management Authority (WGCMA), 'Corner Inlet – a RAMSAR site, right in our backyard', Traralgon, Victoria https://www.wgcma.vic.gov.au/news/latest-news/corner-inlet-a-ramsar-site-right-in-our-backyard Accessed 19 July 2021.

CIN 02: Toxicants

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	?	●
Justification for assessment ratings:	A risk assessment of toxicant threats in Corner Inlet revealed no medium, high or extreme risk to seagrass. Otherwise, there is no monitoring data to enable status or trend assessments to be made. The absence of toxicant monitoring has been previously identified as a knowledge gap in this region. The evidence to assess this indicator is minimal, therefore an indicator confidence assessment cannot be made.		

No monitoring data are available to provide good or fair confidence on the status of toxicants in Corner Inlet and Nooramunga. The absence of toxicant monitoring has been previously identified as a knowledge gap in this region. This uncertainty has been highlighted when proposals to develop industrial estates, port facilities and marinas at locations such as Barry Beach, Port Welshpool and Port Albert have been considered.[172,173]

A significant investigation into chemical toxicants in Corner Inlet was completed in 2016.[174] This project focused on determining whether toxicants are contributing to the seagrass decline in the local marine environment. Corner Inlet, while not experiencing the large declines of seagrass observed in nearby Western Port, had a gradual decline in seagrass cover over approximately four decades to 2013 before a 5-year period of stabilisation. It is currently not certain what the major driver of this decline was, however increased nutrient and sediment runoff from the catchment is the most likely mechanism. The threat and impact of chemical toxicants on seagrass in Corner Inlet had not been thoroughly investigated before the 2016 study, which evaluated the potential threat of chemical toxicants (for example, heavy metals, herbicides, petrochemicals, other pesticides and fire retardants) to seagrass in Corner Inlet.

The risk assessment of toxicant threats in Corner Inlet revealed no medium, high or extreme risk to seagrass. However, two important high to medium risk knowledge gaps were identified. Firstly, no information was available on the direct toxicity of fluazifop-p, the active ingredient in the herbicide Fusilade, which was being used in the intertidal zone of Corner Inlet to control the invasive weed Spartina in 2016. There was high likelihood of exposure to high concentrations of Fusilade through aerial spraying operations carried out in the intertidal zone adjacent to beds of *Zostera muelleri*. Therefore, the effect of Fusilade is deemed to be unknown with an interim risk rating as high.[175]

Secondly, the toxicity and exposure of seagrass to fire retardants was also highlighted as an important unknown risk requiring further attention. The fire retardant Phos-chek has been used during bushfire periods in the southern end of the Inlet but it is not known what concentrations seagrass were exposed to, and whether there were secondary indirect effects of algal blooms and eutrophication.[176]

In 2016, RMIT subsequently undertook the recommended field-based research and found that there were no adverse impacts on seagrass.[177]

See Indicator 34: Seagrass for more information on seagrass in Corner Inlet and Nooramunga.

172. Molloy R, Chidgey S, Webster I, Hancock G, Fox D 2005, 'Corner Inlet environmental audit', CSIRO Land and Water Client Report.
173. Department of Sustainability, Environment, Water, Population and Communities (DSEWPC) 2001, 'Corner Inlet Ramsar site ecological character description', Australian Government, Canberra.
174. Ford J, Barclay K and Day R 2016, 'Using local knowledge to understand and manage ecosystem-related decline in fisheries productivity', Fisheries Research and Development Corporation (FRDC) final project report, no. 2013-021, Melbourne, Victoria.
175. Ibid.
176. Ibid.
177. Shimeta JLS, Verspaandonk E, Nugegoda D, Howe S 2016, 'Long-term ecological consequences of herbicide treatment to control Spartina anglica in an Australian Saltmarsh', *Estuarine, Coastal and Shelf Science*, 176, pp. 58-66.

CIN 03: Water quality (estuaries)

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga		?	High (status) Low (trend)
Justification for assessment ratings:	Through the 2021 Index of Estuary Condition (IEC) assessments, there is high confidence in the status assessment for estuarine water quality in this indicator. As part of the IEC, water quality assessments for 11 estuaries were completed in the West Gippsland catchment region for those estuaries that flow into Corner Inlet and Nooramunga. One estuary was rated as excellent for water quality, two estuaries were rated as good, three as fair, one as poor and four as very poor. The status assessment of fair is due to variable water quality in the estuaries that flow into Corner Inlet and Nooramunga. As this is the first Index of Estuary Condition, and IECs are designed to be point-in-time assessments, no time series data are available to assess trends.		

Table 6 shows the IEC water quality results for estuaries in the West Gippsland catchment region that flow into Corner Inlet and Nooramunga.[178] One estuary received a rating of excellent for water quality, two estuaries were rated as good, three estuaries were rated as fair, one estuary was rated as poor, while four estuaries were rated as very poor.

As this is the first IEC, and IECs are designed to be point-in-time assessments, no time series data are available to assess trends.

Estuaries with very poor water quality included those on the western shore of Corner Inlet (for example, Bennison Creek, Stockyard Creek and Old Hat Creek).[179]

Table 6: IEC results for estuarine water quality within the West Gippsland catchment region that flow into Corner Inlet and Nooramunga; range 1 – 10 (1 poorest condition, 10 best condition). NA = not assessed.[180]

Estuary	Water Quality	Condition Class
Old Hat Creek	2	Very poor
Stockyard Creek	1	Very poor
Bennison Creek	2	Very poor
Franklin River	8	Good
Agnes River	8	Good
Shady Creek	2	Very poor
Nine Mile Creek	10	Excellent
Albert River	6	Fair
Tarra River	4	Poor
Neils Creek	7	Fair
Bruthen Creek	6	Fair

178. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Index of estuary condition', East Melbourne, Victoria.
179. Ibid.
180. Ibid.

CIN 04: Plankton

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	?	●
Justification for assessment ratings:	Phytoplankton is not currently routinely measured in the marine environment of the Corner Inlet and Nooramunga biounits. Therefore, the status and trend assessments have been assessed as unknown and unclear, respectively. The evidence to assess this indicator is minimal, therefore an indicator confidence assessment cannot be made.		

Within the Corner Inlet Ramsar Site ecological character description, phytoplankton is listed as one of the main primary producers. However, there is no recent monitoring data relating to phytoplankton abundance in Corner Inlet and Nooramunga.

A study into seagrass decline in Corner Inlet was completed in 2016 and has some relevance to phytoplankton. This research linked catchment nutrients/sediment, algal blooms and seagrass decline.[181] Phytoplankton is often linked with algal blooms, so given six major algal blooms were observed in Corner Inlet between January 2013 and March 2016, it is likely that phytoplankton in Corner Inlet is probably at deleterious concentrations.

CIN 05: *Enterococci* bacteria

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. EPA Victoria's microbial water quality monitoring occurs at beaches along Port Phillip Bay.		

181. Ford J, Barclay K and Day R 2016, 'Using local knowledge to understand and manage ecosystem-related decline in fisheries productivity', Fisheries Research and Development Corporation (FRDC) final project report, no. 2013-021, Melbourne, Victoria.

CIN 06: Regulated point source discharges to marine waters

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga		?	
Justification for assessment ratings:	There is good information available on the volumes and nutrient loads discharged to marine waters from regulated point sources. However, there is no quantitative analysis available to understand the extent that regulated discharges impact the receiving marine environments. There is also no available analysis of non-compliance of licenced facilities that discharge to marine environments, therefore the extent of non-compliance with licenced discharge limits is unknown.		

Three outfalls managed by South Gippsland Water discharge into Corner Inlet and Nooramunga. These outfalls are relatively very small compared to several other state and national outfalls.

The nitrogen and phosphorous loads from the three Corner Inlet and Nooramunga outfalls are summarised in Table 7. Note that the Toora ocean outfall discharges a relatively small volume compared to other Victorian outfalls. It accommodates one wastewater treatment plant and serves the area of Toora. Approximately 150 KL of treated effluent is discharged to Corner Inlet located at a tidal creek amongst mangroves and 2-3 ML is reused per year for Toora Football Club during summer and Toora recreation reserve.[182]

This indicator narrative is only able to provide commentary of the volumes and nutrient loads discharged to marine waters from regulated point sources, which is comprehensively aggregated and reported by the Clean Ocean Foundation as part of the National Outfall Database.

However, there is no quantitative analysis available to understand the extent that regulated discharges impact the receiving marine environments. EPA Victoria did not provide data and analysis of non-compliance of licenced facilities that discharge to marine environments, therefore the extent of non-compliance with licenced discharge limits is unknown.

Table 7: Coastal outfalls nutrient loads and rankings. A ranking of 1 represents the greatest nutrient load.[183]

Outfall	Total nutrient load for 2017-18 (kg)	Ranking among Victorian coastal outfalls	Ranking among Australian coastal outfalls
Foster	5,624	13th of 17	107th of 140
Port Welshpool	414	17th of 17	137th of 140
Toora	Incomplete data for 2017-18		

182. National Outfall Database, 'Toora outfall' https://www.outfalls.info/detail/locations/50 Accessed 29 July 2021.
183. Gemmill J, Rohmana QA, Fischer A, Blackwell B and Cumming J 2019, 'National outfall database: prospectus report 2019, report to the national environmental science program', Marine Biodiversity Hub, Clean Ocean Foundation.

CIN 07: Stormwater

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga		?	
Justification for assessment ratings:	The stormwater impact on marine water quality in Corner Inlet and Nooramunga remains largely unknown. The evidence to assess this indicator is minimal, therefore an indicator confidence assessment cannot be made.		

As reported by Parks Victoria in 2005, about 30 stormwater and agricultural drains discharge into Corner Inlet, however CSIRO researchers completing an environmental audit of Corner Inlet during 2005 found the impact of urban stormwater drains is largely unknown because of the lack of information on water quality and quantity.[184,185] Little has changed during the past 15 years, with the stormwater impact on marine water quality in Corner Inlet and Nooramunga remaining largely unknown.

Developments such as canal estates, proposed for places such as Port Albert and Port Welshpool, as well as intensification of urban development currently underway in these towns and Foster, Manns Beach, Roberstons Beach and McLoughlins Beach could increase pollutant loads associated with increased stormwater runoff and increased sewage effluent releases.[186]

CIN 08: Total nutrient loads

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga		?	Moderate (status), Low (trend)
Justification for assessment ratings:	Periodic research of nutrient loads in Corner Inlet has shown high nutrient loads are entering Corner Inlet and that these are linked with infrequent algal bloom occurrences in the Inlet. There is no routine monitoring to assess nutrient loads, so the confidence in the status assessment is moderate and the trend is unclear due to the absence of time-series data. The nutrient load targets in the Water Quality Improvement Plan for Corner Inlet are likely to be used as thresholds for future assessments.		

The condition and extent of important habitat including seagrass meadows, sandflats, mangroves and saltmarsh are threatened by nutrient and sediment pollution from predominantly catchment land uses.[187]

There have been periodic studies of nutrient loads in Corner Inlet during this century. An Environmental Audit was completed by the CSIRO during 2005 in response to growing concern from natural resource managers and the community about the health of Corner Inlet.[188] To address one of the key recommendations from the Audit, a sediment and nutrient model of the catchments of Corner Inlet was developed in 2008.[189]

One of the major findings from the 2008 study was that dryland agriculture produces the greatest nutrient loads to Corner Inlet and Nooramunga due to the extensive amount of this land-use within the catchment. Although only accounting for 22% of the total area, production forests produce the highest sediment and substantially higher NO_x loads than other land-uses.

184. Molloy R, Chidgey S, Webster I, Hancock G, Fox D 2005, 'Corner Inlet environmental audit', CSIRO Land and Water Client Report.
185. Parks Victoria 2005, 'Corner Inlet marine national park management plan', Melbourne, Victoria.
186. Department of Sustainability, Environment, Water, Population and Communities (DSEWPC) 2001, 'Corner Inlet Ramsar site ecological character description', Australian Government, Canberra.
187. West Gippsland Catchment Management Authority (WGCMA) 2013, 'Corner Inlet water quality improvement plan 2013', Traralgon, Victoria.
188. CSIRO 2005, 'Corner Inlet environmental audit CSIRO Land and Water Client Report'.
189. West Gippsland Catchment Management Authority (WGCMA) 2008, 'Corner Inlet sediment and nutrient modelling final report', Traralgon, Victoria.

The sewage treatment plant outfall loads were also associated with localised contributions and were noted as an important source to manage, however their overall contribution to Corner Inlet and Nooramunga was estimated to be quite low compared to dryland agriculture. Population growth in the region was not thought to be a significant factor impacting nutrient loads. The highest phosphorus concentrations observed during sampling periods were related to the western catchments between Foster and Yanakie. These higher concentrations were most likely due to substantial phosphorus-based fertiliser use in the area.[190]

Another conclusion from the 2008 research, which was revealed during analysis of historical water quality data, was that a high proportion of the nutrient loads were associated with high-flow events.[191]

As discussed in Indicator 01: Water quality (physicochemical), effort to maintain and improve water quality in Corner Inlet during the most recent decade has focused on reducing the pollutant load entering the marine environment from the catchment. The West Gippsland Catchment Management Authority published a Water Quality Improvement Plan (WQIP) for Corner Inlet in 2013.

The plan contained the following targets for reducing nutrient loads in both Corner Inlet and Nooramunga:

- Corner Inlet catchments, at least 15% total nitrogen and total phosphorus reduction by 2033
- Nooramunga catchments, at least 10% total nitrogen and total phosphorus reduction by 2033.[192]

A research project completed during 2016 monitored the water quality of streams draining to Corner Inlet and confirmed the findings of the WQIP – that high nutrient loads are entering the Inlet from the north and north west, and that the western tributaries have high concentrations of nutrients.[193] The same project also filled a pre-existing knowledge gap by identifying and characterising two types of algal blooms that occur in Corner Inlet. One appears to be fuelled by nutrients coming from the natural breakdown of seagrass and has been occurring for many decades, and the other is linked with nutrients originating in the catchment and is increasing in impact over the past decade. This information is important in informing the on-going nutrient reduction work in the catchment and the associated monitoring requirements.[194]

Sea kayaking at Corner Inlet
© Parks Victoria

190. Ibid.
191. Ibid.
192. West Gippsland Catchment Management Authority (WGCMA) 2013, 'Corner Inlet water quality improvement plan 2013', Traralgon, Victoria.
193. Ford J, Barclay K and Day R 2016, 'Using local knowledge to understand and manage ecosystem-related decline in fisheries productivity', Fisheries Research and Development Corporation (FRDC) final project report, no. 2013-021, Melbourne, Victoria.
194. Ibid.

CIN 09: Total sediment loads

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga		?	
Justification for assessment ratings:	The limited available evidence suggests sediment loads are not having a significant impact on general marine and coastal habitats in Corner Inlet and Nooramunga. This has led to a status assessment of good, however it should be noted that this assessment has been made with low confidence.		

The condition and extent of important habitat including seagrass meadows, sandflats, mangroves and saltmarsh are threatened by nutrient and sediment pollution that results mostly from catchment land uses.[195]

Research published in 2008 concluded that there was limited sediment available and accessible and that typical wind stirring would not generate high sediment concentrations and transports in Corner Inlet and Nooramunga.[196]

Sediment analysis within Corner Inlet and Nooramunga was completed by the University of Wollongong in 2011 and later incorporated into the Corner Inlet Water Quality Improvement Plan 2013.

Key findings from the University of Wollongong study were that:

- Deposition of clays and silts takes place mainly in the upper estuarine reaches of the tributaries of Corner Inlet and Nooramunga, prior to entering the embayment.
- Fine sediment that enters the embayment during high flows does not settle in the energetic main channels and sandflats and is only found in backwater areas.
- Sediments within Corner Inlet and Nooramunga all fall within the ANZECC guidelines for sediment quality.
- The absence of long-term water quality data for the marine waters of Corner Inlet and Nooramunga makes it difficult to determine the level of change in water quality conditions over time.[197,198]

In 2016, declines in seagrass (the key fish habitat) in Corner Inlet were linked with activities in the broader region through catchment runoff of excess nutrients and sediments from land.[199]

195. West Gippsland Catchment Management Authority (WGCMA) 2013, 'Corner Inlet water quality improvement plan 2013', Traralgon, Victoria.
196. Coastal Environmental Consultants 2008, 'Corner Inlet sediment characterisation study final report', report prepared in collaboration with Geomax for the Department of the Environment, Water, Heritage and the Arts (DEWHA), Australian Government, Canberra.
197. McLean E and Jones B 2011, 'Corner Inlet sediment study – trace elements' final report by the University of Wollongong to the West Gippsland Catchment Management Authority (WGCMA).
198. West Gippsland Catchment Management Authority (WGCMA) 2013, 'Corner Inlet water quality improvement plan 2013', Traralgon, Victoria.
199. Ford J, Barclay K and Day R 2016, 'Using local knowledge to understand and manage ecosystem-related decline in fisheries productivity', Fisheries Research and Development Corporation (FRDC) final project report, no. 2013-021, Melbourne, Victoria.

CIN 10: Coastal acid sulfate soils

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga		?	
Justification for assessment ratings:	Potential coastal acid sulfate soil sites have been mapped along the Corner Inlet and Nooramunga coastline. The status has been rated as unknown as there is a lack of published analysis on the impacts to Corner Inlet and Nooramunga, and surrounding coastal areas. The aggregated area of potential coastal acid sulfate soil sites is 20,000 hectares, which is a significant area of land but not near a complete coverage of the Corner Inlet and Nooramunga coastline. Because this mapping is a 'point-in-time' assessment, the trend is unclear. There are no thresholds to guide status and trend assessments and there is no available evidence on the impact of coastal acid sulfate soils, so an indicator confidence assessment cannot be made.		

Victorian coastal lands that have the potential to contain coastal acid sulfate soil were mapped during 2011 and the results for Corner Inlet and Nooramunga are presented here.

Approximately 20,000 hectares of land along the Corner Inlet and Nooramunga coastline was designated as prospective land (that is, land whose geomorphology indicates that there is a potential or prospect of encountering sulfidic material or sulfuric material).

Figure 16 shows the prospective land along the Corner Inlet and Nooramunga coastline, with a majority of the potential coastal acid sulfate soil locations estimated to be in northern coastal regions of Corner Inlet, near Port Franklin, as well as near Port Albert along the Nooramunga coastline.

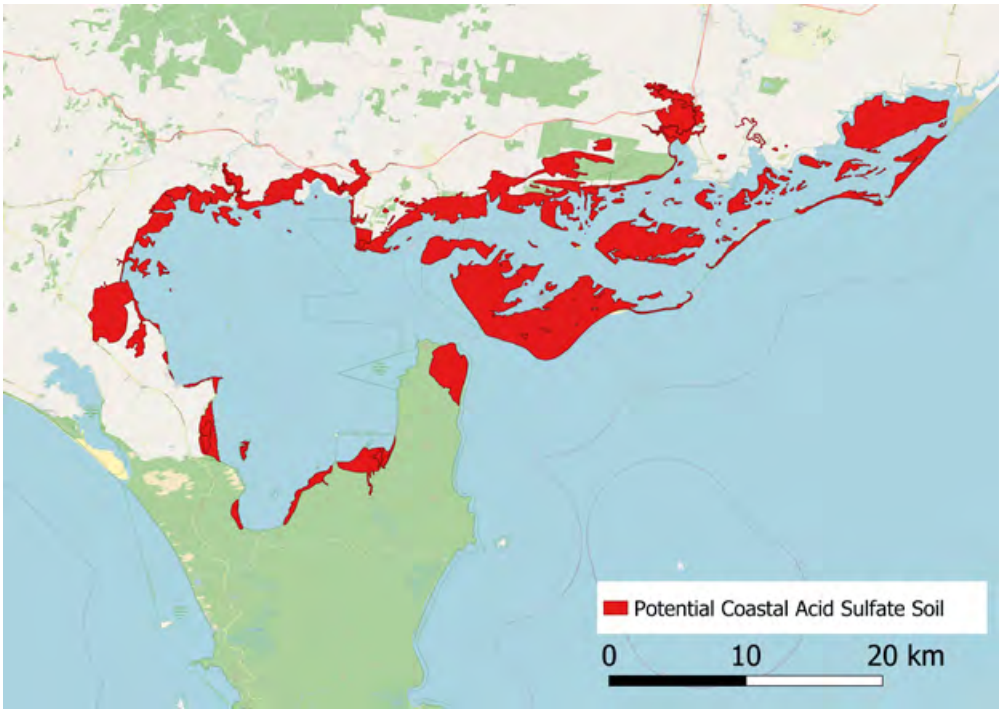


Figure 16: Potential coastal acid sulfate soil sites along the Corner Inlet and Nooramunga coastline.[200]

200. Centre for eResearch and Digital Innovation, 'Soil health knowledge base' https://www.ccmaknowledgebase.vic.gov.au/soilhealth/soils_map.php?visible=true&restore_map=true&layer_id=258# Accessed 17 May 2021.

Gippsland Lakes

GL 01: Water quality (physicochemical)

Region		2021 status	2021 trend	2021 data
Gippsland Lakes	Lake King	Good	→	Good
	Lake Victoria	Good	→	Good
	Lake Wellington	Poor	→	Good

Justification for assessment ratings:	These assessments are based on the Water Quality Index scores for Gippsland Lakes. The eastern Lakes (that is, Lake King and Lake Victoria) have been rated as good for six of the past seven years, while Lake Wellington has been rated as poor for the past three years and poor or very poor in seven of the past ten years. The confidence in the status and trend assessments is high because the Water Quality Index is benchmarked against objectives in the Environment Reference Standard (ERS), while there is adequate spatial and temporal monitoring data.

The Gippsland Lakes are a 70 km-long series of large, shallow coastal lagoons. A narrow, artificially maintained channel at Lakes Entrance connects the lakes to Bass Strait. The catchment consists of mostly state reserves, forests and national parks (60%) and rural land (39%). Five major river systems drain directly into the lakes.[201]

In 2019–20, water quality was very good and good at most locations monitored in the catchment. However, the lower reaches of major rivers, as well as Lake Wellington and Lake Victoria, had fair or poor water quality. The general deterioration of water quality from the catchment to the Lakes is in contrast to Port Phillip Bay and Western Port where water quality in those marine environments has been considerably improved through catchment management.

During 2019-20, water quality in the East Gippsland catchment declined from very good to good for the first time since 2006-07, in a year characterised by extremely low rainfall, severe bushfires and increased rainfall in some areas in late summer. In West Gippsland, water quality followed a similar pattern to previous years and remained good. Water quality was generally better in the upper catchment before declining along the mid and lower reaches of the main rivers where cleared land and urbanisation have impacted water quality.

EPA Victoria has five monitoring locations in the Gippsland Lakes (Figure 17). Monitoring locations closer to the Bass Strait entrance (that is, Shaving Point and Lake King) had better water quality due to greater tidal exchange. Polluted water discharging from rivers impacted inland monitoring locations (that is, Lake Wellington and Lake Victoria).[202]

201. EPA Victoria 2020, 'Report card 2019-20', Carlton, Victoria https://www.epa.vic.gov.au/about-epa/publications/1923 Accessed 17 May 2021.
202. Ibid.

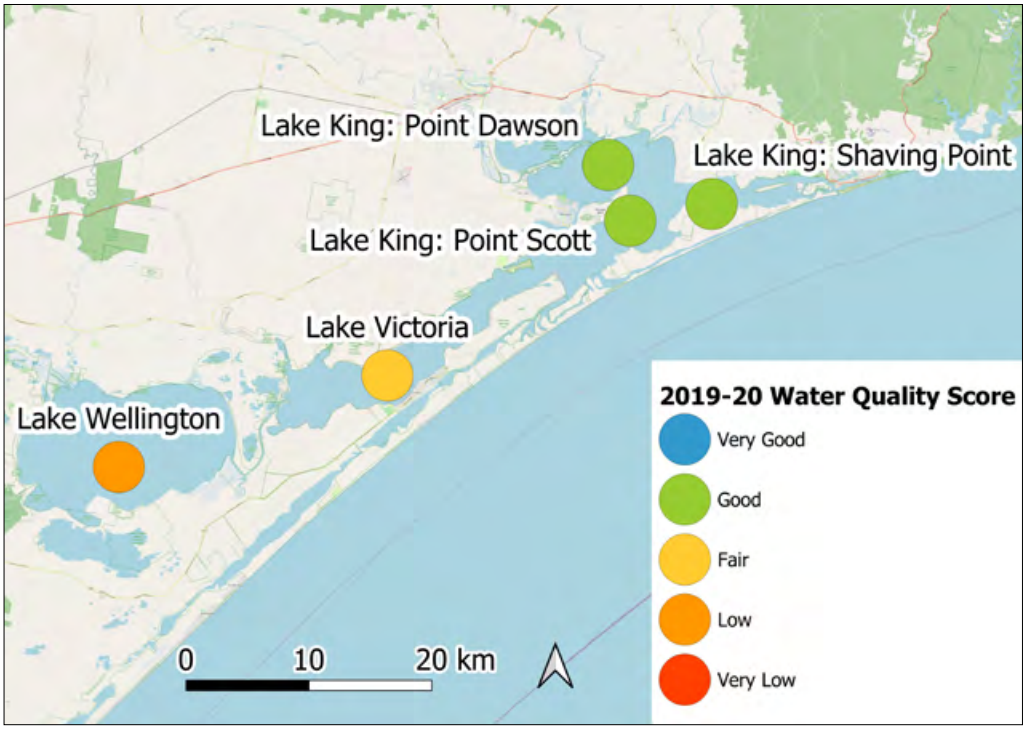


Figure 17: Locations and Water Quality Index scores from marine monitoring sites in Gippsland Lakes.[203]

Overall, water quality was poor in Lake Wellington and good in the eastern lakes (Lake King and Lake Victoria) during 2019–20. While assessments were good for the eastern lakes overall, water quality declined from good to fair between Lake King and Lake Victoria. This was due to the reduced influence of clean water from Bass Strait.[204]

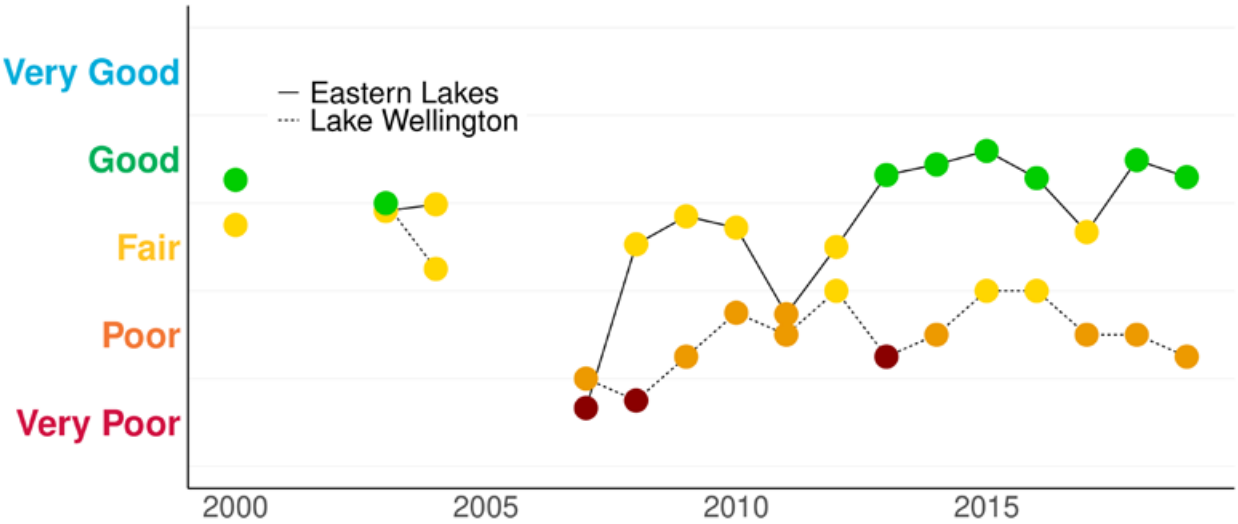


Figure 18: Historical Water Quality Index scores for the Gippsland Lakes.[205]

203. Ibid.
204. Ibid.
205. Image supplied by EPA Victoria.

Theme 1: Water Quality and Catchment Inputs

Lake Wellington is a sink for sediments, nutrients and contaminants. Wind and waves within the shallow waters of the lake can re-suspend sediments and nutrients, with algal blooms often developing because of the high availability of nutrients. These processes are reflected in the poor Water Quality Index (WQI) score in 2019–20. Historically, water quality in Lake Wellington has been rated as poor or very poor.[206] Although Lake Wellington is a sink, it is not a closed system – reducing future inputs will lead to improvements in water quality during similar disturbance events and work is being done to mitigate further deterioration of water quality.

Catchment works have focused on reducing sediment and nutrient loads being transported to Lake Wellington. This has included riparian protection and revegetation, wetland restoration, bed and bank stabilisation, and on-farm nutrient use and effluent loss reduction.

In 2019–20, the Gippsland region experienced drought, with severe bushfires in East Gippsland. Though bushfires temporarily impacted the water quality of major rivers in the East Gippsland catchment that flows into the lakes, this did not cause significant changes to the overall water quality of the Gippsland Lakes.[207]

GL 02: Toxicants

Region	2021 status	2021 trend	2021 data
Gippsland Lakes		?	Moderate (status) Low (trend)
Justification for assessment ratings:	Concentrations of nickel, mercury and arsenic exceeding Australian and New Zealand Environment and Conservation Council (ANZECC) guideline values for sediment quality were measured in Lake Wellington and Lake Victoria during a 2015-2016 study.[208] All other locations had toxicant concentrations within guideline levels. Because this research is a 'point-in-time' assessment, the trend is unclear. This is why the confidence is rated as moderate for status but only as low for trend.		

Toxicants from the catchment are transported through rivers and streams into the Gippsland Lakes. Most toxicants will be bound to sediment particles and deposited in the sediments of receiving waters, which means most toxicant research in Gippsland Lakes focuses on measuring toxicant concentrations in sediments.

In response to toxicants, in particular heavy metals such as mercury, being identified and reported as a knowledge gap within the Gippsland Lakes Ramsar Site Management Plan, a significant study of sediment toxicants was conducted in 2015 and 2016 across the main lakes and two fringing wetlands.[209,210] This study is the basis for this indicator assessment.

Concentrations of nickel, mercury and arsenic exceeding Australian and New Zealand Environment and Conservation Council (ANZECC) guideline values for sediment quality were measured in Lake Wellington and Lake Victoria during the 2015-2016 study.[211] All other locations had toxicant concentrations within guideline levels.

206. Ibid.
207. Ibid.
208. Reeves J and Trewarn A 2016, 'Assessment of heavy metals and other contaminants of the Gippsland Lakes', Federation University Australia, Mt Helen, Victoria.
209. East Gippsland Catchment Management Authority (EGCMA) 2015, 'Gippsland Lakes Ramsar site management plan', Bairnsdale, Victoria.
210. Reeves J and Trewarn A 2016, 'Assessment of heavy metals and other contaminants of the Gippsland Lakes', Federation University Australia, Mt Helen, Victoria.
211. Ibid.

The high concentrations of nickel throughout the Gippsland Lakes is thought to be due to the underlying geology and is common in aquatic systems in Victoria.[212,213]

Concentrations of arsenic in sediments were elevated in Lake Wellington at depth (rather than the surface). Researchers have concluded that the generally low surface levels of arsenic, with higher concentrations found near the floor of the Gippsland Lakes, indicates a low level of risk to ecology and human health. The higher concentrations measured in Lake Wellington at depth are most likely due to deposition from historical activities such as mining.[214]

The 2015-2016 study correlates with historical investigations with respect to mercury. Over the past 30 years, there have been several studies that have indicated mercury may be of concern in the main lakes.[215]

The report detailing the findings of the 2015-2016 study included the following conclusions:

- Mercury is present in the sediments of the lakes above the low trigger value of the sediment quality guidelines. Highest concentrations of mercury are found in the west of the system including the Latrobe River, Lake Wellington, Heart Morass and Lake Victoria West. Mercury is present both in the surface sediments and at depth.
- Arsenic showed elevated concentrations at several sites, but only exceeded trigger values in the Latrobe River and Lake Victoria East. As higher concentrations occurred at depth, a historical source is likely.
- Nickel is present throughout the system and consistently through the cores, suggesting a local geological source.[216]

GL 03: Water quality (estuaries)

Region	2021 status	2021 trend	2021 data
Gippsland Lakes		?	High (status) Low (trend)
Justification for assessment ratings:	Through the 2021 Index of Estuary Condition (IEC) assessments, there is high confidence in the status assessment for estuarine water quality in this indicator. As part of the IEC, water quality assessments for 14 estuaries were completed in the West and East Gippsland catchment regions for those estuaries that flow into the Gippsland Lakes. Two estuaries were rated as excellent for water quality, four estuaries were rated as good, four as fair, one as poor and three rated as very poor. The status assessment of fair is due to variable water quality in the estuaries that flow into the Gippsland Lakes. As this is the first Index of Estuary Condition, and IECs are designed to be point-in-time assessments, no time series data are available to assess trends.		

Table 8 shows the IEC water quality results for estuaries in the West and East Gippsland catchment regions that flow into the Gippsland Lakes.[217] Two estuaries received a rating of excellent for water quality, four estuaries were rated as good, four estuaries were rated as fair, while one estuary was rated as poor and three as very poor. As this is the first IEC, and IECs are designed to be point-in-time assessments, no time series data are available to assess trends.

Water Quality was assessed as moderate in the Latrobe-Thomson estuary. Monitoring for this system was undertaken below the confluence of the Latrobe and Thomson rivers and therefore reflects catchment inputs from both rivers.[218]

212. Ibid.
213. Fabris G, Theodoropoulos T, Sheehan A and Abbott B 1999, 'Mercury and organochlorines in black bream, (Acanthopagrus butcheri), from the Gippsland Lakes, Victoria, Australia: evidence for temporal increases in mercury levels', *Marine Pollution Bulletin*, 38(11), pp. 970–976.
214. Reeves J and Trewarn A 2016, 'Assessment of heavy metals and other contaminants of the Gippsland Lakes, Federation University Australia, Mt Helen, Victoria.
215. Ibid.
216. Ibid.
217. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Index of estuary condition', East Melbourne, Victoria.
218. Ibid.

Slaughterhouse Creek had very poor water quality, which was due to elevated chlorophyll-a concentrations indicating excess nutrients in the water column. Turbidity was also elevated.

These results likely reflect land use within the catchments of this estuary, and possible long water residence times so water is not regularly flushed out of the estuary to counter accumulating inputs of nutrients.[219]

Table 8: IEC results for estuarine water quality within the West and East Gippsland catchment regions that flow into the Gippsland Lakes; range 1 – 10 (1 poorest condition, 10 best condition). NA = not assessed.[220]

Estuary	Water Quality	Condition Class
Latrobe and Thomson Estuary	6	Fair
Lake Wellington Main Drain	3	Very poor
Avon River	2	Very poor
Tom Creek	8	Good
Tom Roberts Creek	6	Fair
Newlands Arms	10	Excellent
Mitchell River	9	Good
Nicholson River	6	Fair
Slaughterhouse Creek	2	Very poor
Tambo River	10	Excellent
Maringa Creek	7	Fair
Mississippi Creek	9	Good
Bunga Inlet	4	Poor
Lake Tyers	9	Good

219. Ibid.
220. Ibid.

GL 04: Plankton

Region		2021 status	2021 trend	2021 data
Gippsland Lakes	Lake King			
	Lake Victoria			
	Lake Wellington			

Justification for assessment ratings:	Chlorophyll-a is a commonly used measure of water quality, and concentrations indicate phytoplankton abundance and productivity in aquatic environments. The results show chlorophyll-a ratings in Lake Wellington have been poor to very poor from 2007-08 onwards, which has been translated to a status assessment of poor and a stable trend that reflects poor to very poor ratings being enduring for more than a decade. Chlorophyll-a ratings have been more favourable in the eastern Lakes (Lake Victoria and Lake King), with five of the past six years rated as good for chlorophyll-a. The confidence in the status and trend assessments is high because chlorophyll-a is assessed against the objectives in the Environment Reference Standard (ERS), while there is adequate spatial and temporal monitoring data.

Lake Wellington is high in nutrients - it generally has the highest phytoplankton biomass of the three main Gippsland Lakes and is a net exporter of nutrients to Lakes Victoria and King.[221] Lake Wellington is susceptible to algal blooms, partly due to the phytoplankton levels in the water body. A focused discussion on algal blooms in the Gippsland Lakes is provided at the end of this indicator narrative. As discussed in Indicator 01: Water quality (physicochemical), Lake Wellington is not as well flushed and has lower salinity than eastern lakes and as such acts as a sink for nutrients and sediments.

Phytoplankton became the dominant aquatic plant life in Lake Wellington following a severe drought in 1968. Previously, the salt-intolerant freshwater-plant (or macrophyte) *Vallisneria australis* had been prevalent but it was unable to survive the increased salinity, higher nutrient loads and reduced water clarity associated with the drought, and subsequent bushfire and flooding.[222]

Sediment cores from Lake King indicate there were blue-green algal blooms in the Lake prior to the opening of the artificial entrance at Lakes Entrance in 1889, when there was less flushing of the system.[223] A second phase of blue-green algal blooms commenced in the late 1980s and has been linked to an increase in phytoplankton that is hypothesised to have increased due to land-use changes and evolving management practices, including higher fertiliser use, irrigation and river regulation.

Load reduction targets exist to improve water quality in Lake Wellington and reduce the frequency and severity of algal blooms in the Gippsland Lakes - especially blue-green algae in the deeper lakes.

The rate of algae in the Lakes varies proportionally with catchment nutrient loads. A reduction in catchment inorganic nutrients by 30% for the western rivers and 20% for the eastern rivers has been estimated via modelling to result in a 15% decrease in the total algae rate.[224]

Chlorophyll-a ratings in Lake Wellington were fair to poor in the early 2000s and have deteriorated to poor to very poor from 2007-08 onwards, with chlorophyll-a ratings in Lake Wellington being rated as very poor during ten of the past 13 years. Chlorophyll-a ratings have been more favourable in the eastern Lakes (that is, Lake Victoria and Lake King), with ratings fluctuating from poor to good since 2000, however five of the past six years have been rated as good for chlorophyll-a.

221. EPA Victoria 2015, 'Gippsland Lakes and catchment literature review', Carlton, Victoria.
222. Boon P, Cook P and Woodland R 2015, 'The Gippsland Lakes: management challenges posed by long-term environmental change', *Marine and Freshwater Research*, 67(6), pp. 721-737.
223. Holland D, Jennings M, Beardall J, Gell P, Doan P, Mills K, Briles C, Zawadzki A and Cook P 2013, 'Two hundred years of blue-green algae blooms in the Gippsland Lakes', Gippsland Lakes Ministerial Advisory Committee.
224. Day P 2018, 'Lake Wellington science review', report commissioned by the West Gippsland Catchment Management Authority (WGCMA) to inform the development of the Lake Wellington Land and Water Management Plan.

Figure 19: Chlorophyll-a Water Quality Index ratings for the Gippsland Lakes.[225]

Algal blooms

Blue-green algae (cyanobacteria) blooms are common in the Gippsland Lakes, with major blooms occurring in recent years. Some species produce toxins that can be passed along the food chain, making it potentially unsafe to eat seafood from the areas.[226]

Algae are a naturally occurring organism present in all waterways. Weather conditions, nutrient levels, salinity and riverine flows are all likely to contribute to conditions that lead to the formation of algal blooms in the Gippsland Lakes. Warmer, calmer weather conditions are likely to lead to a natural increase in the abundance of algae in the Lakes.[227]

In terms of the frequency of algal blooms, the Limit of Acceptable Change (LAC)[228] can be used to guide this indicator narrative. The LAC is that no single cyanobacteria algal bloom event will cover greater than 10% of the combined area of coastal brackish/saline lagoons (that is, Lake King, Lake Victoria, Lake Wellington and Lake Tyers) in two successive years.[229] A long-term change in ecosystem state at Lake King, Lake Victoria or Lake Tyers from relatively clear, seagrass dominated estuarine lagoons to a turbid, algae dominated system (characteristic of Lake Wellington) represents a change in ecological character.[230]

DELWP has advised that although there have been several blooms covering more than 10% of the Lakes in the past two decades, no blooms covered more than 10% of the Lakes in successive years. Based on this, the LAC has been met.

GL 05: *Enterococci* bacteria

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. EPA Victoria's microbial water quality monitoring occurs at beaches along Port Phillip Bay.		

225. Image supplied by EPA Victoria.
226. Department of Health and Human Services (DHHS), 'Gippsland Lakes seafood' https://www2.health.vic.gov.au/public-health/water/blue-green-algae-cyanobacteria/gippsland-lakes-seafood Accessed 15 March 2021.
227. Department of Environment, Land, Water and Planning (DELWP), 'Gippsland Lakes algae update January 2021', East Melbourne, Victoria https://www.water.vic.gov.au/waterways-and-catchments/rivers-estuaries-and-waterways/blue-green-algae/gippsland-lakes-algae-update-january-2021 Accessed 15 March 2021.
228. Limits of acceptable change are defined as the variation that is considered acceptable in a particular component or process of the ecological character of the wetland, without indicating change in ecological character that may lead to a reduction or loss of the criteria for which the site was Ramsar listed.
229. BMT WBM 2011, 'Ecological character description of the Gippsland Lakes Ramsar site – final report', prepared for the Department of Sustainability, Environment, Water, Population and Communities (DSEWPC), Australian Government, Canberra.
230. Ibid.

GL 06: Regulated point source discharges to marine waters

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. There is an ocean outfall at Delray Beach, which is nearby to Lake Reeve, however the discharge is to Bass Strait rather than the Gippsland Lakes so it not suitable for inclusion as part of a Gippsland Lakes regulated point source discharge to marine waters assessment.		

GL 07: Stormwater

	2021 status	2021 trend	2021 data
Gippsland Lakes	●	?	●
Justification for assessment ratings:	There are no available assessments of the contribution of stormwater to pollutant loads entering the Gippsland Lakes. The evidence to assess this indicator is minimal, therefore an indicator confidence assessment cannot be made.		

Much of the stormwater in regional centres within the Gippsland Lakes catchment drains to the Gippsland Lakes.[231] However, there are no available assessments of the contribution of stormwater to pollutant loads entering the Gippsland Lakes. Despite the absence of any quantitative analysis of stormwater contribution to the pollutant loads entering the Gippsland Lakes, there are examples of localised projects that are reducing the adverse impacts of stormwater on the Gippsland Lakes.

Importantly, Integrated Water Management (IWM) in the region is providing an opportunity to limit the impact of stormwater and deliver economic, social and environmental outcomes. This is being done by identifying and investigating new uses of alternative sources of water such as treated wastewater and stormwater as a substitute for current reticulated supplies.[232] An IWM plan has been developed for the Bairnsdale area with a strong focus on integrating the outcomes and multiple benefits of a number of identified IWM project ideas in the area including capturing and treating stormwater, as well as water sensitive urban design and stormwater harvesting.[233]

East Gippsland Shire Council in collaboration with the East Gippsland CMA have developed an existing low-lying area in Lucknow into the East Bairnsdale Wetlands to treat stormwater runoff before discharge into the Gippsland Lakes. Landscaping and the development of a shared trail around the wetland have enhanced the recreational values of the area.[234]

During 2020, Gunaikurnai Land and Waters Aboriginal Corporation planted more than 80,000 native seedlings as part of a project to develop a new wetland in Broadlands, which will provide food and habitat for local wildlife. The wetlands are now being filled with water from nearby roads as part of a project by the East Gippsland Shire Council to lessen the impact of stormwater on the Gippsland Lakes. Two large holding ponds capture stormwater redirected from the local urban environment.[235]

231. Department of Environment, Land, Water and Planning (DELWP) 2019, 'East Gippsland strategic directions statement September 2018', East Melbourne, Victoria.
232. Ibid.
233. Ibid.
234. Ibid.
235. Gunaikurnai Land and Waters Aboriginal Corporation, 'Working together to build a new wetland' https://gunaikurnai.org.au/working-together-to-build-a-new-wetland/ Accessed 15 March 2021.

GL 08: Total nutrient loads

Region	2021 status	2021 trend	2021 data
Gippsland Lakes		↙	
Justification for assessment ratings:	Nutrient loads and flow for the most recent five years of data are within 20% of the long-term median, while total Phosphorous loads are regularly not meeting the 100 tonnes per year target that is in the Environment Reference Standard. This information informs the status rating of fair. The inflow of nitrogen and phosphorus was above the long-term median for the past five years of data (to 2016), indicating a deteriorating trend. The absence of recently analysed data (that is, the most recent data included in the assessment is from 2016) means the confidence is rated as moderate rather than high.		

Excessive nitrogen and phosphorus loads entering the Gippsland Lakes contribute to algal blooms in Gippsland Lakes.[236] This can have significant impacts on the beneficial uses of the Gippsland Lakes. Nutrient loads in the Gippsland Lakes are strongly linked to the volume of river inflows and rainfall.

As part of the development of SEPP (Waters of Victoria) in 2003, Lake Wellington was recognised in as being a highly stressed system requiring significant rehabilitation to protect its values. For this reason, SEPP (Waters of Victoria) included load targets for Lake Wellington, and the Macalister Irrigation District, as one of the major sources of nutrient pollution in the catchment. A load target of 115 tonnes per year was developed for Lake Wellington to drive Lake Wellington down from a highly nutrient polluted (eutrophic) state to a healthier, less nutrient polluted state (mesotrophic). While the load reduction target of 115 tonnes per year of total phosphorus has been met, the large stores of phosphorus in lake sediments have kept the lake in a eutrophic state and further load reduction is required. In 2018, SEPP (Waters) introduced a revised load target for Lake Wellington of 100 tonnes per year of total phosphorous to be achieved by 2030. Modelling was used to define levels of phosphorus reduction that are needed to continue to push Lake Wellington into a mesotrophic state. To achieve this target, it was stated that management interventions were required both from irrigation activities, as well as both dryland agriculture and waterways.[237] Total phosphorous loads needed to reduce by an average of 1.5 tonnes per year to meet the 2030 target in SEPP (Waters). The target to get below 100 tonnes per year of total phosphorous was retained in the Environment Reference Standard that came into effect in 2021, although the 2030 timeframe was removed from the target.[238]

Data on nutrient loads entering the Gippsland Lakes from the six major rivers that connect with the lakes is available.[239] For the five years to 2015-16, total nitrogen loads ranged from a low of 860 tonnes in 2015-16 to a peak of more than 3,000 tonnes in 2011-12. Similarly, total phosphorus loads ranged from a minimum of 73 tonnes in 2015-16 to a maximum of over 350 tonnes in 2011-12. While nutrient loads are inherently linked to flows, with higher loads occurring during periods of greater flows and rainfall, a deeper understanding can be achieved by looking at the ratio of nutrients to volume to determine whether more nutrients are entering the system per unit volume of water.

This type of flow-averaged nutrient concentration assessment shows that the inflow of nitrogen and phosphorus has been above the long-term median for the past five years, which have included both high and low rainfall years. The long-term median of the flow averaged total nitrogen and phosphorus concentrations have been 0.69 and 0.07 respectively. In the past five years, the median ratios have been 0.82 and 0.08 respectively, indicating fair condition.

236. Cook P and Holland D 2012, 'Long term nutrient loads and chlorophyll dynamics in a large temperate Australian lagoon system affected by recurring blooms of cyanobacteria', *Biogeochemistry*, 107(1–3), pp. 261–274.
237. EPA Victoria 2019, 'Development of environmental quality indicators and objectives for SEPP (Waters)', Carlton, Victoria.
238. State Government of Victoria 2021, 'Environment Reference Standard (Environment Protection Act 2017)'.
239. Department of Environment, Land, Water and Planning (DELWP), 'Water measurement information system', East Melbourne, Victoria https://data.water.vic.gov.au/static.htm Accessed 20 July 2021.

Theme 1: Water Quality and Catchment Inputs

Analysis on exponentially weighted moving averages of the ratio of total nitrogen and phosphorus loads to flow provided by the East Gippsland Catchment Management Authority indicates that there has been a step change increase in loads following a previous peak in 2007 that occurred in a year of flooding and followed significant bushfires during 2006-07. It is unclear if this increase is likely to be a sustained trend.

A specific study of Lake Wellington completed in 2018 included analysis of nutrient loads. Winter and spring floods deliver most of the incoming nutrients and sediments to Lake Wellington. Water, carrying nutrients and sediments, flows from Lake Wellington to the deeper Lake Victoria and Lake King. This means Lake Wellington is a 'receiving water' and a 'source'. Nitrogen inputs prime the lakes for blooms of blue-green algae.

Phosphorus loads control the extent and duration of any blue-green algal bloom. The annual nitrogen load to Lake Wellington is estimated to be 1,770–2,800 tonnes per year, which is approximately one and a half times the load compared to conditions that existed prior to European settlement and development in Victoria. The annual phosphorus load is estimated to be 69–140 tonnes per year, which is approximately three times the load compared to conditions that existed prior to European settlement and development in Victoria. Catchment modelling indicates that the main contributing land uses are grazing along the Latrobe River and irrigation along the lower Latrobe River and in the Macalister Irrigation District, while organic runoff from forests is a significant contributor to nitrogen loads.[240]

GL 09: Total sediment loads

Region		2021 status	2021 trend	2021 data
Gippsland Lakes	Lake King	Yellow	?	Red
	Lake Victoria	Yellow	?	Red
	Lake Wellington	Red	?	Red

Justification for assessment ratings:	Recent studies have analysed the amount of sediment loads to the Gippsland Lakes and determined the significant sources of those sediments. Because these studies are 'point-in-time' assessments, no time-series of data exist and the trend is unclear. The status has been rated as poor because the water clarity in some parts of the Gippsland Lakes (that is, Lake Wellington) has recently been rated as very poor and riverine sediment loads likely contribute to this rating, which in turn can adversely impact seagrass. There are no specific thresholds available for this assessment, so the confidence in this assessment is rated as low.

A CSIRO-led research study completed in 2007 modelled catchment sources and determined that river-bank erosion dominates the fine sediment yield delivered to the Gippsland Lakes, amounting to 71% of the total fine sediment delivery. Topsoil (that is, surface soil) contribution to the Lakes was estimated to be less than 15% in the West Gippsland and less than 30% in the East. The study also linked bushfires with increased sediment contribution to the eastern Lakes from hillslope erosion, which is notable given the likelihood of more frequent and intense fire seasons in the future.[241]

Overall, gully and tunnel erosion are a minor component of total yield delivered to the Lakes. Some locally significant regions of gully and tunnel erosion exist, with tunnel erosion in East Gippsland being possibly as much as 15% of the Mitchell River sediment yield.[242]

240. Day P 2018, 'Lake Wellington science review', report commissioned by the West Gippsland Catchment Management Authority (WGCMA) to inform the development of the Lake Wellington Land and Water Management Plan.
241. Hancock G, Wilkinson S and Read A 2007, 'Sources of sediment and nutrients to the Gippsland Lakes assessed using catchment modelling and sediment tracers', CSIRO Land and Water Science Report 70/07.
242. Ibid.

More recently, a specific study of Lake Wellington completed in 2018 included analysis of sediment loads. Winter and spring floods deliver most of the incoming nutrients and sediments to Lake Wellington, with those sediments carrying nutrients and contaminants, increasing turbidity, and impacting phosphorus cycling. Water, carrying nutrients and sediments, flows from Lake Wellington to the deeper Lake Victoria and Lake King. This means Lake Wellington is a 'receiving water' and a 'source'. The estimated annual sediment load to Lake Wellington is 110,000 – 190,000 tonnes per year, which is approximately two times the pre-development load. Catchment modelling indicates that the main contributing land uses are grazing along the Latrobe River and irrigation in the Macalister Irrigation District.[243]

To mitigate these pressures, the West Gippsland CMA, in partnership with Gipps Dairy, and receiving funding from the Australian Government's National Landcare Program, have been helping farmers in the Macalister Irrigation District more efficiently and effectively use fertilisers.[244] This initiative is expected to see a reduction in the amount of nutrients entering the Gippsland Lakes, while also helping farmers reduce their fertiliser costs, have well managed dairy effluent systems and maintaining pasture production.

Sediments can impact seagrass in the Gippsland Lakes. As fully submerged plants, seagrasses are highly susceptible to changes in the underwater light regime and thus to increases in turbidity and suspended sediments. Increased sediment loads from inflowing rivers following heavy rain can hold suspended sediments in the water column and limit light that is available for photosynthesis.

GL 10: Coastal acid sulfate soils

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	?	●
Justification for assessment ratings:	Potential coastal acid sulfate soil sites have been mapped along the Gippsland Lakes coastline. The status has been rated as unknown as there is a lack of published analysis on the impacts to the Gippsland Lakes and surrounding coastal areas. Based on the spatial extent of coastal acid sulfate soils, the risks are likely to be greater for Lake Wellington than the eastern lakes as the area of potential coastal acid sulfate soil sites is nearly a complete coverage of the Lake Wellington coastline. The aggregated area of potential coastal acid sulfate soil sites in the Gippsland Lakes region is 43,000 hectares, which is a significant area of land – the coastal areas surrounding the Gippsland Lakes have a greater area of potential coastal acid sulfate soils than the combined potential area along the Port Phillip Bay, Western Port and Corner Inlet-Nooramunga coastlines. Because this mapping is a 'point-in-time' assessment, the trend is unclear. There are no thresholds to guide status and trend assessments and there is no available evidence on the impact of coastal acid sulfate soils, so an indicator confidence assessment cannot be made.		

Victorian coastal lands that have the potential to contain coastal acid sulfate soil were mapped during 2011 and the results for Gippsland Lakes are presented here.

Approximately 43,000 hectares of land along the Gippsland Lakes coastline was designated as prospective land (that is, land whose geomorphology indicates that there is a potential or prospect of encountering sulfidic material or sulfuric material).

Figure 20 shows the prospective land along the Gippsland Lakes coastline, with a majority of the potential coastal acid sulfate soil locations estimated to be surrounding Lake Wellington.

243. Day P 2018, 'Lake Wellington science review', report commissioned by the West Gippsland Catchment Management Authority (WGCMA) to inform the development of the Lake Wellington Land and Water Management Plan.
244. West Gippsland Catchment Management Authority (WGCMA), 'Macalister farmers get serious about fertilisers', Traralgon, Victoria https://www.wgcma.vic.gov.au/news/latest-news/macalister-farmers-get-smart-about-fertilisers Accessed 20 July 2021.

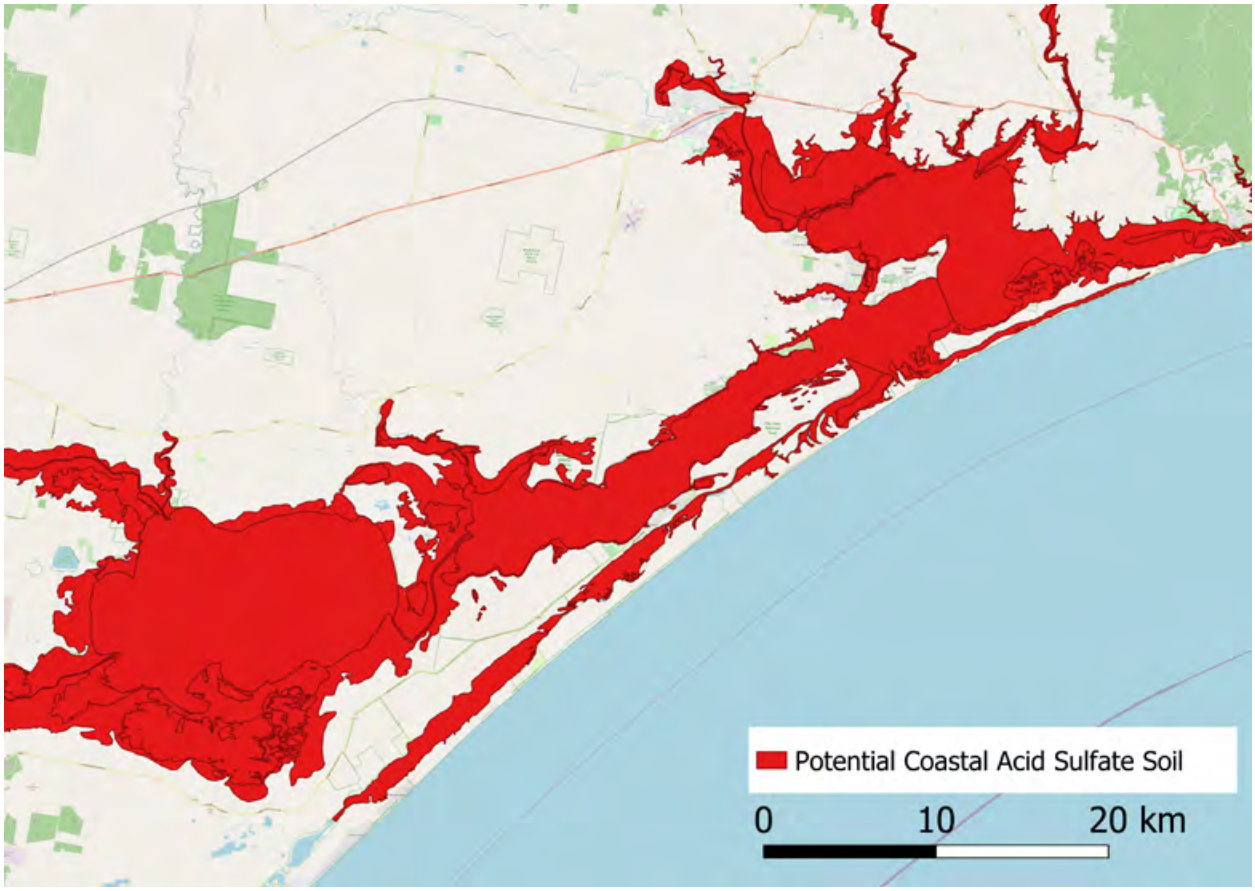


Figure 20: Potential coastal acid sulfate soil sites along the Gippsland Lakes coastline.[245]

The coastal areas surrounding the Gippsland Lakes have a greater area of potential coastal acid sulfate soil than the combined potential area along the Port Phillip Bay, Western Port and Corner Inlet-Nooramunga coastlines combined.

The significant likelihood of increased coastal acid sulfate soil exposure is increased by the coupling of potential coastal acid sulfate soil in the Gippsland Lakes with the significant erosion and coastal inundation risks for the Gippsland Lakes that are detailed in the Climate and Climate Change Impacts chapter.

245. Centre for eResearch and Digital Innovation, 'Soil health knowledge base' https://www.ccmaknowledgebase.vic.gov.au/soilhealth/soils_map.php?visible=true&restore_map=true&layer_id=258# Accessed 17 May 2021.

Statewide/broad-scale

SW 03: Water quality (estuaries)

Region	2021 status	2021 trend	2021 data
Statewide		?	High (status) Low (trend)
Justification for assessment ratings:	Through the 2021 Index of Estuary Condition (IEC) assessments, there is high confidence in the status assessment for estuarine water quality in this indicator. Water Quality was good or excellent in 54% of the state's estuaries. It was poor or very poor in 25% of them, usually estuaries with catchments that were predominantly urban or agricultural. The status assessment of fair reflects variable water quality across the state, although it should be noted that more estuaries recorded good or excellent water quality than poor or very poor. As this is the first Index of Estuary Condition, and IECs are designed to be point-in-time assessments, no time series data are available to assess trends.		

Water Quality was good or excellent in 54% of the state's estuaries. It was poor or very poor in 25% of them, which were usually estuaries with catchments that were predominantly urban or agricultural (Table 9).[246] As this is the first IEC, and IECs are designed to be point-in-time assessments, no time series data are available to assess trends.

Estuaries with very poor or poor Water Quality were characterised by elevated chlorophyll-a and turbidity indicating a combination of nutrient enrichment and sedimentation from the catchments. Estuaries with very poor or poor Water Quality included those with catchments dominated by urban, agricultural, or both land uses.

Estuaries with very poor or poor Water Quality whose catchments are dominated by urban land uses include Kororoit Creek and Elwood Canal. Those with catchments dominated by agricultural land uses include tributaries to Lake Wellington (that is, Avon River and Lake Wellington Main Drain) and western tributaries to Corner Inlet (that is, Bennison Creek, Stockyard Creek and Old Hat Creek). Estuaries with catchments dominated by urban and agricultural land uses include Watsons Creek, Werribee River, and Merri River.[247]

Table 9: Percentage of estuaries in each Water Quality score category in five catchment regions and all estuaries across Victoria where Hydrology was sampled.[248]

Catchment Region	Excellent	Good	Moderate	Poor	Very poor
Glenelg Hopkins (8)	38	50	0	13	0
Corangamite (17)	35	41	18	6	0
Port Phillip and Western Port (20)	10	20	25	10	35
West Gippsland (25)	20	20	24	8	28
East Gippsland (22)	46	18	23	5	9
All (92)	28	26	21	8	17

Numbers in parentheses next to catchment region names indicate the number of estuaries assessed; note that 92 estuaries were sampled for Water Quality but not all had data from sufficient sub-indices to receive an overall IEC score.

246. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Index of estuary condition', East Melbourne, Victoria.
247. Ibid.
248. Ibid.

SW 04: Plankton

Region	2021 status	2021 trend	2021 data
Statewide	N	N	N
Justification for assessment ratings:	Not assessed for this region. Plankton has been assessed in each of the other geographic regions in this chapter. To complement those assessments, a statewide plankton narrative is provided here that includes a broader discussion on phytoplankton and zooplankton across Australia.		

Plankton was a key topic that was covered during Australia's Integrated Marine Observing System (IMOS) 2020 report State and Trends of Australia's Oceans.[249]

Around Australia, IMOS data showed that phytoplankton are generally decreasing in abundance, while zooplankton are generally increasing. Over large time and space scales, zooplankton abundance and biomass typically follow changes in phytoplankton, their primary food source, so the observed divergence shown by the recent data are surprising.[250] Recent work has shown that differences in fish catch across the ocean far exceed differences in phytoplankton production, indicating that zooplankton is playing a major role.[251] The authors of the State and Trends of Australia's Ocean hypothesize that the increase in zooplankton despite the decline in phytoplankton could be because of increases in microzooplankton, which are grazed upon by larger omnivorous zooplankton.

Whether these substantial changes in lower trophic levels are impacting coastal fish communities is unknown and a key knowledge gap to be addressed in the future. Previous research suggests higher zooplankton biomass supports higher fish biomass.[252,253]

The IMOS National Reference Station network does not contain any reference stations along the Victorian coastline, which makes Victoria the only state or territory without a reference station.

This indicator links to the fish indicators within this report. The IMOS data from 2003 to 2019 shows that the southeast region, where Victoria is located, experiences peak phytoplankton biomass in September and October.[254] This period of high phytoplankton biomass provides peak food availability for zooplankton and is often the most important period for larval fish recruitment.

249. Richardson A, Eriksen R, Moltmann T, Hodgson-Johnston I and Wallis J 2020, 'State and trends of Australia's oceans', Integrated Marine Observing System, Hobart.
250. Richardson A and Schoeman D 2004, 'Climate impact on plankton ecosystems in the northeast Atlantic', *Science*, 305(5690), pp. 1609-1612.
251. Stock C, John J, Rykaczewski R, Asch R, Cheung W, Dunne J, Friedland K, Lam V, Sarmiento J, Watson R 2017, 'Reconciling fisheries catch and ocean productivity', *Proceedings of the National Academy of Sciences*, 114(8), pp. E1441-E1449.
252. Chassot E, Bonhommeau S, Dulvy N, Mélin F, Watson R, Gascuel D and Le Pape O 2010, 'Global marine primary production constrains fisheries catches', *Ecology Letters*, 13(4), pp. 495-505.
253. Ware D and Thomson R 2005, 'Bottom-up ecosystem trophic dynamics determine fish production in the Northeast Pacific, *Science*, 308(5726), pp. 1280-1284.
254. Richardson A, Eriksen R, Moltmann T, Hodgson-Johnston I and Wallis J 2020, 'State and trends of Australia's oceans', Integrated Marine Observing System, Hobart.

Theme 2
Litter and Pollution

Commissioner *for* Environmental Sustainability Victoria

Litter and silver gull (*Chroicocephalus novaehollandiae*) at St Kilda Beach
© Claire Ruedin

Theme 2: Litter and Pollution

Background

The number of litter items and microplastics flowing into Port Phillip Bay has been estimated at over 2.5 billion items annually from the Yarra and Maribyrnong Rivers in Melbourne. Approximately 85% of these items are microplastics.[255] A deteriorating trend for litter and plastics is confidently provided in this report due to the observed amount of litter increasing in both the Maribyrnong and the Yarra. A study of microplastic sources found that industrial precincts were responsible for a large majority of microplastics, with the Dandenong Local Government Area (LGA) the location with the most microplastics from the six LGAs studied.

No specific analyses of litter and plastics have occurred in Western Port, Corner Inlet and Nooramunga, and the Gippsland Lakes.

Like other economies with a significant history of settlement and industrial activity, Victoria has a legacy of waste and pollution. Contaminated sites in coastal areas range from landfills and industrial facilities to sites requiring active management to reduce the risk to human health and the environment. There is good information on the numbers of contaminated and potentially contaminated land locations within five km of the coastline for various datasets published on Victoria Unearthed.

Good air quality is essential for human health. The links between air quality, population exposure and health are an increasing focus for research and policy development. The coastal air quality indicator in this report is believed to be the first instance of focused coastal air quality reporting in Australia.

Coastal air quality surrounding the Port Phillip Bay is generally of good quality. However, research of air quality near shipping terminals using lower-quality air monitoring sensors provides evidence of poor concentrations of fine particle pollution near Station Pier with a moderate confidence. This is an issue requiring further investigation and research.

Large bushfires have occurred in coastal Victoria in recent years and the bushfire smoke has been measured at levels significantly more than health-based standards. Extensive monitoring of the air quality surrounding the Gippsland Lakes occurred during the 2019-20 bushfire season and the data show the daily air-quality standard for $PM_{2.5}$ was frequently breached during the summer of 2019-20.

Comparison with insights from State of the Bays 2016 Report and the State of the Environment 2018 Report

This report contains significant advancement in litter and pollution reporting, with the inclusion of dedicated pollution indicators with a coastal focus. It also contains a synthesis of the latest microplastics research in Victoria.

The SotB 2016 Report did not contain any litter or pollution indicator assessments, but a litter narrative was provided in the 'Threats to the bays' chapter. For the SoE 2018 Report, there were light pollution, contaminated land and air quality indicators, however these did not have the coastal focus that they do in this report. Litter and marine debris were included as a pressure within the marine and coastal environments chapter within the SoE 2018 Report and contained a one-page commentary.

255. Charko F, Blake N, Seymore A, Johnstone C, Barnett E, Kowalczyk N and Pattison M 2020, 'Clean bay blueprint – microplastics in Melbourne', Port Phillip EcoCentre.

Indicator 11: Litter and plastics

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		↙			N/A	N/A
Western Port		?			N/A	N/A
Corner Inlet-Nooramunga		?			N/A	N/A
Gippsland Lakes		?			N/A	N/A

Data source:	Port Phillip EcoCentre, Tangaroa Blue Foundation, academic researchers
Measures:	Number of litter items (including plastic and microplastic) in catchment waterways flowing into marine environments

Why this indicator?

Litter affects the aesthetic values of marine waters and is a source of serious pollution, including microplastic pollution. Due to their small size, microplastics are inadvertently consumed as a food source by some marine species targeting plankton. Microplastics can act as a pollutant vector through the food web.

Litter is any solid or liquid domestic or commercial waste that is deposited inappropriately. Litter has negative impacts on visual amenity, reduces water quality and can kill or harm marine animals. Litter traps have been installed at key points within the drainage system to collect litter, but their effectiveness is limited by their design and frequency of cleaning.[256]

Marine debris represents a major threat for the environment and the distribution of debris is significantly correlated with oceanic and atmospheric processes and coastal usage for recreational activities (for example, regional population and distance to the nearest road).

Levels of plastic pollution in the marine environment have rapidly increased in recent years impacting all levels of the marine ecosystem with potentially devastating consequences. Since mass production began in the 1950s, it is estimated that over 8.3 billion tonnes of plastics have been generated.[257] In 2018, global plastic production reached almost 360 million tonnes, with China the largest producer.[258] Emissions of plastic waste to the environment are also predicted to rise and may reach up to 53 million tonnes per year by 2030.[259]

Plastics have been detected in all parts of the environment, from rivers, oceans, air, soil, deep-sea sediments and biota.[260,261,262,263] The durability of plastic, a characteristic that has made it commonplace in the modern world, has resulted in its persistence in the environment. Plastics can remain in the environment for hundreds of years, which means that plastic accumulates in the environment over time.

Small plastics are described as microplastics, typically defined as particles less than 5 mm in size.[264]

256. Victorian Environmental Assessment Council (VEAC) 2019, 'Assessment of the values of Victoria's marine environment'.
257. Geyer R, Jambeck J and Law K 2017, 'Production, use, and fate of all plastics ever made', *Science Advances*, 3(7), e1700782.
258. PlasticsEurope 2019, 'Plastics - the facts 2019'.
259. Borrelle S, Ringma J, Law K, Monnahan C, Lebreton L, McGivern A, Murphy E, Jambeck J, Leonard G, Hilleary M, Eriksen M, Possingham H, De Frond H, Gerber L, Polidoro B, Tahir A, Bernard M, Mallos N, Barnes M and Rochman C 2020, 'Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution', *Science*, 369, 1515.
260. Thompson R, Olsen Y, Mitchell R, Davis A, Rowland S, John A, McGonigle D and Russell A 2004, 'Lost at sea: where is all the plastic?', Science, 304(5672), 838, DOI:10.1126/science.1094559.
261. Jambeck J, Geyer R, Wilcox C, Siegler T, Perryman M, Andrady A, Narayan R and Lavender Law K 2015, 'Plastic waste inputs from land into the ocean', *Science*, 347(6223), pp. 768-71, DOI:10.1126/science.1260352.
262. Barrett J, Chase Z, Zhang J, Banaszak Holl M, and Willis K, Williams A, Hardesty B and Wilcox C 2020, 'Microplastic pollution in deep-sea sediments from the Great Australian Bight', *Frontiers in Marine Science*, 7, 808, https://doi.org/10.3389/fmars.2020.576170.
263. Allen S, Allen D, Phoenix V, Le Roux G, Durántez Jiménez P, Simonneau A, Binet S and Galop D 2019, 'Atmospheric transport and deposition of microplastics in a remote mountain catchment', *Nature Geoscience*, 12, pp. 339–344.
264. Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection 2015, 'Sources, fate and effects of microplastics in the marine environment: a global assessment'.

Microplastics can be categorised as 'primary' or 'secondary'. Primary microplastics start their life as small particles, specifically manufactured for their small size, for example, raw resin pellets or 'nurdles'. Secondary microplastics are a result of larger plastics breaking up into smaller pieces, for example, a drink bottle that over time breaks up into many little pieces.

Microplastics originate from a variety of sources, including plastic waste and litter, microbeads and scrubbing agents, raw resin pellets, synthetic textiles, the abrasion of car tyres, footwear, artificial turf and as dust generated by the construction industry. While microplastics may enter the environment from point sources, such as wastewater treatment plants, a large proportion is likely to originate from diffuse sources, such as litter, dust and road surfaces.[265] Many of these diffuse sources are transported through stormwater systems.[266]

Approximately 80% of marine plastic debris is of land-based origin.[267] In Australia, long-term monitoring indicates that 75% of all coastal debris is plastic and the amount of plastic debris can be linked to regional population.[268] The most comprehensive survey of plastic marine debris in Australian coastal waters estimated more than 4,000 pieces of plastic per square kilometre was littered across the ocean surface.[269] These plastics were predominantly small fragments resulting from the breakdown of larger plastic items.

Due to their small size, microplastics are inadvertently consumed as a food source by some marine species targeting plankton. Microplastics can act as a pollutant vector through the food web.[270]

Currently, there are no standardised methods for the detection and quantification of microplastics, which poses a challenge to robust and comparable monitoring and assessment of concentrations in the environment.[271,272] There are several methods currently used to identify and quantify microplastics and the type of analysis depends on the target size range. The most common is visual identification for plastics and microplastics greater than 1 mm that can be seen by the naked eye.[273]

A large volunteer and citizen science effort contributes to the data collection for this indicator and further commentary on the resilience and capacities of volunteer groups and organisations to continue their involvement is provided for the Stewardship and collaborative management theme.

Melbourne Water, RMIT University and DELWP are collaborating to understand the impact of litter, including microplastics, on the social and ecological values of waterways and bays.[274] The project aims to develop standardised guidelines for conducting litter assessments to support Melbourne Water activities to manage litter along waterways. The project is scheduled to be completed in 2023 and is likely to inform future State of the Marine and Coastal Environment reports.

265. Ziajahromi S, Neale P and Leusch F 2016, 'Wastewater treatment plant effluent as a source of microplastics: review of the fate, chemical interactions and potential risks to aquatic organisms', *Water Science and Technology*, 74, pp. 2253–2269.
266. Sustainability Victoria 2019, 'Microplastics and Port Phillip Bay', Melbourne, Victoria.
267. Jambeck J, Geyer R, Wilcox C, Siegler T, Perryman M, Andrady A, Narayan R and Lavender Law K 2015, 'Plastic waste inputs from land into the ocean', 347(6223), pp. 768-71, DOI:10.1126/science.1260352.
268. Hardesty B, Schuyler Q, Lawson T, Opie K and Wilcox C 2016, 'Understanding debris sources and transport from the coastal margin to the ocean'. CSIRO: EP165651.
269. Reisser J, Shaw J, Wilcox C, Hardesty B, Proietti M, Thums M and Pattiaratchi C 2013, 'Marine plastic pollution in waters around Australia: characteristics, concentrations, and pathways', *PLOS ONE*, 8, e80466.
270. Setälä O, Lehtiniemi M, Coppock R and Cole M 2018, 'Microplastics in marine food webs', in 'Microplastic contamination in aquatic environments', Elsevier, pp.339-363.
271. Science Advice for Policy by European Academies (SAPEA) 2019, 'A scientific perspective on microplastics in nature and society' https://www.sapea.info/topics/microplastics/
272. Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection 2019, 'Guidelines for the monitoring and assessment of plastic litter in the ocean'.
273. Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection 2015, 'Sources, fate and effects of microplastics in the marine environment: a global assessment'.
274. RMIT University, 'Litter, litter everywhere! How do we best assess it?', https://www.rmit.edu.au/about/schools-colleges/science/research/research-centres-groups/aquatic-environmental-stress/projects/litter-framework Accessed 26 July 2021.

Theme 2: Litter and Pollution

Indicator 12: Light pollution

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		?			N/A	N/A
Western Port		?			N/A	N/A
Corner Inlet-Nooramunga		?			N/A	N/A
Gippsland Lakes		?			N/A	N/A
Statewide					?	

Data source:	https://www.lightpollutionmap.info/, academic researchers
Measures:	Artificial light at night measured as radiance (Watts per square cm)

Why this indicator?

Like other economies with a significant history of settlement and industrial activity, Victoria has a legacy of waste and pollution. Contaminated sites range from landfills and industrial sites to sites requiring active management to reduce the risk to human health and the environment.

Light pollution is excessive or obtrusive artificial light that has an adverse impact on biodiversity, and potentially human health. It is a global issue, impacting at both national and regional scales, and increasing in prevalence as the world becomes more populated and industrialised. In addition to the negative biodiversity and health effects, outdoor lighting is currently inefficient and drains energy resources while carrying a significant financial burden – poorly-aimed and unshielded outdoor lights are estimated to waste $US 2 billion of energy in the United States each year.[275]

There are no systematic measurements of light pollution conducted in Victoria, however artificial light at night is increasing globally by about 2% per year.[276]

Animals perceive light differently from humans and artificial light can disrupt critical behaviour and cause physiological changes in wildlife.[277] Light pollution threatens reproduction and migratory habits of insects, amphibians, fish, birds, bats and other animals, while a distortion of the natural day/night cycle can affect plants.[278]

Examples of these impacts are:

- hatchling marine turtles may not be able to find the ocean when beaches are lit[279]
- fledgling seabirds may not take their first flight if their nesting habitat never becomes dark[280]
- tammar wallabies exposed to artificial light have been shown to delay reproduction[281]
- clownfish eggs incubated under constant light do not hatch.[282]

275. United States National Optical Astronomy Observatory, 'Wasted lights and wasted nights: globe at night tracks light pollution' https://www.noao.edu/news/2011/pr1101.php Accessed 19 May 2021.
276. Kyba C, Kuester T, Sánchez de Miguel A, Baugh K, Jechow A, Hölker F, Bennie J, Elvidge C, Gaston K and Guanter L 2017, 'Artificially lit surface of Earth at night increasing in radiance and extent', *Science Advances*, 3 (11), e1701528.
277. Russart K and Nelson R 2018, 'Artificial light at night alters behavior in laboratory and wild animals', *JEZ-A Ecological and Integrative Physiology*, 329(8-9), pp. 401-408.
278. Hölker F, Wolter C, Perkin E, Tockner K 2010, 'Light pollution as a biodiversity threat', *Trends in Ecology and Evolution*, 25, pp. 681–682.
279. Witherington B and Martin R 2003, 'Understanding, assessing, and resolving light-pollution problems on sea turtle nesting beaches', Florida Fish and Wildlife Conservation Commission FMRI technical report TR-2, Jensen Beach, Florida.
280. Rodríguez A, Holmes N, Ryan PG, Wilson K-J, Faulquier L, Murillo Y, Raine AF, Penniman J, Neves V, Rodríguez B, Negro JJ, Chiaradia A, Dann P, Anderson T, Metzger B, Shirai M, Deppe L, Wheeler J, Hodum P, Gouveia C, Carmo V, Carreira GP, Delgado-Alburqueque L, Guerra-Correa C, Couzi F-X, Travers M and Le Corre M 2017, 'A global review of seabird mortality caused by land-based artificial lights', *Conservation Biology*, 31, pp. 986-1001.
281. Robert K, Lesku J, Partecke J and Chambers B 2015, 'Artificial light at night desynchronizes strictly seasonal reproduction in a wild mammal', *Proceedings of the Royal Society B*, 282.
282. Fobert E, Burke da Silva K and Swearer SE 2019, 'Artificial light at night causes reproductive failure in clownfish', *Biology Letters*, 15 e20190272.

Theme 2: Litter and Pollution

National Light Pollution Guidelines for Wildlife were published by the Commonwealth Government in January 2020.[283] In the introduction of these guidelines, natural darkness was described as providing a conservation value in the same way that clean water, air and soil has intrinsic value.

Visible Infrared Imaging Radiometer Suite (VIIRS) data shows that Victoria's artificial light at night is most pronounced over Melbourne.[284] In the absence of any routine monitoring of the extent and impact of artificial light at night on Victorian marine and coastal ecosystems and species, the VIIRS measurements have been used to provide an indicative guide to the extent of artificial light at night within each geographical region covered in this report.

Indicator 13: Coastal contaminated land

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		?			N/A	N/A
Western Port		?			N/A	N/A
Corner Inlet-Nooramunga		?			N/A	N/A
Gippsland Lakes		?			N/A	N/A
Statewide					?	

Data source:	EPA
Measures:	Numbers of contaminated and potentially contaminated land locations within 5 km of the coastline for various datasets published on Victoria Unearthed

Why this indicator?

Like other economies with a significant history of settlement and industrial activity, Victoria has a legacy of waste and pollution. Contaminated sites range from landfills and industrial sites to sites requiring active management to reduce the risk to human health and the environment.

Like other economies with a significant history of settlement and industrial activity, Victoria has a legacy of waste and pollution. Contaminated sites range from old mines and industrial sites to petrol stations and dry-cleaning operations.[285]

This indicator covers contaminated land sites within five km of the Victorian coastline.

No complete database of contaminated sites exists for Victoria, although DELWP and EPA Victoria partnered to produce Victoria Unearthed, which is an online mapping tool that brings together relevant information on potential land and groundwater contamination.[286]

Data from the following sources included within Victoria Unearthed has been used to inform the regional status assessments for this indicator.

283. Commonwealth of Australia 2020, 'National light pollution guidelines for wildlife including marine turtles, seabirds and migratory shorebirds'.
284. Jurij Stare 'Light pollution map' https://www.lightpollutionmap.info/help.html
285. Ministerial Advisory Committee 2016, 'Independent Inquiry into the EPA'.
286. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria Unearthed', East Melbourne, Victoria.

Priority sites

EPA Victoria's Priority Sites Register (PSR) is the best available data source to inform the extent of currently known land contamination. Priority sites are sites for which EPA Victoria has issued a clean-up notice or pollution abatement notice due to land and/or groundwater pollution. The condition of these sites is not compatible with the current or approved use of the site without active management to reduce the risk to human health and the environment. Such management can include clean-up, monitoring and/or institutional controls.[287] The PSR, maintained by EPA Victoria and publicly available since 1998, is a listing of all sites for which EPA has formalised requirements to manage contamination. Once a site has complied with notices it is removed from the PSR list.[288]

Environmental audits

EPA Victoria Environmental Audits most commonly take place when land is proposed for new use and is potentially contaminated, or if it is already covered by an Environmental Audit Overlay.[289] A certificate of environmental audit is issued for a property where, following an audit, an environmental auditor believes the environmental condition of the land is suitable for any beneficial use.

A 53X audit is an environmental audit that verifies that potentially contaminated land can be used for a specific purpose (industrial, commercial or residential). The number of completed 53X audits shows how many contaminated sites have been improved to be suitable for a more sensitive land use and can be used to show the scale of land quality improvement at contaminated sites across Victoria. Note that a 53X audit mainly applies when there is a proposed new sensitive use for potentially contaminated land. For example, when there is a proposal to develop residential properties on industrial land. This audit involves assessing the land's condition, including a site history review and site investigation through a sampling program. The outcome of a 53X audit determines whether the site is suitable for all or some nominated uses, or not suitable for any use at all.

53V Environmental Audits are for understanding the risk to human health and environment posed by an industrial activity. It can assess the risk of possible harm to a site. The outcome of a 53V audit is an audit report. The audit report has recommendations for ongoing land management. This is to minimise the risks identified, or for further investigation to confirm risks.

Landfills

The Victorian Landfill Register created by EPA in 2018 lists all current and known closed landfills in Victoria. Landfills can cause contamination, but once a landfill is closed, operators are obliged to rehabilitate and manage their sites. Even when closed, careful management of sites is required. Many rehabilitated landfills are now safe parks and public spaces, enjoyed by the community.[290]

Groundwater Quality Restricted Use Zones

Groundwater Quality Restricted Use Zones (GQRUZ) are areas where there has been historic groundwater pollution due to previous industrial or other activities. These zones have been subject to clean up in line with the relevant environmental standards. However, restrictions remain on what the water can be used for if it is extracted via a groundwater bore. A GQRUZ remains when attempts have been made to clean up the groundwater at the affected site, but full clean-up was not possible - as it is often difficult to remove 100% of groundwater pollution. It also may be impractical to clean up groundwater to the level needed to restore it to its original condition. EPA Victoria then identifies restrictions that should remain on how the water can be used without further treatment. GQRUZ do not represent a comprehensive list of all sites where groundwater quality may not be suitable for use. Rather, they represent locations where EPA Victoria has formally recognised that groundwater is polluted, following site investigations under EPA's environmental audit program.[291]

287. EPA Victoria, 'Priority sites register', Carlton, Victoria https://www.epa.vic.gov.au/your-environment/land-and-groundwater/priority-sites-register Accessed 3 December 2018.
288. State Government of Victoria, 'EPA Victoria priority sites register (PSR) - location points' https://discover.data.vic.gov.au/dataset/epa-victoria-priority-sites-register-psr-location-points Accessed 23 March 2021.
289. State Government of Victoria, 'EPA Victoria environmental audit reports - location polygons' https://discover.data.vic.gov.au/dataset/epa-victoria-environmental-audit-reports-location-polygons Accessed 23 March 2021.
290. State Government of Victoria, 'EPA Victoria Victorian landfill register (VLR) - location points' https://discover.data.vic.gov.au/dataset/epa-victoria-victorian-landfill-register-vlr-location-points Accessed 23 March 2021.
291. State Government of Victoria, 'EPA Victoria groundwater quality restriction use zones (GQRUZ) - location points' https://discover.data.vic.gov.au/dataset/epa-victoria-groundwater-quality-restriction-use-zones-gqruz-location-points Accessed 23 March 2021.

Theme 2: Litter and Pollution

EPA Victoria Licenced Sites

Licences are a category of regulation within Environment Protection Regulations 2021 that address complex activities that justify the highest level of regulatory control due to the significant risk of harm to human health and the environment or a high potential for mismanagement. Decisions on licence applications involve a detailed assessment and a licence that is granted will include customised conditions and undergo ongoing oversight by EPA.[292]

Future reporting

In future State of the Marine and Coastal Environment reports, the type of information presented in this indicator will be spatially analysed to determine whether there are clusters of coastal contaminated land. A small number of contaminated sites across a region that are clustered can lead to significant impacts.

292. EPA Victoria 2021, 'Permissions scheme policy', publication 1799.2, Carlton, Victoria.

Indicator 14: Coastal air quality

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	(ozone, nitrogen dioxide, carbon monoxide, sulfur dioxide) (fine particle pollution)	→	(near shipping terminals) (elsewhere)	●	N/A	N/A
Western Port	●	?	●	●	N/A	N/A
Corner Inlet-Nooramunga	●	?	●	●	N/A	N/A
Gippsland Lakes	(fine particle pollution during bushfire periods) (all other times)	?	(fine particulate pollution during bushfire periods) (all other times)	●	N/A	N/A

Data source:	EPA, academic researchers
Measures:	Number of exceedences of air quality standards

Why this indicator?

Good air quality is essential for human health. The links between air quality, population exposure and health are an increasing focus for research and policy development.

Good air quality is essential for human health. The links between air quality, population exposure and health are an increasing focus for research and policy development. The greatest adverse health effects from air pollution are usually experienced in densely populated areas that are exposed to emissions from motor vehicles, industrial facilities and domestic activities such as using wood heaters, while significant smoke impacts from bushfires and planned burns (for example, fuel reduction, coupe and ecological burns) can cause poor air quality in urban and rural areas.

Victoria's air quality is considered good relative to international standards, although poor air quality is still measured near major industrial facilities, during major incidents (for example, bushfires, industrial fires and dust storms) and during periods of planned burns. Ozone pollution can infrequently cause poor air quality in coastal locations in summer months, especially areas surrounding Port Phillip Bay as pollution from metropolitan Melbourne blows over the Bay during the prevailing northerly winds that occur most summer mornings, then the pollution reacts with sunlight to form ozone pollution that is blown back over coastal areas in the late afternoon as part of a sea breeze.

Reporting on this indicator is believed to be the first instance of focused coastal air quality reporting in Australia. As part of its network of standard monitoring sites, EPA Victoria currently monitors air quality at three locations within five km inshore of the coastline: three in Melbourne and one in Geelong. During 2021, EPA Victoria expanded its monitoring network to include several sensor monitoring sites, with nine of these located along Victoria's coastline. The new air quality sensors were installed in Portland, Warrnambool, Lorne, Torquay, Drysdale, Wonthaggi, Bairnsdale, Lakes Entrance and Mallacoota.[293] During significant smoke events, such as the bushfires during the summer of 2019-20, EPA Victoria also coordinates air-quality morning at short-term incident air quality-monitoring sites as part of its emergency management function.

Port Phillip Bay

PPB 11: Litter and plastics

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	●	↙	●	●	N/A	N/A
Justification for assessment ratings:	A deteriorating trend is provided with moderate confidence due to the estimated amount of litter increasing in both the Maribyrnong and the Yarra. The status is unknown because, although the number of litter items and microplastics flowing into Port Phillip Bay has been estimated, there is an absence of thresholds that can be used to guide the assessment. The lack of any thresholds that are based on quantitative analysis on the impacts of litter and plastics means that no status assessment can be provided. In other words, we don't know if the current status of litter and plastics is good, fair or poor, but we have moderate confidence that the amount of litter and microplastics is increasing.					

A three-year litter study completed in 2020 prepared Port Phillip Bay's first catchment-to-coast microplastic litter profile. The project, which was run by the Port Phillip EcoCentre and included monthly microplastic trawls in the Yarra and Maribyrnong rivers, showed the extent of plastic pollution in urban water catchments.[294,295]

The project team found that over 2.5 billion litter items flow into Port Phillip Bay annually from the Yarra and Maribyrnong Rivers in Melbourne. Over two billion (approximately 85%) of these items are microplastics.[296] Some types of plastics were particularly prevalent, for example, the Yarra Riverkeeper reports polystyrene has consistently been found to be the most frequently littered item along the Yarra River since 2018.[297] Although large variations in monthly collections were noted through the entire study period, the Yarra River was found to carry significantly more litter than the Maribyrnong.

293. EPA Victoria, 'EPA AirWatch', Carlton, Victoria https://www.epa.vic.gov.au/for-community/airwatch Accessed 13 July 2021.
294. Charko F, Blake N, Seymore A, Johnstone C, Barnett E, Kowalczyk N and Pattison M 2020, 'Clean bay blueprint – microplastics in Melbourne', Port Phillip EcoCentre, Melbourne, Victoria.
295. Victorian Environmental Assessment Council (VEAC) 2019, 'Assessment of the values of Victoria's marine environment'.
296. Charko F, Blake N, Seymore A, Johnstone C, Barnett E, Kowalczyk N and Pattison M 2020, 'Clean bay blueprint – microplastics in Melbourne', Port Phillip EcoCentre, Melbourne, Victoria.
297. Barman S, Goodsell K, Yardley D and Kowalczyk N 2020, 'Polystyrene pollution in the Yarra River: sources and solutions', Yarra Riverkeeper Association, Melbourne, Victoria.

A deteriorating trend has been observed due to the amount of litter increasing in both the Maribyrnong and the Yarra, with plastic pollution in the Yarra increasing rapidly. Plastic litter in the Yarra increased by 400% in 2017 compared to 2016, and then in 2019 it again more than doubled compared to 2018 levels. The Maribyrnong saw a more gradual increase over time but has still increased by more than 50% each year since 2017.[298]

In view of the high quantities of litter and microplastics recorded, the negative effects plastic pollution may have on wildlife in Port Phillip Bay, and the potential threat to human health in the longer term, six recommendations were made for land managers, government, industry and researchers as part of the Clean Bay Blueprint project.[299] These recommendations are listed below:

- improve product stewardship
- cultivate effective partnerships
- support local councils in waste management
- continue monitoring (micro)plastics pollution
- increase education and 'plastic literacy' of all plastic users
- conduct further research.[300]

Many organisations and citizen science groups are involved in localised litter and plastics projects. Some of these projects are described below and highlight the positive impact that collaborations between community, non-government organisations, industry, government and academia can have to increase our knowledge and awareness of litter and pollution, as well as demonstrably reducing the level of pollution.

An example of this is Tangaroa Blue Foundation, which conducted surveys of plastic resin pellets from 2018 to 2020 at various points between plastics industry facilities and Port Phillip Bay.[301] This project was initiated by the Tangaroa Blue Foundation, supported by partner organisations including: Chemistry Australia, Streamline Media, City of Kingston, City of Wyndham, City of Greater Dandenong, Cleanwater Group, EPA Victoria and funding through the Victorian Government's Port Phillip Bay Fund.[302]

As part of the project, three stormwater drain traps were installed in each of the Cities of Greater Dandenong, Kingston and Wyndham. Each trap was installed in an industrial area close to an operating plastics factory where previous surveys had shown plastic resin pellet loss occurring. The data were used by several industrial operators to measure the success of intervention measures implemented in their businesses. There was a decline in pellet loss over time for Dandenong where mitigation strategies were implemented following EPA site inspections. In Kingston one trap showed an increase in pellet loss after new machinery was installed, whilst the other two Kingston traps showed a decline in pellet loss following mitigation strategies. In Wyndham one trap showed increased pellet loss while the other two nearby showed a decrease. Mitigation strategies were being implemented following EPA visits. During the sixteen months of the project an estimated 218,000 pellets and fine waste particles were intercepted and prevented from reaching the natural environment and eventually Port Phillip Bay. Tangaroa Blue Foundation's project report noted that 'the substantial changes in awareness, activity and commitment to addressing the problem from both industry and governance bodies will have a continuing positive impact on pellet loss provided momentum is sustained into the future'.[303]

The Let's Strain the Drains project was funded by the Victorian State Government and delivered by Tangaroa Blue Foundation, Cleanwater Group and Sustainability Victoria, with support from the Cities of Wyndham, Hobsons Bay, Moreland, Kingston, Maribyrnong, and Greater Dandenong, and data analysis support from the University of NSW. The project targeted upstream sources of pollutants by installing and monitoring 120 at-source litter traps in stormwater infrastructure of six metropolitan councils around the Bay. Being a significant transport pathway for pollutants, stormwater is a key piece of the marine debris puzzle as it acts as an outflow point for litter in urban runoff.

298. Charko F, Blake N, Seymore A, Johnstone C, Barnett E, Kowalczyk N and Pattison M 2020, 'Clean bay blueprint – microplastics in Melbourne', Port Phillip EcoCentre, Melbourne, Victoria.
299. Ibid.
300. Ibid.
301. Tangaroa Blue Foundation, 'Engaging community, industry and government to reduce plastic resin pellets flowing into Port Phillip Bay July 2018 – June 2020', Dunsborough, Western Australia https://www.tangaroablue.org/engaging-community-industry-and-government-to-reduce-plastic-resin-pellets-flowing-into-port-phillip-bay/ Accessed 3 August 2021.
302. Ibid.
303. Ibid.

Monitoring work took place from November 2019 to May 2020 and involved community audit events that sorted and counted captured pollutants according to Tangaroa Blue Foundation's Australian Marine Debris Initiative (AMDI) database methodology.

During the project period a total of 75,931 macro-litter items and 677,114 micro-litter items were captured with the top two macro-litter items being cigarette butts and miscellaneous paper. Figure 21 shows that industrial precincts were responsible for a large majority of microplastics detected in the project, with the most microplastics detected in the Dandenong Local Government Area.

A follow-up Let's Stain the Drains project began in Warrnambool during 2021 and is expected to run for 12 months.[305] This project is supported by the Victorian State Government through the Coastcare Victoria Community Grant.

304. Tangaroa Blue Foundation, 'Project Report – Let's strain the drains – monitoring land-based sources of marine debris in Port Phillip Bay', (image created by Brie Sherow), Dunsborough, Western Australia.
305. Tangaroa Blue Foundation, 'Initial results – let's strain the drains, Warrnambool', Dunsborough, Western Australia https://www.tangaroablue.org/lets-strain-the-drains-warrnambool-2/ Accessed 3 August 2021.

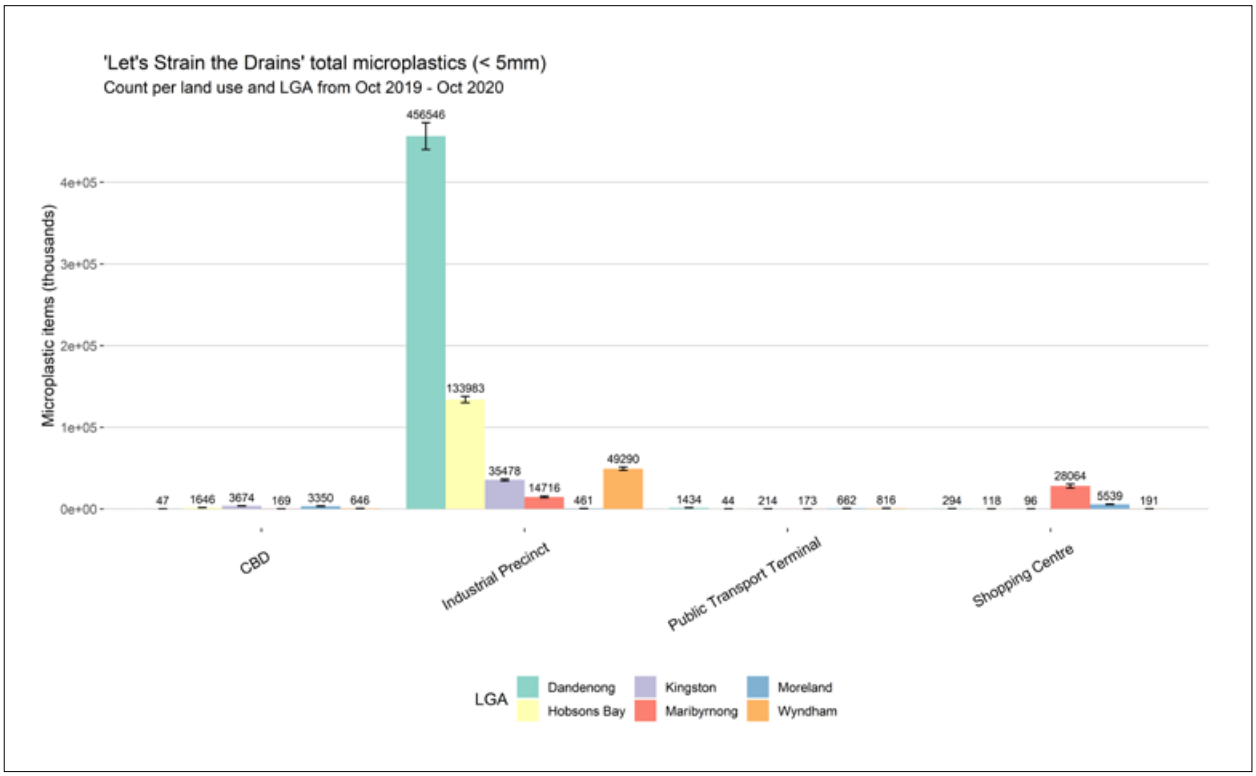


Figure 21: Counts of microplastics (less than 5 mm) by land use and Local Government Area.[304]

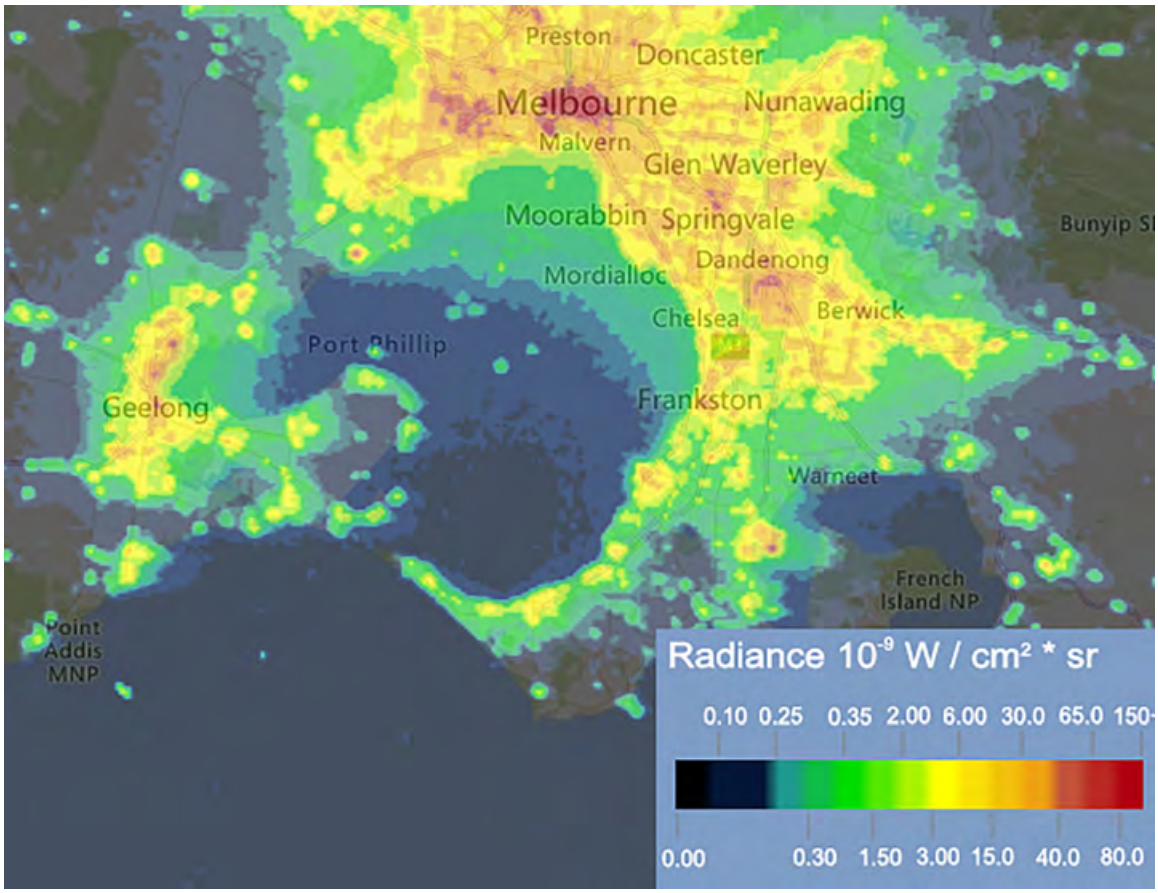
PPB 12: Light pollution

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	●	?	●	●	N/A	N/A
Justification for assessment ratings:	There is insufficient information to provide status and trend assessments for this indicator. The evidence to assess this indicator is minimal, therefore an indicator confidence assessment cannot be made.					

In the absence of any routine monitoring of the extent and impact of artificial light at night on Victorian marine and coastal ecosystems and species, Visible Infrared Imaging Radiometer Suite (VIIRS) measurements have been used to provide an indicative guide to the extent of artificial light at night within Port Phillip Bay. VIIRS data shows that Victoria's artificial light at night is most pronounced over Melbourne and Port Phillip Bay.

Figure 22 shows a screenshot from lightpollutionmap.info that shows significant artificial light at night across the Port Phillip Bay coastline, with peak levels experienced along the northern coastline to the south of Melbourne's central business district.[306]

306. Jurij Stare 'Light pollution map' https://www.lightpollutionmap.info/ Accessed 19 May 2021.
307. Jurij Stare 'Light pollution map' https://www.lightpollutionmap.info/help.html Accessed 19 May 2021.
308. National Oceanic and Atmospheric Administration (NOAA) Earth observation group, 'Visible infrared imaging radiometer suite (VIIRS)' National Geophysical Data Center https://ngdc.noaa.gov/eog/viirs/index.html Accessed 06 July 2020.



The unit of radiance is W/cm² * sr, which is a SI radiometry unit for radiance. Radiance is radiant flux emitted, reflected, transmitted or received by a surface, per unit solid angle per unit projected area.[307]

Figure 22: Image of artificial light at night across Port Phillip Bay.[308]

To enhance the knowledge of the impacts of artificial light at night on marine and coastal ecosystems, current research being conducted by the University of Melbourne is looking at the effect of light pollution on temperate reef fishes. This project is aiming to:

- quantify the degree of nocturnal light pollution in the coastal waters of Port Phillip Bay
- evaluate whether there are differences in the composition of diurnally and nocturnally active fish assemblages among coastal habitats that vary in their level of exposure to artificial light at night
- assess whether species of fishes 'attracted' to artificial light at night exposed habitats suffer reduced or enhanced survival.[309]

PPB 13: Coastal contaminated land

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		?			N/A	N/A

Justification for assessment ratings:	The status assessment of fair is based on there being several sites within five km of the Port Phillip Bay coastline that are known to be contaminated or are the location of current activity involving a relatively high risk of contamination. An example is the groundwater contamination identified beneath Fishermans Bend. The trend is unclear because information from Victoria Unearthed is 'point-in-time' spatial data. Although the quality of data are good, the confidence for this assessment is low because there are no thresholds available to guide the status assessment. The assessment is a subjective interpretation which concludes that management of the Priority Sites Register provides moderate protection of natural ecosystems and biodiversity. The relatively large number of coastal contaminated sites along the Port Phillip Bay coastline, relative to other Victorian coastal regions, suggests that contaminated land is exerting moderate pressure on coastal environmental condition and human health.

Given the extent of urban development along the Port Phillip Bay coastline to accommodate the coastal regions of Melbourne (a population of 4.9 million) and Geelong (a population of 253,000), it is not surprising that there are significantly more sites with contaminated, potentially contaminated or remediated land along the Port Phillip Bay coastline than other coastal regions in Victoria.

Priority sites

As at March 2021, there were 88 sites within five km of the Port Phillip Bay coastline which were listed on the Priority Sites Register (PSR). To provide context for the extent of contamination of the other geographic regions included in this report, the Western Port coastline had the second highest number of sites on the PSR with four sites included.

Groundwater Quality Restricted Use Zones

As at March 2021, 40% of EPA Victoria's Groundwater Quality Restricted Use Zones (GQRUZs) (189 out of 476) were located within five km of the Port Phillip Bay coastline, indicating the scale of groundwater pollution and restrictions near Port Phillip Bay.

EPA Victoria Licenced Sites

As at March 2021, more than 10% of EPA Victoria's licenced sites (67 out of 637) were located within five km of the Port Phillip Bay coastline, which shows the ongoing risk of contaminated land along the Port Phillip Bay coastline as these licenced sites are premises with the potential for significant environmental impact.

Environmental audits

More than 300 53X Audits have occurred for land within five km of the Port Phillip Bay coastline, which provides an indication that significant land remediation has taken place in this region.

309. The University of Melbourne, '*Marine biology* MSc projects 2021'.

Table 10: Numbers of contaminated and potentially contaminated land locations within five km of the Port Phillip Bay coastline for various datasets published on Victoria Unearthed.

Item	Number within 5 km of the Port Phillip Bay coastline as at March 2021
Priority sites[310]	88
Groundwater Quality Restricted Use Zones[311]	189
Currently Operating Landfills[312]	0
Closed Landfills[313]	39
Licenced sites[314]	67
53V Environmental Audits[315,316]	41
53X Environmental Audits[317,318]	340

Fishermans Bend is Australia's largest urban renewal project, covering about 485 hectares in central Melbourne, south of the Yarra River and CBD. The district will consist of five precincts across two municipalities – the cities of Melbourne and Port Phillip – and connect Melbourne's CBD to Port Phillip Bay. It is expected that by 2050 it will be home to about 80,000 residents and provide employment for up to 80,000 people. EPA Victoria oversaw groundwater studies across all five precincts in Fishermans Bend.[319]

Groundwater contamination was identified beneath Fishermans Bend. The main contaminants found on a regional scale included: metals (aluminium, arsenic, total chromium, iron, lead, manganese, nickel), ammonia, nitrate, chloride, fluoride, sodium, sulfate, total recoverable hydrocarbons, and PFAS.[320]

Some contaminant levels were elevated above drinking water and recreational guidelines. Due to the availability of reticulated (tap) water, groundwater is not necessary for domestic use in the area. The results of the investigation were used by EPA Victoria to identify a GQRUZ. The results have also informed the development of the Fishermans Bend Framework by the Fishermans Bend Taskforce.[321]

310. State Government of Victoria, 'EPA Victoria priority sites register (PSR) - location points' https://discover.data.vic.gov.au/dataset/epa-victoria-priority-sites-register-psr-location-points Accessed 23 March 2021.
311. State Government of Victoria, 'EPA Victoria groundwater quality restriction use zones (GQRUZ) - location points' https://discover.data.vic.gov.au/dataset/epa-victoria-groundwater-quality-restriction-use-zones-gqruz-location-points Accessed 23 March 2021.
312. State Government of Victoria, 'EPA Victoria Victorian landfill register (VLR) - location points' https://discover.data.vic.gov.au/dataset/epa-victoria-victorian-landfill-register-vlr-location-points Accessed 23 March 2021.
313. Ibid.
314. https://discover.data.vic.gov.au/dataset/epa-victoria-licence-location-polygons Accessed 23 March 2021.
315. State Government of Victoria, 'EPA Victoria environmental audit reports - location polygons' https://discover.data.vic.gov.au/dataset/epa-victoria-environmental-audit-reports-location-polygons Accessed 23 March 2021.
316. EPA Victoria, 'Types of environmental audits', Carlton, Victoria https://www.epa.vic.gov.au/for-business/find-a-topic/environmental-audit/types-of-environmental-audits Accessed 23 March 2021.
317. State Government of Victoria, 'EPA Victoria environmental audit reports - location polygons', https://discover.data.vic.gov.au/dataset/epa-victoria-environmental-audit-reports-location-polygons Accessed 23 March 2021.
318. EPA Victoria, 'Types of environmental audits', Carlton, Victoria https://www.epa.vic.gov.au/for-business/find-a-topic/environmental-audit/types-of-environmental-audits Accessed 23 March 2021.
319. EPA Victoria 2017, '1674.1: Fact sheet: Fishermans Bend groundwater studies 2015-2017', Carlton, Victoria.
320. Ibid.
321. Ibid.

PPB 14: Coastal air quality

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	(ozone, nitrogen dioxide, carbon monoxide and sulfur dioxide) (fine particle pollution)	→	(near shipping terminals) (elsewhere)	●	N/A	N/A
Justification for assessment ratings:	The status assessments are based on the compliance of air quality at Victorian air-quality monitoring stations with the National Environment Protection (Ambient Air Quality) Measure. Focused research of air quality near shipping terminals using lower-quality air monitoring sensors provides evidence of poor concentrations of fine particle pollution near Station Pier with a moderate confidence.					

The air quality standards for particle pollution and ozone are exceeded in Melbourne and Geelong more frequently than for other pollutants. Despite this Victoria's particle pollution is reasonably low by global standards. The most frequent breaches of air quality standards in coastal areas occur due to smoke from bushfires and planned burns. Data from the SoE 2018 Report showed there were approximately ten poor air quality days per year due to ozone pollution across Melbourne during the 1980s, which has reduced to fewer than one per year since 2010. The number of poor air quality days due to fine particle pollution, known as $PM_{2.5}$ (particles less than 2.5 micrometres in diameter), has only been monitored in Victoria since the early 2000s and there are generally fewer than five poor air quality days per year except for years with major bushfires.

EPA Victoria monitors air quality at three coastal air-quality monitoring stations along Port Phillip Bay. Compliance with the National Environment Protection (Ambient Air Quality) Measure (referred to as the Measure) for 2019 is detailed in Table 11, which shows coastal air quality in monitored regions of coastal Melbourne and Geelong did not exceed standards except for particle pollution. Insufficient data was collected at Point Cook to demonstrate compliance due to issues associated with the station's power supply, while the relocation of the Altona station in 2019 meant that insufficient data to demonstrate compliance was also collected there.[322]

Table 11: Compliance summary for coastal air quality monitoring stations and pollutants within five km of Port Phillip Bay, 2019.[323]

Pollutant	Location	Number of exceedances (days)	Performance against standards and goals
Carbon monoxide	Geelong South	0	Met
Nitrogen dioxide	Geelong South	0	Met
Ozone	Geelong South	0	Met
	Point Cook	0	Not met*
Sulfur dioxide	Altona	0	Not met*
	Geelong South	0	Met
PM10 (particles less than 10 micrometres in diameter)	Geelong South	11	Not met
PM2.5 (particles less than 2.5 micrometres in diameter)	Geelong South	1	Not met

322. EPA Victoria 2020, 'Air monitoring report 2019 – Compliance with the national environment protection (ambient air quality) measure', Carlton, Victoria.
323. Ibid.

* due to insufficient monitoring throughout the year

When this indicator assessment was made, EPA's air quality compliance report for 2020 had not been published and the data were unavailable. However, increased air-quality monitoring occurred during the 2019-20 bushfire season as part of EPA's incident air monitoring role as part of the State Emergency Management Plan and the results of this increased air-quality monitoring program for 2019-20 have been supplied by EPA. Air quality monitoring data for Brighton showed the daily air-quality standard for $PM_{2.5}$ was breached on 19 days at during the summer of 2019-20, which is significant when considered in the context that the Measure has a goal of zero days per year breaching the $PM_{2.5}$ standard. The level of pollution at Brighton due to bushfire smoke was consistent with that experienced across greater Melbourne and Geelong, with the highest number of days breaching the $PM_{2.5}$ standard during the summer of 2019-20 being recorded at Box Hill (24 days) and the fewest measured at Geelong South and Macleod (12 days).

Shipping emissions are known to affect communities in coastal locations, especially near harbours. In recent years, residents in apartments at Beacon Cove, Port Melbourne, have been concerned about exposure to air pollution from ships. This residential area is near Station Pier. To investigate the spatial and temporal variability of emissions reaching the shore, the Victorian Ports Corporation (Melbourne) monitored $PM_{2.5}$ concentrations next to Station Pier for a 26-month period between 2016 and 2018. The results of the monitoring showed that annual average $PM_{2.5}$ concentrations exceeded the $PM_{2.5}$ standard (8.0 µg/m^3) in the Measure in two successive years, with the average for the second year (9.7 µg/m^3) being higher than the first (8.5 µg/m^3).[324]

As shipping emission plumes are intermittent and fluctuate spatially, there are limitations with using a single fixed air-quality monitor to detect the pollution. As part of a collaborative research project led by Queensland University of Technology, seven low-cost sensors monitored air quality in residential areas near Station Pier from December 2018 to March 2019. Four of the sensors monitored air quality at ground level and three were located on the upper balconies of two high-rise apartment blocks. Both the daily average $PM_{2.5}$ concentrations and the number of short-term spikes in $PM_{2.5}$ concentrations over 5-minute periods were generally greater at the elevated monitoring sites, highlighting the impact of altitude on potential exposure to the shipping pollution.[325]

On average, the spikes observed at the seven monitoring location were ~4–5 times above the normal background value. Because of their very short duration, these spikes did not significantly raise the daily $PM_{2.5}$ averages at any of the locations. However, some incremental contributions to the daily averages did increase the number of days when $PM_{2.5}$ concentrations exceeded the $PM_{2.5}$ air quality standard in the Measure. More days were measured to exceed the $PM_{2.5}$ air quality standard near Station Pier than the nearest air quality station in EPA Victoria's ambient air quality monitoring network.[326]

Although the long-term health effects of elevated PM concentrations are known, few studies have been conducted on the risks of short-term exposures to extreme spikes—a topic that merits additional research. Furthermore, the research concluded that if maritime traffic increases, ports will not comply with future pollution standards unless measures to reduce ship emissions are implemented.[327]

324. Jayaratne R, Kuhn T, Christensen B, Liu X, Zing I, Lamont R, Dunbabin M, Maddox J, Fisher G and Morawska L 2020, 'Using a network of low-cost particle sensors to assess the impact of ship emissions on a residential community', *Aerosol and Air Quality Research*, 20(12), pp. 2754-2764.

325. Ibid.
326. Ibid.
327. Ibid.

Western Port

WP 11: Litter and plastics

Region	2021 status	2021 trend	2021 data
Western Port		?	
Justification for assessment ratings:	There are no specific analyses of litter in Western Port, therefore the status and trend have been assessed as unknown and unclear, respectively. Given the relatively smaller urban environment, litter and microplastics are likely to pose a lesser risk in Western Port than in Port Phillip Bay where more studies have been completed.		

As noted in the Western Port Ramsar Site Management Plan published during 2017, there are no specific analyses of litter in Western Port, but given the relatively smaller urban environment, litter and microplastics are likely to pose a lesser risk in Western Port than in Port Phillip Bay.[328]

Entanglement due to litter has been observed in Western Port. Some birds in Western Port and several species, notably Pacific and silver gulls, crested terns, little pied cormorants and pelicans, are often found in the Western Port area entangled in fishing line, or with fishhooks or jigs attached, and found either dead or incapacitated.[329] Seabirds and shorebirds are also susceptible to ingestion of microplastics with effects on nutrition and toxicity reported.[330] Furthermore, from 1997 to 2013, researchers found 359 entangled Australian fur seals (mainly juveniles and pups) at Seal Rocks at Phillip Island, equivalent to 1% of the site's population. The researchers found that commercial fishing operations were the main source of entanglement materials that included trawl nets, fishing line and box straps. They determined that neither the decline in regional fishing intensity nor changing seal population size influenced the incidence of entanglements.[331]

Between 2010 and 2013, the Zoos Victoria Seal the Loop Program collected 21.7 km of fishing line in specially designed bins dotted along the Victorian coastline.[332] By 2013, the bins were collecting 25 metres daily or nine km annually. Zoos Victoria and Phillip Island Nature Parks launched the 'When balloons fly, seabirds die' campaign to educate the community about the impact that balloons are having on marine life and to urge people to stop using balloons outdoors. A 2016 CSIRO paper noted that short-tailed shearwaters on Australia's east coast ingested 82% of all balloons recorded in a survey of marine debris, possibly due to the balloons resembling the birds' main prey, the red arrow squid.[333] This research on the impacts of balloons on wildlife led to Victorian banning the release of balloons outdoors in 2021.[334]

328. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Western Port Ramsar site management plan', East Melbourne, Victoria.
329. Dann P 2011, 'Birds and marine mammals', in 'Understanding the Western Port environment: a summary of current knowledge and priorities for future research', edited by Melbourne Water, Melbourne, pp. 156–169.
330. Sutherland W, Alves JA, Amano T, Chang CH, Davidson NC, Finlayson M, Gill JA, Gill RE, González PM, Gunnarsson, TG, Kleijn D, Spray CJ, Székely, T, and Thompson DBA 2012, 'A horizon scanning assessment of current and potential future threats to migratory shorebirds', *Ibis*, 154(4), pp. 663–679.
331. McIntosh RR, Kirkwood R, Sutherland DR and Dann P 2015, 'Drivers and annual estimates of marine wildlife entanglement rates: a long-term case study with Australian fur seals,' *Marine Pollution Bulletin*, 101, pp. 716-723.
332. Zoos Victoria 2013, 'Seal the loop 2012-2013 report', Melbourne, Victoria.
333. Roman L, Schuyler QA, Hardesty BD and Townsend KA 2016, 'Anthropogenic debris ingestion by avifauna in eastern Australia', *PLOS ONE*, 11(8), pp. 1-14. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0158343 Accessed 19 May 2021.
334. EPA Victoria, 'Report helium balloon releases', Carlton, Victoria https://www.epa.vic.gov.au/report-pollution/report-balloon-releases Accessed 13 August 2021.

WP 12: Light pollution

Region	2021 status	2021 trend	2021 data
Western Port		?	
Justification for assessment ratings:	There is insufficient information to provide status and trend assessments for this indicator. The evidence to assess this indicator is minimal, therefore an indicator confidence assessment cannot be made.		

The majority of published research about light pollution impacts in Victoria is focused on Phillip Island, with research investigating the effect of artificial light at night on one of the world's largest colonies of listed migratory short-tailed shearwaters (*Ardenna tenuirostris*). Phillip Island supports more than 6% of the global population of this species.[335]

Shearwaters nest in burrows and are nocturnally active at their breeding colonies, when fledglings leave their nests at night. When exposed to artificial light fledglings can be disoriented and grounded. Some fledglings may reach the ocean, but then be attracted back toward coastal lighting. Fledglings are also vulnerable to collision with infrastructure when disoriented and once grounded become vulnerable to predation or roadkill.[336]

A study published in 2017 analysed seabird survival patterns on Phillip Island in relation to artificial light at night. The study found many birds became grounded on roads after being attracted by artificial light. Short-tailed shearwater fledglings captured at colonies just before departure were compared with fledglings washed up on beaches and with fledglings attracted by artificial light along roads. Fledglings collected at the beach were much lighter in weight, and hence had a much lower chance of survival, than fledglings collected at the colony or on the roads.[337]

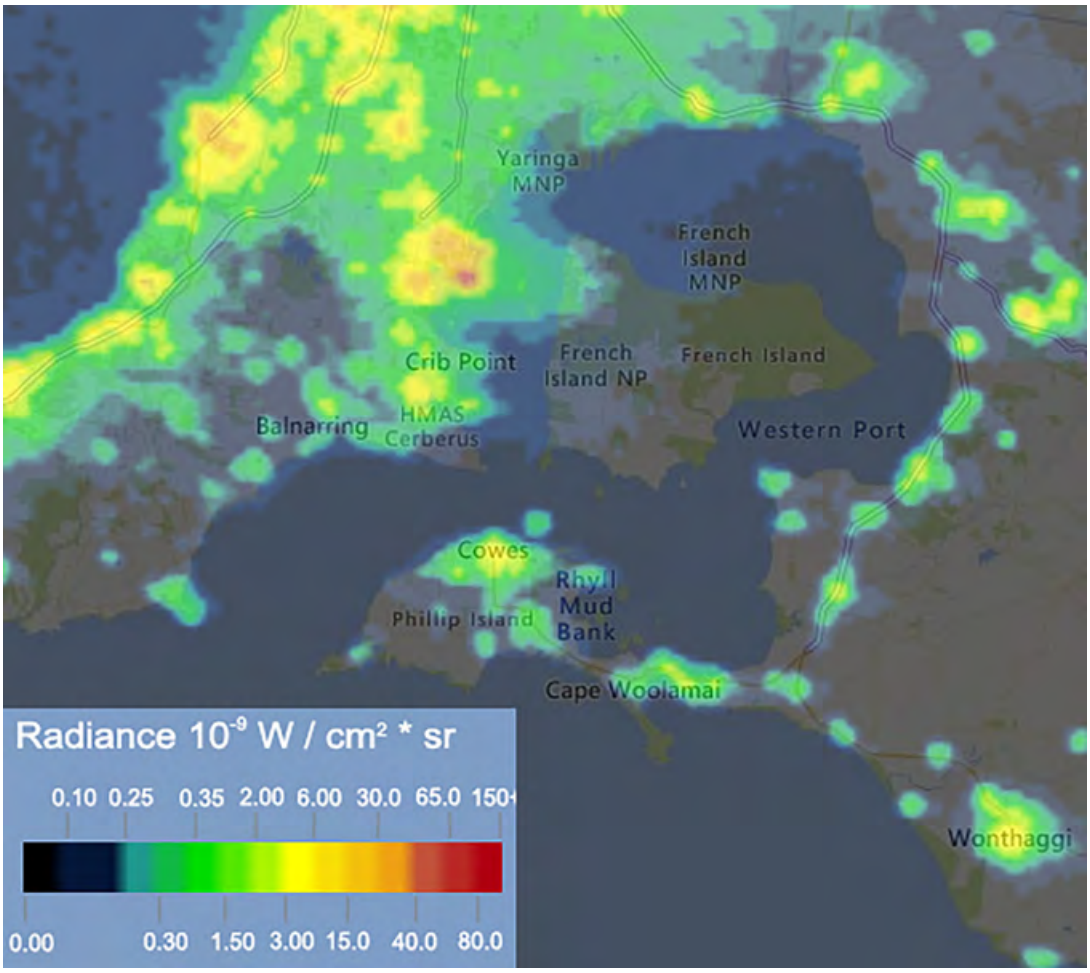
The National Light Pollution Guidelines for Wildlife highlighted the work being done to mitigate the impact of artificial light at night on Short-tailed shearwaters at Phillip Island.[338] Phillip Island attracts over a million visitors a year during peak holiday seasons to visit the little penguin (*Eudyptula minor*) ecotourism centre. Most visitors drive from Melbourne across a bridge to access the island. The increase in road traffic at sunset during the Easter break coincides with the maiden flight of fledgling shearwaters from their burrows.[339]

In response to the deaths of fledglings, Phillip Island Nature Parks has an annual shearwater rescue program to remove and safely release grounded birds.[340] In collaboration with SP Ausnet and Regional Roads Victoria, road lights on the bridge to the island are turned off during the fledgling period.[341] To address human safety concerns, speed limits are reduced and warning signals put in place during fledgling season.[342,343] The reduced road lighting and associated traffic controls and warning signals, combined with a strong rescue program, have reduced the mortality rate of shearwaters.[344]

335. Rodríguez A, Burgan G, Dann P, Jessop R, Negro JJ and Chiaradia A 2014, 'Fatal attraction of short-tailed shearwaters to artificial lights', *PLOS ONE*, 9(10), e110114.
336. Rodríguez A, Holmes N, Ryan PG, Wilson K-J, Faulquier L, Murillo Y, Raine AF, Penniman J, Neves V, Rodríguez B, Negro JJ, Chiaradia A, Dann P, Anderson T, Metzger B, Shirai M, Deppe L, Wheeler J, Hodum P, Gouveia C, Carmo V, Carreira GP, Delgado-Alburqueque L, Guerra-Correa C, Couzi F-X, Travers M and Le Corre M 2017, 'A global review of seabird mortality caused by land-based artificial lights', *Conservation Biology*, 31, pp. 986-1001.
337. Rodríguez A, Moffett J, Revoltós A, Wasiak P, McIntosh RR, Sutherland DR, Renwick L, Dann P and Chiaradia A 2017, 'Light pollution and seabird fledglings: Targeting efforts in rescue programs', *Journal of Wildlife Management*, 81, pp. 734–741.
338. Commonwealth of Australia 2020, 'National light pollution guidelines for wildlife including marine turtles, seabirds and migratory shorebirds'.
339. Rodríguez A, Burgan G, Dann P, Jessop R, Negro JJ and Chiaradia A 2014, 'Fatal attraction of short-tailed shearwaters to artificial lights', *PLOS ONE*, 9(10), e110114.
340. Ibid.
341. Rodríguez A, Moffett J, Revoltós A, Wasiak P, McIntosh RR, Sutherland DR, Renwick L, Dann P and Chiaradia A 2017, 'Light pollution and seabird fledglings: Targeting efforts in rescue programs', *Journal of Wildlife Management*, 81, pp. 734–741.
342. Ibid.
343. Rodríguez A, Dann P and Chiaradia A 2017, 'Reducing light-induced mortality of seabirds: high pressure sodium lights decrease the fatal attraction of shearwaters', *Journal for Nature Conservation*, 39, pp. 68-72.
344. Rodríguez A, Burgan G, Dann P, Jessop R, Negro JJ, Chiaradia A 2014, 'Fatal attraction of short-tailed shearwaters to artificial lights', *PLOS ONE*, 9(10), e110114

In the absence of any routine monitoring of the extent and impact of artificial light at night on Victorian marine and coastal ecosystems and species, Visible Infrared Imaging Radiometer Suite (VIIRS) measurements have been used to provide an indicative guide to the extent of artificial light at night within Western Port.

Figure 23 shows a screenshot from lightpollutionmap.info that shows significant artificial light at night across the north and north western coastline of Western Port, as well as at Cowes on Phillip Island.[345] Parts of the eastern and south western coastline of Western Port are largely unaffected by artificial light at night.



The unit of radiance is W/cm² * sr, is a SI radiometry unit for radiance. Radiance is radiant flux emitted, reflected, transmitted or received by a surface, per unit solid angle per unit projected area.[346]

Figure 23: Image of artificial light at night across Western Port.[347]

345. Jurij Stare 'Light pollution map' https://www.lightpollutionmap.info/ Accessed 19 May 2021.
346. Jurij Stare 'Light pollution map' https://www.lightpollutionmap.info/help.html Accessed 19 May 2021.
347. National Oceanic and Atmospheric Administration (NOAA) Earth observation group, 'Visible infrared imaging radiometer suite (VIIRS)' National Geophysical Data Center https://ngdc.noaa.gov/eog/viirs/index.html Accessed 06 July 2020.

WP 13: Coastal contaminated land

Region	2021 status	2021 trend	2021 data
Western Port		?	
Justification for assessment ratings:	The status assessment of good is based on there being only a few sites within five km of the Western Port coastline that are known to be contaminated or are the location of current activity involving a relatively high risk of contamination. The trend is unclear because information from Victoria Unearthed is 'point-in-time' spatial data. Although the quality of data are good, the confidence for this assessment is low because there are no thresholds available to guide the status assessment. The assessment is a subjective interpretation which concludes that the relatively small number of coastal contaminated sites along the Western Port coastline exerts minimal pressure on environmental condition and human health in this region.		

Priority sites

As at March 2021, there were four sites within five km of the Western Port coastline which were listed on the Priority Sites Register (PSR). To provide context for the minimal extent of known contamination near Western Port from the PSR, there were 88 sites on the PSR which were situated along the Port Phillip Bay coastline.

Groundwater Quality Restricted Use Zones

As at March 2021, only one of the 476 Groundwater Quality Restricted Use Zones (GQRUZs) across Victoria were located within five km of the Western Port coastline, indicating there is minimal groundwater pollution and restrictions near Western Port.

EPA Victoria Licenced Sites

As at March 2021, 12 out of EPA Victoria's 637 licenced sites were located within five km of the Western Port coastline, which further indicates a relatively minor extent and likelihood of contaminated land compared with Port Phillip Bay where 67 sites were located within five km of the coastline.

Environmental audits

Only two 53X Audits have occurred for land within five km of the Western Port coastline, which provides an indication that significant land remediation has not taken place in this region, partly due to a lack of legacy contamination necessitating land remediation.

Table 12: Numbers of contaminated and potentially contaminated land locations within five km of the Western Port coastline for various datasets published on Victoria Unearthed.

Item	Number within 5 km of the Western Port coastline as at March 2021
Priority sites[348]	4
Groundwater Quality Restricted Use Zones[349]	1
Currently Operating Landfills[350]	0
Closed Landfills[351]	6
Licenced sites[352]	12
53V Environmental Audits[353,354]	6
53X Environmental Audits[355,356]	2

348. State Government of Victoria, 'EPA Victoria priority sites register (PSR) - location points' https://discover.data.vic.gov.au/dataset/epa-victoria-priority-sites-register-psr-location-points Accessed 23 March 2021.
349. State Government of Victoria, 'EPA Victoria groundwater quality restriction use zones (GQRUZ) - location points' https://discover.data.vic.gov.au/dataset/epa-victoria-groundwater-quality-restriction-use-zones-gqruz-location-points Accessed 23 March 2021.
350. State Government of Victoria, 'EPA Victoria Victorian landfill register (VLR) - location points' https://discover.data.vic.gov.au/dataset/epa-victoria-victorian-landfill-register-vlr-location-points Accessed 23 March 2021.
351. Ibid.
352. State Government of Victoria, 'EPA Victoria licence - location polygons' https://discover.data.vic.gov.au/dataset/epa-victoria-licence-location-polygons Accessed 23 March 2021.

WP 14: Coastal air quality

Region	2021 status	2021 trend	2021 data
Western Port		?	
Justification for assessment ratings:	EPA Victoria does not currently measure air quality along the Western Port coastline.		

EPA Victoria does not monitor air quality along the Western Port coastline. During 2021, EPA Victoria expanded its monitoring network to include several air-quality monitoring sites, with nine of these located along Victoria's coastline. The closest of these to Western Port is located in nearby Wonthaggi.[357]

Future State of the Marine and Coastal Environment reports will include a statewide coastal air quality assessment that analyses the air-quality monitoring data collected from the newly installed sites. It is hoped that these will include assessments of point source air pollution emitted from industrial facilities licenced by EPA Victoria, such as the Esso Australia Pty Ltd plant at Hastings that has licence limits on air pollution discharges applied by EPA. Some licence compliance and air pollution information is currently available on EPA Victoria's Interaction Portal.[358] However, the format of this material (scanned images of documents) makes trend assessments and compliance analysis difficult.

Corner Inlet and Nooramunga

CIN 11: Litter and plastics

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga		?	
Justification for assessment ratings:	No litter and plastic pollution data has previously been reported for Corner Inlet and Nooramunga. Given the relatively smaller urban environment, litter and microplastics are likely to pose a lesser risk in Corner Inlet and Nooramunga than in Port Phillip Bay where more studies have been completed.		

353. State Government of Victoria, 'EPA Victoria environmental audit reports - location polygons' https://discover.data.vic.gov.au/dataset/epa-victoria-environmental-audit-reports-location-polygons Accessed 23 March 2021.
354. EPA Victoria, 'Environmental audits', Carlton, Victoria https://www.epa.vic.gov.au/for-business/find-a-topic/environmental-audit-system/environmental-audits Accessed 23 March 2021.
355. State Government of Victoria, 'EPA Victoria environmental audit reports - location polygons', https://discover.data.vic.gov.au/dataset/epa-victoria-environmental-audit-reports-location-polygons Accessed 23 March 2021.
356. EPA Victoria, 'Environmental audits', Carlton, Victoria https://www.epa.vic.gov.au/for-business/find-a-topic/environmental-audit-system/environmental-audits Accessed 15 November 2021.
357. EPA Victoria, 'EPA AirWatch', Carlton, Victoria https://www.epa.vic.gov.au/for-community/airwatch Accessed 13 July 2021.
358. EPA Victoria, 'Search for a licence, approval or APS', Carlton, Victoria https://www.epa.vic.gov.au/for-business/permissions/search-for-licence Accessed 15 November 2021.

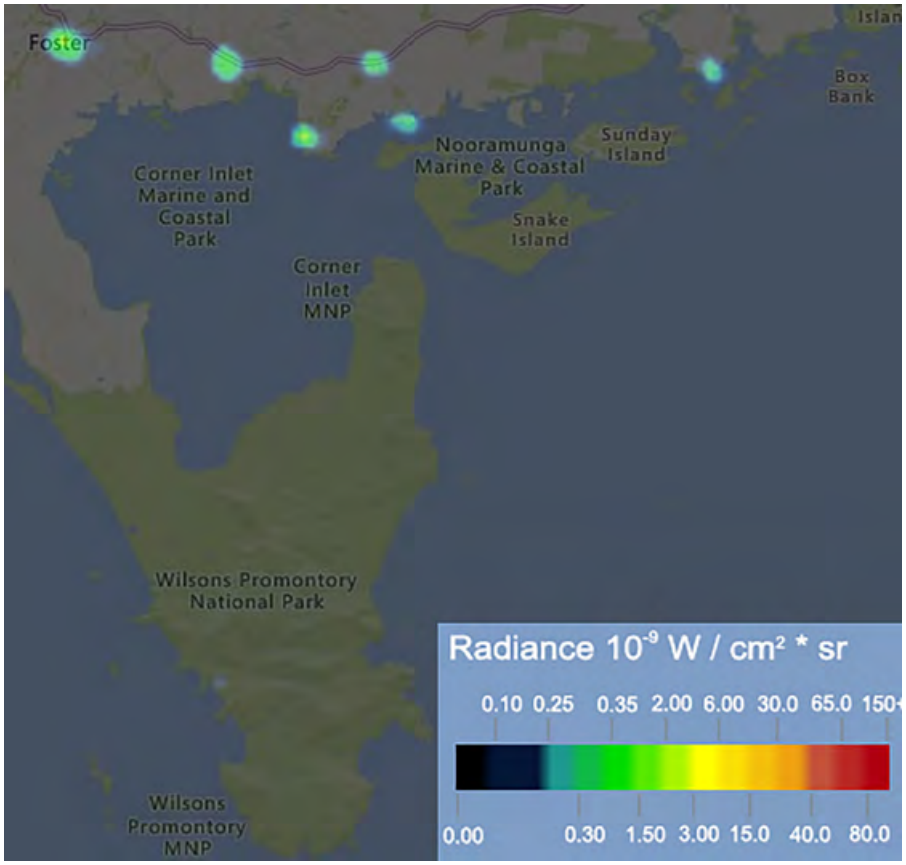
Theme 2: Litter and Pollution

CIN 12: Light pollution			
Region	**2021 status**	**2021 trend**	**2021 data**
Corner Inlet-Nooramunga	●	?	●
Justification for assessment ratings:	There is insufficient information to provide status and trend assessments for this indicator. The evidence to assess this indicator is minimal, therefore an indicator confidence assessment cannot be made.		

In the absence of any routine monitoring of the extent and impact of artificial light at night on Victorian marine and coastal ecosystems and species, Visible Infrared Imaging Radiometer Suite (VIIRS) measurements have been used to provide an indicative guide to the extent of artificial light at night within Corner Inlet and Nooramunga.

Figure 24 shows a screenshot from lightpollutionmap.info that shows the Corner Inlet and Nooramunga coastline is unaffected by artificial light at night other than at a small number of townships located along the coastline.[359]

359. Jurij Stare 'Light pollution map' https://www.lightpollutionmap.info/ Accessed 19 May 2021.
360. Jurij Stare 'Light pollution map' https://www.lightpollutionmap.info/help.html Accessed 19 May 2021.
361. National Oceanic and Atmospheric Administration (NOAA) Earth observation group, 'Visible infrared imaging radiometer suite (VIIRS)' National Geophysical Data Center https://ngdc.noaa.gov/eog/viirs/index.html Accessed 06 July 2020.



The unit of radiance is W/cm² * sr, which is a SI radiometry unit for radiance. Radiance is radiant flux emitted, reflected, transmitted or received by a surface, per unit solid angle per unit projected area.[360]

Figure 24: Image of artificial light at night across Corner Inlet.[361]

CIN 13: Coastal contaminated land

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga		?	
Justification for assessment ratings:	The status assessment of good is based on there being only a few sites within five km of the Corner Inlet and Nooramunga coastline that are known to be contaminated or are the location of current activity involving a relatively high risk of contamination. Because the information available via Victoria Unearthed is 'point-in-time' spatial data, the trend is unclear. Although the quality of data are good, the confidence for this assessment is low because there are no thresholds available to guide the status assessment. The assessment is a subjective interpretation which concludes that the relatively small number of coastal contaminated sites along the Corner Inlet and Nooramunga coastline, relative to other Victorian coastal regions. This suggests that contaminated land is exerting minimal pressure on coastal environmental condition and human health.		

Priority sites

As at March 2021, there were two sites within five km of the Corner Inlet and Nooramunga coastline which were listed on the Priority Sites Register (PSR). To provide context for the minimal extent of known contamination near Corner Inlet and Nooramunga from the PSR, there were 88 sites on the PSR which were situated along the Port Phillip Bay coastline.

Groundwater Quality Restricted Use Zones

As at March 2021, none of the 476 Groundwater Quality Restricted Use Zones (GQRUZs) across Victoria were located within five km of the Corner Inlet and Nooramunga coastline, indicating there is minimal groundwater pollution and restrictions near Corner Inlet and Nooramunga.

EPA Victoria Licenced Sites

As at March 2021, five out of EPA Victoria's 637 licenced sites were located within five km of the Corner Inlet and Nooramunga coastline, which further indicates a minimal extent and likelihood of contaminated land compared with Port Phillip Bay where 67 sites were located within five km of the coastline.

Environmental audits

No 53X Audits have occurred for land within five km of the Corner Inlet and Nooramunga coastline, which provides an indication that significant land remediation has not taken place in this region, partly due to a lack of legacy contamination necessitating land remediation.

Table 13: Numbers of contaminated and potentially contaminated land locations within five km of the Corner Inlet and Nooramunga coastline for various datasets published on Victoria Unearthed.

Item	Number within 5 km of the Corner Inlet and Nooramunga coastline as at March 2021
Priority sites[362]	2
Groundwater Quality Restricted Use Zones[363]	0
Currently Operating Landfills[364]	0
Closed Landfills[365]	3
Licenced sites[366]	5
53V Environmental Audits[367,368]	1
53X Environmental Audits[369,370]	0

CIN 14: Coastal air quality

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	?	●
Justification for assessment ratings:	EPA Victoria does not currently measure air quality along the Corner Inlet and Nooramunga coastline.		

EPA Victoria does not monitor air quality along the Corner Inlet and Nooramunga coastline. During 2021, EPA Victoria expanded its monitoring network to include several air-quality monitoring sites, with nine of these located along Victoria's coastline. None of these are located near the Corner Inlet and Nooramunga coastline.[371] Given there are no significant point sources of pollution and a generally less dense population along the Corner Inlet and Nooramunga coastline, relative to many other coastal areas in Victoria, it is anticipated that Corner Inlet and Nooramunga has generally good air quality. Future State of the Marine and Coastal Environment reports will include a statewide coastal air quality assessment that analyses the air-quality monitoring data collected from the newly installed monitoring sites. Air quality monitored at some of the less populated locations is likely to be indicative of air quality in Corner Inlet and Nooramunga.

362. State Government of Victoria, 'EPA Victoria priority sites register (PSR) - location points' https://discover.data.vic.gov.au/dataset/epa-victoria-priority-sites-register-psr-location-points Accessed 23 March 2021.
363. State Government of Victoria, 'EPA Victoria groundwater quality restriction use zones (GQRUZ) - location points, https://discover.data.vic.gov.au/dataset/epa-victoria-groundwater-quality-restriction-use-zones-gqruz-location-points Accessed 23 March 2021.
364. State Government of Victoria, 'EPA Victoria Victorian landfill register (VLR) - location points' https://discover.data.vic.gov.au/dataset/epa-victoria-victorian-landfill-register-vlr-location-points Accessed 23 March 2021.
365. Ibid.
366. State Government of Victoria, 'EPA Victoria licence - location polygons' https://discover.data.vic.gov.au/dataset/epa-victoria-licence-location-polygons Accessed 23 March 2021.
367. State Government of Victoria, 'EPA Victoria environmental audit reports - location polygons' https://discover.data.vic.gov.au/dataset/epa-victoria-environmental-audit-reports-location-polygons Accessed 23 March 2021.
368. EPA Victoria, 'Environmental audits', Carlton, Victoria https://www.epa.vic.gov.au/for-business/find-a-topic/environmental-audit-system/environmental-audits Accessed 15 November 2021.
369. State Government of Victoria, 'EPA Victoria environmental audit reports - location polygons' https://discover.data.vic.gov.au/dataset/epa-victoria-environmental-audit-reports-location-polygons Accessed 23 March 2021.
370. EPA Victoria, 'Environmental audits', Carlton, Victoria https://www.epa.vic.gov.au/for-business/find-a-topic/environmental-audit-system/environmental-audits Accessed 15 November 2021.
371. EPA Victoria, 'EPA AirWatch', Carlton, Victoria https://www.epa.vic.gov.au/for-community/airwatch Accessed 13 July 2021.

Gippsland Lakes

GL 11: Litter and plastics

Region	2021 status	2021 trend	2021 data
Gippsland Lakes		?	
Justification for assessment ratings:	No litter and plastic pollution data has previously been reported for the Gippsland Lakes. Given the relatively smaller urban environment, litter and microplastics are likely to pose a lesser risk in the Gippsland Lakes than in Port Phillip Bay where more studies have been completed.		

As part of Marine Mammal Foundation's Marine Environment Litter Program, there is a dedicated Gippsland Lakes program – Litter Free Lakes – that highlights the impact of litter on the Gippsland Lakes' marine biodiversity to create long-lasting behaviour change to protect the Lakes' marine life. This program highlights the links between this indicator, Indicator 74: Stewardship and Indicator 76: Volunteering, with community involvement a core element of reducing the volume of litter and enabling hands-on beach clean-ups and litter audits.

Submissions provided to the federal senate inquiry into the threat of marine plastic pollution provide anecdotal information of silage and hay baling plastic wrap in the river systems around the Gippsland Lakes, which are located adjacent to farms.[372]

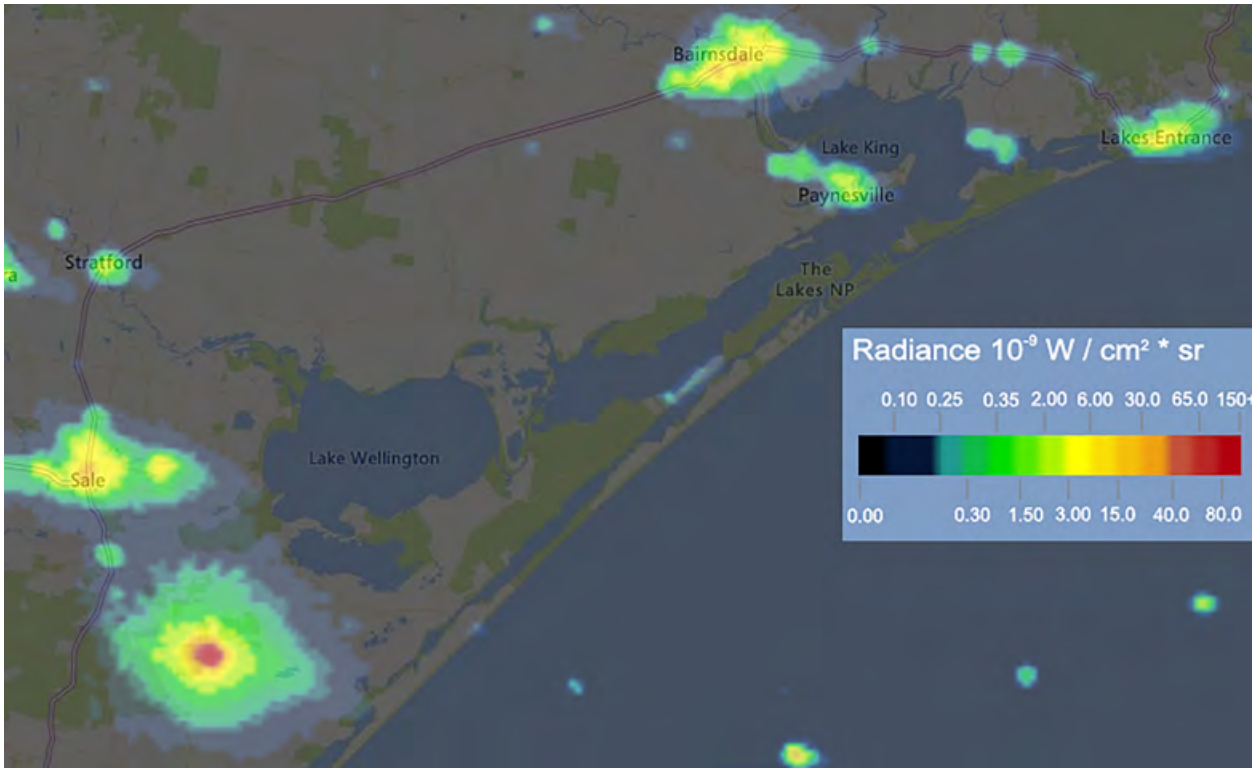
GL 12: Light pollution

Region	2021 status	2021 trend	2021 data
Gippsland Lakes		?	
Justification for assessment ratings:	There is insufficient information to provide status and trend assessments for this indicator. The evidence to assess this indicator is minimal, therefore an indicator confidence assessment cannot be made.		

In the absence of any routine monitoring of the extent and impact of artificial light at night on Victorian marine and coastal ecosystems and species, Visible Infrared Imaging Radiometer Suite (VIIRS) measurements have been used to provide an indicative guide to the extent of artificial light at night within the Gippsland Lakes. Figure 25 shows a screenshot from lightpollutionmap.info that shows significant artificial light at night associated with the gas plants at Longford, to the south west of Lake Wellington.[373]

There is also artificial light at night in the immediate vicinity of Sale, Bairnsdale, Lakes Entrance and Paynesville, while the oil rigs that are in Bass Strait offshore from the Gippsland Lakes also contribute a significant amount of artificial light. For most other areas along the Gippsland Lakes coastline there is minimal or no artificial light at night.

372. Parliament of Australia, 'Submission 116', Senate inquiry into the threat of marine plastic pollution in Australia and Australian Waters https://www.aph.gov.au/DocumentStore.ashx?id=326c34c6-9093-43df-a6fc-5b7e8411430a&subId=403678 Accessed 22 March 2021.
373. Jurij Stare 'Light pollution map' https://www.lightpollutionmap.info/ Accessed 19 May 2021.



The unit of radiance is W/cm² * sr, which is a SI radiometry unit for radiance. Radiance is radiant flux emitted, reflected, transmitted or received by a surface, per unit solid angle per unit projected area.[374]

Figure 25: Image of artificial light at night across Gippsland Lakes.[375]

GL 13: Coastal contaminated land

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	?	●
Justification for assessment ratings:	The status assessment of good is based on there being only a few sites within five km of the Gippsland Lakes coastline that are known to be contaminated or are the location of current activity involving a relatively high risk of contamination. The trend is unclear because information from Victoria Unearthed is 'point-in-time' spatial data. Although the quality of data are good, the confidence for this assessment is low because there are no thresholds available to guide the status assessment. The assessment is a subjective interpretation which concludes that the relatively small number of coastal contaminated sites along the Gippsland Lakes coastline, relative to other Victorian coastal regions. This suggests that contaminated land is exerting minimal pressure on coastal environmental condition and human health.		

Priority sites

As at March 2021, there were three sites within five km of the Gippsland Lakes coastline which were listed on the Priority Sites Register (PSR). To provide context for the minimal extent of known contamination near the Gippsland Lakes from the PSR, there were 88 sites on the PSR which were situated along the Port Phillip Bay coastline.

Groundwater Quality Restricted Use Zones

As at March 2021, none of the 476 (Groundwater Quality Restricted Use Zones) GQRUZs across Victoria were located within five km of the Gippsland Lakes coastline, indicating there is minimal groundwater pollution and restrictions near the Lakes.

374. Jurij Stare 'Light pollution map' https://www.lightpollutionmap.info/help.html Accessed 19 May 2021.
375. National Oceanic and Atmospheric Administration (NOAA) Earth observation group, 'Visible infrared imaging radiometer suite (VIIRS)' National Geophysical Data Center https://ngdc.noaa.gov/eog/viirs/index.html Accessed 06 July 2020.

EPA Victoria Licenced Sites

As at March 2021, 14 out of EPA Victoria's 637 licenced sites were located within five km of the Gippsland Lakes coastline, which further indicates a minimal extent and likelihood of contaminated land compared with Port Phillip Bay where 67 sites were located within five km of the coastline.

Environmental audits

Only one 53X Audit has occurred for land within five km of the Gippsland Lakes coastline, which provides an indication that significant land remediation has not taken place in these areas, partly due to a lack of legacy contamination necessitating land remediation.

Landfills

There is one currently operating landfill within five km of the lakes, which is at Datsun Downs near Lake Coleman.

Table 14: Numbers of contaminated and potentially contaminated land locations within five km of the Gippsland Lakes coastline for various datasets published on Victoria Unearthed.

Item	Number within 5 km of the Gippsland Lakes coastline as at March 2021
Priority sites[376]	3
Groundwater Quality Restricted Use Zones[377]	0
Currently Operating Landfills[378]	1
Closed Landfills[379]	7
Licenced sites[380]	14
53V Environmental Audits[381,382]	12
53X Environmental Audits[383,384]	1

376. State Government of Victoria, 'EPA Victoria priority sites register (PSR) - location points' https://discover.data.vic.gov.au/dataset/epa-victoria-priority-sites-register-psr-location-points Accessed 23 March 2021.
377. State Government of Victoria, 'EPA Victoria groundwater quality restriction use zones (GQRUZ) - location points' https://discover.data.vic.gov.au/dataset/epa-victoria-groundwater-quality-restriction-use-zones-gqruz-location-points Accessed 23 March 2021.
378. State Government of Victoria, 'EPA Victoria Victorian landfill register (VLR) - location points' https://discover.data.vic.gov.au/dataset/epa-victoria-victorian-landfill-register-vlr-location-points Accessed 23 March 2021.
379. Ibid.
380. State Government of Victoria, 'EPA Victoria licence - location polygons' https://discover.data.vic.gov.au/dataset/epa-victoria-licence-location-polygons Accessed 23 March 2021.
381. State Government of Victoria, 'EPA Victoria environmental audit reports - location polygons' https://discover.data.vic.gov.au/dataset/epa-victoria-environmental-audit-reports-location-polygons Accessed 23 March 2021.
382. EPA Victoria, 'Environmental audits', Carlton, Victoria https://www.epa.vic.gov.au/for-business/find-a-topic/environmental-audit-system/environmental-audits Accessed 15 November 2021.
383. State Government of Victoria, 'EPA Victoria environmental audit reports - location polygons' https://discover.data.vic.gov.au/dataset/epa-victoria-environmental-audit-reports-location-polygons Accessed 23 March 2021.
384. EPA Victoria, 'Environmental audits', Carlton, Victoria https://www.epa.vic.gov.au/for-business/find-a-topic/environmental-audit-system/environmental-audits Accessed 15 November 2021.

Theme 2: Litter and Pollution

GL 14: Coastal air quality			
Region	**2021 status**	**2021 trend**	**2021 data**
Gippsland Lakes	(fine particle pollution during bushfire periods) (all other times)	?	(fine particle pollution during bushfire periods) (all other times)
Justification for assessment ratings:	The status assessments are based on the compliance of air quality at Victorian air-quality monitoring stations with the National Environment Protection (Ambient Air Quality) Measure. Air-quality monitoring does not routinely occur along the Gippsland Lakes coastline, with recent monitoring only conducted as part of the emergency management response to significant amounts of bushfire smoke in the region.		

EPA Victoria has not historically operated air-quality monitoring stations along the Gippsland Lakes coastline. However, extensive monitoring of the region's air quality did occur during the 2019-20 bushfire season and the data show the daily air-quality standard for $PM_{2.5}$ was frequently breached during the summer of 2019-20. The most frequent poor air quality along the Gippsland Lakes coastline was recorded at Bairnsdale where the $PM_{2.5}$ air quality standard was breached on 37 days between 26 November 2019 and 20 February 2020, which is significant when considered in the context that the National Environment Protection (Ambient Air Quality) Measure has a goal of zero days per year breaching the $PM_{2.5}$ standard.

The frequency and magnitude of the poor air quality along the east Gippsland coastline due to bushfire smoke during 2019-20 was significantly worse than was measured across greater Melbourne and Geelong, with the highest number of days breaching the $PM_{2.5}$ standard in the Port Phillip region during the summer of 2019-20 occurring at Box Hill (24 days).

Note that when EPA Victoria expanded its air-quality monitoring network during 2021, new sensor monitoring sites were installed along the Gippsland Lakes coastline at Bairnsdale and Lakes Entrance.[385] There is no historical information for these two new monitoring stations, however analysis will be provided in future State of the Marine and Coastal Environment reports.

385. EPA Victoria, 'EPA AirWatch', Carlton, Victoria https://www.epa.vic.gov.au/for-community/airwatch Accessed 13 July 2021.

Theme 3
Biodiversity

Commissioner *for* Environmental Sustainability Victoria

Pacific gull (*Larus pacificus*) and Australian fur seal (*Arctocephalus pusillus doriferus*) on Kanowna Island, Wilsons Promontory Marine National Park
© Michael Sale

Theme 3: Biodiversity

Background

The Biodiversity chapter contains comprehensive indicator assessments on coastal vegetation, invertebrates on intertidal and subtidal reefs, fish, birds and marine mammals.

A few key stories emerged during the analysis of the information for commercially and recreationally important fish and invertebrates:

- Black bream and dusky flathead have both been rated as having a poor status in the Gippsland Lakes.
- Based on the two fisheries management units with the largest catches of blacklip abalone in Victoria both being classified as having depleting stocks, the statewide status of blacklip abalone has been assessed as poor, with a deteriorating trend.
- The recreational fishery for adult snapper in Port Phillip Bay is considered sustainable at its current level, however there is a declining trend in the recreational fishery for adult snapper in Western Port. However, recent strong recruitment in Port Phillip Bay is expected to reverse any declining biomass trends and drive a rebuilding of adult biomass and improved fishery performance in Western Port over the next five to ten years.
- King George whiting is expected to remain sustainable in Port Phillip Bay, Western Port and Corner Inlet.

The conservation of coastal ecosystems in protected areas is a broad indicator that covers a range of coastal ecosystems and conservation efforts. The protection levels for coastal ecological EVCs vary. Parks Victoria manages around 70% of the Victorian coast as national and state parks or as coastal reserves. However, analysis indicates that several coastal EVCs have limited data coverage in protected areas.

The engagement that CES has undertaken with our co-creation partners to develop the Method for localising the SDGs (Part 2, Phase 3) has shone a light on the need for complementary top-down and bottom-up approaches to improve biodiversity outcomes at the local scale. Greater collaboration among Victorian Government agencies to manage current threats to coastal fringe ecosystems at risk from climate change (for example, saltmarsh, mangroves, seagrasses) is required, as are clear engagement strategies for working with local management authorities, NGOs and volunteers. Actions to conserve coastal ecosystems could include assessing threats to biodiversity and Ramsar areas, understanding conservation and protection needs, removing hard barriers for inland migration of marine species, and delivering programs co-ordinated over multiple agencies and community groups.

The status and trend assessments for the bird indicators are generally consistent with assessments made in previous reports by the Commissioner for Environmental Sustainability. The main declines noted in the marine and coastal waterbirds and migratory shorebirds indicators were associated with trans-equatorial migratory shorebirds. These declines are most likely to be due to habitat loss on their migratory flyways in east Asia, particularly the Yellow Sea's tidal mudflats.

Little penguins continue to thrive on Phillip Island and around the St Kilda breakwater area. Little penguin numbers on Phillip Island are estimated to be 32,000 while penguin numbers at St Kilda are estimated at 1,400.[386]

There is a stable population of approximately 100 dolphins living in Port Phillip Bay. Western Port has a small but stable resident population of 20 dolphins. There is also an estimated population of between 60 to 100 dolphins living in the Lakes however there has been a significant recent mortality event within this population linked with bushfires in the region during 2019-20 and associated with skin infections observed on several dolphins.

386. Commissioner for Environmental Sustainability (CES) 2018, 'Victorian State of the Environment 2018', Melbourne, Victoria.

The health of Australian fur seal (*Arctocephalus pusillus doriferus*) colonies in terms of numbers, pup production and disease, including toxicants in the environment, can indicate trends in the general health of the marine environment. Fur seal colonies at Cape Bridgewater, Chinaman's Hat, Phillip Island and Wilsons Promontory have also become major tourist assets. There are an estimated 20,000 to 30,000 Australian fur seals in the Seal Rocks colony at the western entrance to Western Port.

Parks Victoria's study of macroinvertebrate species in Point Addis Marine National Park found consistent declines over the last 15 years of blacklip abalone and turban shell. The study also included a comparison between southern rock lobsters inside and outside of the Point Addis Marine National Park protected waters. Over 3.5 times the abundance and 4.5 times the number of legal rock lobsters were captured within the Park. The analysis showed abundance and biomass of southern rock lobsters outside the MPA to increase closer to the MPA boundary, suggesting that the Point Addis Marine National Park may be positively affecting the supply individuals to surrounding waters open to fishing.[387]

Comparison with insights from State of the Bays 2016 Report and the State of the Environment 2018 Report

Several indicators in this chapter have an identical or similar scope to indicators in the Marine and Coastal Environments chapter of the SoE 2018 Report, which means that clear comparisons can be made. In the SoE 2018, there was reasonably good data available for invertebrates in Port Phillip Bay and marine protected areas, and for birds. The information and assessments in the indicator assessments for these indicators in this report are generally consistent with previous reporting by the Commissioner.

This report contains more detail and new data on the fish indicators to provide a significant update for this theme compared to the Commissioner's previous reports. The fish assessments in the SotB 2016 Report were based on good data, while the data quality was rated as poor and assessments could not be made for the Impacts of fisheries production indicator in the SoE 2018 Report. For southern sand flathead in Port Phillip Bay, the indicator has been assessed as poor in this report, as it was in the SotB 2016 Report, however the more recent data shows the stock has now stabilised at a lower biomass under a lower recruitment regime, and recruitment has been sufficient to balance natural and fishing mortality at this lower level. This report also updates on the recreational fishery for adult snapper in Port Phillip Bay, with record snapper spawning in the region during 2018 likely to result in a snapper population boom in Port Phillip Bay during 2022 and 2023.

The inclusion of a marine mammals indicator in this report, which was not part of the SotB 2016 or SoE 2018 Reports, highlights the threat to the critically endangered dolphin population in the Gippsland Lakes from skin irritations.

387. Ierodiaconou D, Wines S, Carnell P, Tinkler P, Allan B, Carey J, Young M, Howe S, Pocklington J 2020, 'An enhanced signs of healthy parks monitoring program for Victoria's marine national parks and marine sanctuaries: Point Addis marine national park', Parks Victoria technical series no. 114.

Theme 3: Biodiversity

Indicator 15: Conservation of coastal ecosystems in protected areas

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide	Poor	?	Poor	Poor	→	Poor

Data source:	Parks Victoria
Measures:	Percentage of the land within 5 km of the high-water mark managed as national and state parks or as coastal reserves | Conservation status of ecological vegetation classes | Area of ecological vegetation classes within 5 km of the high-water mark

Why this indicator?

By assessing the area and type of coastal ecosystems with formal protection and the degree of protection, it is possible to then determine whether Australia (and Victoria) is meeting international benchmarks for protection.

Indicator 16: Saltmarsh

Region		2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		Poor	→	Poor	Poor	→	Poor
Western Port		Good	→	Poor	Good	↙	Poor
Corner Inlet-Nooramunga	Corner Inlet	Poor	→	Poor	Unknown	N/A	N/A
	Nooramunga	Poor	→	Poor	Unknown	N/A	N/A
	Nooramunga islands	Good	→	Poor	Unknown	N/A	N/A
Gippsland Lakes		Poor	?	Poor	Good	?	Poor

Data source:	Academic researchers, DELWP
Measures:	Extent of saltmarsh | Change in saltmarsh extent since European settlement

Why this indicator?

Saltmarsh is a critical habitat for many species. Subtropical and Temperate Coastal Saltmarsh is listed as a threatened ecological community under the *Environment Protection and Biodiversity Conservation Act 1999.*

This indicator measures the spatial extent of saltmarsh, a critical habitat for many species, and will assist management responses. Subtropical and Temperate Coastal Saltmarsh is listed as a threatened ecological community under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Coastal saltmarsh (Ecological Vegetation Class 9) is one of the most common and spatially extensive coastal wetland Ecological Vegetation Classes (EVCs). The most recent inventory of coastal wetlands estimated there were 19,212 hectares of coastal saltmarsh along the Victorian coastline.[388] Of these, 6,390 hectares of coastal saltmarsh were on private land.

A survey of 30 geographic coastal sectors that compared pre-1750s and current saltmarsh extents found seven of the coastal sectors had 35–65% of saltmarsh remaining. Seven were 100% intact, one had expanded to 130% (Lang Lang), and the other fifteen ranged from 70–95%.[389,390]

Future reporting of this indicator will include an analysis of saltmarsh condition to compliment the information provided for saltmarsh extent.

Indicator 17: Mangroves

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	Good	?	Adequate	Poor	N/A	N/A
Western Port	Good	↗	Adequate	Good	?	Good
Corner Inlet-Nooramunga	Good	→	Adequate	Adequate	?	Good

Data source:	Academic researchers, DELWP
Measures:	Extent of mangroves | Change in mangrove extent since European settlement

Why this indicator?

Mangroves are critical habitats for many marine and coastal species and provide many ecosystem services for coastal communities.

Mangroves are critical habitats for many marine and coastal species and provide ecosystem services for coastal communities. This indicator measures the spatial extent of mangroves. Negative changes in mangrove extent may signal the need for management responses.

Mangrove shrubland (Ecological Vegetation Class 140) is one of the most common and spatially extensive coastal wetland Ecological Vegetation Classes (EVCs). The most recent inventory of coastal wetlands estimated there were 5,177 hectares of mangroves along the Victorian coastline.[391]

A survey of 30 geographic coastal sectors compared pre-1750s and current mangrove extents. Of the 30 coastal sectors analysed, only 14 had mangroves present.[392] On a statewide basis, 90% of the pre-1750's extent of mangroves remains.

Most coastal sectors have 100% remaining, except for: Corner Inlet and Western Port, with 80% and 90% respectively; Shallow Inlet, where an estimated 250 hectares have been lost; and Anderson Inlet, where mangrove extent has increased.[393]

Future reporting of this indicator will include an analysis of mangrove condition to compliment the information provided for mangrove extent.

388. Boon P, Allen R, Carr G, Frood D, Harty C, McMahon A, Mathews S, Rosengren N, Sinclair S, White M and Yugovic J 2015, 'Coastal wetlands of Victoria, south-eastern Australia: providing the inventory and condition information needed for their effective management and conservation', *Aquatic Conservation Marine and Freshwater Ecosystems*, 25(4), pp. 454–479.
389. Ibid.
390. Boon P, Allen R, Carr G, Frood D, Harty C, McMahon A, Mathews S, Rosengren N, Sinclair S, White M and Yugovic J 2011, 'Mangroves and coastal saltmarsh of Victoria: distribution, condition, threats and management', Institute for Sustainability and Innovation, Victoria University, Melbourne, Victoria.
391. Boon P, Allen R, Carr G, Frood D, Harty C, McMahon A, Mathews S, Rosengren N, Sinclair S, White M and Yugovic J 2015, 'Coastal wetlands of Victoria, south-eastern Australia: providing the inventory and condition information needed for their effective management and conservation', *Aquatic Conservation Marine and Freshwater Ecosystems*, 25(4), pp. 454–479.
392. Ibid.
393. Boon P 2017, 'Are mangroves in Victoria (south-eastern Australia) already responding to climate change?', *Marine and Freshwater Research*, 68(12), pp. 2366–2374.

Indicator 18: Wetland and estuarine vegetation

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	Fair	?	Good	Not assessed	N/A	N/A
Western Port	Good	?	Fair	Not assessed	N/A	N/A
Corner Inlet-Nooramunga	Fair	?	Good	Not assessed	N/A	N/A
Gippsland Lakes	Good (estuarine flora); Fair (wetland habitat extent); Poor (condition of paperbark-dominated wetlands)	?	Good (estuarine flora); Fair (wetland habitat extent, condition of paperbark-dominated wetlands)	Not assessed	N/A	N/A
Statewide	Good	?	Good	Not assessed	N/A	N/A

Data source:	Academic researchers, DELWP
Measures:	The Index of Estuary Condition flora sub-index

Why this indicator?

The condition of estuarine flora is threatened by anthropogenic land use, hydrological modifications, and invasions by exotic plants.

This is a high-level summary indicator that provides an overview of coastal, wetland and estuarine vegetations beyond those vegetation types covered as standalone indicators (for example, saltmarsh and mangroves).

A key part of this indicator is a flora assessment based on that part of the Index of Estuary Condition (IEC). The IEC provides a consistent condition assessment method that can be applied statewide. There are five themes that make up the Index: fauna, flora, water quality, physical form and hydrology. Each theme contains multiple measures and standard methods have been developed for these.[394]

The IEC assessment program aims to:

- report on the condition of estuaries across Victoria
- assist the prioritisation of management investment among estuaries
- provide a baseline for assessing long-term and large-magnitude changes in resource condition.

The condition of estuarine flora is threatened by anthropogenic land use, hydrological modifications, and invasions by exotic plants. The flora sub-index of the IEC consists of two measures: Fringing Vegetation and Submerged Vegetation. Fringing vegetation includes intertidal and riparian plants that provide important habitat for estuarine fauna such as fish and waterbirds, and its condition can influence the condition of the rest of the estuary (for example, by filtering overland flows of water, chemicals, and organisms that come from the surrounding catchment).

394. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Index of estuary condition', East Melbourne, Victoria.

It also has important aesthetic values. Submerged vegetation, such as seagrass, also provides habitat for estuarine fauna, and promotes crucial ecological processes such as nutrient processing and organic matter breakdown.[395] As two measures are used to assess flora for the IEC, estuaries with different components of the flora in different condition may achieve similar scores for the flora sub-index.

For instance, an estuary with largely intact fringing vegetation but submerged vegetation lacking seagrass and dominated by macroalgae will receive a similar score to an estuary with fringing vegetation that is adversely affected by built structures and weeds but with submerged vegetation dominated by seagrass.[396]

Indicator 19: Species of conservation concern

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		?			N/A	N/A
Western Port		?			N/A	N/A
Corner Inlet-Nooramunga		?			N/A	N/A
Gippsland Lakes		?			N/A	N/A
Statewide		?			N/A	N/A

Data source:	Victorian Biodiversity Atlas
Measures:	Number of species of conservation concern that are listed within the Victorian Biodiversity Atlas for each region

Why this indicator?

In 2019, VEAC reported that there were 179 species and five ecological communities that occur in Victorian marine waters and are included in any list, annex, appendix or other mechanism under relevant legislation or international agreement.

The *Flora and Fauna Guarantee Act 1988* (the FFG Act) provides for the listing of taxa (genera, species, subspecies and varieties), threatened communities of flora and fauna and potentially threatening processes.[397]

There are 3 lists:

- The Excluded List contains native flora and fauna taxa which are not to be conserved because they constitute a serious threat to human welfare (note: the only item on this list is human disease organisms)
- The Threatened List contains taxa and communities of native flora and fauna which are threatened
- The Processes List contains potentially threatening processes.[398]

Previously, Victoria had multiple lists of threatened species - those listed under the FFG Act, and non-statutory lists called the Victorian Threatened Species Advisory Lists. Recent amendments to the FFG Act have removed duplication by establishing a single comprehensive list of threatened flora and fauna species. This will continue to be known as the FFG Act Threatened List. With the new comprehensive list now in effect, the Advisory Lists have been revoked.[399]

395. Ibid.
396. Ibid.
397. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Threatened list and processes list' East Melbourne, Victoria https://www.environment.vic.gov.au/conserving-threatened-species/threatened-list Accessed 17 August 2021.
398. Ibid.
399. Ibid.

The new Threatened List of 1,993 species, published in June 2021, consists of 49 mammals, 104 birds, 40 reptiles, 15 amphibians, 37 fish, 124 invertebrates, 1,556 vascular plants, 60 non-vascular plants and 8 fungi and lichens.[400]

Reasons for their decline include the loss, fragmentation and degradation of habitat due to clearing for agriculture, urban development, timber harvesting, weed invasion, inappropriate fire regimes, grazing, climate change, and alteration to flows and temperature regimes in rivers.[401] The Threatened list does not categorise by spatial location or environmental type (for example, marine).

The Victorian Government has been coordinating marine species conservation assessments for many years. In 1999, the Department of Natural Resources and Environment (DNRE) commissioned Museum Victoria to compile a list of marine taxa that might be considered as priorities for conservation management.[402] This study was the first systematic attempt to identify marine invertebrate species of conservation concern for Victoria. Better-known marine invertebrates were considered suitable for the study, including molluscs (for example, gastropods, bivalves and opisthobranchs), echinoderms (for example, seastars, brittle-stars, sea-urchins, feather stars and sea-cucumbers) and decapod crustaceans (for example, crabs, prawns, shrimps, and crayfish). The study suggested that the conservation of species with restricted distributions (either endemics or occurring in isolated populations) required area-based management, with management options including reserves, management plans or knowledge when making management decisions.

The Victorian Environmental Assessment Council's (VEAC's) 2019 Assessment of the Values of Victoria's Marine Environment included a sub-section on Conservation-listed species and noted there has been less investment in the recognition of rare and threatened taxa in the marine environment compared to terrestrial species.[403] VEAC's Assessment also tabulated numbers of species and communities that occur in Victorian marine waters and are included in any list, annex, appendix or other mechanism under relevant legislation or international agreement.[404] There were 179 species and five ecological communities, with many more large, charismatic species listed (for example, marine mammals and birds) than invertebrates.[405] VEAC reported that this was not an indication of the conservation status of marine invertebrates. Rather, that it reflected the existing state of knowledge and priorities for species' listing.[406]

Intertidal and subtidal reef monitoring

Parks Victoria's long-term Subtidal Reef Monitoring Program (SRMP) was designed using best scientific practices in the early 1990s and commenced in 1998.[407] These surveys were conducted in marine national parks and sanctuaries across the state.[408]

As part of Parks Victoria's long-term Intertidal Reef Monitoring Program (IRMP) that commenced in 2002, information was collected at Victoria's Marine Protected Areas on the status of Victorian intertidal reef flora and fauna, as well as the nature and magnitude of trends in species populations and species diversity through time.[409]

The SRMP and IRMP have been superseded by Signs of Healthy Parks, which, as stated by Parks Victoria, provides a framework for systematic and integrated ecological monitoring of the health of the state's ecosystems.[410] A draft statewide monitoring plan based on conservation, management and monitoring priorities identified for each park through the Conservation Planning process, has been developed.[411]

400. Ibid.
401. Department of Environment, Land, Water and Planning (DELWP) 2018, 'Threatened plants and animals', Arthur Rylah Institute (ARI), Heidelberg, Victoria https://www.ari.vic.gov.au/research/threatened-plants-and-animals Accessed 11 April 2021.
402. O'Hara T and Barmby V 2000, 'Victorian marine species of conservation concern: molluscs, echinoderms and decapod crustaceans,' Parks, Flora and Fauna Division, Department of Natural Resources and Environment (DNRE), East Melbourne, Victoria.
403. Victorian Environmental Assessment Council (VEAC) 2019, 'Assessment of the values of Victoria's marine environment', Melbourne, Victoria.
404. Ibid.
405. Ibid.
406. Ibid.
407. Ierodiaconou D, Wines S, Carnell P, Tinkler P, Allan B, Carey J, Young M, Howe S, Pocklington J 2020, 'An enhanced signs of healthy parks monitoring program for Victoria's marine national parks and marine sanctuaries: Point Addis marine national park', Parks Victoria technical series no. 114, Melbourne, Victoria.
408. Ibid.
409. Edmunds M, Woods B and Donnelly D 2014, 'Intertidal reef monitoring program: Central Victoria marine protected areas March 2014', Parks Victoria technical series no. 97, Melbourne, Victoria.
410. Parks Victoria, 'Signs of healthy parks' https://www.parks.vic.gov.au/get-into-nature/conservation-and-science/science-and-research/signs-of-healthy-parks Accessed 25 July 2021.
411. Ierodiaconou D, Wines S, Carnell P, Tinkler P, Allan B, Carey J, Young M, Howe S, Pocklington J 2020, 'An enhanced signs of healthy parks monitoring program for Victoria's marine national parks and marine sanctuaries: Point Addis marine national park', Parks Victoria technical series no. 114, Melbourne, Victoria.

The new monitoring program will focus on key ecological attributes and threats in at least one of the large marine national parks within each bioregion, currently identified as Discovery Bay Marine National Park (Otway bioregion), Point Addis Marine National Park (Central Victoria bioregion), Port Phillip Heads Marine National Park (Victorian embayments bioregion), Wilsons Promontory Marine National Park (Flinders bioregion) and Cape Howe Marine National Park (Twofold Shelf bioregion).[412]

Parks Victoria is progressing monitoring and assessment, and has already published a technical report for Point Addis Marine National Park with plans to publish technical reports within the next couple of years for Port Phillip Heads, Wilsons Promontory, Cape Howe and Discovery Bay Marine National Parks. This work is addressing intertidal reef knowledge gaps in marine protected areas and will further increase the confidence of indicator assessments in future State of the Marine and Coastal Environment reports.

Indicator 20: Mobile invertebrates on intertidal reefs

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	Good	→	Poor	Unknown	?	Poor
Other marine protected areas	Good	→	Poor	Good	→	Good

Data source:	Parks Victoria
Measures:	Parks Victoria control charts

Why this indicator?

Intertidal invertebrates are important food sources for marine and coastal animals and are popular with people rambling across shore platforms. Any declines in populations or cover could indicate the effects of illegal harvesting, trampling, reduced water quality or climate change.

Intertidal invertebrates are important food sources for marine and coastal animals and are popular with people rambling across shore platforms. Any declines in populations or cover could indicate the effects of illegal harvesting, trampling, reduced water quality or climate change.

With collection of IRMP data ceasing in 2014, and the only technical report published as part of the new monitoring and reporting program being a specific report for the Point Addis Marine National Park, analysis for this indicator is limited to data at Point Addis Marine National Park or data collected up to 2014 as part of the IRMP.

412. Ibid.

Theme 3: Biodiversity

Indicator 21: Sessile invertebrates on intertidal reefs

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	Good	→	Poor	Poor	N/A	N/A
Other marine protected areas	Good	→	Poor	Good	→	Good

Data source:	Parks Victoria
Measures:	Parks Victoria control charts

Why this indicator?

Sessile invertebrates are important food sources for marine and coastal animals. Declining populations or cover could indicate impacts from illegal harvesting, trampling, reduced water quality, invasive species or climate change.

Sessile invertebrates are important food sources for marine and coastal animals. Declining populations or cover could indicate impacts from illegal harvesting, trampling, reduced water quality, invasive species or climate change.

Like for the mobile invertebrates on intertidal reefs indicator, information has previously been collected at Victoria's marine protected areas on the status of Victorian intertidal reef flora and fauna as part of Parks Victoria's long-term Intertidal Reef Monitoring Program (IRMP). With collection of IRMP data ceasing in 2014, and the only technical report published as part of the new monitoring and reporting program being a specific report for the Point Addis Marine National Park, analysis for this indicator is limited to data at Point Addis Marine National Park or data collected up to 2014 as part of the IRMP.

Indicator 22: Invertebrates on subtidal reefs

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	Fair	↗ (north) → (south)	Fair	Fair	↙ (north) → (south)	Good
Other marine protected areas	Good	?	Fair	Fair	?	Good

Data source:	Parks Victoria, Reef Life Surveys
Measures:	Parks Victoria control charts | The number of mobile macroinvertebrate species recorded on individual Reef Life Surveys (species per 50 m^2)

Why this indicator?

Some mobile megafaunal invertebrates, such as abalone and rock lobster, are key species in marine national parks and sanctuaries. Outside the park boundaries they are targeted by commercial and recreational fishers. Monitoring can assist Parks Victoria's compliance program and provide data on trends in catches and stocks to support fisheries management.

Some mobile megafaunal invertebrates, such as abalone and rock lobster, are key species in marine national parks and sanctuaries. Outside the park boundaries they are targeted by commercial and recreational fishers. Monitoring can assist Parks Victoria's compliance program and provide data on trends in catches and stocks to support fisheries management.

Indicator 23: Commercially and recreationally important invertebrates

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	(commercial scallop, short-spined sea urchin)	(commercial scallop, short-spined sea urchin)	(commercial scallop, short-spined sea urchin)		N/A	N/A
Statewide	(southern calamari, Maori octopus) (southern rock lobster) (blacklip abalone) (pipi, greenlip abalone)	(southern calamari, Maori octopus, southern rock lobster) (blacklip abalone) (pipi, greenlip abalone)	(southern calamari, southern rock lobster) (Maori octopus, blacklip abalone) (pipi, greenlip abalone)		N/A	N/A

Data source:	Victorian Fisheries Authority
Measures:	Landings (tonnes) | Catch per unit of effort (fish per angler hour) Recruitment (using fishery independent sampling of recruits and or pre-recruits) Percentage of fishers satisfied with their fishing experience

Why this indicator?

Many invertebrates (for example, molluscs, crustaceans, squid) represent important fisheries in Victoria. An understanding of the abundance, distribution and life histories of these species is critical to their sustainable management.

Many invertebrates (for example, molluscs, crustaceans, squid) represent important fisheries in Victoria. An understanding of the abundance, distribution and life histories of these species is critical to their sustainable management.

The Victorian Fisheries Authority (VFA) is the state agency responsible for managing the invertebrates that are fished by recreational and/or commercial fishers.[413]

During 2020, the VFA published a report on the status of key Victorian fish stocks as at 2019 to determine their exploitation status.[414] This report followed a similar report that was published by the VFA in 2017.[415] The key results of those reports are utilised in the regional assessments for this indicator.

Five invertebrate species were assessed in accordance with the Status of Australian Fish Stocks (SAFS) classification system and reported by the VFA. A stock is defined as a genetically or functionally discrete population that is largely distinct from other populations of the same species and can be regarded as a separate homogeneous group for management or assessment purposes.[416]

413. Victorian Fisheries Authority (VFA) 2020, 'Review of key Victorian fish stocks — 2019'.
414. Ibid.
415. Victorian Fisheries Authority (VFA) 2017, 'Review of key Victorian fish stocks — 2017'.
416. Fisheries Research and Development Corporation (FRDC), 'Glossary' https://www.fish.gov.au/about/glossary Accessed 10 February 2021.

The SAFS classifications are defined as:

- Sustainable – Stock for which biomass (or biomass proxy) is at a level sufficient to ensure that, on average, future levels of recruitment are adequate (not recruitment overfished) and for which fishing pressure is adequately controlled to avoid the stock becoming recruitment overfished.
- Recovering – Biomass is depleted and recruitment is impaired, but management measures are in place to promote stock recovery, and there is evidence that recovery is occurring.
- Depleting – Biomass is not yet depleted and recruitment is not yet impaired, but fishing pressure is too high (overfishing is occurring) and pressuring the stock in the direction of becoming recruitment impaired.
- Depleted – Spawning stock biomass that has been reduced through catch and/or non-fishing effects, so that average recruitment levels are significantly reduced (recruitment is impaired). Current management is not adequate to recover the stock, or adequate management measures have been put in place but have not yet resulted in measurable improvements.
- Environmentally limited – Spawning stock biomass has been reduced to the point where average recruitment levels are significantly reduced, primarily due to substantial environmental changes/impacts, or disease outbreaks (the stock is not recruitment impaired). Note that this category has been removed from 2018 onwards.[417]
- Undefined – Not enough information exists to determine stock status.[418]

This indicator encompasses the five invertebrates reported by the VFA as part of their 2019 review of key Victorian fish stocks, as well as southern rock lobster (*Jasus edwardsii*), blacklip abalone (*Haliotis rubra rubra*) and greenlip abalone (*Haliotis laevigata*). The indicator assessments in this report include analysis of a metric of Catch Per Unit of Effort (CPUE), which is an informative metric for relative fish abundance through time in stock assessments and management decision rules. CPUE is the number or weight of fish caught by a unit of fishing effort, such as tonnes caught per day or per fishing operation.

Further background on the eight invertebrates analysed for this indicator is provided below.

Southern calamari: The population of southern calamari (*Sepioteuthis australis*) in Victorian waters is genetically similar and considered a single stock. Southern calamari live for less than one year and the main spawning period is spring and summer in inshore coastal regions with eggs laid in seagrass and reef algal habitats.[419]

Port Phillip Bay Commercial Scallop: The commercial scallop (*Pecten fumatus*) is a large mollusc that inhabits soft sediment habitats throughout southern Australia from Shark Bay in Western Australia to central Queensland, including Tasmania. The commercial scallop, as its name implies, is the major target of scallop fisheries in southern Australia.[420]

Scallops are fast growing, maturing after just 1–2 years and reaching a harvestable size in around three years, but growth rates can vary geographically. They can live for more than 10 years but are prone to large die-offs leading to large natural fluctuations in abundance.[421]

As reported by the VFA, there has been minimal commercial scallop fishing in the Victorian-managed waters of northeast Bass Strait, thus, this indicator assessment only considers the Port Phillip Bay dive fishery.[422]

Pipi: Genetically, the Victorian pipi population comprises at least two biological stocks at either end of Bass Strait, centred around Discovery Bay in the west and Venus Bay in the east.[423]

Victorian pipi stocks support recreational and commercial fisheries in several main areas. Commercial fisheries occur mainly in Discovery Bay and Venus Bay and are restricted to four areas across the state. Recreational fisheries occur across the state including coastal beaches, bays and inlets, although the predominant recreational harvest areas are also at Venus and Discovery Bay.

417. Fisheries Research and Development Corporation (FRDC), 'What are the status of Australian fish stock reports?' https://www.fish.gov.au/about/what-are-the-status-of-australian-fish-stock-reports Accessed 10 February 2021.
418. Fisheries Research and Development Corporation (FRDC), 'Glossary' https://www.fish.gov.au/about/glossary Accessed 10 February 2021.
419. Victorian Fisheries Authority (VFA) 2020, 'Review of key Victorian fish stocks — 2019'.
420. Ibid.
421. Ibid.
422. Ibid.
423. Ibid.

In its 2019 report, the VFA considered Victorian pipi as a single stock but only Discovery Bay supports a significant fishery, so that location was used to assess the state of the stock.[424]

Sea Urchins: Two species of sea urchin are abundant in Victoria: the long-spined sea urchin (*Centrostephanus rodgersii*) and the short-spined sea urchin (*Heliocidaris erythrogramma*). Except for several isolated specimens found occasionally during the past two decades, the long-spined urchin is mostly confined to the reef habitats of East Gippsland where changing environmental conditions, predominantly due to strengthening and warming of the East Australian Current, have led to them proliferating and denuding reefs of overstorey macroalgae (that is, kelp forests) to form barrens. As a result, ongoing culling takes place on barrens habitat and the urchin fishery is, at times, subsidised to encourage increased harvesting of urchins in areas important to the abalone fishery.[425] This is discussed further in the seafloor integrity and health section of this report. Short-spined urchins can also form barrens, but these have mostly affected seagrass meadows in the Geelong Arm of Port Phillip Bay and Corner Inlet.[426]

The fishery is managed as two separate areas, with specific access licences for the Port Phillip zone and eastern zone. Given the geographic separation between areas where short-spined sea urchins are caught (that is, Far East Gippsland and Port Phillip Bay) and the likely lack of larval dispersal due to the short larval phase of several weeks they are considered to be individual stocks. Nevertheless, because historic reporting of short-spined urchin catches from the eastern zone has been sporadic and at times unreliable the assessment for this species focusses on the Port Phillip Zone.[427]

Octopus: Two species of octopus are predominantly landed in Victorian commercial fisheries: the Maori octopus (*Macroctopus maorum*) and the pale octopus (*Octopus pallidus*). Octopus are a by-product of the southern rock lobster fishery and are landed in relatively low quantities throughout the geographic range of the fishery. Given the VFA reported that Maori octopus are likely to dominate the octopus by-product of the rock lobster fishery, this species is the focus of this indicator assessment.[428]

Southern rock lobster: In addition to the species described above, the Victorian Rock Lobster Fishery Management Plan requires annual assessment of the southern rock lobster (*Jasus edwardsii*) stock in Victoria to enable a review of the stock and setting of the annual Total Allowable Commercial Catch (TACC).[429]

The Victorian rock lobster fishery is divided into two separately managed zones; the western zone and the eastern zone. The two zones are assessed separately and a TACC for each zone is determined using the fishery's harvest strategy. Each licence holder is then assigned a proportion of the zonal TACC based on the quota units attached to their licence. The quota units are transferable, through permanent sale or temporary lease, throughout the zone.[430] For this report, these two management units are encompassed within the statewide assessment for this indicator.

The performance of the fishery is evaluated by the VFA against the stock performance indicators and associated limit reference points specified in the fishery's harvest strategy. The key indicators are egg production, standardised CPUE and pre-recruit abundance. Available biomass is used as a secondary reference point and is monitored as part of the overall stock health.[431]

Southern rock lobster is considered to be a single biological stock across southern Australia because the species occurs in a continuous distribution across this range and has extensive and protracted pelagic larval dispersal phase.[432] The pelagic phyllosoma larval phase lasts around 12–18 months.[433] Larval release occurs across the southern continental shelf, which is a high-current area, facilitating dispersal.[434]

424. Ibid.
425. Ibid.
426. Ibid.
427. Ibid.
428. Ibid.
429. Victorian Fisheries Authority (VFA) 2017, 'Victorian rock lobster fishery management plan 2017', Melbourne, Victoria.
430. Victorian Fisheries Authority (VFA) 2017, 'Victorian rock lobster fishery stock assessment report – 2019/20 Season', Melbourne, Victoria.
431. Ibid.
432. Fisheries Research and Development Corporation (FRDC), 'Southern rock lobster (2020)' https://www.fish.gov.au/report/294-Southern-Rock-Lobster-2020 Accessed 30 July 2020.
433. Ibid.
434. Ibid.

Oceanographic modelling has also indicated that southern rock lobster dispersal occurs over large spatial scales, indicating that there is a single biological stock.[435] Genetic analyses also indicate that it is a single stock.[436] In addition to the two fishery management zones in Victoria outlined above, the assessment of stock status at the biological stock level—southern Australia – is also used to guide the southern rock lobster indicator assessments in this report.

Abalone: Victorian abalone stocks are among the few worldwide that have yielded sustainable wild harvests. Until recently, this has been demonstrated by long-term stable abundance indices estimated by fishery-independent surveys and a long-term harvest record that has been managed by TACC.[437]

As part of 2015 Victorian Wild Harvest Abalone Fishery Management Plan, the Victorian Government's stated primary objective for the abalone fishery was to optimise its long-term value for the Victorian community, in accordance with the objectives and provisions specified in the *Fisheries Act 1995*.[438]

This indicator encompasses an assessment of blacklip abalone (*Haliotis rubra rubra*) and greenlip abalone (*Haliotis laevigata*). Greenlip abalone is distributed across southern mainland Australia and northern Tasmania. The biological stock structure of greenlip abalone has recently been examined.[439,440] Genetic evidence has confirmed that greenlip abalone comprise numerous independent biological stocks, but at a spatially broader scale than the biological stock structure evident for blacklip abalone.[441] The indicator assessments are based on stock status presented at the management unit level:

- Blacklip abalone: Victoria western, central and eastern zone fisheries
- Greenlip abalone: Victoria western zone and central zone fisheries.

This indicator links to the Water Quality and Catchment Inputs theme. Fishers need to be careful when targeting shellfish, including pipis, oysters, mussels and scallops. Shellfish are particularly sensitive to poor water quality as they filter algae and other microscopic organisms in the water. If the water is polluted, shellfish can accumulate harmful substances in their flesh and organs. Eating contaminated shellfish can result in serious illness or death.[442]

435. Bruce B, Griffin D and Bradford R 2007, 'Larval transport and recruitment processes of southern rock lobster', Fisheries Research and Development Corporation Project 2002/007, CSIRO Marine and Atmospheric Research, Hobart.
436. Ovenden JR, Brasher DJ and White R 1992, 'Mitochondrial DNA analyses of the red rock lobster *Jasus edwardsii* supports an apparent absence of population subdivision throughout Australasia', *Marine Biology*, 112: 319–326.
437. Department of Economic Development, Jobs, Transport and Resources (DEDJTR) 2015, 'Victorian wild harvest abalone fishery management plan' Melbourne, Victoria.
438. Ibid.
439. Mayfield S, Miller KJ, and Mundy CM 2014, 'Towards understanding greenlip abalone population structure', final report to the Fisheries Research and Development Corporation (FRDC), project 2010/013, South Australia Research and Development Institute, Adelaide.
440. Miller KJ, Maynard BT and Mundy CN 2009, 'Genetic diversity and gene flow in collapsed and healthy abalone fisheries', *Molecular Ecology*, 18, pp. 200–211.
441. Fisheries Research and Development Corporation (FRDC), 'Greenlip abalone (2020)' https://www.fish.gov.au/report/284-Greenlip-Abalone-2020 Accessed 30 July 2020.
442. Victorian Fisheries Authority (VFA), 'Eating your catch safely' https://vfa.vic.gov.au/recreational-fishing/recreational-fishing-guide/food-safety Accessed 19 February 2021.

Indicator 24: Commercially and recreationally important fish

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	(snapper, King George whiting) (southern sand flathead)	(King George whiting) (snapper, southern sand flathead)	(snapper, King George whiting) (southern sand flathead)		N/A	N/A
Western Port	(snapper, King George whiting)	(King George whiting) (snapper)	(snapper) (King George whiting)		N/A	N/A
Corner Inlet-Nooramunga	(King George whiting, rock flathead)	(King George whiting) (rock flathead)	(King George whiting, rock flathead)		N/A	N/A
Gippsland Lakes	(black bream, dusky flathead)	(dusky flathead) (black bream)	(black bream, dusky flathead)		N/A	N/A
Statewide	(bluethroat, purple wrasse)	(bluethroat, purple wrasse)	(bluethroat, purple wrasse)		?	

Data source:	VFA, academic researchers
Measures:	Landings (tonnes) | Catch per unit of effort (fish per angler hour) Recruitment (using fishery independent sampling of recruits and or pre-recruits) Percentage of fishers satisfied with their fishing experience

Why this indicator?

There are many fish species that represent important fisheries in Victoria. An understanding of the abundance, distribution and life histories of these species is critical to their sustainable management.

The Victorian Fisheries Authority (VFA) is the state agency responsible for managing the more than 90 wild fish stocks that are fished by recreational and/or commercial fishers.[443] Note that discussion and assessment of recreational fishing and commercial fishing is discussed in more detail in Indicator 65: Recreational fishing and Indicator 67: Commercial fishing, in this report. This indicator focusses on the status of the commercially and recreationally important fish stocks.

During 2020, the VFA published a report on the status of key Victorian fish stocks to determine their exploitation status.[444] This report followed a similar report that was published by the VFA in 2017.[445] The key results of those reports are utilised in the regional assessments for this indicator.

Twenty-seven species were assessed in accordance with the Status of Australian Fish Stocks (SAFS) classification system and reported by the VFA in 2020, with those assessments made across 35 stocks. Note that some species are assessed for multiple stocks. A stock is defined as a genetically or functionally discrete population that is largely distinct from other populations of the same species and can be regarded as a separate homogeneous group for management or assessment purposes.[446]

443. Victorian Fisheries Authority (VFA) 2020, 'Review of key Victorian fish stocks — 2019'.
444. Ibid.
445. Ibid.
446. Fisheries Research and Development Corporation (FRDC), 'Glossary' https://www.fish.gov.au/about/glossary Accessed 10 February 2021.

The 35 stock assessments reported in the 2020 report is an increase by six in the number of stock assessments the VFA made in its 2017 report. This indicates a slightly more comprehensive assessment of fish stocks has been made in the most recent report. Twenty-five of the 35 (71%) stocks were assessed as sustainable. A further six stocks were discussed in the report without being formally classified in accordance with the SAFS criteria. The SAFS classifications are defined in Indicator 23: Commercially and recreationally important invertebrates.

VFA has developed an internal index to determine the relative importance of each species/stock based on consideration of relative catch, gross value of production, assumed relative catch and social value. Of the 41 total stocks included in VFAs most recent report, nine stocks within the geographic scope of this report were categorised by VFA as being of high 'relative importance'. Those nine stocks, and their SAFS classifications, are shown in Table 15.

Table 15: Summary of current stock classifications for stocks classed as having high relative importance.[447,448]

Species	Management Unit/Stock	VFA classification (2017)	SAFS 2018 classification
Black bream	Gippsland Lakes	Sustainable	Depleting
Blue throat wrasse	Coastal waters	Sustainable	Sustainable
Dusky flathead	Gippsland Lakes	Not assessed	Sustainable (statewide)
King George whiting	State-wide	Sustainable	Sustainable
Purple wrasse	Coastal waters	Sustainable	Sustainable
Rock flathead	Corner Inlet-Nooramunga	Sustainable	Not assessed
Snapper	Western stock	Sustainable	Sustainable
Southern calamari[449]	State-wide	Sustainable	Sustainable
Southern sand flathead	Port Phillip Bay	Environmentally limited	Recovering

This indicator encompasses the nine stocks rated by the VFA as being of high relative importance. The indicator assessments in this report include analysis of a metric of Catch Per Unit of Effort (CPUE), which is an informative metric for relative fish abundance through time in stock assessments and management decision rules. CPUE is the number or weight of fish caught by a unit of fishing effort, such as tonnes caught per day or per fishing operation.

Further background on the nine stocks analysed for this indicator is provided below.

Snapper: The Victorian snapper population is comprised of two stocks.

- Western Victorian stock: Wilsons Promontory (VIC) to Investigator Strait (SA)
- Eastern Victorian stock: Wilsons Promontory to southern NSW.

The main snapper spawning period is from November to January, with Port Phillip Bay the main spawning area responsible for most of the western stock replenishment. The spawning that occurs along inshore reefs between Corner Inlet-Nooramunga and Lakes Entrance is important for replenishing the eastern Victorian stock.[450]

447. Victorian Fisheries Authority (VFA) 2017, 'Review of key Victorian fish stocks — 2017'.
448. Victorian Fisheries Authority (VFA) 2020, 'Review of key Victorian fish stocks — 2019'.
449. Note the southern calamari is included in Indicator 23: Commercially and recreationally important invertebrates.
450. Victorian Fisheries Authority (VFA) 2020, 'Review of key Victorian fish stocks — 2019'.

In this report snapper is assessed for the Port Phillip Bay, Western Port and Corner Inlet regions.

King George whiting: the Victorian King George whiting population is a statewide stock that extends into eastern South Australia. The main fisheries are in Port Phillip Bay, Western Port and Corner Inlet, with both commercial and recreational components in Port Phillip Bay and Corner Inlet. Due to their migration patterns, most King George whiting targeted in Victorian bays and inlets are harvested as immature fish of less than four years of age. This is because juvenile whiting migrate from bays and inlets at 3–5 years of age to complete their adult lives in coastal waters where they can live to approximately 20 years old. It is likely that King George whiting recruit into Victorian bay and inlet fisheries from spawning events in coastal waters off far western Victoria and south-east South Australia. Offshore spawning and a long-larval dispersal phase prior to settlement in bay and inlet nursery areas mean that settlement rates of larvae are highly variable from year to year depending on ocean currents. This variability, coupled with a short residence time for juveniles within bay and inlet nursery areas (two to three years when most fish are available for harvest), means that fisheries production and catch rates are naturally highly variable.[451]

In this report King George whiting is assessed for the Port Phillip Bay, Western Port, and Corner Inlet regions.

Southern sand flathead: southern sand flathead are distributed along the entire Victorian coast in coastal waters and in all bays and inlets. The most important fishery for this species is in Port Phillip Bay, with smaller fisheries in Western Port, Corner Inlet, and coastal waters. Most of the Victorian sand flathead catch is taken by recreational anglers, with only minor commercial harvesting.[452]

Black bream: black bream populations in the Gippsland Lakes, Lake Tyers, Mallacoota Inlet, the Hopkins and Glenelg Rivers, and other minor inlets and river estuaries are self-replenishing discrete stocks, with limited mixing among adjacent estuaries.[453]

Rock flathead: rock flathead is an important fish for the commercial fishery in Corner Inlet. Up until 2016, when the phasing out of netting began, the species was also important to the Port Phillip Bay commercial fishery. There are very small recreational catches in Port Phillip Bay and Corner Inlet.[454] Netting was completely banned from Corio Bay in 2018 and will be phased out in the rest of Port Phillip Bay in 2022.

Southern calamari: the population of southern calamari in Victorian waters is genetically similar and considered a single stock with phenotypic variation. Southern calamari live for less than one year and the main spawning period is spring and summer in inshore coastal regions with eggs laid in seagrass and reef algal habitats.[455]

Bluethroat and purple wrasse: wrasse are reef dwelling. The main spawning period is spring, and wrasse are territorial, inhabiting specific reefs. Victorian wrasse populations support mostly local port-based commercial fisheries and wrasse are harvested from inshore waters (that is, less than 30 m depth) year-round for the live fish restaurant market. There is also a small recreational fishery.[456]

Dusky flathead: dusky flathead are predominantly an estuarine species captured by commercial fishers in Gippsland Lakes and by recreational anglers in the estuaries of eastern Victoria. The relatively short lifespan for this species coupled with potentially high, albeit highly variable, fecundity (fertility) implies that environmental conditions will have the greatest influence over the stock recruitment.[457]

451. Ibid.
452. Ibid.
453. Ibid.
454. Ibid.
455. Ibid.
456. Ibid.
457. Hicks T, Kopf R and Humphries P 2015, 'Fecundity and egg quality of dusky flathead (*Platycephalus fuscus*) in East Gippsland, Victoria', Institute for Land Water and Society, Charles Sturt University, report no. 94, prepared for the recreational fishing grants program, Fisheries Victoria, Department of Economic Development, Jobs, Transport and Resources (DEDJTR), Melbourne, Victoria, pp. 1–34.

In addition to the data on spawning and catch rates, fisher satisfaction can be considered as a supplementary measure that provides indicative information to inform the abundance of fish species at a point in time. The theory of this is that higher satisfaction ratings from fishers are likely to be associated with more plentiful numbers of fish available to be caught. There are assumptions in this hypothesis, so for now its use is solely as indicative information on the sustainability of fish stocks, however it does provide useful insights and highlights the possibilities of combining social information to complement fish stock assessments. The prospect of a holistic assessment of the sustainability of recreational and commercial fishing that encompasses the sustainability of fish stocks and the satisfaction of anglers is a significant opportunity for the future. Initial analysis is provided within the regional indicator assessments of this indicator as well as the fishing indicators in the Communities chapter.

At a national level, research published during 2018 found that, regardless of a high global ranking for fisheries sustainability, catches from Australian wild fisheries decreased by 31% over the decade to 2018. The biomass of large fishes observed on underwater transects decreased significantly over the same period on fished reefs (36% decline) and in marine park zones that allow limited fishing (18% decline), but with a negligible overall change in no-fishing marine reserves. Populations of exploited fishes generally rose within marine reserves and declined outside the reserves, whereas unexploited species showed little difference in population trends within or outside reserves.[458]

Indicator 25: Subtidal reef fish

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	(north) (south)	(north) (south)		(north) (south)	(north) (south)	(north) (south)
Other marine protected areas						

Data source:	Parks Victoria, Reef Life Surveys, ReefWatch
Measures:	Parks Victoria control charts | The number of mobile macroinvertebrate species recorded on individual Reef Life Surveys (species per 50 m^2) | Fish species sightings and abundances

Why this indicator?

Reef fish are highly visible and colourful elements of subtidal reefs. They are key species in marine national parks and sanctuaries and are popular with divers and snorkellers. Monitored changes in their populations could indicate excessive harvesting, water pollution or climate change, and could alert agencies to the need for management action.

Reef fish are highly visible and colourful elements of subtidal reefs. They are key species in marine national parks and sanctuaries and are popular with divers and snorkellers. Monitored changes in their populations could indicate excessive harvesting, water pollution or climate change, and could alert agencies to the need for management action.

This indicator links closely to the Seagrass indicator in the Seafloor Integrity and Health theme.

458. Edgar G, Ward T, Stuart-Smith R 2018, 'Rapid declines across Australian fishery stocks indicate global sustainability targets will not be achieved without an expanded network of "no-fishing" reserves', *Aquatic Conservation: Marine and Freshwater Ecosystems*, 28, pp. 1337-1350.

Indicator 26: Diadromous fish

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		?			N/A	N/A

Data source:	Academic researchers, DELWP, Melbourne Water
Measures:	Ramsar site limits of acceptable change assessments for Australian grayling

Why this indicator?

Diadromous species are those that must undertake migrations between estuarine or marine and freshwater environments to complete their life cycle. Worldwide, many migratory fish species are threatened with extinction due to human activities.

Diadromous species are those that must undertake migrations between estuarine or marine and freshwater environments to complete their life cycle.[459] Worldwide, many migratory fish species are threatened with extinction due to human activities.[460] Diadromous species migrate between marine and estuarine or freshwater habitats as part of their life cycle, often over long distances (hundreds to thousands of km) at multiple life stages, which presents major risks to survival.[461] The spatial scale and diversity of marine, estuarine and freshwater habitats over which diadromous species migrate exacerbates anthropogenic stressors, which increases population vulnerability and raises significant challenges for conservation.[462] Among diadromous fishes, anguillid eels are particularly threatened, with 11 of the 19 species and subspecies listed as 'near threatened' or worse on the International Union for Conservation of Nature's Red List of Threatened Species.[463,464]

Diadromous fishes are a frequent but poorly understood component of coastal riverine fish communities in Australia. There are major information gaps about the lifecycles and ecology of many of these species, with information on facultative diadromy (that is, those that usually display a diadromous lifecycle but abandon it at times), navigation, marine and early life stages being particularly limited.[465] In many cases, this lack of information has led to poor management decisions and consequently many of the Australian diadromous species are under increasing threat from a range of environmental impacts.

459. Tonkin Z, Jones C, Clunie P, Vivian L, Amtstaetter F, Jones M, Koster W, Mole B, O'Connor J, Brooks J, Caffrey L and Lyon J 2020, 'Victorian environmental flows monitoring and assessment program stage 6 synthesis report 2016-2020', technical report series no. 316, Arthur Rylah Institute (ARI), Department of Environment, Land, Water and Planning (DELWP), Heidelberg, Victoria.
460. Koster W, Aarestrup K, Birnie-Gauvin K, Church B, Dawson D, Lyon J, O'Connor J, Righton D, Rose D, Westerberg H and Stuart I 2021, 'First tracking of the oceanic spawning migrations of Australasian short- finned eels (*Anguilla Australis*)', 22 June 2021, preprint (Version 1) available at Research Square https://doi.org/10.21203/rs.3.rs-622777/v1 Accessed 17 August 2021.
461. Limburg KE and Waldman JR 2009, 'Dramatic declines in North Atlantic diadromous fishes', *BioScience*, 59, pp. 955-965.
462. Lennox RJ, Paukert CP, Aarestrup K, Auger-Méthé M, Baumgartner L, Birnie-Gauvin K, Bøe K, Brink K, Brownscombe JW and Chen Y 2019, 'One hundred pressing questions on the future of global fish migration science, conservation, and policy', *Frontiers in Ecology and Evolution*, 7 https://doi.org/10.3389/fevo.2019.00286.
463. Koster W, Aarestrup K, Birnie-Gauvin K, Church B, Dawson D, Lyon J, O'Connor J, Righton D, Rose D, Westerberg H and Stuart I 2021, 'First tracking of the oceanic spawning migrations of Australasian short- finned eels (*Anguilla Australis*)', 22 June 2021, preprint (version 1) available at Research Square https://doi.org/10.21203/rs.3.rs-622777/v1 Accessed 17 August 2021.
464. International Union for Conservation of Nature (IUCN), 'The IUCN red list of threatened species' https://www.iucnredlist.org/ Accessed 14 July 2021.
465. Miles N, Walsh C, Butler G, Ueda H, West R 2013, 'Australian diadromous fishes – challenges and solutions for understanding migrations in the 21st century', *Marine and Freshwater Research*, 65, pp. 12-24 https://doi.org/10.1071/MF12340 Accessed 14 July 2020.

Seventy percent of fish species inhabiting coastal freshwater rivers of Victoria are diadromous, requiring movement between fresh and marine waters for part of their life cycle.[466] Current evidence suggests that flow can enhance both spawning and juvenile upstream migration.[467] As a result, Victorian seasonal watering plans for both the central and western regions include the provision of environmental water releases to attract diadromous fishes into rivers and to protect and increase native fish populations.[468]

To support this management action, it is important to understand the relationship between discharge and fish colonisation, and to evaluate the effectiveness of environmental flow releases in promoting migration from marine and estuarine habitats into coastal rivers. This can then allow waterway managers to refine the management of environmental flow delivery to provide better outcomes (for example, to optimise the timing, magnitude and duration of releases).[469]

There are two species of anguillid eels found in Victoria; the long-finned eel (*Anguilla reinhardtii*) and short-finned eel (*Anguilla australis*).[470] These eels are an important part of Victoria's biodiversity, supporting commercial and recreational fisheries and having significant cultural values to Traditional Owners. Adults of these eel species generally spend decades in freshwater habitats (for example, rivers and wetlands) feeding and growing before metamorphosing into silver eels. The silver eels migrate downstream, often during high river flows, and into the sea to spawn. During these oceanic spawning migrations, adult eels travel several thousand km to warm tropical waters. After spawning, the adults die and the newly hatched leaf shaped larvae (called *leptocephali*) commence a journey toward the coast, drifting on ocean currents and developing into glass eels before eventually entering rivers. The young eels, now known as elvers, migrate further upstream into freshwater, developing into yellow eels and eventually becoming adults. These adults will then return to the sea to spawn.[471]

Seabirds, shorebirds and waterbirds (Indicators 27-30)

Seabirds, shorebirds and waterbirds are the most visible elements of marine and coastal animal life. Albatrosses, pelicans, penguins, spoonbills, sandpipers, hooded plovers and other birds rely on healthy marine and coastal environments, some for feeding and others for breeding. Trends in their numbers and distribution can provide important data for agencies responsible for habitat management and species conservation.

Reduced bird numbers may indicate a change in the availability of prey species, perhaps due to fishing pressure, climate change or catchment-based water pollution. Declining populations may also suggest the loss or degradation of their habitat in Victoria or elsewhere. Conserving their habitat in Victoria can provide refuges for bird species suffering habitat loss in other parts of their range.

To support the conservation of threatened international migratory species that visit each year, Australia has signed a number of international agreements that it must uphold, while resident threatened birds are listed under various statutes that require species conservation measures.

This section reviews indicators for marine and coastal waterbirds, migratory shorebirds, piscivorous (fish-eating) birds and penguins.

466. Harris J 1984, 'Impoundment of coastal drainages of south-eastern Australia, and a review of its relevance to fish migrations', Australian Zoologist, 21, pp. 235-250.
467. Amtstaetter F, Yen J, Hale R, Koster W, O'Connor J, Stuart I, Tonkin Z 2021, 'Elevated river discharge enhances the immigration of juvenile catadromous and amphidromous fishes into temperate coastal rivers', *Journal of Fish Biology*, 99(1), pp. 61-72.
468. Victorian Environmental Water Holder 2016, 'Seasonal watering plan 2016-17', Melbourne, Victoria.
469. Department of Environment, Land, Water and Planning (DELWP) 2017, 'VEFMAP stage 6 part b: program design and monitoring methods', a report by Arthur Rylah Institute for Environmental Research (ARI) and Integrated Water and Catchments Division, Department of Environment, Land, Water and Planning (DELWP), Victoria.
470. Department of Environment, Land, Water and Planning (DELWP), 'Tracking eel migration using satellites' https://www.ari.vic.gov.au/research/field-techniques-and-monitoring/tracking-eel-migration-using-satellites Accessed 14 July 2021.
471. Ibid.

Indicator 27: Marine and coastal waterbirds

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	Fair	→	Fair	Unknown	?	Poor
Western Port	Fair	↙	Good	Fair	↙	Good
Corner Inlet-Nooramunga	Fair	→	Fair	Not applicable	N/A	N/A
Gippsland Lakes	Fair	?	Fair	Fair	Species-dependent	Good

Data source:	BirdLife Australia, academic researchers, DELWP, Melbourne Water
Measures:	Waterbird abundance | Breeding and diversity

Why this indicator?

Maintaining a robust set of time-series data on waterbird numbers can assist agencies in monitoring and management.

Waterbirds in Australia have very large (that is, often continental or international scale) distributions and so their presence and abundance at a particular location is influenced not only by conditions at the site, but of conditions elsewhere in their distributional range. For example, declines in international migratory shorebirds have been linked to the decline in habitat in staging areas, particularly in the Yellow Sea's tidal mudflats.[472,473] This loss of habitat is driven by land reclamation of tidal flats for industrial projects to support a growing population and economy.[474] There is also evidence of a decline in food resources through the harvesting of invertebrates for other purposes (for example, prawn farms); habitat degradation by pollution and impacts of hunting on shorebirds, particularly snipe.[475] There is already evidence of this having a measurable effect on waterbird abundance of several species in Australia.[476]

As summarised in the Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar Site management plan, there is growing evidence that disturbance of waterbirds by human activities (for example, walking, boating, vehicles) can have significant negative impacts on both feeding behaviour and habitat use.[477] Sea level rise is another stressor, with waders and beach nesting birds especially vulnerable to sea level rise and any loss in intertidal habitat (for example, mudflats and saltmarsh) would affect waterbird diversity and abundance.[478] This may include loss of intertidal feeding habitat and supratidal habitat needed for roosting and nesting.

Waterbird data from 2020 and 2021 will need to be assessed with respect to the coronavirus (COVID-19) pandemic. There were very few amateur bird sightings reported in 2020, which means that counts in that year and, likely, 2021 are highly likely to be lower due to fewer observations rather than a decline in actual bird numbers.

472. MacKinnon J, Verkuil Y, Murray N 2012, 'IUCN situation analysis on East and Southeast Asian intertidal habitats, with particular reference to the Yellow Sea (including the Bohai Sea)', International Union for Conservation of Nature (IUCN), occasional paper of the IUCN species survival commission no. 47, Gland, Switzerland and Cambridge.
473. Murray N, Ma Z, Fuller R 2015, 'Tidal flats of the Yellow Sea: a review of ecosystem status and anthropogenic threats', *Austral Ecology*, 40, pp. 472-481.
474. Yang H, Chen B, Barter M, Piersma T, Zhou C, Li F, Zheng W, 2011, 'Impacts of tidal land reclamation in Bohai Bay, China: ongoing losses of critical Yellow Sea waterbird staging and wintering sites', *Bird Conservation International*, pp. 241-259.
475. Melville D, Chen Y, Ma Z, 2016, 'Shorebirds along the Yellow Sea coast of China face an uncertain future - a review of threats', Emu, 116, pp. 100–110.
476. Clemens, R, Rogers D, Hansen B, Gosbell K, Minton C, Straw P, Bamford M, Woehler E, Milton D, Weston M, Venables B, Weller D, Hassell C, Rutherford B, Onton K, Herrod A, Studds C, Choi C, Dhanjal-Adams K, Murray N, Skilleter G and Fuller R 2016, 'Continental-scale decreases in shorebird populations in Australia', Emu, 116, pp. 199-135.
477. Department of Environment, Land, Water and Planning (DELWP) 2018, 'Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar site management plan', East Melbourne, Victoria.
478. Robinson R, Crick H, Learmonth J, Maclean I, Thomas C, Bairlein F, Forchhammer M, Francis C, Gill J, Godley B, Harwood J, Hays G, Huntley B, Hutson A, Pierce G, Rehfisch M, Sims D, Santos M, Sparks, T, Stroud D and Visser M 2009, 'Travelling through a warming world: climate change and migratory species', *Endangered Species Research*, 7(2), pp. 87–99.

Indicator 28: Migratory shorebirds

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay						
Western Port					N/A	N/A
Corner Inlet-Nooramunga						
Gippsland Lakes		?			N/A	N/A

Data source:	BirdLife Australia, academic researchers, DELWP, Melbourne Water
Measures:	Migratory shorebird abundance and breeding

Why this indicator?

Measuring trends in the distribution and abundance of migratory shorebirds can assist federal and state agencies and community organisations to protect habitats and minimise threats.

Migratory shorebirds visit Victoria each summer to feed on invertebrates on the mudflats in coastal and inland wetlands. Each year they travel from their breeding areas in the tundra regions of the northern hemisphere and back again along particular routes known as flyways. Along the way they stop at suitable wetlands to feed and build reserves of fat for the next stage of their journey.[479]

The conservation of wetlands which provide suitable habitat - for breeding along the migratory route, at their non-breeding summer destinations in Victoria and elsewhere - is critical to their survival and requires international cooperation.[480]

Shallow Inlet, Corner Inlet, Western Port, the western shoreline of Port Phillip Bay and the Bellarine Peninsula and Discovery Bay have been recognised for their importance to migratory shorebirds through listing as shorebird sites on the East Asian-Australasian Flyway Site Network.[481]

Migratory shorebirds have been severely affected by the loss of habitats along their international flyways particularly in the Yellow Sea's tidal mudflats. However, habitat loss has also occurred in Australia due to population growth, urbanisation and agricultural development.[482]

Measuring trends in the distribution and abundance of migratory shorebirds can assist federal and state agencies and community organisations to protect habitats and minimise threats.

479. Department of Environment, Land, Water and Planning (DELWP), 'Migratory shorebirds', East Melbourne, Victoria https://www.water.vic.gov.au/waterways-and-catchments/rivers-estuaries-and-waterways/wetlands/migratory-shorebirds Accessed 13 July 2020.
480. Ibid.
481. Ibid.
482. Commissioner for Environmental Sustainability (CES) 2018, 'Victorian State of the Environment 2018', Melbourne, Victoria.

Indicator 29: Piscivorous (fish-eating) birds

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay					N/A	N/A
Western Port						
Corner Inlet-Nooramunga						

Data source:	BirdLife Australia, academic researchers, DELWP, Melbourne Water
Measures:	Piscivorous bird abundance and diversity

Why this indicator?

Population numbers and trends in fish-eating birds can assist agencies in monitoring and management. It is important to understand the causes of changes in numbers of top-order predators such as piscivorous birds, as they could indicate fundamental changes in the ecology of the marine and coastal areas.

It is important to understand the causes of changes in numbers of top-order predators such as piscivorous birds, as they could indicate fundamental changes in the ecology of the marine and coastal areas. Management actions could then be devised and assessed to address such changes as appropriate.[483]

Indicator 30: Little penguins

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay						
Western Port						

Data source:	Earthcare St Kilda, Phillip Island Nature Parks
Measures:	Estimated population size | Number of unique penguins tracked | Number of chicks microchipped

Why this indicator?

The health of little penguin (*Eudyptula minor*) colonies in terms of numbers, breeding success and body weight can indicate trends in the general health of the marine environment. Little penguin colonies at Phillip Island and St Kilda have also become major tourist assets, with any decline in their health having potential economic impacts.

483. Menkhorst P, Loyn R, Liu C, Hansen B, Mackay M, Dann P 2015, 'Trends in numbers of piscivorous birds in Western Port and West Corner Inlet, Victoria, 1987–2012', Arthur Rylah Institute for Environmental Research (ARI), unpublished client report for Melbourne Water, Department of Environment, Land, Water and Planning (DELWP), Heidelberg, Victoria.

Indicator 31: Marine mammals

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	(dolphins)	(dolphins)	(dolphins)		N/A	N/A
Western Port	(dolphins and seals)	(dolphins) (seals)	(seals) (dolphins)		N/A	N/A
Gippsland Lakes	(dolphins)	(dolphins)	(dolphins)		N/A	N/A

Data source:	Dolphin Research Institute, Marine Mammal Foundation, Phillip Island Nature Parks, academic researchers
Measures:	Marine mammal population estimates

Why this indicator?

Victorian waters are home to a diversity of marine mammal species, including whales, dolphins and seals. DELWP states that twenty-five species of whales, two species of dolphin and six species of seals live or migrate through Victorian waters.

Victorian waters are home to a diversity of marine mammal species, including whales, dolphins and seals. DELWP states that twenty-five species of whales, two species of dolphin and six species of seals live or migrate through Victorian waters.[484]

Cetacean species (for example, whales and dolphins) are considered for assessment in this report based on the species being resident to an area or areas within Victorian state waters, temporarily residing in Victorian state waters for the purpose of calving or feeding or migrating through waters within 3 nautical miles of the coast (that is, within Victorian state waters). There are further constraints on this report, with the geographic regions focussed on Port Phillip Bay, Western Port, Corner Inlet and Nooramunga and the Gippsland Lakes.

Research published during 2011 highlighted the detection of a new species of dolphin, the burrunan dolphin (*Tursiops australis*), in Port Phillip Bay and the Gippsland Lakes. In accordance with the *Flora and Fauna Guarantee Act 1988* (FFG Act), DELWP keeps and publishes a list of threatened species. As at June 2021, the burrunan dolphin was listed as a critically endangered species.[485] However, its presence as a unique species is disputed, with the burrunan dolphin not accepted as a species by the International Community for Marine Taxonomy. A research study published during 2020, analysed 264 skulls of bottlenose dolphins from nine Australian museums and two European museums. A variety of statistical analyses concluded that, based on morphology, the burrunan dolphin (*Tursiops australis*) could not be separated from the common bottlenose dolphin (*Tursiops truncates*).[486] It is also not included in the International Union for Conservation of Nature's Red List of threatened species. It is the position of the Victorian Government that burrunan dolphins are currently listed as a critically endangered species in accordance the *Flora and Fauna Guarantee Act 1988*, therefore they are included in the narrative of this report.

484. Department of Environment, Land, Water and Planning (DELWP), 'Whales, dolphins and seals' https://www.wildlife.vic.gov.au/our-wildlife/whales,-dolphins-and-seals Accessed 30 July 2021.
485. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Flora and Fauna Guarantee Act 1988 - Threatened List June 2021', East Melbourne, Victoria.
486. Jedensjö M, Kemper C, Milella M, Willems E and Krützen M 2020, 'Taxonomy and distribution of bottlenose dolphins in Australian waters: an osteological clarification', *Canadian Journal of Zoology*, 98.

A large body of scientific literature is available for the Australian fur seal *(Arctocephalus pusillus doriferus)* in Victoria, including abundance, strandings, population trends, entanglement prevalence in marine plastic, toxicology and health status, foraging ecology and diet.[487,488,489] Fur seals are important upper trophic level predators that are a protected marine species in Australia. This species is an excellent indicator species for Bass Strait and Western Port. The health of Australian fur seal colonies in terms of numbers, pup production and disease, including toxicants in the environment, can indicate trends in the general health of the marine environment.[490]

The fur seal colony at Phillip Island, as well as those at Cape Bridgewater Chinaman's Hat, and Wilsons Promontory, have also become major tourist assets, with any decline in their health having potential economic impacts.[491]

This indicator also links with many other indicators and themes in this report including: Water quality (physicochemical), Toxicants, Illegal activities, Recreational and commercial fishing, Shipping and ports, Recreational boating and Litter and plastics.

Australian fur seal (*Arctocephalus pusillus doriferus*)
© Michael Sale

487. McIntosh RR, Kirkman SP, Thalmann S, Sutherland DR, Mitchell A, Arnould JPY, Salton M, Slip DJ, Dann P and Kirkwood R 2018, 'Understanding meta-population trends of the Australian fur seal, with insights for adaptive monitoring', *PLOS ONE*, 13(9), e0200253.
488. McIntosh RR, Sorrell KJ, Thalmann S, Mitchell T, Gray R, Schnagl H, Arnould JPY, Dann P and Kirkwood R (in review). Sustained reduction in numbers of Australian fur seal pups: implications for future population monitoring. *PLOS ONE*.
489. Kirkwood R, Pemberton D, Gales R, Hoskins AJ, Mitchell A, Shaughnessy PD and Arnould JPY 2010, 'Continued population recovery by Australian fur seals', *Marine and Freshwater Research*, 61, pp. 695-701.
490. McIntosh RR, Kirkman SP, Thalmann S, Sutherland DR, Mitchell A, Arnould JPY, Salton M, Slip DJ, Dann P and Kirkwood R 2018, 'Understanding meta-population trends of the Australian fur seal, with insights for adaptive monitoring', *PLOS ONE*, 13(9), e0200253.
491. Ibid.

Port Phillip Bay

PPB 15: Conservation of coastal ecosystems in protected areas

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The conservation of coastal ecosystems in protected areas within five km of Port Phillip Bay is encompassed within a broad analysis of the entire Victorian coastline in the statewide assessment for this indicator.		

PPB 16: Saltmarsh

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	●	→	●
Justification for assessment ratings:	While there have been significant losses of saltmarsh cover since European settlement, approximately half of the saltmarsh cover remains today. The Limit of Acceptable Change (LAC) for saltmarsh in the Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar Site is that total saltmarsh extent will not decline below 900 hectares. This is being met. Limited information on saltmarsh condition suggests most saltmarsh communities were healthy or near-stressed. The status of fair is based on a balance of the significant losses of saltmarsh cover since European settlement, with the LAC for saltmarsh being met in the Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar Site where more than half of the saltmarsh communities are not under significant stress. The confidence in the assessments is rated as moderate rather than high because the most recent assessments of saltmarsh extent and condition are from 2011.		

Research published in 2012 showed that about half of Port Phillip Bay's pre-1750s saltmarsh cover of 3,710 hectares remains today.[492] The losses are the result of Melbourne's growth, port development, conversion to evaporating ponds for saltworks, housing at Sanctuary Lakes and the creation of the Western Treatment Plant that significantly impacted the once extensive string of marshes that stretched between the Werribee River and Point Wilson. Only the RAAF Lake and The Spit (Point Wilson) remain as large, relatively intact marshes in this part of the Victorian coast.

The research described above was used to inform the Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar Site ecological character report that was published in December 2020.[493] The 2020 report stated that the greatest proportion of saltmarsh occurs in the Lake Connewarre complex (68%), with 26% occurring in the Werribee / Avalon and Point Wilson / Limeburners Bay complex, while Point Cooke and Mud Islands each support 3%. It should be noted that there are also extensive areas of coastal saltmarsh along the shoreline of Swan Bay.

The Limit of Acceptable Change (LAC) for saltmarsh in the Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar Site is that total saltmarsh extent will not decline below 900 hectares. The LAC for saltmarsh is being met with the most recent assessment finding 1,225 hectares of saltmarsh within the Ramsar site boundary.[494]

Condition of saltmarsh communities was assessed over four years 2008–11 at two locations within the Ramsar site, Mud Islands and The Spit (in the Werribee / Avalon portion of the Ramsar site).

492. Sinclair S and Boon P 2012, 'Changes in the area of coastal marsh in Victoria since the mid 19th century', *Cunninghamia*, 12 (2), pp. 153-176.
493. Hale J 2020, 'Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar site ecological character description, for catchments, waterways cities and towns', Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria.
494. Ibid.

Species richness was low at both locations, with nine species recorded, which is typical of saltmarsh communities. Saltmarsh communities were highly variable both spatially and temporally, but generally 60–70% of communities were assessed as healthy or near stressed at both locations.[495,496]

The Spit Nature Conservation Reserve and orange-bellied parrots

The extent of saltmarsh at The Spit Nature Conservation Reserve was identified as a relatively intact saltmarsh during the 2012 study. In 2019, the Port Phillip and Western Port CMA removed some barriers from a road culvert to improve the hydrology of the Reserve. This resulted in significant improvements to the saltmarsh vegetation and wildlife.[497] The reserve lies within the Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar Site and supports endangered species, threatened ecological communities and thousands of waterbirds. It also provides an important food source for fish and sustains a variety of species during critical stages in their lifecycles. For example, the orange-bellied parrot (*Neophema chrysogaster*) is endemic to south-eastern Australia, breeding in south-western Tasmania in a narrow section of coast. The birds then migrate to the coasts of Victoria and South Australia for the non-breeding period of April-October.[498]

As noted in the Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar Site ecological character description report, the most important sites for orange-bellied parrots in Victoria were considered to be along the coast between the Werribee River mouth and Point Wilson (including coastal parts of the Western Treatment Plant and The Spit Nature Conservation Reserve), the Lake Connewarre Complex and the western shore of Swan Island.[499]

While there have been changes in orange-bellied parrot populations at some Victorian sites due to saltmarsh decline and more widespread, temporary changes during the millennium drought; orange-bellied parrot numbers have likely declined due to factors in more than just the non-breeding habitat in Victoria. As an example, while many habitat areas recovered after the millennium drought, orange-bellied parrot numbers, and annual survival rates, did not improve. Factors that drove the decline were broader than mainland habitat condition and likely included lack of suitable aged feeding vegetation in the Tasmanian breeding range.[500]

In recent years the numbers of birds using habitat at The Spit has increased for two reasons:

1. DELWP and Zoos Victoria have released birds at the Western Treatment Plant in autumns of 2017, 2018, 2019, and at The Spit in 2018, 2019, 2020 and 2021. The Mainland Release Trial aims to release flocks of captive-bred birds at suitable sites with the hope they will attract, hold, and improve the survival of, naturally migrating birds. Natural migrants have joined released birds at The Spit in 2019, 2020 and 2021.
2. A combination of increased availability of suitable aged class feeding vegetation in the Tasmanian breeding range and large-scale releases of juvenile captive-bred birds in Tasmania prior to the northern migration during 2020 and 2021. These factors have likely led to record numbers of orange-bellied parrots flying north on migration; resulting in higher numbers being seen at some mainland sites; including The Spit.[501]

It is likely that the current habitat in Victoria is sufficient to cater for the approximate 50 orange-bellied parrot population that has persisted for the last decade or so. As population size grows however, the birds will expand their area of habitat use. This is already being observed and means there is a need to continue conserving and restoring habitats to allow this expansion and population growth to continue.[502]

495. Ibid.
496. Hale J 2011, 'Baywide monitoring program: Ramsar listed wetlands – monitoring of saltmarsh health and extent and intertidal mudflat extent (2008 to 2011)', Port of Melbourne Corporation, Melbourne, Australia.
497. Port Phillip and Westernport Catchment Management Authority (PPWCMA), 'Improving hydrology at The Spit Nature Conservation Reserve' 24 August 2021 https://www.ppwcma.vic.gov.au/improving-hydrology-at-the-spit-nature-conservation-reserve/ Accessed 15 November 2021.
498. Hale J 2020, 'Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar site ecological character description, for catchments, waterways cities and towns', Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria.
499. Ibid.
500. Natural Environment Program Officer, DELWP, personal communication, 19 July 2021.
501. Ibid.
502. Ibid.

A series of impediments to the natural hydrology of the area feeding the saltmarsh vegetation community were identified during 2020, with the impediments including a road easement through the conservation reserve that was linked to measurable restrictions of tidal movement entering and exiting the inland section of 60 hectares of saltmarsh.

In addition, changes to the natural waterway within the immediate catchment has diverted freshwater flows away from the saltmarsh. The cumulative impact of these changes resulted in a gradual decline in condition over many decades. A series of recommendations were made to reconnect these important threatened ecological communities and inform a restoration plan for the site.[503]

PPB 17: Mangroves

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	●	?	●
Justification for assessment ratings:	There are currently 52 hectares of mangroves in the Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar Site, which meets the Limit of Acceptable Change (LAC) for mangroves in the Ramsar site. This is reflected in a status of good. There is no pre-European settlement baseline data to compare this value against. Therefore, the trend is unclear. The confidence in the assessments is rated as moderate rather than high because the most recent assessments of mangrove extent and condition are from 2011.		

Within the Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar Site there are around 52 hectares of mangrove shrubland in the Barwon Estuary within the Lake Connewarre Complex.[504] Mangrove shrubland occurs adjacent to the Ramsar site in Limeburners Bay and at Point Cooke.

Research published in 2012 was not able to establish a historic baseline of mangrove extent in Port Phillip Bay.[505]

The Limit of Acceptable Change (LAC) for mangroves in the Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar Site is that total mangrove extent will not decline below 40 hectares. The LAC for saltmarsh is being met with the most recent assessment finding 52 hectares of saltmarsh within the Ramsar site boundary.[506]

The mangrove community at Jawbone Marine Sanctuary has been noted as very unusual because it grows on the sediment amongst massive basalt boulders rather than on intertidal mudflats, which is unique for Victoria.[507] The nearby Merrett rifle range shore platform, with its quaternary volcanics, intertidal reef, shell deposits and mangroves is of regional geological significance. There is an area of mangrove and saltmarsh habitat at the eastern end of the sanctuary near Kororoit Creek fronted by wide sand flats.[508]

503. Port Phillip and Westernport Catchment Management Authority (PPWCMA), 'Improving hydrology at The Spit Nature Conservation Reserve' 24 August 2021 https://www.ppwcma.vic.gov.au/improving-hydrology-at-the-spit-nature-conservation-reserve/ Accessed 15 November 2021.
504. Boon P, Allen R, Carr G, Frood D, Harty C, McMahon A, Mathews S, Rosengren N, Sinclair S, White M and Yugovic J 2011, 'Mangroves and coastal saltmarsh of Victoria: distribution, condition, threats and management', Institute for Sustainability and Innovation, Victoria University, Melbourne, Victoria.
505. Sinclair S and Boon P 2012, 'Changes in the area of coastal marsh in Victoria since the mid 19th century', *Cunninghamia*, 12(2), pp. 153-176.
506. Hale J 2020, 'Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar site ecological character description, for catchments, waterways cities and towns', Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria.
507. Plummer A, Morris L, Blake S, Ball D, 2003, 'Marine natural values study, Victorian marine national parks and sanctuaries', Parks Victoria technical series no. 1, Melbourne, Victoria.
508. Barton J, Pope A, Howe S, 2012, 'Marine natural values study vol 2: marine protected areas of the Victorian embayments bioregion, part 1 Port Phillip Bay', Parks Victoria technical series no. 77, Melbourne, Victoria.

PPB 18: Wetland and estuarine vegetation

Region	2021 status	2021 trend	2021 data
Port Phillip Bay		?	
Justification for assessment ratings:	Through the 2021 Index of Estuary Condition (IEC) assessments, there is high confidence in the status assessment for estuarine flora in this indicator. As part of the IEC, flora assessments for 9 of the 11 estuaries in the Port Phillip catchment region were completed, with two estuaries receiving ratings of good for flora, five estuaries rated as fair and two estuaries rated as poor.		

Freshwater vegetation

Freshwater wetland vegetation is a critical component of the ecological character of the Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar Site within parts of the Lake Connewarre complex (mainly Reedy Lake) and at the lagoons and wetlands of the Western Treatment Plant.[509]

The Limit of Acceptable Change (LAC) for freshwater vegetation in the Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar Site is that a habitat mosaic will be maintained at Reedy Lake that comprises open water, emergent native vegetation (for example, sedges, rushes and reeds) and lignum shrubland with no habitat comprising more than 70% of the total wetland area for more than five successive years.[510]

DELWP has advised that the most recent LAC assessment took place in 2019 and the LAC was met. The 2019 assessment incorporated research from 2014 that indicated the freshwater aquatic vegetation breakdown was:

- 63% emergent vegetation (sedges and reeds)
- 21% open water
- 12% lignum shrubland
- 4% other communities.[511]

More recent assessments, that did not include mapping, indicate that the habitat mosaic remains and there have been improvements in some vegetation communities.[512]

Fringing vegetation

A pilot study conducted during 2018 tested a method to report on fringing vegetation as part of the Index of Estuary Condition (IEC). The pilot study identified three distinct indicators that allow managers and planners to rapidly understand which issues are affecting each estuary and consider land management interventions accordingly. For example, the pilot study clearly showed that the fringing vegetation on Anglesea estuary has been damaged and restricted by prior building works, but that the remaining vegetation is relatively free from weeds and retains its expected structure.[513]

Estuarine flora

Table 16 shows the IEC flora results for estuaries in the Port Phillip Catchment Region.[514] Two estuaries received ratings of good for flora, five estuaries were rated as fair and two estuaries were rated as poor, while two estuaries were not assessed. As this is the first IEC, and IECs are designed to be point-in-time assessments, no time series data are available to assess trends.

509. Hale J 2020, 'Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar site ecological character description, for catchments, waterways cities and towns', Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria.
510. Ibid.
511. Ecological Associates 2014, 'Reedy Lake vegetation monitoring final report', Ecological Associates report BX010-2-B prepared for Corangamite Catchment Management Authority (CCMA), Colac.
512. Papas, P, Downe J, Osler D 2020, 'WetMAP observations and results for Reedy Lake (February 2020 update)' Arthur Rylah Institute for Environmental Research (ARI), Department of Environment, Land, Water and Planning (DELWP), Heidelberg, Victoria.
513. Sinclair S and Kohout M 2018, 'Assessment of fringing vegetation for the index of estuary condition', Arthur Rylah Institute for Environmental Research (ARI), technical report series no. 290, Department of Environment, Land, Water and Planning (DELWP), Heidelberg, Victoria.

Table 16: IEC results for estuarine flora within the Port Phillip catchment region; range 1 – 10 (1 poorest condition, 10 best condition).[515]

Estuary	Flora	Condition Class
Little River	6	Fair
Werribee River	5	Poor
Skeleton River	9	Good
Laverton Creek	6	Fair
Kororoit Creek	6	Fair
Yarra River	7	Fair
Elwood Canal	NA	
Mordialloc Creek	4	Poor
Patterson River	NA	
Kananook Creek	8	Good
Balcombe Creek	7	Fair

NA = not assessed.

PPB 19: Species of conservation concern

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	●	?	●
Justification for assessment ratings:	The data analysed and reported for this indicator provide information on the number of species of conservation concern. The status and trend assessments are unknown and unclear, respectively, because no information is available to ascertain how these species are being tracked and managed, and no trend data are available to assess how these species are tracking over time.		

Publicly accessible data from the Victorian Biodiversity Atlas has been analysed to determine the presence of threatened and vulnerable marine and coastal species within Port Phillip Bay.

Within the Victorian Biodiversity Atlas there are 2,589 fauna species and 1,686 flora species that are mapped to be within the two marine biounits in Port Phillip Bay. Of these, there are 77 fauna species and 15 flora species that are denoted by the atlas as being listed within the FFG Act, listed as endangered, threatened or vulnerable within the Environment Protection and Biodiversity Conservation Act 1999, or included as on DELWP's advisory list as endangered, threatened, vulnerable or poorly known. Given that recent amendments to the FFG Act have removed duplication by establishing a single comprehensive list of threatened flora and fauna species and revoking Advisory Lists,[516] any updates to the Victorian Biodiversity Atlas attribute fields will be incorporated in future State of the Marine and Coastal Environment reports.

Of the combined 92 species of conservation concern that are listed within the Victorian Biodiversity Atlas, 56 (61%) have records within the past 20 years.

There is a lack of published analysis and time series data available to assess how these species are tracking over time and this will be an area of focus for future State of the Marine and Coastal Environment reports.

514. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Index of estuary condition', East Melbourne, Victoria.
515. Ibid.
516. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Threatened list and processes list' East Melbourne, Victoria https://www.environment.vic.gov.au/conserving-threatened-species/threatened-list Accessed 17 August 2021.

PPB 20: Mobile invertebrates on intertidal reefs

Region	2021 status	2021 trend	2021 data
Port Phillip Bay			
Justification for assessment ratings:	The status assessment of good is based on the available information provided as part of Parks Victoria's long-term Intertidal Reef Monitoring Program. No reports have been published since 2014, with the only subsequent information contributing to this status assessment being draft control charts from 2018. Due to the lack of recent evidence, the confidence in the status and trend assessments is low. Parks Victoria is progressing monitoring and assessment with a technical report in preparation for the Port Phillip Heads Marine National Park, which is likely to address knowledge gaps and increase the confidence in this indicator assessment in future State of the Marine and Coastal Environment reports.		

As part of Parks Victoria's long-term Intertidal Reef Monitoring Program (IRMP), information was collected at Victoria's Marine Protected Areas on the status of Victorian intertidal reef flora and fauna, as well as the nature and magnitude of trends in species populations and species diversity through time.[517]

Within Port Phillip Bay, intertidal survey sites were established by Parks Victoria on reefs in the northern Port Phillip Bay marine sanctuaries at Point Cooke, Jawbone and Ricketts Point. Reference sites were also surveyed in association with each of these sanctuaries. An intertidal survey site and reference site was also established at Port Phillip Heads Marine National Park. The IRMP used standardised visual census methods for surveying invertebrates on intertidal reefs.[518]

Intertidal reefs in PPB generally have a lower, and less variable, richness and diversity of mobile invertebrate species than sites along the open coastline.[519] As reported in the Victorian State of the Environment 2018 Report, Parks Victoria draft control charts assessed the condition of mobile invertebrates in marine national parks, including Port Phillip Heads Marine National Park, as good.[520]

Port Phillip Heads Marine National Park

The intertidal reef surveyed for the Port Phillip Heads Marine National Park was located at Point Lonsdale, on the western side of Port Phillip Heads. As reported by Parks Victoria in 2014, the mobile invertebrate communities at Point Lonsdale and the reference site at Cheviot Bay were similar for most surveys. The slit limpet (*Montfortula rugosa*) and false limpet (*Siphonaria spp.*) were prevalent at both sites. Other limpets (*Cellana tramoserica, Patelloida alticostata and Notoacmea spp.*) were also common. There was a remarkable similarity of temporal changes at both sites but there was a relatively large shift in community structure to 2014, corresponding in a spike in abundance of *Cellana tramoserica*.[521]

The *Bembicium nanum* (conniwink) density was consistently higher at Point Lonsdale compared with Cheviot Bay until 2010, after which there was a downward trend to densities similar to Cheviot Bay.[522] The mean density of the limpet *Cellana tramoserica* at Point Lonsdale decreased from 15 to less than one individual per 0.25 m^2 in 2013, however there was a marked spike in abundance in 2014. Cheviot Bay generally had lower abundances of *Cellana tramoserica*.[523]

Montfortula rugosa was the most abundant mobile invertebrate species at both sites and densities were considerably variable between surveys with no apparent longer-term trends. The mean length of the limpet *Cellana tramoserica* was relatively stable at both Point Lonsdale and Cheviot Bay with similar mean lengths at both sites for the past few years.[524]

517. Edmunds M, Woods B and Donnelly D 2014, 'Intertidal reef monitoring program: central Victoria marine protected areas March 2014', Parks Victoria technical series no. 97, Melbourne, Victoria.
518. Ibid.
519. Edmunds M, Stewart K, Pritchard K and Zavalas R 2010, 'Victorian intertidal reef monitoring program: the reef biota of central Victoria's marine protected areas. Volume 3', Parks Victoria technical series no. 61, Melbourne, Victoria.
520. Commissioner for Environmental Sustainability (CES) 2018, 'Victorian State of the Environment 2018', Melbourne, Victoria.
521. Edmunds M, Woods B and Donnelly D 2014, 'Intertidal reef monitoring program: central Victoria marine protected areas March 2014', Parks Victoria technical series no. 97, Melbourne, Victoria.
522. Ibid.
523. Ibid.
524. Ibid.

Parks Victoria has advised that a technical report focussing on Port Phillip Heads Marine National Park is currently in preparation. Preliminary analysis supplied to the Commissioner for Environmental Sustainability shows that research has been focused on using unmanned aerial vehicles to assess algal cover, specifically *Hormosira bankssi*. The focus on algal cover links to this indicator on mobile invertebrates as *Hormosira bankssi* is a keystone habitat forming species

Point Cooke Marine Sanctuary

As reported by Parks Victoria in 2014, mobile invertebrates appeared consistently lower in density at Point Cooke Marine Sanctuary than the reference site at Altona. Most mobile invertebrates occurred in greater abundance in the lower areas of the shore.[525]

The mobile invertebrate community at Point Cooke was dominated by herbivorous gastropods, particularly *Austrocochlea porcata* (zebra top snail) and *Bembicium melanostoma* (conniwink). The reference site was at Altona where commonly found species were also *Austrocochlea porcata* and *Bembicium melanostoma*.[526]

Austrocochlea porcata was the most abundant invertebrate at both sites, generally occurring in highest densities at Altona. There was a peak in abundances from 2009 to 2011 before a decline in subsequent years to 2014.[527]

Turbo undulatus (warrener) was recorded in low densities on the low shore at Point Cooke in most surveys but has only been intermittently recorded in low densities at Altona.[528]

The carnivorous gastropods *Cominella lineolata* (spotted cominella) and *Lepsiella vinosa* occurred at low densities at both Altona and Point Cooke.[529]

The limpet *Cellana tramoserica* was rarely present at Point Cooke throughout the survey period and was consistently present at Altona in low abundances.[530]

A slight declining trend in mean size of *Austrocochlea porcata* was apparent for Point Cooke and Altona, while the mean size of *Cellana tramoserica* was relatively constant at both sites, apart from a dip at Altona in 2010.[531]

Jawbone Marine Sanctuary

As reported by Parks Victoria in 2014, the mobile invertebrate population structure at Jawbone Marine Sanctuary was dominated by the zebra top shell *Austrocochlea porcata*, conniwinks *Bembicium melanostoma*, the black nerite *Nerita atramentosa* and the variegated limpet *Cellana tramoserica*. At the reference site at Williamstown, the dominant invertebrates were the herbivorous gastropods *Bembicium spp,* and *Austrocochlea porcata*.[532]

The density of *Austrocochlea porcata* was largely stable at Jawbone until 2011, with a subsequent spike in 2012 followed by lower abundances in 2013. The Williamstown reference site had a peak in abundance from 2009 to 2011.[533]

Cellana tramoserica had persistently low densities at Williamstown. At Jawbone, densities had a declining trend from 2004 to 2009, with a spike and subsequent decline from 2010.[534]

The mean size of *Austrocochlea porcata* was slightly lower and more variable at Jawbone than Williamstown, however there was no trend apparent at either site. The mean size of *Cellana tramoserica* was very similar between Jawbone and Williamstown and there was little change between 2004 and 2012. In 2013 and 2014, there was a considerably higher mean size within the Jawbone Marine Sanctuary and a corresponding decrease at the Williamstown reference site.[535]

Ricketts Point Marine Sanctuary

As reported by Parks Victoria in 2014, at Ricketts Point Marine Sanctuary the limpet *Cellana tramoserica* was consistently very low in abundance and densities were consistently higher at the reference site at Halfmoon Bay.[536]

525. Ibid.
526. Ibid.
527. Ibid.
528. Ibid.
529. Ibid.
530. Ibid.
531. Ibid.
532. Ibid.
533. Ibid.
534. Ibid.
535. Ibid.
536. Ibid.

The gastropod *Austrocochlea porcata* was the most abundant mobile invertebrate at Ricketts Point, while a trend of slightly decreasing abundance was apparent at the Half Moon Bay reference site.[537]

The mean size of both *Cellana tramoserica* and *Austrocochlea porcata* had distinct periodic dips at both sites, at approximately four-year time cycles.[538]

Anemones, such as *Aulactinia veratra* and *Actinia tenebrosa*, and the seastars *Tosia australis*, *Meridiastra calcar* and *Coscinasterias muricata* were present at Half Moon Bay in small rock pools on the seaward edge of the intertidal reef.[539]

PPB 21: Sessile invertebrates on intertidal reefs

Region	2021 status	2021 trend	2021 data
Port Phillip Bay			
Justification for assessment ratings:	The status assessment of good is based on the available information provided as part of Parks Victoria's long-term Intertidal Reef Monitoring Program. No reports have been published since 2014, with the only subsequent information contributing to this status assessment being draft control charts from 2018. Due to the lack of recent evidence, the confidence in the status and trend assessments is low. Parks Victoria is progressing monitoring and assessment with a technical report in preparation for the Port Phillip Heads Marine National Park, which is likely to address knowledge gaps and increase the confidence in this indicator assessment in future State of the Marine and Coastal Environment reports.		

As part of Parks Victoria's long-term Intertidal Reef Monitoring Program (IRMP), information is collected at Victoria's Marine Protected Areas on the status of Victorian intertidal reef flora and fauna, as well as the nature and magnitude of trends in species populations and species diversity through time.[540]

Within Port Phillip Bay, intertidal survey sites were established on reefs in the northern Port Phillip Bay marine sanctuaries at Point Cooke, Jawbone and Ricketts Point. Reference sites were also surveyed in association with each of these sanctuaries. An intertidal survey site and reference site was also established at Port Phillip Heads Marine National Park. The IRMP uses standardised visual census methods for surveying invertebrates on intertidal reefs.[541]

As reported in the Victorian State of the Environment 2018 Report, Parks Victoria has prepared draft control charts for several marine national parks and sanctuaries to track changes in indicators of key natural values and impacts of threats. Sessile invertebrates are a key ecological attribute on intertidal reefs in 12 parks, with their condition assessed as good in Port Phillip Heads Marine National Park. As reported in the State of the Environment 2018 Report, there is no available data for intertidal reefs outside the boundaries of protected areas.[542]

Port Phillip Heads Marine National Park

As reported by Parks Victoria in 2012, habitat forming sessile invertebrates include the tube worm *Galeolaria caespitosa* and two species of mussels: the beaked *Austromytilus rostratus* and the flea *Limnoperna pulex*, which occur in low abundances on the intertidal reef.[543] Other sessile invertebrates include four species of barnacles: *Chamaesipho tasmanica, Chthamalus antennatus, Tesseropora rosea* and *Tetraclitella purpurascens*, the ascidian *Pyura stolonifera*, and three anemones: *Aulactinia veratra, Actinia tenebrosa* and *Oulactis muscosa*.

537. Ibid.
538. Ibid.
539. Ibid.
540. Ibid.
541. Ibid.
542. Commissioner for Environmental Sustainability (CES) 2018, 'Victorian State of the Environment 2018', Melbourne, Victoria.
543. Barton J, Pope A, Howe S, 2012, 'Marine natural values study vol 2: marine protected areas of the Victorian embayments bioregion, part 1 Port Phillip Bay', Parks Victoria technical series no. 77, Melbourne, Victoria.

The intertidal reef surveyed for the Port Phillip Heads Marine National Park was located at Point Lonsdale, on the western side of Port Phillip Heads. In 2014, Parks Victoria reported that the sessile species community structure was very similar at Point Lonsdale and the reference site at Cheviot Bay, while sessile species diversity remained low and stable at both sites, which was noted to be most likely due to the dominance of the brown alga *Hormosira banksii*.[544]

Point Cooke Marine Sanctuary

As reported by Parks Victoria in 2012, aggregating sessile invertebrates are not dominant. Strong southerly winds often cause large amounts of subtidal drift algae to be washed onto the intertidal reef. At times wrack can smother intertidal flora and fauna and create anoxic (that is, oxygen depleted) conditions in rock pools causing die off. Despite aggregating sessile invertebrates not significantly contributing to the structure of the reef, there are small patches of *Galeolaria caespitosa* and the blue mussel *Mytilis edulis* low on the shoreline. The anemones, red waratah *Actinia tenebrosa*, green *Aulactinia veratra*, sand *Oulactis muscosa* and white-striped *Anthothoe albocincta* are also found on the intertidal reef.[545]

Jawbone Marine Sanctuary

The abundance of macroalgae and sessile invertebrates is very low at Jawbone Marine Sanctuary and, as at 2010, covered less than 5% of the reef.[546]

As reported by Parks Victoria in 2014, the algal cover differs significantly between Jawbone Marine Sanctuary and the reference site at Williamstown and this drives a difference in sessile invertebrate community structures. The Jawbone assemblage consisted of predominantly green algae *Ulva spp* and algal turf, while the cover at Williamstown was mostly the brown alga Neptune's Necklace *Hormosira banksii*. The calcareous tubeworm *Galeolaria caespitosa* is a prominent sessile invertebrate in Jawbone.[547]

Sessile species richness had a generally increasing trend for both sites over the monitoring period, but Williamstown had a marked decline from 2012 to 2014. Sessile species diversity was relatively stable for Williamstown, while within the Jawbone Marine Sanctuary there was a trend of increasing diversity since 2010.[548]

Ricketts Point Marine Sanctuary

As reported by Parks Victoria in 2012, within Ricketts Point Marine Sanctuary, small patches of the calcareous tubeworm *Galeolaria caespitosa* are present, occurring in higher abundance low on the shore. The eastern shore barnacle *Chthamalus antennatus* is also present in low abundances, as are the little black horse mussel *Limnoperna pulex* (also known as flea mussel) and red waratah anemone *Actinia tenebrosa*.

544. Edmunds M, Woods B and Donnelly D 2014, 'Intertidal reef monitoring program: Central Victoria marine protected areas March 2014', Parks Victoria technical series no. 97, Melbourne, Victoria.
545. Barton J, Pope A, Howe S, 2012, 'Marine natural values study vol 2: marine protected areas of the Victorian embayments bioregion, part 1 Port Phillip Bay', Parks Victoria technical series no. 77, Melbourne, Victoria.
546. Edmunds M, Stewart K, Pritchard K and Zavalas R 2010, 'Victorian intertidal reef monitoring program: the reef biota of central Victoria's marine protected areas. Volume 3', Parks Victoria technical series no. 61, Melbourne, Victoria.
547. Edmunds M, Woods B and Donnelly D 2014, 'Intertidal reef monitoring program: Central Victoria marine protected areas March 2014', Parks Victoria technical series no. 97, Melbourne, Victoria.
548. Ibid.

PPB 22: Invertebrates on subtidal reefs

Region	2021 status	2021 trend	2021 data
Port Phillip Bay		(north) (south)	
Justification for assessment ratings:	The status assessment of fair is based on the available information provided as part of Parks Victoria's long-term Subtidal Reef Monitoring Program and the, more recent, Reef Life Survey data. The Reef Life Survey data shows the trend over the past decade is an increasing number of species in the Port Phillip Bay's north, with fluctuations in the south but a generally stable underlying trend.		

The subtidal reef biota (for example, macroalgae, invertebrates and fish) for a number of marine national parks and sanctuaries (and reference sites outside) were surveyed between 2011 and 2013, with the results compared with earlier surveys and published in Parks Victoria's Technical Report Series.

For the three marine sanctuaries in the north of Port Phillip Bay – Point Cooke, Jawbone and Ricketts Point – blacklip abalone at Point Cook had been replaced by short-spined sea urchins, which had also become dominant at Jawbone and were heavily grazing Ricketts Point. However, invertebrate species richness and diversity were stable at Ricketts Point, and the total abundance of species increased significantly at Jawbone, driven by increased urchin numbers.

The Reef Ecosystem Evaluation Framework (REEF) evaluation survey determined that species' community assemblages and the ecosystem health of reefs vary regionally within Port Phillip Bay. Generally, northern and western reefs are considered to have diminished quality.[549] Megafaunal invertebrates are diverse in the north of the bay, in part due to the additional nutrients from the Western Treatment Plant, Yarra River and Kororoit Creek inflows.[550]

The last survey of native seastars at Port Phillip Heads revealed some seastar communities were diseased with necrosis. Across Victoria, native seastar numbers have fallen over the past decade, with very low numbers recorded for the past seven years.[551] Greenlip abalone are recovering in terms of abundance and size – both in marine protected areas and at reference sites outside these areas.[552]

Parks Victoria control charts rated the health of megafaunal invertebrates as good in the Port Phillip Heads Marine National Park in the south of the bay, while in the north the ratings were unknown in Point Cook and Jawbone and fair in Ricketts Point.

In addition to Parks Victoria's subtidal monitoring program, Reef Life Survey volunteers have been conducting surveys in Australian Marine Parks since 2009. For some locations, these are the only ecological surveys that have ever been done. Reef Life Survey is a unique collaboration of professional scientists working alongside citizen volunteers, with Reef Life Survey divers using a standard method to identify invertebrates.[553]

Reef Life Survey data shows there are more species of invertebrates in the north of Port Phillip Bay compared to the south. The trend over the past decade shows an increasing number of species in the north, with fluctuations in the south but a generally stable underlying trend. The trend could be related to the trend in fish species in the subtidal reef fish indicator, with fish often being predators of invertebrates. There are more fish species in the southern Port Phillip Bay, and hence more predators eating the invertebrates.

549. Johnson C, Swearer S, Ling S, Reeves S, Kriegisch N, Treml E, Ford J, Fobert E, Black K, Weston K, and Sherman C 2015, 'The Reef Ecosystem Evaluation Framework (REEF): managing resilience in temperate environments', Melbourne, Victoria, pp. 1-39.
550. Commissioner for Environmental Sustainability (CES) 2016, 'State of the Bays 2016', Melbourne, Victoria.
551. Ibid.
552. Edmunds M, Stewart K and Pritchard K 2010, 'Victorian subtidal reef monitoring program: the reef biota at Port Phillip Heads marine national park', Volume 4, Parks Victoria technical series no. 63, Melbourne, Victoria.
553. Reef Life Survey, 'About RLS' https://reeflifesurvey.com/about-rls/ Accessed 25 July 2021.

The three most frequently recorded invertebrates in the Reef Life Survey data for Port Phillip Bay were the biscuit seastar, the purple urchin and the blacklip abalone. There has been a big increase in the purple urchin's abundance during the past decade that has coincided with a decrease in biscuit seastars. This is possibly due to the urchins outcompeting the seastars. The urchins are noted as aggressive herbivores that eat lots of kelp – also a food source for biscuit seastars. An increasing abundance of urchins also means less room for other species. The story is slightly different in the south of Port Phillip Bay where, in addition to the fish predation, there is more kelp and the movement of the kelp is enough to discourage or dislodge urchins, while the extra wave energy can also knock the urchins around. Over the whole of the bay, kelp is declining, which is concerning because these underwater forests are a key habitat and food source for many creatures.

Figure 26: Number of mobile macroinvertebrate species recorded on individual surveys (species per 50 m²) in Port Phillip Bay and completed as part of the Reef Life Survey program.[554]

554. Reef Life Survey, 'Reef life explorer' https://reeflifesurvey.com/explorer/map Accessed 19 May 2021.

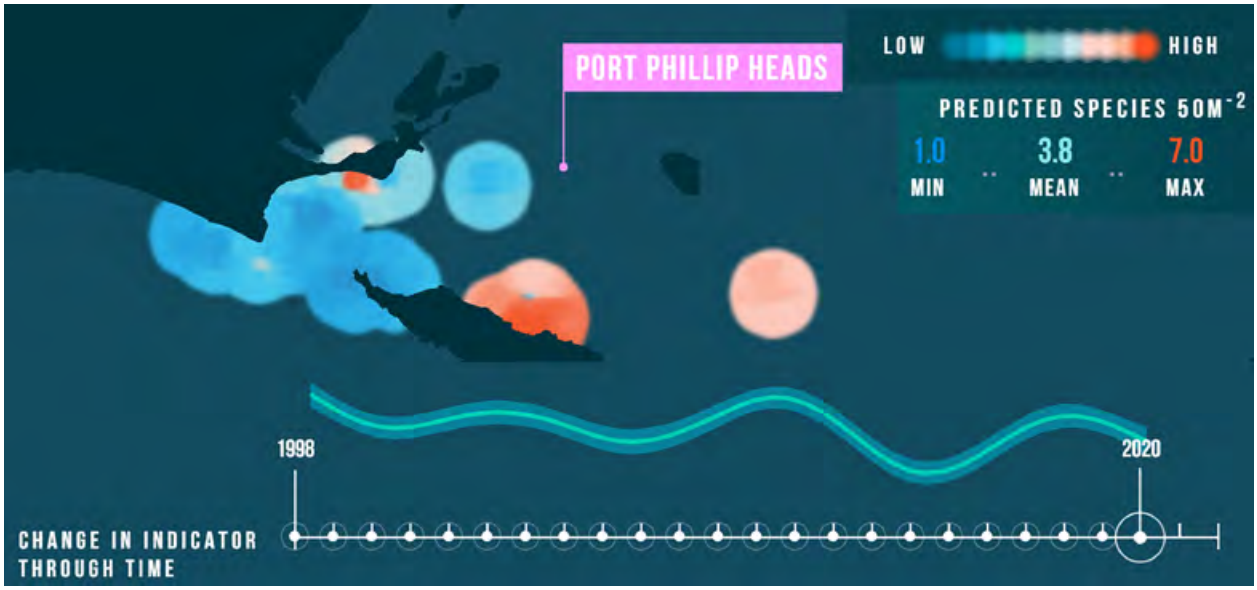


Figure 27: Number of mobile macroinvertebrate species recorded on individual surveys (species per 50 m²) in Port Phillip Heads and completed as part of the Reef Life Survey program.[555]

PPB 23: Commercially and recreationally important invertebrates

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	(commercial scallop, short-spined sea urchin)	(commercial scallop, short-spined sea urchin)	(commercial scallop, short-spined sea urchin)
Justification for assessment ratings:	**Commercial Scallop:** As time progresses it will become apparent how the natural variation in scallop abundance impacts the dive fishery, but at present, given the very minimal landings of commercial scallops, it is highly unlikely that the Port Phillip Bay commercial scallop dive fishery is causing recruitment impairment and the stock can be considered as sustainable. The term sustainable is used in accordance with the Status of Australian Fish Stocks classification, which translates to a good status and stable trend for this report. **Short-spined sea urchin:** There is no information to suggest that the stock is in any danger of depletion. Based on the available evidence, the short spined sea urchin stock in Port Phillip Bay is sustainable in accordance with the Status of Australian Fish Stocks terminology, which translates to a good status and stable trend for this report.		

Commercial Scallop

Commercial scallop abundance naturally fluctuates by several orders of magnitude, which means the short time-series of data for Port Phillip Bay needs to be interpreted with caution. Fishing commenced in the Port Phillip Bay commercial scallop dive fishery in 2014, the year after the single exclusive license was issued. Fishing effort then increased gradually, reaching a maximum in 2016 and 2017 before decreasing slightly during 2018. Catch has followed a similar trend, increasing from 2014 through to highs in 2016 and 2017, but it decreased substantially in 2018.[556] A commercial scallop fishery also operated in Port Phillip Bay until 1997 when it was closed to commercial operators.[557]

555. Ibid.
556. Victorian Fisheries Authority (VFA) 2020, 'Review of key Victorian fish stocks — 2019'.
557. Victorian Fisheries Authority (VFA), 'Scallop' https://vfa.vic.gov.au/commercial-fishing/commercial-fisheries/scallop Accessed 17 August 2021.

Given the natural variability in commercial scallop abundance, the decrease in Catch Per Unit of Effort (CPUE) observed in 2018 is not necessarily a sign of overfishing. In fact, overfishing is unlikely given the landings (less than 60 tonnes) were a small fraction of the estimated total abundance (greater than 11,000 tonnes in 2015). As a result, it is likely that the decrease in CPUE observed in 2018 is largely due to naturally lower scallop abundance, which has resulted in a decrease in fishing effort as fishers are receiving lower returns for their effort. As time progresses it will become apparent how the natural variation in scallop abundance impacts the dive fishery, but at present, given the very minimal landings of commercial scallops, it is highly unlikely that the Port Phillip Bay commercial scallop dive fishery is causing recruitment impairment and the stock can be considered as sustainable.[558]

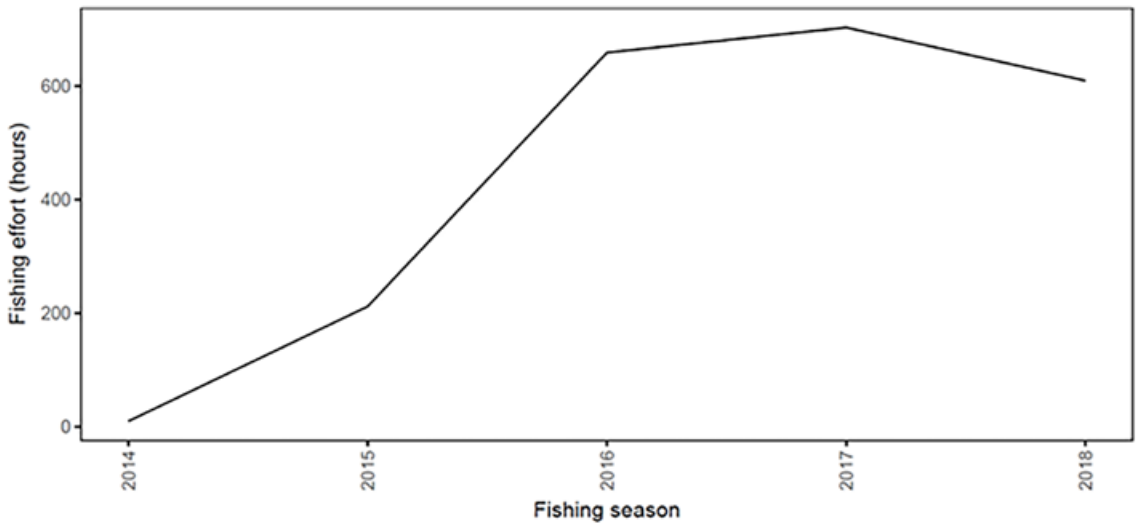


Figure 28: Annual fishing effort in the Port Phillip Bay commercial scallop dive fishery (2014–2018 fishing seasons).[559]

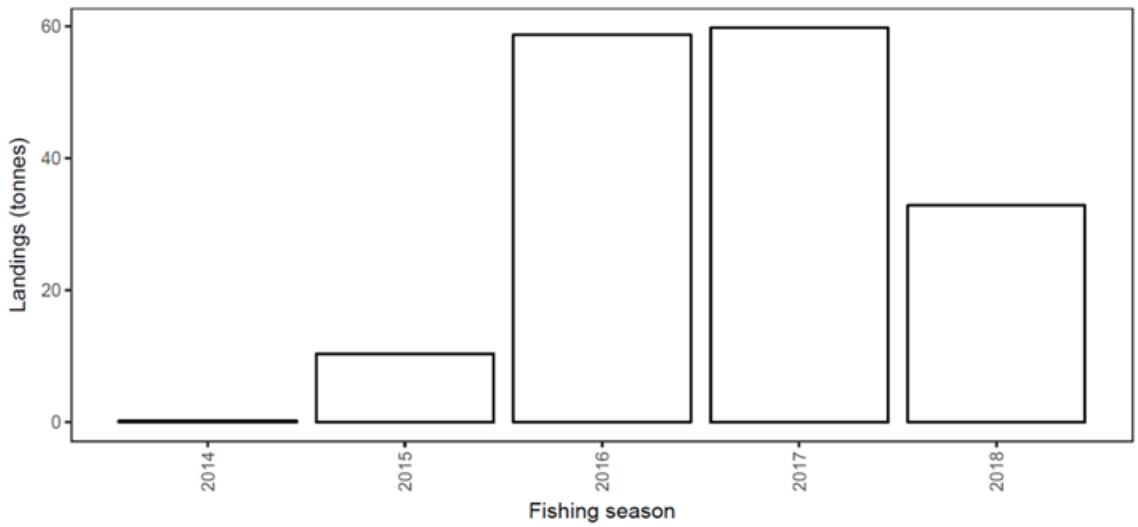


Figure 29: Annual landings of commercial scallops from the Port Phillip Bay commercial scallop dive fishery (2014–2018 fishing seasons).[560]

558. Victorian Fisheries Authority (VFA) 2020, 'Review of key Victorian fish stocks — 2019'.
559. Ibid.
560. Ibid.

Short-spined sea urchin

Catch, effort and CPUE remain relatively stable within this fishery. Landings were consistent at between 20 and 30 tonnes for the three years 2017, before halving during 2018. Effort has remained more stable during this period with a slight decrease in 2018.[561]

The VFA reports that conversations with industry suggest market demand and/or price are the primary factors dictating the amount of fishing effort and hence catch. Interpretation of CPUE is complicated by the fact that this species is very abundant, but only a proportion of the stock is of acceptable quality for processing. As such, it is possible that the fishery could reach maximum production (that is, catch as many urchins with marketable roe as is financially viable) without posing a risk to the stock as a whole. There is no information to suggest that the stock is in any danger of depletion. Based on the available evidence, the short spined sea urchin stock in Port Phillip Bay is sustainable.[562]

PPB 24: Commercially and recreationally important fish

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	(snapper, King George whiting) (southern sand flathead)	(King George whiting) (snapper, southern sand flathead)	(snapper, King George whiting) (southern sand flathead)
Justification for assessment ratings:	**Snapper:** The recreational fishery for adult snapper in Port Phillip Bay is considered sustainable at its current level, appearing to have stabilised since 2014. Commercial fishing pressure has reduced substantially in recent years, while record snapper spawning in the region during 2018 is likely to result in a snapper population boom in Port Phillip Bay during 2022 and 2023. **Southern sand flathead:** The evidence suggests that the stock has now stabilised at a lower biomass under a lower recruitment regime, and recruitment has been sufficient to balance natural and fishing mortality at this lower level. **King George whiting:** The recent strong post-larval recruitment is expected to drive a strong increase in catch per unit of effort over the next few years so the stock should remain sustainable.		

Three key species of fish that can tell us a lot about the state of Port Phillip Bay are:

- King George whiting
- snapper
- sand flathead.

These species indicate the health of fish in the bay more generally, as well as other processes (for example, seagrass health and snapper as an important predator). Information on juvenile fishes of the three indicator species can help predict the size and sustainability of the fish population in the future. The health and numbers of juvenile fishes of each species is linked to changes in environmental condition, habitat and adult breeding.

561. Ibid.
562. Ibid.

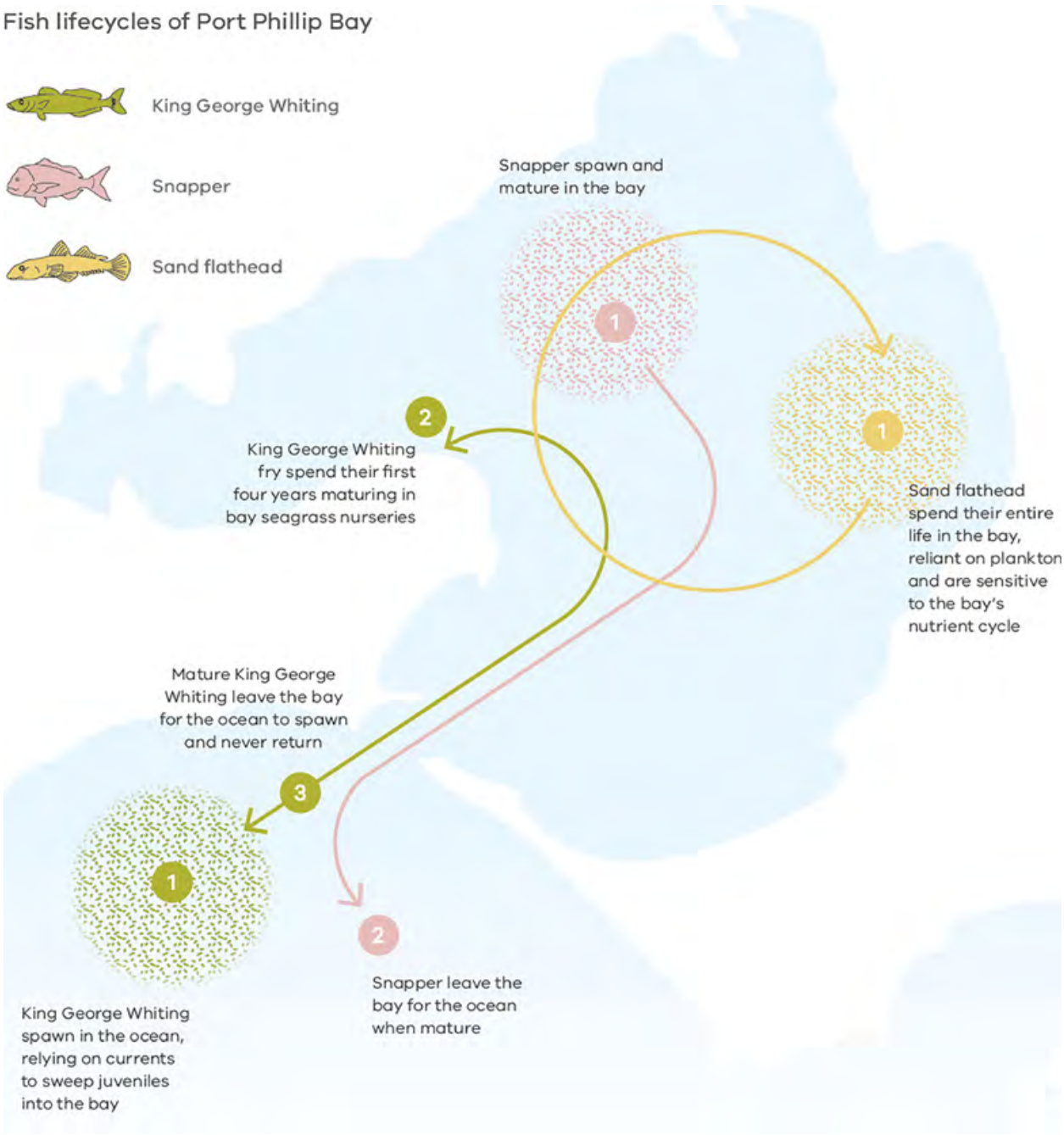


Figure 30: Fish life cycles in Port Phillip Bay.[563]

Snapper

The recreational fishery for adult snapper in Port Phillip Bay is considered sustainable at its current level, appearing to have stabilised since 2014.

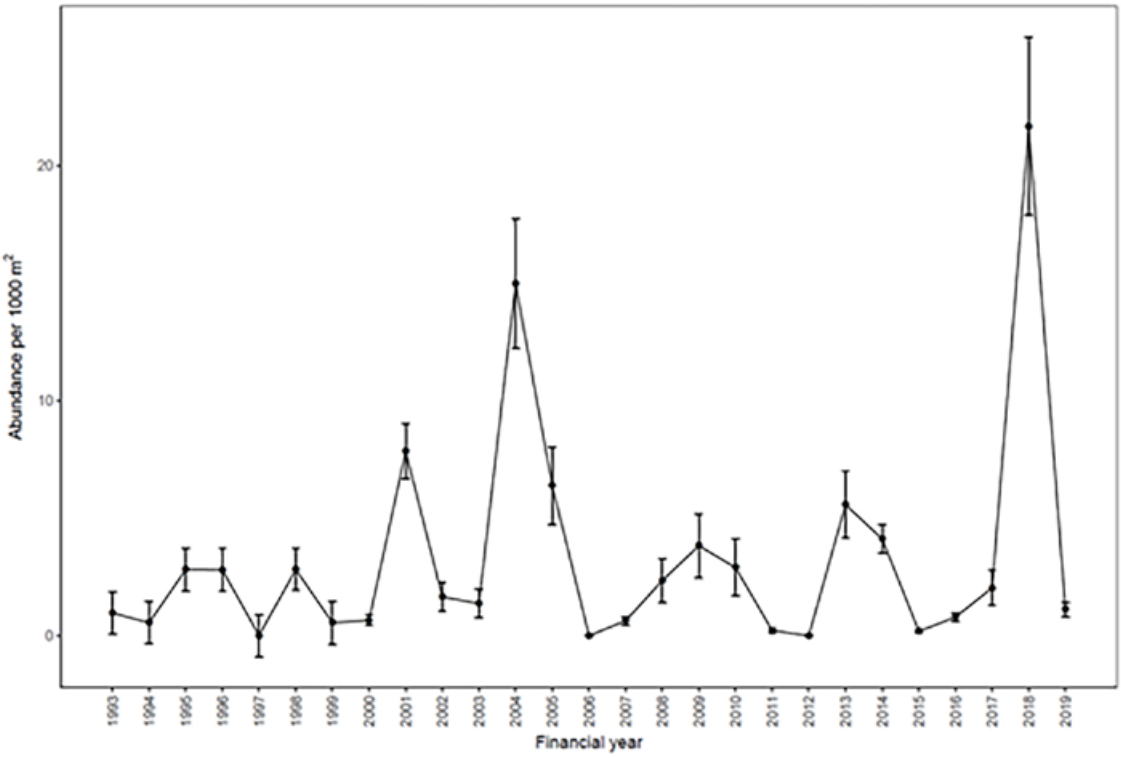
The abundance of snapper in Port Phillip Bay is closely linked with the snapper spawning. It generally takes four to five years for an increase in snapper spawning to result in more snapper in Port Phillip Bay. In 2018, trawl surveys detected a record pre-recruit (0+ age) abundance of snapper. This record recruitment is likely to result in a snapper population boom in Port Phillip Bay during 2022 and 2023.[564] The status is currently rated as fair and likely to improve to good by the next State of the Marine and Coastal Environment Report, due in 2024.

563. Commissioner for Environmental Sustainability (CES) 2016, 'State of the Bays 2016', designed by Greg Harbour https://stateofthebays.vic.gov.au/sotb/chapter/fish
564. Victorian Fisheries Authority (VFA) 2020, 'Review of key Victorian fish stocks — 2019'.

Standardised CPUE of adult snapper by the commercial and recreational anglers decreased from the late 2000s to the early 2010s in Port Phillip Bay. The decrease in the recreational catch rate in Port Phillip Bay was rapid from 2013 to 2014 but has since stabilised between the minimum and average values recorded since measurement commenced in 1977.[565]

Commercial fishing pressure has reduced substantially in recent years due to the Port Phillip Bay buy-outs. Figure 31 shows the snapper harvest from commercial operators during 2018 dropped to its lowest value this century in 2018, following a sharp decline since 2011.

There are few long-term trends in the size of snapper caught, however the median length for the October-December period has been lower since 2014 for the Port Phillip Bay recreational fishery. This is most likely due to lower numbers of larger fish being caught since 2013 by the surveyed anglers.

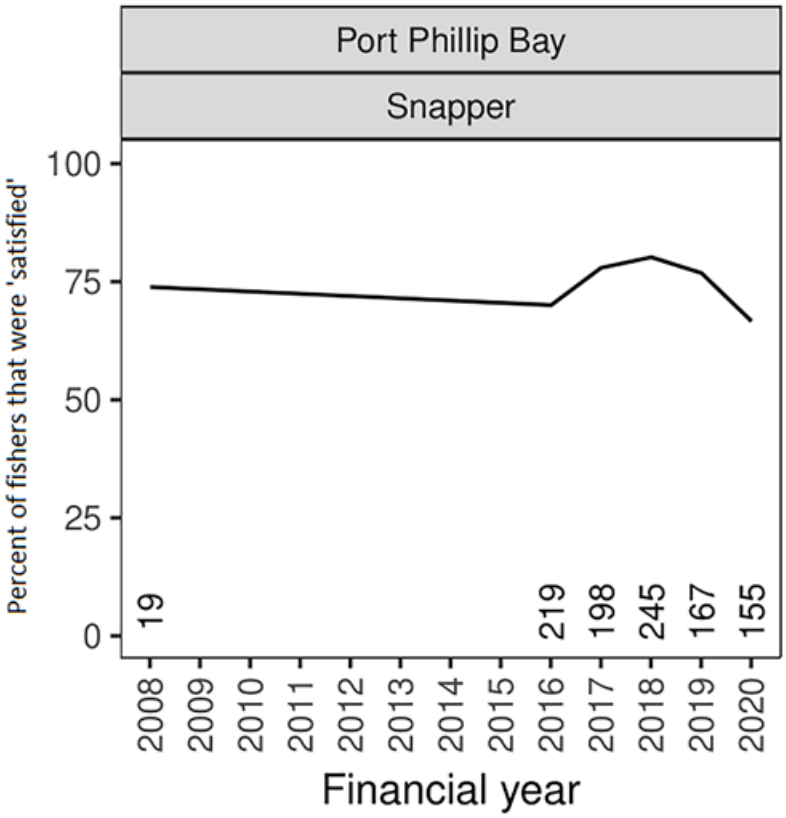


Note: SE can only be calculated from 2000 onwards, data prior is based on extrapolation of beam trawl to earlier otter trawl data using a regression relationship from 11 years when the otter trawl and beam trawl surveys overlapped.

Figure 31: Port Phillip Bay snapper pre-recruit (0+ age) trawl survey catch rates (± standard error) 1993–2019.[566]

In addition to the data on snapper spawning and catch rates, fisher satisfaction can be considered as a supplementary measure that provides indicative information to inform the abundance of fish species at a point in time. The theory of this is that higher satisfaction ratings from fishers are likely to be associated with more plentiful numbers of fish available to be caught. During the five years from 2016 to 2020, each year between 65% and 80% of surveyed fishers that were targeting snapper in Port Phillip Bay reported being satisfied with their fishing experience. This is indicative of there being suitable snapper abundance to ensure most anglers have been enjoying a positive fishing experience.

565. Ibid.
566. Ibid.



The numbers above the x-axis represent the number of survey respondents.

Figure 32: Percent of fishers targeting snapper in Port Phillip Bay that were satisfied with their fishing experience.[567]

King George whiting

The stock status for King George whiting is directly related to juvenile life stages and is highly variable given it is primarily influenced by recruitment dynamics.

Commercial harvests have dropped considerably since 2016 in Port Phillip Bay and are now at their lowest levels since records began in 1978. This has been mostly driven by a reduction in netting effort due to commercial licence buy-outs.[568]

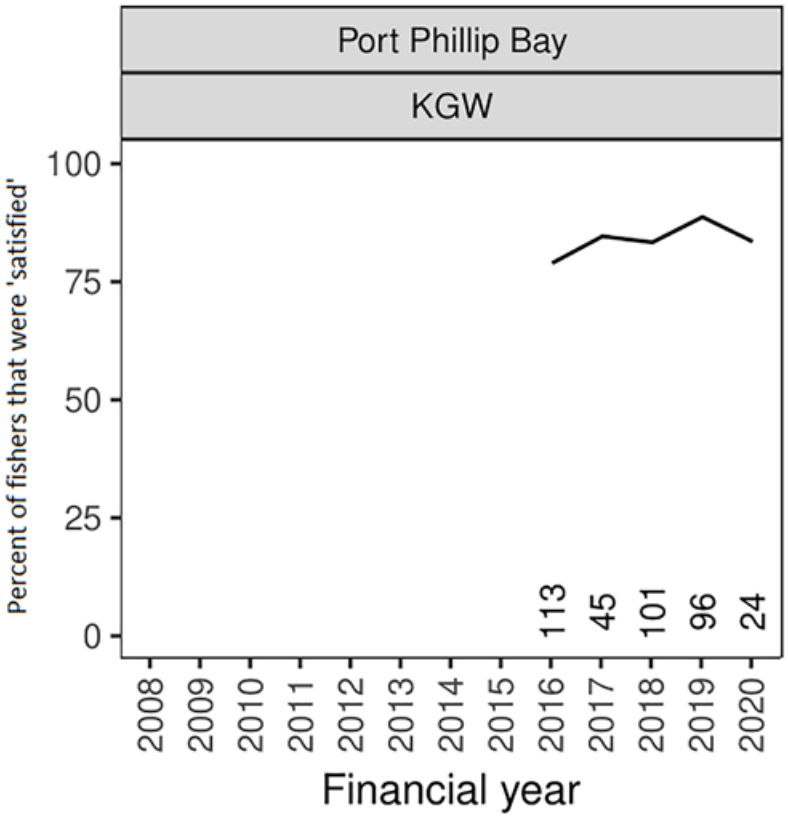
Data for both commercial and recreational fishers shows an approximate doubling of CPUE since the last significant dips, which occurred in 2013 for commercial fishers and 2012 for recreational fishers.[569]

Recruitment of post-larval King George whiting to Port Phillip Bay was relatively strong for the three years to 2019. This is a good sign for other Victorian bays and inlets as the Port Phillip Bay survey data are generally indicative of post-larval recruitment to other Victorian bays and inlets. These three cohorts will drive increased availability and catch rates for bay and inlet fisheries over the next three years. The recent strong post-larval recruitment is expected to drive a strong increase in CPUE over the next few years so the stock should remain sustainable.[570] The status is currently rated as fair and likely to improve to good by the next State of the Marine and Coastal Environment Report, due in 2024.

567. Image supplied by the Victorian Fisheries Authority (VFA).
568. Victorian Fisheries Authority (VFA) 2020, 'Review of key Victorian fish stocks — 2019'.
569. Ibid.
570. Ibid.

In addition to the data on King George whiting spawning and catch rates, fisher satisfaction can be considered as a supplementary measure that provides indicative information to inform the abundance of fish species at a point in time. The theory of this is that higher satisfaction ratings from fishers are likely to be associated with more plentiful numbers of fish available to be caught.

During the five years from 2016 to 2020, each year more than 75% of surveyed fishers that were targeting King George whiting in Port Phillip Bay reported being satisfied with their fishing experience. This is indicative of there being suitable King George whiting abundance to ensure most anglers have been enjoying a positive fishing experience.



The numbers above the x-axis represent the number of survey respondents.

Figure 33: Percent of fishers targeting King George whiting in Port Phillip Bay that were satisfied with their fishing experience.[571]

Southern sand flathead

There is currently negligible commercial fishing pressure on southern sand flathead in Port Phillip Bay with virtually all the commercial catch being taken from Bass Strait during the past two years. Changes in, or the current status of, recreational fishing pressure are less certain.

There are two stories to be told about southern sand flathead in Port Phillip Bay. One story is a clear decline in the southern sand flathead population that has since stabilised, while the other story is less certain and relates to the classification of this stock.

571. Image supplied by the Victorian Fisheries Authority (VFA).

The southern sand flathead population has been stable over the last decade but at lower levels of abundance than during the 1990s. This deterioration seems to be well established and the decline in abundance is a result of prolonged low recruitment since 2000, which was partly driven by a drier climate at the time of the millennium drought.

The key debate is whether the southern sand flathead stock should be classified as recovering or depleted. It was previously classified as environmentally limited in the Status of Australian Fish Stocks 2016 and in VFA's 2017 Review of Key Victorian Fish Stocks report. That category has since been removed from the classification options, which leaves the decision of whether to classify southern sand flathead as recovering or depleted.

Recovering stocks are those with depleted biomass and impaired recruitment but management measures are in place to promote stock recovery, and there is evidence that recovery is occurring. Depleted stocks have biomass that has been reduced to that extent that average recruitment levels are significantly reduced and current management is not adequately recovering the stock.

In the context of southern sand flathead in Port Phillip Bay, it seems the clauses relating to depleted biomass are applicable because recruitment levels since 2000 have been much lower, driving the biomass declines observed from the early 2000s to 2010. It appears that the stock has now stabilised at a lower biomass under this lower recruitment regime, and recruitment has been sufficient to balance natural and fishing mortality at this lower level. The contention exists on whether current management is promoting stock recovery. It is unclear whether that is the case.

Further illustrating this uncertainty, VFA hosted a workshop of fisheries managers and scientists in 2017 to evaluate the evidence and reach a consensus on the exploitation status for each stock. Most of the 2017 workshop participants classified the Port Phillip Bay sand flathead stock as overfished based on the presented information. In response to this the VFA engaged an inter-agency working group to investigate replicating freshwater flows that have historically triggered recruitment of sand flathead. A secondary project examined the feasibility of stocking sand flathead into Port Phillip Bay to rebuild populations.

There are recent signs of slow recovery in recreational catch rates, however, due to a lack of recent strong recruitment events, any ongoing recovery in stock biomass is expected to remain slow.

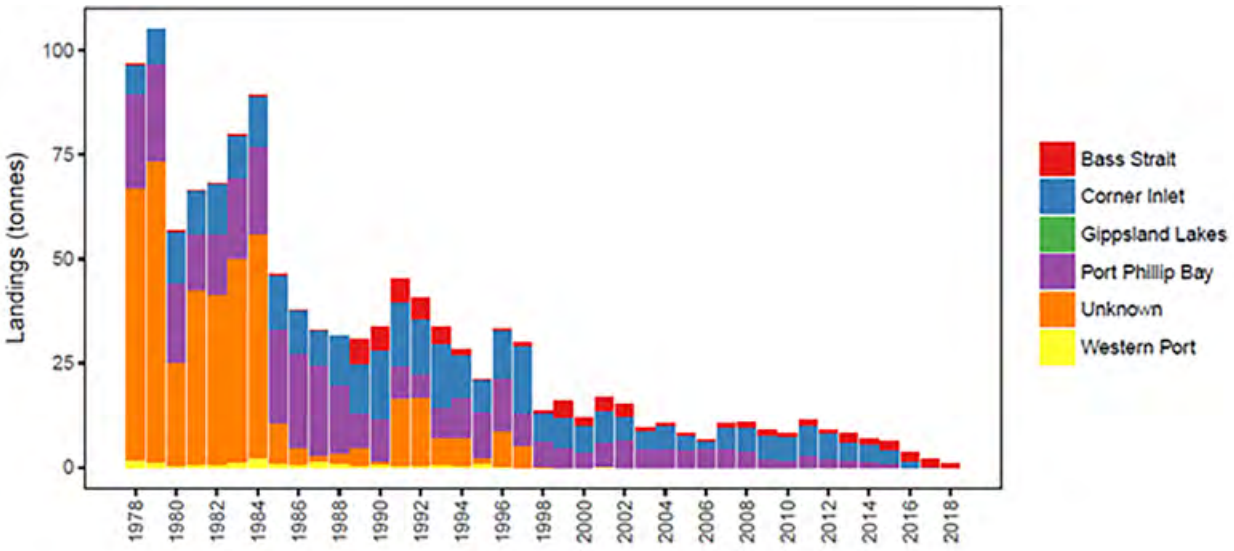
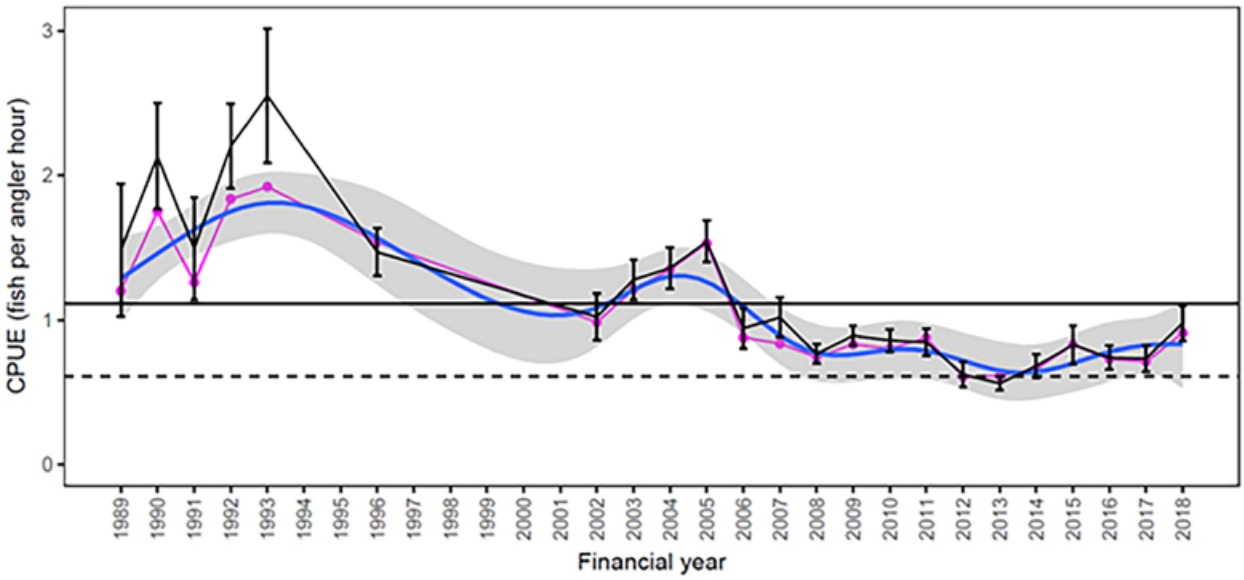


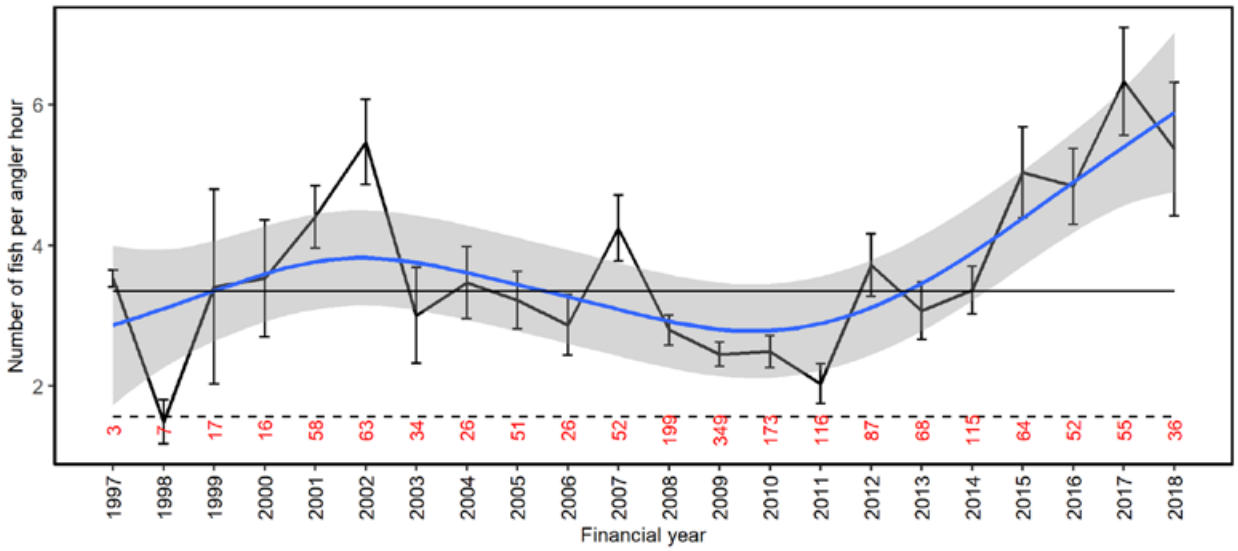
Figure 34: Southern sand flathead commercial catches in Victorian waters by financial year 1978–2018.[572]

572. Victorian Fisheries Authority (VFA) 2020, 'Review of key Victorian fish stocks — 2019'.



Black line is nominal CPUE (±SE), magenta line is standardised CPUE, blue line is a Generalised Additive Model (GAM) of the standardised CPUE trend with the shaded grey area representing the 95% confidence interval of the GAM. Horizontal black line is the mean standardised CPUE during the reference period (i.e. all years up to and including 2015) and the dashed black line is the minimum standardised CPUE within the reference period. Note: Catch rates were standardised prior to 2009 when the size limit was increased from 25 to 27 cms using the proportion of fish >27 cms in the catches of fishers interviewed during creel surveys in earlier years.

Figure 35: Catch-per-unit-effort of southern sand flathead by recreational anglers interviewed in creel surveys undertaken in Port Phillip Bay during 1989–2018 financial years.[573]

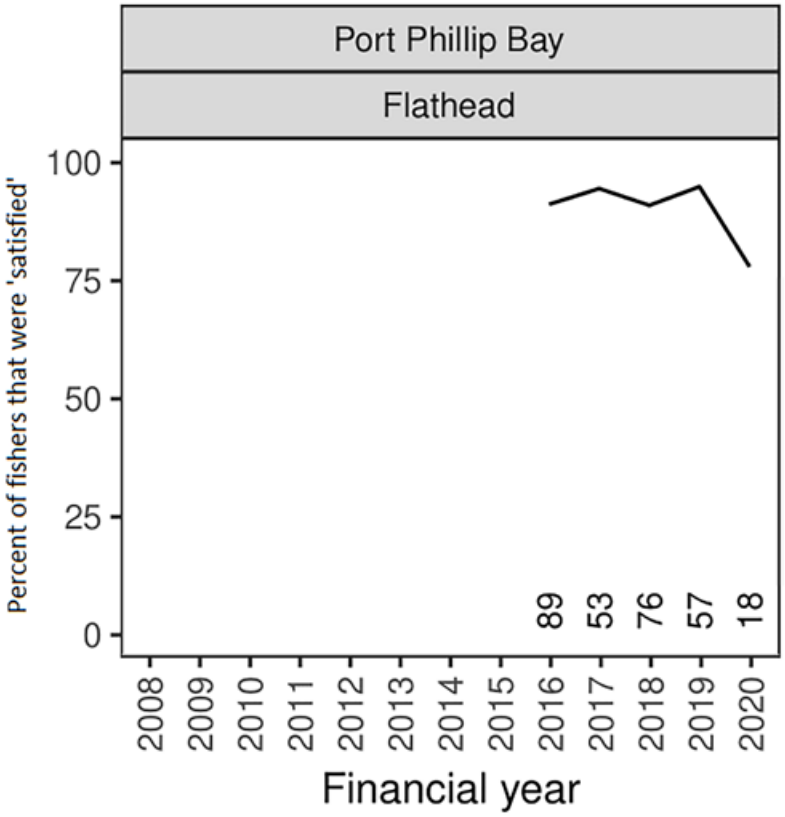


Blue line is a Generalised Additive Model (GAM) of the standardised CPUE trend with the shaded grey area representing the 95% confidence interval of the GAM. Horizontal black line is the mean CPUE during the reference period (1997–2015) and the dashed black line is the minimum CPUE within the reference period.

Figure 36: Nominal catch-per-unit-effort (± standard error) (black line) for diary angler targeted flathead trips, all sizes, in Port Phillip Bay during 1997–2018.[574]

573. Ibid.
574. Ibid.

In addition to the data on flathead spawning and catch rates, fisher satisfaction can be considered as a supplementary measure that provides indicative information to inform the abundance of fish species at a point in time. The theory of this is that higher satisfaction ratings from fishers are likely to be associated with more plentiful numbers of fish available to be caught. During the five years from 2016 to 2020, each year more than 75% of surveyed fishers that were targeting flathead[575] in Port Phillip Bay reported being satisfied with their fishing experience. This is indicative of there being suitable flathead abundance to ensure most anglers have been enjoying a positive fishing experience. There was a downward shift in satisfaction during 2020 that should be tracked in future years, however the decreasing satisfaction coincided with a small sample size of survey respondents – possibly due to restrictions associated with coronavirus (COVID-19) – indicating the results are less reliable.



The numbers above the x-axis represent the number of survey respondents.

Figure 37: Percent of fishers targeting flathead in Port Phillip Bay that were satisfied with their fishing experience.[576]

575. Note that this data includes other species of flathead, such as yank flathead and rock flathead, so the interpretation should be treated in caution.
576. Image supplied by the Victorian Fisheries Authority (VFA).

Indicator 25: Subtidal reef fish

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	(north) (south)	(north) (south)	
Justification for assessment ratings:	The data show a pattern of fewer fish species in the north of the Bay and more in the south, particularly around the entrance to the Bay. During the past decade, there has been a decline in the number of fish species in the north and a slight increase in the number of species in southern Port Phillip Bay.		

Significant increases in diversity and changes in faunal composition of fish assemblages on shallow rocky reefs in Port Phillip Bay were observed during a 17-year assessment that spanned 1992 to 2009. This analysis provided evidence of long-term changes in faunal composition and diversity within the bay.[577] The highest fish diversity was found on the bay's east coast reefs with significant changes within fish assemblages, including increased abundance of the southern hulafish (*Trachinops caudimaculatus*), zebra fish (*Girella zebra*) and scalyfin (*Parma victoriae*), which was possibly due to improved environmental conditions.

As reported in the Victorian State of the Environment 2018 Report, data from Parks Victoria's long-term Subtidal Reef Monitoring Program, two rounds of Reef Life Survey monitoring data at The Heads and several years of surveys in the three marine sanctuaries in the bay's north have been integrated with Parks Victoria's control charts and provide a good dataset for the bay's reef fish.

The sanctuaries generally had a low number of fish species and abundance with no consistent trends, with the southern hulafish (*Trachinops caudimaculatus*) dominating the fish assemblages. In southern Port Phillip Bay, the health of reef fish communities was rated as good. Reflecting the improving health of the ecosystem there, western blue groper numbers, which used to be abundant, were increasing at Nepean Bay and Point Lonsdale, and were reported at nearby South Channel Fort, as well as Barwon Bluff and Beware Reef marine sanctuaries along the open coast. In the bay's northern sanctuaries, the health of reef fish communities was rated as unknown in Jawbone and fair in Point Cooke and Ricketts Point in the State of the Bays 2016 Report.[578]

In addition to Parks Victoria's subtidal monitoring program, Reef Life Survey volunteers have been conducting surveys in Australian marine parks since 2009. For some locations, these are the only ecological surveys that have ever been done. Reef Life Survey is a unique collaboration of professional scientists working alongside citizen volunteers, with Reef Life Survey divers using a standard method to identify fish.[579]

Reef Life Survey data shows a pattern of fewer fish species in the north of the Bay and more in the south, particularly around the entrance to the Bay. The greatest number of fish species per 500 m^2 has been recorded at Pope's Eye.

577. Jung C, Swearer S, Jenkins G 2010, 'Changes in diversity in the fish assemblage of a southern Australian embayment: consistent spatial structuring at decadal scales', *Marine and Freshwater Research*, 61, pp. 1425–143.
578. Commissioner for Environmental Sustainability (CES) 2016, State of the Bays 2016', Melbourne, Victoria.
579. Parks Australia, 'Reef life survey' https://parksaustralia.gov.au/marine/science/reef-life-survey/ Accessed 9 April 2021.

During the past decade, there has been a decline in the number of fish species in the north. Ten years ago there were roughly 8-10 species on a 500m² transect in northern Port Phillip Bay; now divers might see 2-3 species. During this time there has been a slight increase in the number of species in southern PPB. The decline in the north is related to habitat declines, while the water in the south is highly flushed from Bass Strait and the habitat is more preserved. The results for the number of species, are generally replicated when looking at the biomass data. The number of species is often a more reliable measure of fish trends because of the variability associated with seeing a very small number of heavier species. For example, one smooth stingray that can grow to 350 kg in weight was spotted at a site a decade ago, then in the next survey no smooth stingrays were spotted, so a big decline was recorded in that location for biomass even though it was just the absence of one fish.

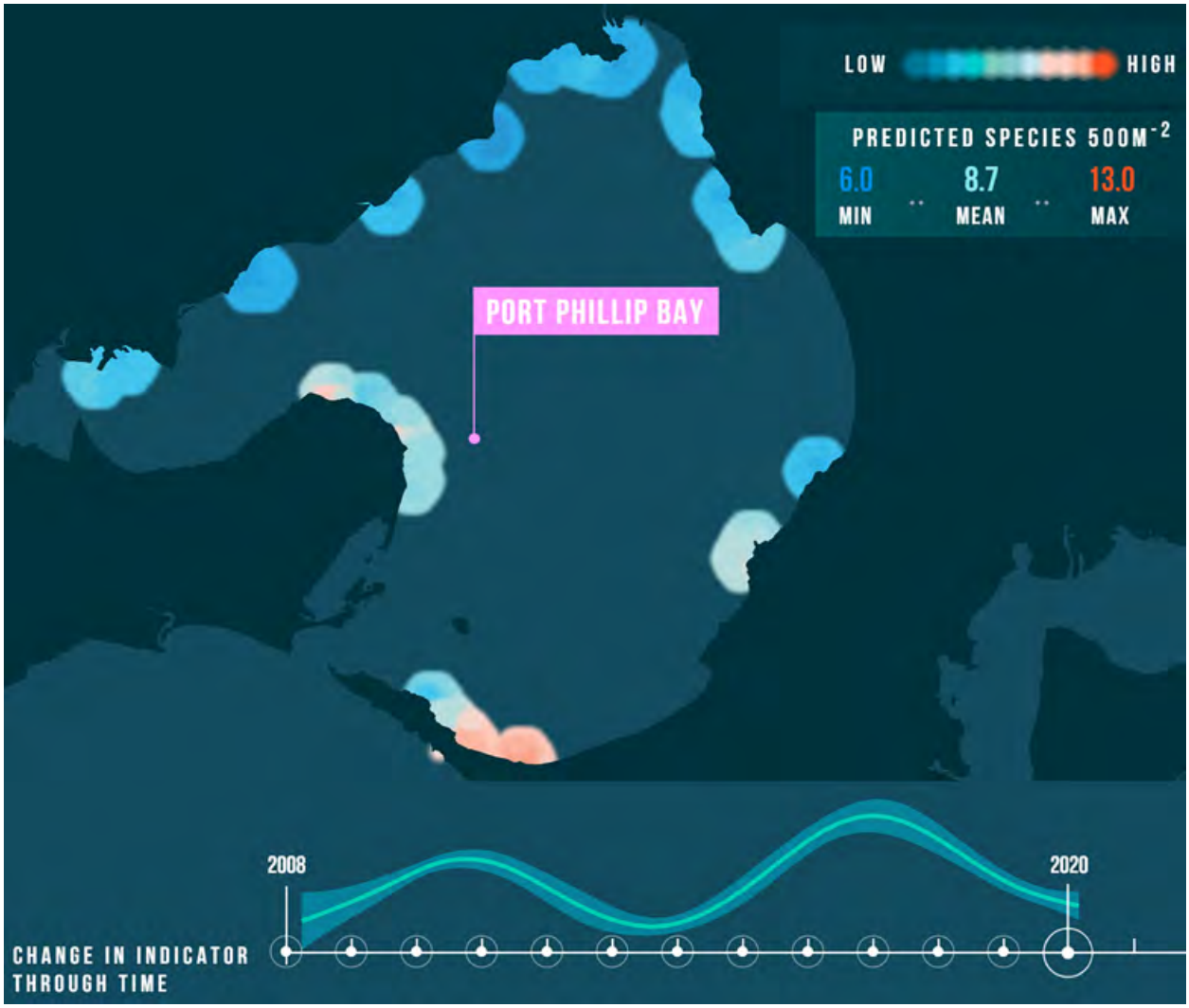


Figure 38: Number of fish species recorded on individual surveys (species per 50 m²) in Port Phillip Bay and completed as part of the Reef Life Survey program.[580]

580. Ibid.

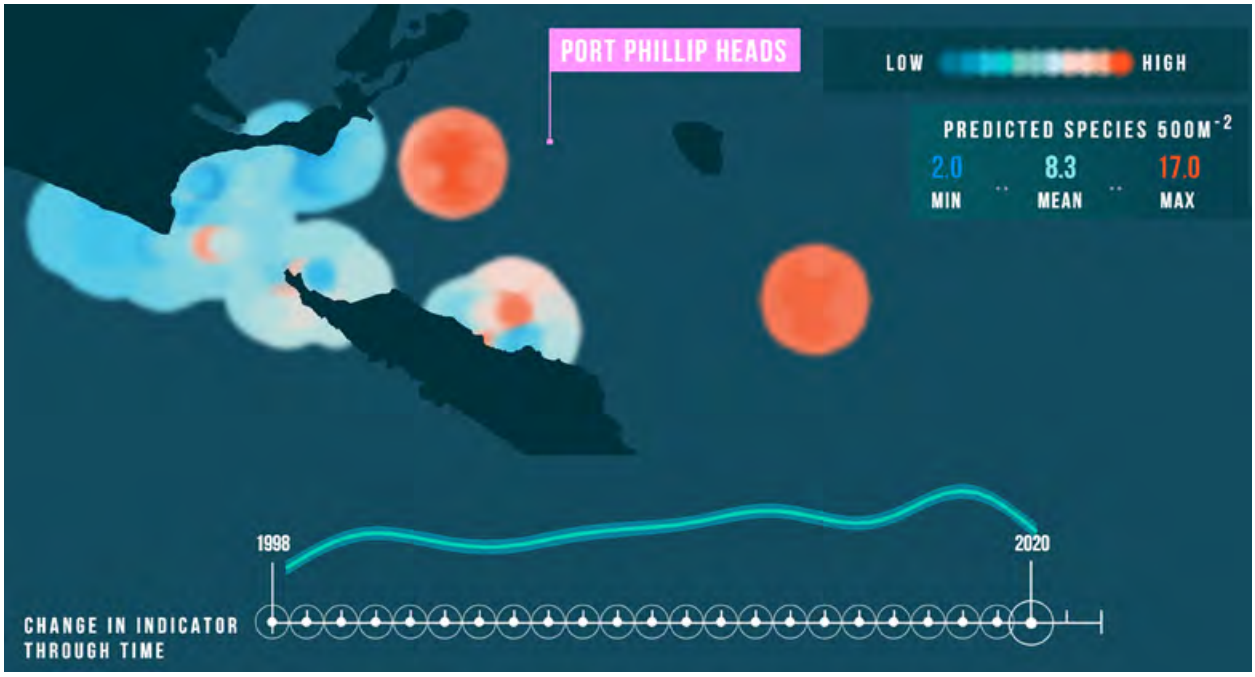


Figure 39: Number of fish species recorded on individual surveys (species per 50 m²) in Port Phillip Heads and completed as part of the Reef Life Survey program.[581]

ReefWatch is the Victorian National Parks Association's marine citizen science program. It provides projects that engage divers, snorkelers, rock pool ramblers and beach combers to contribute their observations, images and knowledge to expand our understanding of Victoria's unique marine life. ReefWatch coordinates several marine citizen science programs, including the Great Victorian Fish Count.[582]

The Great Victorian Fish Count is Victoria's largest marine citizen science event, and each year it continues to connect communities to our coast. Key findings from the 2019 Great Victorian Fish count were:

- The blue throat wrasse was the most commonly sighted species, recorded in over 80% of all surveys.
- For the first time, the second most observed species was the zebra fish, reported over 30% more often than usual. This may be due to the larger number of rocky reef sites surveyed this year or may be an increase in abundance.
- The face of the 2019 Fish Count, the ornate cowfish, was recorded in 20% of all surveys - similar to sightings in previous years.
- Western blue groper sightings doubled this year, occurring in 12% of surveys.
- Other frequently recorded species included:
  - Magpie perch
  - Six-spined leatherjacket
  - Dusky morwong
  - Sea sweep
- No sightings of the southern blue devil were recorded. This was likely due to deep reefs not being surveyed during 2019.
- Marine national parks and sanctuaries continue to be popular sites for the Fish Count. While only 5% of Victoria's coastal waters are 'no-take zones' where removing animals and plants is banned, 34% of surveys done for the 2019 Great Victorian Fish Count were done in marine protected areas.[583]

581. Ibid.
582. Victorian National Parks Association (VNPA) 2020, '2019 Great Victorian fish count'.
583. Ibid.

Figure 40: Summary of fish species sightings and abundances across Victoria.[584]

PPB 26: Diadromous fish

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	N	N	N
Justification for assessment ratings:	Not assessed for this region. Diadromous fish are assessed in the Statewide chapter. A brief narrative is provided below for Port Phillip Bay.		

The Limit of Acceptable Change (LAC) for the Australian grayling in the Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar Site is that the Australian grayling continues to be supported in the Barwon River system.[585]

The Australian grayling passes through the Ramsar site as part of its lifecycle but is unlikely to be easily detectable within the Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar Site during these brief periods of migration.[586]

Nonetheless, DELWP has advised that the most recent LAC assessment took place in 2020 and the LAC was met.

Further discussion on diadromous fishes is included in the statewide assessment for this indicator.

584. Ibid.
585. Hale J 2020, 'Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar site ecological character description, for catchments, waterways cities and towns', Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria.
586. Ibid.

PPB 27: Marine and coastal waterbirds

Region	2021 status	2021 trend	2021 data
Port Phillip Bay			
Justification for assessment ratings:	The Limit of Acceptable Change (LAC) assessments from 2020 show that LACs for waterbird abundance and diversity were being met in the Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar Site. The most recent LAC assessment for waterbird breeding took place in 2016 and there was insufficient data to assess this LAC. For threatened waterbird species, the most recent LAC assessment took place in 2020 and the LAC was met for all species except the lesser sand plover. Data from 2019-20 shows record numbers of many types of waterbirds near the Western Treatment Plant. The status rating is fair rather than good because the 2020 count of the straw-necked Ibis was the lowest since 2017, while the LAC for the lesser sand plover was not met.		

Waterbird abundance, diversity and breeding are all assessed against Limits of Acceptable Change (LACs) in the in the Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar Site. There is also a LAC for threatened waterbird species. The LACs are based on five-year data periods; either five-year rolling averages or presence of species recorded in the site for a specified number of seasons during a five-year period.[587]

DELWP has advised that the most recent LAC assessments took place in 2020 for waterbird abundance and diversity and the LACs were both met, with the assessments based on data for 2015 to 2019 from Birdlife Australia for shorebirds and DELWP for non-shorebirds. The data are freely available from the Atlas of Living Australia.

The LAC for waterbird breeding contains specific thresholds for breeding at Mud Islands and the Western Treatment Plant.[588] The importance of Mud Islands to waterbird breeding is well established; but historical data indicate a succession of different colonial nesting species since the 1940s.[589] Whether this succession is due to altered habitat conditions or other factors remains unknown.[590]

DELWP has advised that the most recent LAC assessment for waterbird breeding took place in 2016 and there was insufficient data to assess the LAC. There has been no dedicated or comprehensive survey of breeding waterbirds at Mud Islands since 2009, with a survey in progress to renew this data. Records from the Atlas of Living Australia indicate significant breeding at Mud Islands in 2016 with the following individuals recorded (although numbers of nests are unknown):

- straw-necked ibis (50,000 individuals)
- silver gull (30,000)
- Australian white ibis (5,000)
- crested tern (2,500)
- pied cormorant (250).

For threatened waterbird species, DELWP has advised that the most recent LAC assessment took place in 2020 and the LAC was met for all species except the lesser sand plover. The lesser sand plover has not been present in any of the five years from 2015 to 2019, which for this migratory species is likely to be due to factors external to the management of the Ramsar site (for example, loss of habitat in the Yellow Sea).

587. Ibid.
588. Ibid.
589. Menkhorst P 2010, 'A survey of colonially-breeding birds on mud islands, Port Phillip, Victoria; with an annotated list of all terrestrial vertebrates', Arthur Rylah Institute for Environmental Research (ARI), Department of Environment, Land, Water and Planning (DELWP), Heidelberg, Victoria.
590. Hale J 2020, 'Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar site ecological character description, for catchments, waterways cities and towns', Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria.

Waterbird populations at the Western Treatment Plant

The narrative for this section is a summary of the 2020 annual report for the monitoring waterbird populations at the Western Treatment Plant.[591]

The Western Treatment Plant (WTP) attracts internationally significant numbers of waterbirds and forms part of a series of coastal wetlands recognised under the Ramsar Convention as being of international significance. Melbourne Water is required to contribute to the conservation of these waterbird populations to meet its obligations under State and Commonwealth legislation, while continuing to treat about half of Melbourne's wastewater at the property.

During 2003–2005, Melbourne Water implemented a series of changes to the sewage treatment processes at the WTP – the Environment Improvement Program (EIP). The EIP aimed to provide enhanced treatment of wastewater to meet obligations for cleaner discharge into Port Phillip, in keeping with the requirements of Victoria's *Environment Protection Act 1970*. Because the WTP harbours several 'matters of national environmental significance', the EIP was deemed a 'controlled action' under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), necessitating approval by the Commonwealth Government. Under the conditions of the Commonwealth Government approval of the EIP, waterbirds were to be monitored annually at the WTP and the adjacent tidal flats, which form part of The Spit Nature Conservation Reserve, for 15 years (that is, until 2018) to assess whether changes in bird numbers were sufficiently large to trigger management responses, as specified in the Melbourne Water Environment Protection and Biodiversity Strategic Compliance Plan. The waterbird groups to be monitored were those for which the WTP is recognised as supporting nationally significant populations (that is, shorebirds and waterfowl, including coots and grebes), and those for which there were concerns about possible negative impacts due to the EIP (that is, ibis and 'freshwater' terns).

During 2019-20, as for the previous year, numbers of all monitored waterbird groups except ibis were high in the reporting period and no triggers for further management action were met.

- Summer counts of shorebirds, waterfowl and whiskered terns were the highest yet recorded. The count of over 70,000 Australian shelduck in December 2019 is exceptional.
- Waterfowl numbers at the WTP have increased by more than 50% over the past seven years.
- Counts of Holarctic shorebirds in summer were also record highs, but winter counts were below average.
- The high counts of waterfowl, some shorebirds and whiskered tern are likely related to drought conditions elsewhere in eastern Australia and highlight the significance of the WTP as a drought refuge for east Australian waterbird populations.

Shorebirds: Shorebird numbers were high during 2019-20 with the February count producing the highest ever count of over 25,000 shorebirds, largely driven by very high numbers (>10,000) of sharp-tailed sandpiper.

Waterfowl: Waterfowl were very numerous in 2019-20 – both the February count (~179,000 birds) and the mean count were the highest on record. It is likely that these high numbers were a response to drought conditions in inland eastern Australia. Dabbling ducks and grazing ducks were in particularly high numbers in late summer (February).

Ibis: The maximum count of straw-necked Ibis was the lowest since 2017 and the mean count was the lowest since surveys began in 2001. The largest count (1,400) occurred early in the season, rather than the expected pattern of a build in numbers to mid-late season with a sudden drop in winter. In 2020, 36% of observations were in terrestrial margin paddocks, including the largest flock; this area of the WTP remained an important foraging option for ibis.

Freshwater terns: The count of over 10,000 whiskered terns in December 2019 is the highest count yet for this species. By February, virtually all had left the WTP.

Large Wading Birds: Nine species of large wading bird were recorded, including all five Australian species from the family *Threskiornithidae* (3 ibis and 2 spoonbills) and three *Ardeidae* (1 heron and 2 egrets) plus the brolga. The most abundant large wading bird was the straw-necked Ibis.

591. Menkhorst P, Macak P, Rogers D, Stamation K and Fansen B 2020, 'Monitoring waterbird populations at the Western Treatment Plant – 2020 annual report', unpublished Client Report for Melbourne Water', Arthur Rylah Institute for Environmental Research (ARI), Department of Environment, Land, Water and Planning (DELWP), Heidelberg, Victoria.

Breeding Waterbirds: Only one species was definitively recorded breeding at the WTP during the 2019-20 surveys – the black swan. In June 2020, cygnets or adults sitting on nests were recorded throughout the lagoon system. One pair of brolga also raised a single young, probably nesting in the 'dry' saltmarsh of The Spit Nature Conservation Reserve.

PPB 28: Migratory shorebirds

Region	2021 status	2021 trend	2021 data
Port Phillip Bay			
Justification for assessment ratings:	The numbers of red-necked stint (*Calidris ruficollis*), curlew sandpipers (*Calidris ferruginea*) and sharp-tailed sandpipers (*Calidris acuminate*) are declining in line with populations throughout the world over the past 20 years. The status is rated as fair because there are still significant numbers of migratory shorebirds stopping at sites along Port Phillip Bay (for example, more than 10,000 sharp-tailed sandpipers were counted near the Western Treatment Plant during 2019-20), while a 2020 assessment found Limits of Acceptable Change were being met for key migratory shorebird species in the Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar Site.		

The Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar Site supports migratory shorebirds, with over 30 species of international migratory shorebirds recorded in the site. Of these, the site regularly supports 22 species, most of which utilise the site during the summer non-breeding months. Many juvenile birds, as well as the southern breeding double-banded plover (*Charadrius bicinctus*), utilise the site during winter.[592]

Red-necked stint, curlew sandpiper and sharp-tailed sandpiper are three key species of roosting shorebirds for Port Phillip Bay. DELWP has advised that the most recent LAC assessments for these species for the Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar Site took place in 2020 and the LAC was met for all three species.

Since 1981, red-necked stint (*Calidris ruficollis*), curlew sandpipers (*Calidris ferruginea*) and sharp-tailed sandpipers (*Calidris acuminate*) have been counted during high tide twice a year at eight coastal sites in Port Phillip Bay. Their numbers are declining in line with populations throughout the world over the past 20 years, largely due to the development and reclamation of intertidal flats in Asia, especially the Yellow Sea. However, periods of drought and high rainfall can cause variations in wetland coverage and affect shorebird distribution in Australia (for example, there were fewer sharp-tailed sandpipers (*Calidris acuminate*) on the intertidal areas of Port Phillip Bay, reflecting their movement to inland areas after drought).[593]

Despite the generally declining migratory shorebird population counted in coastal areas along Port Phillip Bay, overall shorebird numbers counted near the Western Treatment Plant were high during 2019-20 and largely driven by very high numbers (more than 10,000) of sharp-tailed sandpiper.

592. Hale J 2020, 'Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar site ecological character description, for catchments, waterways cities and towns', Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria.

593. Loyn R, Rogers DI, Swindley RJ, Stamation K, Macak P and Menkhorst P 2014, 'Waterbird monitoring at the western treatment plant, 2000–12: the effects of climate and sewage treatment processes on waterbird populations', Arthur Rylah Institute for Environmental Research (ARI) technical report no. 256, Department of Environment, Land, Water and Planning (DELWP), Heidelberg, Victoria.

PPB 29: Piscivorous (fish-eating) birds

Region	2021 status	2021 trend	2021 data
Port Phillip Bay			
Justification for assessment ratings:	The status is rated as good because Mud Islands supports very large numbers of fish-eating waterbirds, mainly of petrels and gulls. A 2020 assessment found limits of acceptable change were being met for piscivorous species in the Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar Site.		

Fish-eating species such as gulls and terns are supported by mud islands within the Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar Site.[594] Four colonial nesting fish-eating species breed in the Western Treatment Plant: pied cormorant (*Phalacrocorax varius*), little pied cormorant (*Phalacrocorax melanoleucos*), great cormorant (*Phalacrocorax carbo*), little black cormorant (*Phalacrocorax sulcirostris*) and Australasian darter (*Anhinga novaehollandiae*).[595]

The breeding colony is overwhelmingly dominated by pied cormorants, who comprise between 80% and 100% of nests.

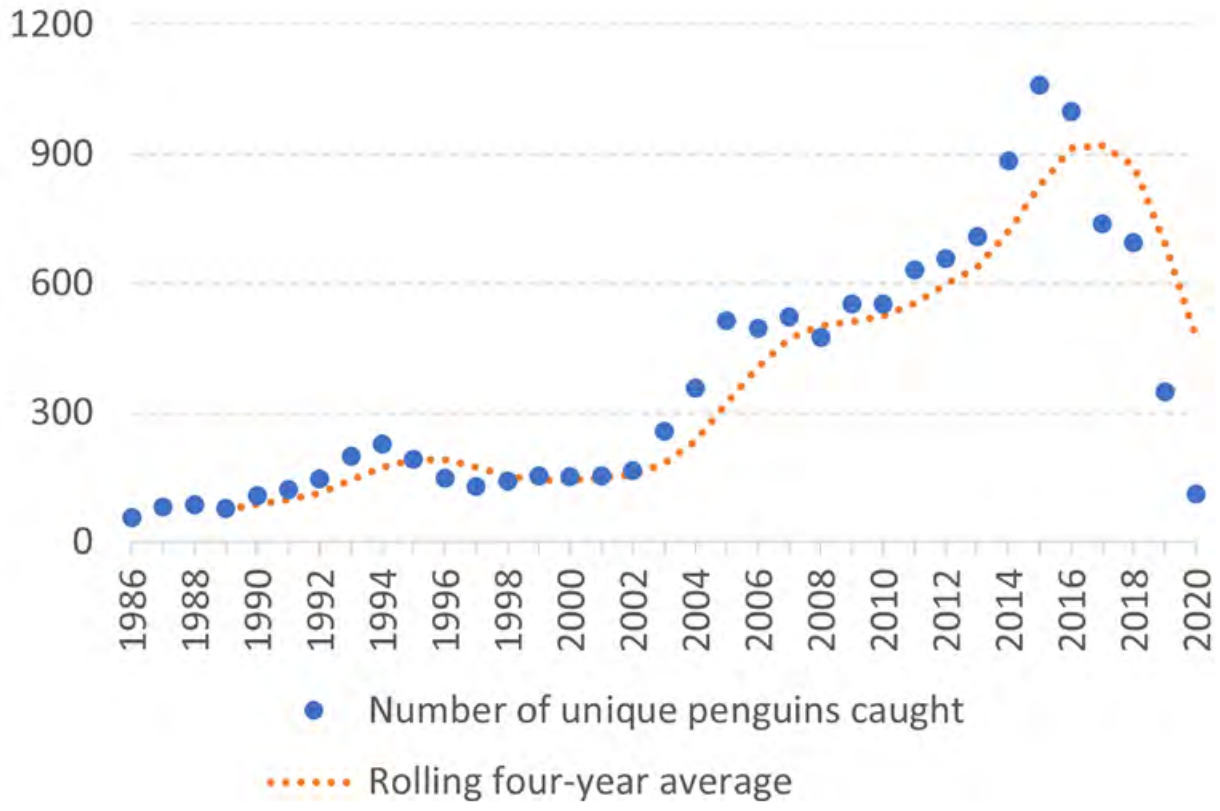
DELWP has advised that the most recent LAC assessments for waterbirds, including piscivorous birds, for the Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar Site took place in 2020 and the LAC was met for all piscivorous birds.

PPB 30: Little penguins

Region	2021 status	2021 trend	2021 data
Port Phillip Bay			
Justification for assessment ratings:	Penguin numbers at St Kilda Harbour breakwater have grown to an estimated population of 1,400 since they were first observed in the 1960s. Based on this the status has been rated as good and the trend as improving, however the confidence is only moderate because there is no routine monitoring of the population and there are no existing thresholds available to guide the assessment.		

Penguins first appeared at the St Kilda Harbour breakwater in 1960, but nesting birds were not seen for another two to three years. Since then, penguin numbers have steadily grown and have been estimated at 1,400.[596] For 30 years volunteers from the local community group, Earthcare St Kilda, have monitored the colony (including microchipping of birds and measuring their weight) and acted as guides for the many people who visit the colony each night. Data supplied by Earthcare St Kilda shows the number of unique penguins tracked at the St Kilda penguin colony has increased dramatically this century from approximately 150 in 2000 to more than 1,000 in 2015. This increase is likely a result of an increase in capture effort as well as an increase in the population size of the colony.

594. Hale J 2020, 'Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar site ecological character description, for catchments, waterways cities and towns', Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria.
595. Loyn R, Rogers DI, Swindley RJ, Stamation K, Macak P and Menkhorst P 2014, 'Waterbird monitoring at the Western Treatment Plant 2000-2012: the effects of climate and sewage treatment processes on waterbird populations', Arthur Rylah Institute for Environmental Research (ARI) technical report series no. 256, Department of Environment, Land, Water and Planning (DELWP), Heidelberg, Victoria.
596. Commissioner for Environmental Sustainability (CES) 2018, 'Victorian State of the Environment 2018', Melbourne, Victoria.



The trendline shows a moving average over a period of four years.

Figure 41: Number of unique penguins caught each year from 1986 to 2019.[597]

The number of chicks microchipped each year supports the theory of an increasing population as capture effort remained relatively consistent from 2002 to 2017 and the number of chicks microchipped increased during this period. From 2007 to 2017, volunteers microchipped 1,411 chicks, of which 522 returned to the colony - a return rate of 36%.

A renewal of the animal ethics permit in 2018 and the impacts of coronavirus (COVID-19) in 2020 resulted in a reduction in the number of nights surveyed during these years, which are likely reasons for the reduction in unique penguins tracked in recent years. Earthcare St Kilda is currently developing a new monitoring program and aiming to reduce the number of penguins requiring capture for accurate population monitoring.

Joint studies from Monash University and Phillip Island Nature Parks provide extensive information on their diet, the influence of drought on their breeding success, their movements in the Port Phillip Bay under diverse conditions.[598,599,600,601,602,603]

The low flow of the Yarra River during drought has an adverse effect on St Kilda penguins breeding success and foraging success.[604,605] From this it can be inferred these penguins indicate the health and level of the nutrient contribution of the Yarra River into Port Phillip Bay.

597. Data supplied by Earthcare St Kilda.
598. Chiaradia A, Forero MG, Hobson KA, Swearer SE, Hume F, Renwick L, Dann P 2012, 'Diet segregation between two colonies of little penguins *Eudyptula minor* in southeast Australia', *Austral Ecology*, 37(5), pp. 610-619.
599. Kowalczyk ND, Reina RD, Preston TJ, Chiaradia A 2015, 'Selective foraging within estuarine plume fronts by an inshore resident seabird', *Frontiers in Marine Science*, 2(42), DOI:10.3389/fmars.2015.00042.
600. Kowalczyk ND, Reina RD, Preston TJ, Chiaradia A 2015, 'Environmental variability drives shifts in the foraging behaviour and reproductive success of an inshore seabird', *Oecologia*, 178(4), pp. 967-979.
601. Kowalczyk ND, Chiaradia A, Preston TJ, Reina RD 2015, 'Fine-scale dietary changes between the breeding and non-breeding diet of a resident seabird', Royal Society Open Science, 2(4), https://doi.org/10.3389/fmars.2015.00042.
602. Preston TJ, Chiaradia A, Caarels SA, Reina RD 2010, 'Fine scale biologging of an inshore marine animal', *Journal of Experimental Marine Biology and Ecology*, 390(2), pp. 196-202.
603. Preston TJ, Ropert-Coudert Y, Kato A, Chiaradia A, Kirkwood R, Dann P, Reina RD 2008, 'Foraging behaviour of little penguins *Eudyptula minor* in an artificially modified environment', *Endangered Species Research*, 4, pp. 95-103.
604. Kowalczyk ND, Reina RD, Preston TJ, Chiaradia A 2015, 'Selective foraging within estuarine plume fronts by an inshore resident seabird', *Frontiers in Marine Science*, 2(42), DOI:10.3389/fmars.2015.00042.
605. Kowalczyk ND, Reina RD, Preston TJ, Chiaradia A 2015, 'Environmental variability drives shifts in the foraging behaviour and reproductive success of an inshore seabird', *Oecologia*, 178(4), pp. 967-979.

Tourism sector promotion has encouraged more people to visit each night, increasing pressure on the colony. On winter nights there are 200 to 400 visitors, growing to 600 in summer and totalling approximately 140,000 per year.[606] Between 2013–14 and 2016–17, volunteers collected six km of fishing line and 372 hooks, as well as 2,500 kg of litter.[607] Penguin entanglements with recreational fishing lines and hooks and the presence of litter in burrows has also been reported, while the use of flash photography by tourists is an ongoing problem impacting on the health of the penguin colony.

PPB 31: Marine mammals

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	(dolphins)	(dolphins)	(dolphins)
Justification for assessment ratings:	Dolphins: There is contention about the species of dolphins residing in Port Phillip Bay, but there is strong agreement that there is a stable population of more than 100 dolphins living there. Even though this might seem a small population, it is likely to have been reasonably stable for a long period of time (that is, reasonably stable from the 1960s), which is why the status is rated as fair rather than poor.		

Dolphins

The Port Phillip Bay's dolphins, referred to in this indicator assessment as burrunan dolphins (*Tursiops australis*),[608] are smaller in size and paler in colour than their offshore counterparts. Furthermore, spots are not present on their belly, a characteristic seen in Indo-Pacific bottlenose dolphins.

The Dolphin Research Institute (DRI) estimates there has been a reasonably stable population of 80-120 dolphins living in Port Phillip Bay during 2020. Based on anecdotal evidence, it is likely that the numbers of resident dolphins have increased in Port Philip Bay since the 1960s.

This population estimate is supported by analysis provided by the Marine Mammal Foundation, with its data suggesting a population of 97 to 139 dolphins with a 95% confidence interval.

Research published during 2011 highlighted the detection of a burrunan dolphin (*Tursiops australis*) population in Port Phillip Bay, comprising a small, genetically distinct and isolated population of approximately 120 individuals.[609] Individuals are classified as resident to Port Phillip Bay as they are frequently sighted during dedicated, seasonal boat-based surveys conducted by the Marine Mammals Foundation.[610] As at June 2021, the burrunan dolphin was listed as a critically endangered species.[611]

Common dolphins (*Delphinus delphis*) are visually and genetically very different from the bays' resident dolphins. Common dolphins can be recognised by the gold stripe that runs along their side. They are also smaller in size. Since 2006, the DRI estimates a community of 30-40 common dolphins have also become resident in Port Phillip Bay. Port Phillip is the only semi-enclosed shallow bay in world where these normally oceanic species have become resident. There is some mixing with transient common dolphins that enter the bay.

An ongoing study of dolphin health by the DRI shows that Port Phillip Bay's resident dolphins show resilience to skin infections and quite severe injuries, which provides optimism that their population will be stable in the future.

606. Earthcare St Kilda 2018, 'Penguin report 2016-17', St Kilda, Victoria.
607. Ibid.
608. The burrunan dolphin's presence as a unique species is disputed. For the purpose of this indicator assessment, the State of the Marine and Coastal Environment 2021 Report is following the listing in the Flora and Fauna Guarantee Act 1998 and referring to the dolphins in Port Phillip Bay as burrunan dolphins rather than the common bottlenose dolphin (*Tursiops truncates*). Further information is provided in the opening summary section for Indicator 31: Marine mammals. Regardless of whether the dolphins in Port Phillip Bay are classified as burrunan dolphins or common bottlenose dolphins, there is agreement that the population is stable at approximately 100.
609. Charlton-Robb K, Gershwin L, Thompson R, Austin J, Owen K and McKechnie S 2011, 'A new dolphin species, the burrunan dolphin *Tursiops australis* sp. nov., endemic to southern Australian coastal waters', *PLOS ONE*, 6(9), e24047.
610. Charlton-Robb, K., Taylor A and McKechnie S 2015, 'Population genetic structure of the burrunan dolphin (*Tursiops australis*) in coastal waters of south-eastern Australia: conservation implications', Conservation Genetics, 16(1), pp. 195-207 https://doi.org/10.1007/s10592-014-0652-6 Accessed 11 April 2021.
611. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Flora and Fauna Guarantee Act 1988 - threatened list June 2021', East Melbourne, Victoria.

Despite the risks (for example, human interactions with tourism and private vessels, high water temperatures and severe algal blooms) facing dolphins in Port Phillip Bay, the DRI reports that population numbers have likely been stable for three decades.

Seals

Population trends are available for fur seals in Victoria, but they are not known to breed in Port Phillip Bay, therefore seals are only included in the indicator narrative, rather than also being part of the status, trend and confidence assessments.[612,613]

The Australian fur seal (*Arctocephalus pusillus doriferus*) is the predominant seal species seen in Port Phillip Bay. The seals can be found occasionally resting on beaches around the bay, and more commonly towards the heads around the Mornington and Bellarine Peninsulas. The fur seals that have been tracked using satellite and GPS devices have not entered Port Phillip Bay;[614] however, some clearly do visit Chinaman's Hat to haul-out (that is, where the animals come out of the water to spend time on land), rest and play.[615]

The bay's Australian fur seals can also be spotted hauling-out on man-made structures found within the bay – particularly those around Port Phillip Heads. In addition to Chinaman's Hat, these include Pope's Eye, South Channel Fort and South Channel Marker. Port Phillip Bay is occasionally visited by other seal species including subantarctic fur seals (*Arctocephalus tropicalis*), Australian sea lions (*Neophoca cinereal*), southern elephant seals (*Mirounga leonine*) and leopard seals (*Hydrurga leptonyx*).

Litter, both general rubbish and fishing waste, are the chief threats to the seals. Curious seals can occasionally swim into debris and become entangled.[616] As the seals' habitat is altered and degraded due to human activity they may start to rely on humans for food. By becoming used to and more familiar with humans, the seals may lose their normal ability to spot danger or hazards. This can result in the seals getting tangled in debris, injured (for example, by being hit by a boat's propeller), or may lead to conflict with humans or domestic animals. Dogs pose a threat to seals resting on beaches. If seals are unable to escape dogs and are bitten, they are at risk of getting a transmittable disease, posing a threat to the rest of the seal population.

612. McIntosh RR, Kirkman SP, Thalmann S, Sutherland DR, Mitchell A, Arnould JPY, Salton M, Slip DJ, Dann P and Kirkwood R 2018, 'Understanding meta-population trends of the Australian fur seal, with insights for adaptive monitoring', *PLOS ONE*, 13(9), e0200253.
613. McIntosh RR, Sorrell KJ, Thalmann S, Mitchell T, Gray R, Schnagl H, Arnould JPY, Dann P and Kirkwood R (in review). Sustained reduction in numbers of Australian fur seal pups: implications for future population monitoring. *PLOS ONE*.
614. Salton M, Kirkwood R, Slip DJ and Harcourt R 2019, 'Mechanisms for sex-based segregation in foraging behaviour by a polygynous marine carnivore', *Marine Ecology Progress Series*, 624, pp. 213-226.
615. Scarpaci C, Nugegoda D and Corkeron PJ 2005, 'Tourists swimming with Australian fur seals (*Arctocephalus Pusillus*) in Port Phillip Bay, Victoria, Australia: are tourists at risk?', *Tourism in Marine Environments*, 1(2), pp. 89-95.
616. McIntosh RR, Kirkwood R, Sutherland DR, Dann P 2015, 'Drivers and annual estimates of marine wildlife entanglement rates: a long-term case study with Australian fur seals', *Marine Pollution Bulletin*, 101(2), pp. 716-725.

Western Port

WP 15: Conservation of coastal ecosystems in protected areas

Region	2021 status	2021 trend	2021 data
Western Port	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The conservation of coastal ecosystems in protected areas within five km of Western Port is encompassed within a broad analysis of the entire Victorian coastline in the statewide assessment for this indicator.		

WP 16: Saltmarsh

Region	2021 status	2021 trend	2021 data
Western Port	●	→	●
Justification for assessment ratings:	There has been minimal loss of saltmarsh cover since European settlement, with approximately 90% of the saltmarsh cover remaining in 2012. The Limit of Acceptable Change (LAC) for saltmarsh in the Western Port Ramsar Site is that total saltmarsh extent will not decline below 900 hectares. This is being met. Based on this, the status for this indicator has been assessed as good.		

Western Port saltmarshes contain a wide variety of species organised in numerous sub-communities, each characterised by different wetting and drying regimes driving vegetation structure and composition.[617]

Research published in 2012 assessed that along the Western Port coastline, about 90% of saltmarsh that once covered 1,460 hectares remains today.[618] In addition to the impact of mangrove encroachment and subsequent saltmarsh displacement along tidal creeks, significant portions of saltmarsh were removed for agriculture. Saltmarsh has returned in some areas, particularly around the northern and western shores of Western Port, for example near Tooradin airport, however, concerns over declining saltmarsh extent remain, with erosion a problem on the eastern shoreline.[619] Although loss of saltmarsh to mangrove habitat in Western Port is low (5–10% of saltmarsh area) compared with 30% across south-east Australia, it remains a challenge for managers.[620]

DELWP has advised that the most recent LAC assessment for saltmarsh in Western Port took place in 2016 and the LAC was met. The Limit of Acceptable Change (LAC) for saltmarsh in Western Port is that total saltmarsh extent will not decline below 900 hectares. The most recent assessment of saltmarsh extent in Western Port, completed in 2011, found 1,143 hectares of saltmarsh and no evidence of a significant decline in saltmarsh extent.[621] It is important to note that much of the Western Port saltmarsh lies outside the Ramsar site boundary, in particular the majority of the saltmarsh on the northern shore of French Island is outside the Ramsar site.[622]

617. Sinclair S and Boon P 2012, 'Changes in the area of coastal marsh in Victoria since the mid 19th century', *Cunninghamia*, 12(2), pp. 153–176.
618. Ibid.
619. Commissioner for Environmental Sustainability (CES) 2016, 'State of the Bays 2016', Melbourne, Victoria.
620. Ibid.
621. Boon PI, Allen T, Brook J, Carr G, Frood D, Hoye J, Harty C, McMahon A, Mathews S, Rosengren NJ, Sinclair S, White M and Yogovic J 2011, 'Mangroves and coastal saltmarsh of Victoria: distribution, condition, threats and management', Institute for Sustainability and Innovation Victoria University, Melbourne.
622. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Western Port Ramsar site management plan', East Melbourne, Victoria.

The saltmarshes of Western Port face many threats. For example, sea level rise will increase the time that water covers saltmarsh, facilitating mangrove encroachment. This has been occurring at several sites including Rhyll, Koo Wee Rup, French Island and Quail Island.[623]

Exotic plant species are another threat. Saltmarsh inhabit harsh environments and this has led to the erroneous assumption that they are largely immune from infestation by exotic plant species. However, the Victorian Saltmarsh Study identified 118 exotic species in Victorian saltmarshes.[624] Of these, only two species, both from the genus *Spartina*, invade the lower intertidal areas occupied by mangroves in Western Port while the rest invade the drier middle and upper saltmarsh.[625]

There is a current project being undertaken by Deakin University which will expand the use of historical photography to undertake a bay-wide analysis of historical changes in coastal vegetation. This study will also utilise models to predict future distribution under various climate change projections.

As part of Melbourne Water's Understanding the Western Port Environment 2018 synthesis report, long-term mangrove and saltmarsh monitoring was identified as a future direction and opportunity. It was envisaged that a long-term monitoring program could be implemented to identify the impact of rising temperatures and sea-levels along with more frequent extreme weather events. For example, this could be done by analysing remotely sensed images and tide height data to validate predictions from coastal vegetation models being developed as part of the current Deakin University project outlined above.[626]

WP 17: Mangroves

Region	2021 status	2021 trend	2021 data
Western Port			
Justification for assessment ratings:	There has been minimal loss of mangrove habitat in Western Port since European settlement, with approximately 90% of the mangrove habitat remaining in 2012. This assessment was used to inform an estimate of 1,700 hectares of mangrove extent in the Western Port Ramsar Site, which meets the Limit of Acceptable Change (LAC) for mangroves in the Ramsar site to remain above 900 hectares. This is reflected in a status of good, while the trend is rated as improving based on advice from DELWP that the mangrove extent in the Western Port Ramsar Site has increased by 40% since 1982. The confidence in the assessments is rated as moderate rather than high because the most recent assessments of mangrove extent and condition are nearly a decade old.		

Mangroves in Western Port are represented by a single species – *Avicennia marina var. australasica*, the grey or white mangrove – and are close to their latitudinal limit with the southernmost occurrence 100 km southeast at Corner Inlet.

Western Port has retained 90–95% of its pre-1750s mangrove habitat, estimated at 1,320 hectares.[627] Losses have been caused by harvesting in the 19th century to produce barilla ash, land claim for industrial and port development, and the drainage of adjacent land.[628] In some areas, mangroves have expanded in area, including encroaching on saltmarsh, yet it is still unclear whether they are advancing seawards or landwards.[629]

DELWP has advised that the Limit of Acceptable Change (LAC) for mangroves in the Western Port Ramsar Site is being met, with an estimated 1,700 hectares of mangroves in the Ramsar site being well above the LAC that requires more than 900 hectares of mangroves. DELWP also advise that 1,700 hectares of mangroves represents an increase of 40% since 1982 when the site was Ramsar listed.

623. Commissioner for Environmental Sustainability (CES) 2016, 'State of the Bays 2016', Melbourne, Victoria.
624. Sinclair S and Boon P 2012, 'Changes in the area of coastal marsh in Victoria since the mid 19th century', *Cunninghamia*, 12(2), pp. 153–176.
625. Melbourne Water 2018, 'Understanding the Western Port environment: a summary of research findings from the Western Port environment research program 2011-2017 and priorities for future research', Melbourne, Victoria.
626. Ibid.
627. Boon P, Allen R, Carr G, Frood D, Harty C, McMahon A, Mathews S, Rosengren N, Sinclair S, White M and Yugovic J 2011, 'Mangroves and coastal saltmarsh of Victoria: distribution, condition, threats and management', Institute for Sustainability and Innovation, Victoria University, Melbourne, Victoria.
628. Ibid.
629. Ibid.

A 2005 study used aerial photos to determine that mangroves were encroaching into saltmarshes in some areas of Western Port, although this appears to have occurred in the more developed areas around Rhyll and Koo Wee Rup compared to the less disturbed French Island.[630] This study was restricted to a few sites around Western Port, and there is a current project being undertaken by Deakin University which will expand the use of historical photography to undertake a bay-wide analysis of historical changes in coastal vegetation.[631]

Exotic plant species are a threat to mangroves. Mangroves inhabit harsh environments and this has led to the erroneous assumption that they are largely immune from infestation by exotic plant species. However, research completed in 2012 found two exotic species - both from the genus *Spartina* - invade the lower intertidal areas occupied by mangroves in Western Port. More information on exotic plant species is available as part of the Coastal Invasive Plants indicator.

As part of Melbourne Water's Understanding the Western Port Environment 2018 synthesis report, long-term mangrove and saltmarsh monitoring was identified as a future direction and opportunity. It was envisaged that a long-term monitoring program could be implemented to identify the impact of rising temperatures and sea-levels along with more frequent extreme weather events. For example, this could be done by analysing remotely sensed images and tide height data to validate predictions from coastal vegetation models being developed as part of the current Deakin University project outlined above.[632]

The growing recognition of the importance of mangroves has seen increased restoration efforts focused on mangroves in Western Port over the last decade. These efforts were also summarised in Melbourne Water's Understanding the Western Port Environment 2018 synthesis report. Most mangrove restoration activity in Western Port has focused on establishing a protective band of mangroves along the eroding coastline in the northeast of the bay (the Lang Lang cliffs) as well as some smaller scale projects aimed at restoring mangroves around Grantville. Successful mangrove restoration is notoriously difficult and community groups that have initiated mangrove restoration in Western Port have had mixed success to date.[633]

The mangrove planting that has occurred along the high-energy Lang Lang coastline has led to an increase in knowledge about the best methods to improve the planting success. Survival of seedlings in the first 12 months after planting was found to substantially increase when PVC plant guards were installed, although additional protection measures are required as plants mature (for example, height adjustable guards and complementary erosion protection structures). Mangrove field planting trials also showed larger seedlings grown in the nursery generally had higher survival rates. The largest seeds collected from the ground had generally higher germination rates and produced larger seedlings than seeds picked from trees. This knowledge led to a recommendation that the largest seeds are collected in the middle of the summer fruiting season to optimise seedling growth and survival before the pre-winter planting.[634]

630. Rogers K, Saintilan N and Heijnis H 2005, 'Mangrove encroachment of salt marsh in Western Port Bay, Victoria: the role of sedimentation, subsidence, and sea level rise', *Estuaries*, 28, pp. 551–559.
631. Melbourne Water 2018, 'Understanding the Western Port Environment: a summary of research findings from the Western Port environment research program 2011-2017 and priorities for future research', Melbourne, Victoria.
632. Ibid.
633. Ibid.
634. Ibid.

WP 18: Wetland and estuarine vegetation

Region	2021 status	2021 trend	2021 data
Western Port		?	
Justification for assessment ratings:	As part of the Index of Estuary Condition, flora assessments for 8 of the 10 estuaries in the Western Port catchment region were completed, with two estuaries receiving ratings of excellent for flora, four estuaries rated as good and two estuaries rated as fair. Through the 2021 Index of Estuary Condition (IEC) assessments, only two estuaries were rated on both fringing and submerged vegetation, with the six estuaries receiving the best ratings not assessed for submerged vegetation. Because of this, there is a moderate, rather than high, confidence in the status assessment for estuarine flora in this indicator.		

Estuarine flora

Table 17 shows the IEC flora results for estuaries in the Western Port catchment region.[635] Two estuaries received ratings of excellent for flora, four estuaries were rated as good and two estuaries were rated as fair, while two estuaries were not assessed. As this is the first IEC, and they are designed to be point-in-time assessments, no time series data are available to assess trends.

Several of the estuaries with flora in excellent or good condition flow into Western Port and have fringing vegetation dominated by mangroves.[636] Sediment inputs to Western Port are acknowledged as a threat to seagrasses (see Indicator 34: Seagrass). All six estuaries that were rated as good or excellent for flora, were only assessed for fringing vegetation, with no assessments made for submerged vegetation. Because of this, flora scores should be interpreted with some caution.

Table 17: IEC results for estuarine flora within the Western Port catchment region.[637]

Estuary	Flora	Condition Class
Merricks Creek	9	Good
Warringine Creek	10	Excellent
Watsons Creek	10	Excellent
Cardinia Creek	9	Good
Deep Creek	9	Good
Bunyip River	9	Good
Yallock Drain	NA	
Lang Lang River	NA	
Bass River	7	Fair
Saltwater Creek	7	Fair

Range 1 – 10 (1 poorest condition, 10 best condition). NA = not assessed.

635. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Index of estuary condition', East Melbourne, Victoria.
636. Ibid.
637. Ibid.

WP 19: Species of conservation concern

Region	2021 status	2021 trend	2021 data
Western Port	●	?	●
Justification for assessment ratings:	The data analysed and reported for this indicator provide information on the number of species of conservation concern. The status and trend assessments are unknown and unclear, respectively, because no information is available to ascertain how these species are being tracked and managed, and no trend data are available to assess how these species are tracking over time.		

Publicly accessible data from the Victorian Biodiversity Atlas has been analysed to determine the presence of threatened and vulnerable marine and coastal species within Western Port.

Within the Victorian Biodiversity Atlas there are 1,238 fauna species and 1,286 flora species that are mapped to be within the Western Port marine biounit. Of these, there are 66 fauna species and 6 flora species that are denoted by the Atlas as being listed within the FFG Act, listed as endangered, threatened or vulnerable within the Environment Protection and Biodiversity Conservation Act 1999, or included as on DELWP's advisory list as endangered, threatened, vulnerable or poorly known.

Given that recent amendments to the FFG Act have removed duplication by establishing a single comprehensive list of threatened flora and fauna species and revoking Advisory Lists,[638] any updates to the Victorian Biodiversity Atlas attribute fields will be incorporated in future State of the Marine and Coastal Environment reports.

Of the combined 72 species of conservation concern that are listed within the Victorian Biodiversity Atlas, 42 (58%) have records within the past 20 years.

There is a lack of published analysis and time series data available to assess how these species are tracking over time and this will be an area of focus for future State of the Marine and Coastal Environment reports.

WP 20: Mobile invertebrates on intertidal reefs

Region	2021 status	2021 trend	2021 data
Western Port	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The flora and fauna of intertidal reefs within the marine protected areas of Western Port have not been surveyed.		

WP 21: Sessile invertebrates on intertidal reefs

Region	2021 status	2021 trend	2021 data
Western Port	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The flora and fauna of intertidal reefs within the marine protected areas of Western Port have not been surveyed.		

638. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Threatened list and processes list' East Melbourne, Victoria https://www.environment.vic.gov.au/conserving-threatened-species/threatened-list Accessed 17 August 2021.

WP 22: Invertebrates on subtidal reefs

Region	2021 status	2021 trend	2021 data
Western Port	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The flora and fauna of subtidal reefs within the marine protected areas of Western Port have not been surveyed. A brief narrative is provided below.		

Future State of the Marine and Coastal Environment reports are likely to be able to incorporate findings from the Western Port Bryozoan Reef Research Project that involves a collaboration between the private sector, the public sector and academia.[639]

The Western Port Bryozoan Reefs are unique in that they form extensive shallow water biogenic reefs with high relief that are not seen elsewhere. The bryozoan reef community of Western Port occurs in a turbid, low light environment in relatively shallow water (5-12 metres).

Their distribution is restricted and research to date suggests that a combination of depth, low light conditions (which precludes competitive algal growth), currents and planktonic food resources are among the factors limiting their extent.

Based on research to date, this biotope is likely to be of global significance as there are no other records of fenestrate (net-like) bryozoans forming continuous reef structure, with high vertical relief, in shallow water occurring anywhere else in the world.

WP 23: Commercially and recreationally important invertebrates

Region	2021 status	2021 trend	2021 data
Western Port	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. This is due to there not being any commercially and recreationally important invertebrate stocks in Western Port.		

WP 24: Commercially and recreationally important fish

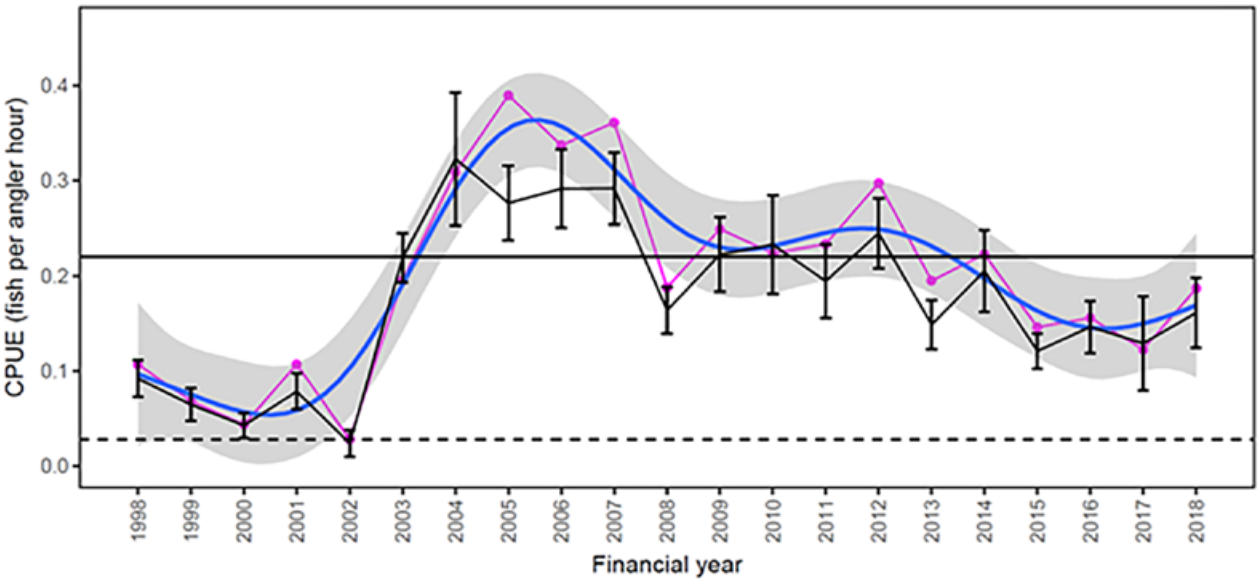
Region	2021 status	2021 trend	2021 data
Western Port	● (snapper, King George whiting)	→ (King George whiting) ↙ (snapper)	● (snapper) ● (King George whiting)
Justification for assessment ratings:	Snapper: There is a declining trend in the recreational fishery for adult snapper in Western Port. Recent strong recruitment is expected to reverse any declining biomass trends and drive a rebuilding of adult biomass and improved fishery performance over the next five to ten years. King George whiting: There is only limited data for King George whiting in Western Port. A slight decline in recreational fishing catch per unit of effort was measured during the 2010s, however recent strong post-larval recruitment is expected to drive a rapid increase in catch per unit of effort over the next few years so the stock should remain sustainable.		

639. Fathom Pacific, 'Western Port bryozoan reef project' https://fathompacific.com/project-spotlight/western-port-bryozoan-reef-project/ Accessed 25 July 2021.

Snapper

There is a declining trend in the recreational fishery for adult snapper in Western Port. The decline is thought to be related to local dynamics rather than a deterioration in the overall stock of snapper for Western Victoria.[640] Recent strong recruitment is expected to reverse any declining biomass trends and drive a rebuilding of adult biomass and improved fishery performance over the next five to ten years.[641]

Standardised CPUE for recreational anglers during 2018 in Western Port for the October-December period was approximately halfway between the reference period average and the reference period low point. A consistent declining trend in CPUE has been observed since 2005.[642]

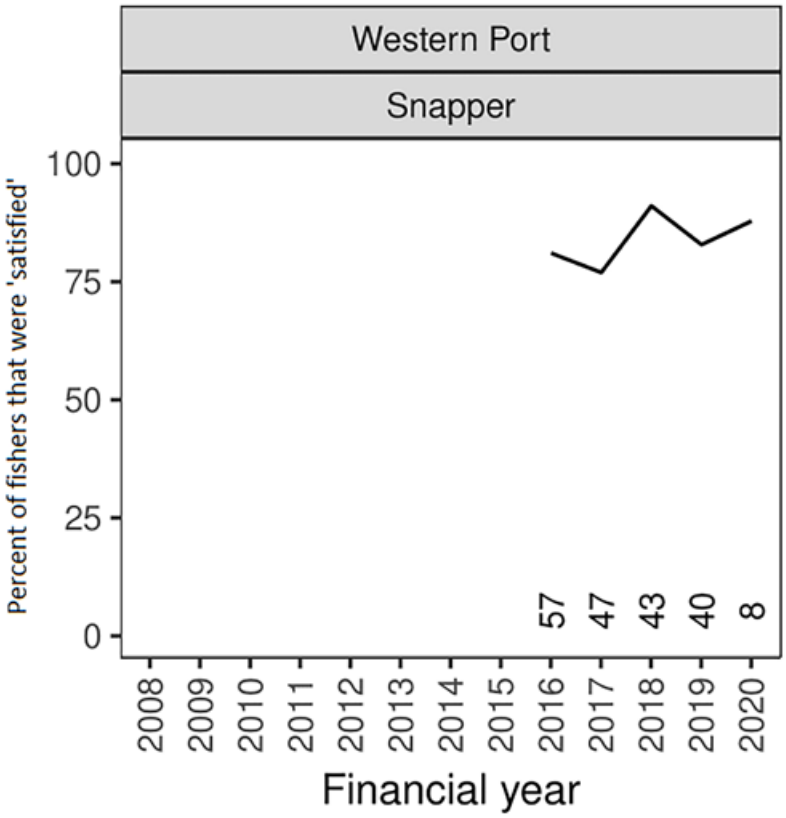


Black line is nominal CPUE (±SE), magenta line is standardised CPUE, blue line is a generalised additive model GAM of the standardised trend with the shaded grey area representing the 95% confidence interval of the GAM. Horizontal black line is the mean standardised CPUE during the reference period (2002-2015) and the dashed black line is the minimum standardised CPUE within the reference period.

Figure 42: Catch-per-unit effort of snapper by recreational anglers interviewed in creel surveys undertaken in Western Port between October and December during 1998–2018 financial years.[643]

In addition to the data on snapper spawning and catch rates, fisher satisfaction can be considered as a supplementary measure that provides indicative information to inform the abundance of fish species at a point in time. The theory of this is that higher satisfaction ratings from fishers are likely to be associated with more plentiful numbers of fish available to be caught. During the five years from 2016 to 2020, each year more than 75% of surveyed fishers that were targeting snapper in Western Port reported being satisfied with their fishing experience. This is indicative of there being suitable snapper abundance to ensure most anglers have been enjoying a positive fishing experience.

640. Note that the western Victorian stock of snapper is considered in VFA reporting to extend from Wilsons Promontory in Victoria to Investigator Strait in South Australia
641. Victorian Fisheries Authority (VFA) 2020, 'Review of key Victorian fish stocks — 2019'.
642. Ibid.
643. Ibid.



The numbers above the x-axis represent the number of survey respondents.

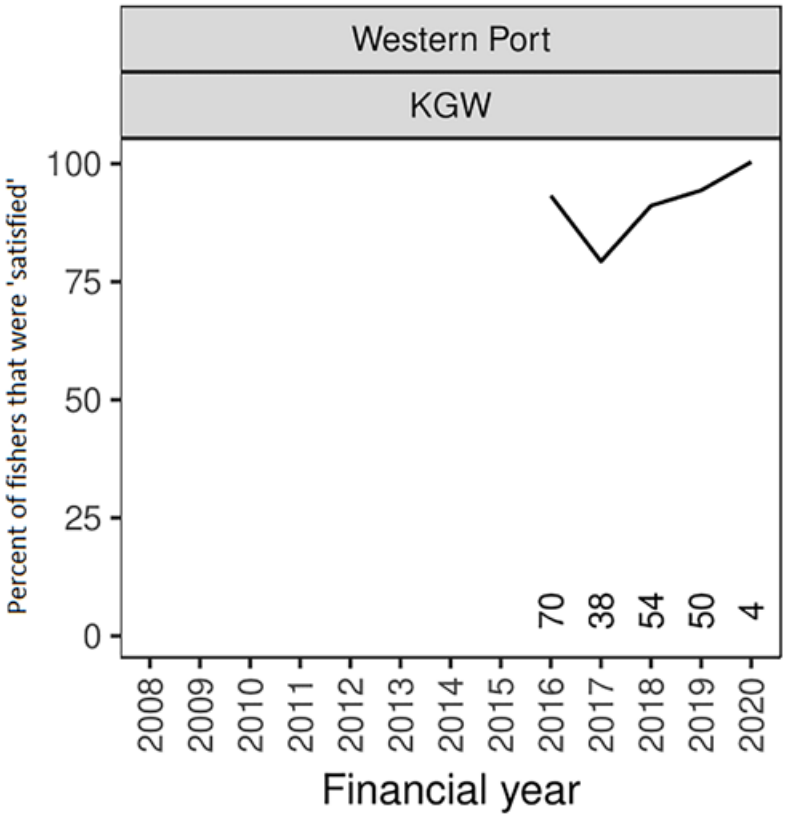
Figure 43: Percent of fishers targeting snapper in Western Port that were satisfied with their fishing experience.[644]

King George whiting

There are only limited data for King George whiting in Western Port. A generally gradual increase in recreational fishing CPUE was measured during the 1990s and 2000s before a plateau and slow decline in the 2010s. The recent strong post-larval recruitment measured in Port Phillip Bay is expected to also be reflected in recruitment in Western Port and should drive an increase in CPUE over the next few years so the stock should remain sustainable.[645]

In addition to the data on King George whiting spawning and catch rates, fisher satisfaction can be considered as a supplementary measure that provides indicative information to inform the abundance of fish species at a point in time. The theory of this is that higher satisfaction ratings from fishers are likely to be associated with more plentiful numbers of fish available to be caught. During the five years from 2016 to 2020, each year more than 75% of surveyed fishers that were targeting King George whiting in Western Port reported being satisfied with their fishing experience. This is indicative of there being suitable King George whiting abundance to ensure most anglers have been enjoying a positive fishing experience.

644. Image supplied by the Victorian Fisheries Authority (VFA).
645. Victorian Fisheries Authority (VFA) 2020, 'Review of key Victorian fish stocks — 2019'.



The numbers above the x-axis represent the number of survey respondents.

Figure 44: Percent of fishers targeting King George whiting in Western Port that were satisfied with their fishing experience.[646]

Information on other commercially and recreationally important fish species

In addition to the stocks covered above that were categorised by VFA as being of high 'relative importance' (see indicator description narrative for more details on this), a characterisation of the status of recreational fishing in Western Port published in 2015 reached the following conclusions:

- Flathead showed a slightly decreasing trend in catch rate that may be related to the much more significant decrease in sand flathead catch rates in Port Phillip Bay over the same period.[647] This decline is thought to be mainly driven by a period of poor recruitment related to environmental conditions.[648]
- Although catch rates of elephant fish were relatively stable across the survey period, the contraction of the spatial distribution in the catch rates from the Rhyll segment may be a cause for concern through hyperstability in catch rates where decline in the population is masked by increased aggregation.[649]
- It was difficult to discern any effects of the 2008 ban on commercial netting in the recreational data; catch rates of many species did not change markedly at this time, and while garfish showed an increase in catch rate at this point, calamari catch rate showed a decrease.
- For most species, the results suggested that variation in catches by recreational fishers was primarily influenced by the environmental drivers of recruitment of young fish to the Western Port ecosystem.[650]

646. Image supplied by the Victorian Fisheries Authority (VFA).
647. Hirst A, Rees C, Hamer P, Conron S and Kemp J 2014, 'The decline of sand flathead stocks in Port Phillip Bay: magnitude, causes and future prospects', Fisheries Victoria Recreational Fishing Grant Program Research Report, Queenscliff, Victoria.
648. Ibid.
649. Braccini et al. 2008
650. Jenkins GP and Conron S 2015, 'Characterising the status of the Western Port recreational fishery in relation to biodiversity value: phase 1', technical report, School *of* Biosciences. Melbourne University.

WP 25: Subtidal reef fish

Region	2021 status	2021 trend	2021 data
Western Port	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The flora and fauna of subtidal reefs within the marine protected areas of Western Port have not been surveyed.		

WP 26: Diadromous fish

Region	2021 status	2021 trend	2021 data
Western Port	N	N	N
Justification for assessment ratings:	Not assessed for this region. Diadromous fish are assessed in the Statewide chapter. A brief narrative is provided below for Western Port.		

The Limit of Acceptable Change (LAC) for the Australian grayling in the Western Port Ramsar Site is that the Australian grayling continues to be supported in one or more of the catchments draining into Western Port.[651]

DELWP has advised that, based on findings from the Victorian Environmental Flows Monitoring and Assessment Program,[652] the LAC for Australian grayling in Western Port was assessed as being met during 2020.

This LAC assessment is consistent with the assessment included in the 2017 Western Port Ramsar Site Management Plan, which stated that data from the Bunyip River (2008–10) indicated that the Australian grayling are present, spawning and migrating through that river system.[653]

Further discussion on diadromous fish is included in the statewide assessment for this indicator.

651. Hale J 2020, 'Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar site ecological character description, for catchments, waterways cities and towns', Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria.
652. Tonkin Z, Jones C, Clunie P, Vivian L, Amtstaetter F, Jones M, Koster W, Mole B, O'Connor J, Brooks J, Caffrey L and Lyon J 2020, 'Victorian environmental flows monitoring and assessment program. stage 6 synthesis report 2016-2020', technical report series no. 316, Arthur Rylah Institute (ARI), Department of Environment, Land, Water and Planning (DELWP), Heidelberg, Victoria.
653. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Western Port Ramsar site management plan', East Melbourne, Victoria.

WP 27: Marine and coastal waterbirds

Region	2021 status	2021 trend	2021 data
Western Port			
Justification for assessment ratings:	Population trends were determined for 39 of the 85 observed waterbird species (excluding seabirds). Populations of 22 waterbird species in Western Port declined between 1973-2015, 15 species remained stable (despite fluctuations and some changes in distribution) and two of the 39 species have increased.[654] This indicator assessment summarises these results, with an overall trend assessment of deteriorating because populations of the majority of waterbird species have declined. The status has been rated as fair because waterbirds are still present in significant numbers in Western Port, which is noted as an important habitat for waterbirds.		

Waterbirds have been counted in Western Port at least three times per year since 1973 in a coordinated citizen science survey run by Birdlife Australia. Surveys have focused on strategic sites including high-tide roosts and associated stretches of coast and nearby wetlands.

Population trends were determined for 39 of the 85 observed waterbird species (excluding seabirds). Populations of 22 waterbird species in Western Port declined between 1973-2015, 15 species remained stable (despite fluctuations and some changes in distribution) and two of the 39 species have increased.[655] This indicator assessment summarises these results, with the migratory shorebirds and piscivorous birds indicators providing extra detail and focusing on those specific waterbirds.

The general decline in waterbirds reflects diminishing wetland availability, local reductions in fish prey, increased predation pressure and changes in inland wetland resources.[656]

Despite the observed declines in some waterbird species over the last two decades, Western Port continues to be an extremely important habitat for waterbirds and attention should be given to the needs of all species so they continue to thrive.[657]

654. Hansen B, Menkhorst P, Moloney P and Loyn R 2015, 'Long-term waterbird monitoring in Western Port, Victoria, reveals significant declines in multiple species', *Austral Ecology*, 40, pp. 513-527.
655. Ibid.
656. Ibid.
657. Melbourne Water 2018, 'Understanding the Western Port environment: a summary of research findings from the Western Port environment research program 2011-2017 and priorities for future research', Melbourne, Victoria.

Table 18: population trends for 39 Western Port waterbird species over 35 years (1974-2009) surveyed by BirdLife Australia.[658]

Observed trend in abundance	Common name	Scientific name
Significant decline in abundance relative to start of survey period	Australian pelican Great cormorant Little pied cormorant Crested tern Silver gull White-faced heron Grey teal Masked lapwing Common greenshank Curlew sandpiper Eastern curlew Grey-tailed tattler Ruddy turnstone	*Pelecanus conspicillatus* *Phalacrocorax carbo* *Phalacrocorax melanoleucos* *Thalasseus bergil* *Chroicocephalus novaehollandiae* *Egretta novaehollandiae* *Anas gracilis* *Vanellus miles* *Tringa nebularia* *Calidris ferruginea* *Numenius madagascariensis* *Tringa brevipes* *Arenaria interpres*
Increased initially followed by decline	Hoary-headed grebe Australian shelduck Chestnut teal Pacific black duck Pacific golden plover Red knot Bar-tailed godwit Whimbrel	*Poliocephalus poliocephalus* *Tadorna tadornides* *Anas castanea* *Anas superciliosus* *Pluvialis fulva* *Calidris canutus* *Limosa lapponica* *Numenius phaeopus*
Initially found regularly in low numbers, becoming extremely rare/absent	Lesser sand plover Greater sand plover	*Charadrius mongolus* *Charadrius leschenaultia*
Significant increase	Australian pied oystercatcher Straw-necked ibis	*Haematopus longirostris* *Threskiornis spinicollis*
Marked increase in the central-eastern part of the bay from an extremely low base	Red-necked avocet Banded stilt Whiskered tern Gull-billed tern	*Recurvirostra novaehollandiae* *Cladorhynchus leucocephalus* *Chlidonius hybridus* *Gelochelidon nilotica*
No significant net trends	Black swan Australian white ibis Royal spoonbill Pacific gull Caspian tern Red-necked stint Double-banded plover Pied cormorant Red-capped plover	*Cygnus atratus* *Threskiornis molucca* *Platalea regla* *Larus pacificus* *Hydroprogne caspia* *Calidris ruficollis* *Charadrius bicinctus* *Phalacrocorax varius* *Charadrius ruficapillus*
Marked increase on Phillip Island and parts of French Island from a low base	Cape barren goose	*Cereopsis novaehollandiae*

658. Ibid.

Black swans form 69% of the waterbird biomass in the survey area and may be useful as a highly visible indicator of seagrass distribution and health. The black swan was the only bird species seen to feed on seagrass as a primary consumer, and seagrass was the main food that black swans were seen taking in tidal waters. Swans virtually disappeared from one part of the bay (Corinella segment) in the early 1980s, following a major documented loss of seagrass from that area.

Numbers of swans elsewhere in the bay fluctuated in various ways, with no uniform linear trend in either direction.[659] This shows that counts of swans are providing strong signals about ecological change at the local level, and it will be valuable to correlate these changes in swan abundance with satellite data on seagrass distribution when it becomes available. The highly visible nature of the black swan means that, if correlations are found, counts and distributions of black swans may provide a useful, cost-effective citizen science tool for detecting changes in seagrass distribution.

Waterbird abundance and breeding are assessed against Limits of Acceptable Change (LACs) in the Western Port Ramsar Site. The LACs are based on five-year data periods; either five-year rolling averages or presence of species recorded in the site for a specified number of seasons during a five-year period.[660]

DELWP has advised that the most recent LAC assessments took place in 2020 for waterbird abundance and breeding and the LACs were both met, except for the abundance of migratory waders. The exceedance of the waterbird LAC for international migratory waders is likely due to external factors (for example, habitat loss along the flyway) as Australian resident shorebirds, who use the same habitat were not found to have shown a similar decline during the LAC assessment.

659. Ibid.
660. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Western Port Ramsar site management plan', East Melbourne, Victoria.

WP 28: Migratory shorebirds

Region	2021 status	2021 trend	2021 data
Western Port			
Justification for assessment ratings:	There have been observed declines in several species of trans-equatorial migratory shorebirds that visit Western Port. The status has been rated as fair because migratory shorebirds are still present in significant numbers in Western Port, which is noted as an important habitat for waterbirds.		

The main declines noted in the marine and coastal waterbirds indicator were associated with trans-equatorial migratory shorebirds. These declines may be due to habitat loss on their migratory flyways in east Asia, particularly the Yellow Sea.

For trans-equatorial migratory shorebirds (breeding in North East Asia or Alaska), the patterns generally involved maximum numbers being observed in Western Port during summer and minimum numbers in winter (as expected, because they breed in the northern hemisphere when it is summer there, during the austral winter). Small numbers of most species remained over winter (young birds), but this was not the case for sharp-tailed sandpiper *Calidris acuminata*, Pacific golden plover *Pluvialis fulva*, lesser sand plover *Charadrius mongolus* and greater sand plover *Charadrius leschenaultii*, which were absent (or extremely rare) in winter. Numbers tended to be higher in late summer than early summer, especially for species such as common greenshank *Tringa nebularia* and sharp-tailed sandpiper that may visit ephemeral inland wetlands before resorting to coastal waters as these wetlands dry over summer. Numbers of the double-banded plover (*Charadrius bicinctus*), which breeds in New Zealand were highest in winter, with just a few early arrivals, usually juveniles, in late summer.[661]

661. Melbourne Water 2018, 'Understanding the Western Port environment: a summary of research findings from the Western Port environment research program 2011-2017 and priorities for future research', Melbourne, Victoria.

Five migratory shorebird species (common greenshank *Tringa nebularia*, curlew sandpiper *Calidris ferruginea*, eastern curlew *Numenius madagascariensis*, grey-tailed tattler *Tringa brevipes* and ruddy turnstone *Arenaria interpres*) were among the 13 waterbirds observed to have declined significantly during the 35 years from 1974 to 2009. Of the nine species that increased initially and then declined, four were migratory shorebirds (Pacific golden plover *Pluvialis fulva*, red knot *Calidris canutus*, bar-tailed godwit *Limosa lapponica* and whimbrel *Numenius phaeopus*).[662]

Two additional species of migratory shorebird (lesser sand-plover *Charadrius mongolus* and greater sand plover *Charadrius leschenaultii*) were regularly found in low numbers at the start of the survey but have become extremely rare or absent.[663]

The red-necked stint and double-banded plover were the only common migratory shorebirds not to show significant declines in number.[664]

Six threatened international migratory bird species are included within the Western Port Ramsar Site Management Plan.

The LACs are that:

- The abundance of eastern curlew, curlew sandpiper and fairy tern will not decline below 1% of the population as stated in the most recent Wetlands International Population Estimate (based on a five-year rolling average of annual maximum counts).
- There is a presence of bar-tailed godwit, lesser sand plover and red knot in at least three out of every five years.[665]

DELWP has advised that the most recent LAC assessment took place in 2020 and the LAC was met for the fairy tern, bar-tailed godwit and red knot, while it was exceeded for the eastern curlew, curlew sandpiper and lesser sand plover. This indicates a deteriorating trend, given the LAC was listed as being met for the eastern curlew and lesser sand plover in the 2017 Western Port Ramsar Site Management Plan.[666] This deterioration is most likely due to external factors (for example, habitat loss along the flyway) as Australian resident shorebirds, who use the same habitat were not found to have shown a similar decline during the LAC assessment.

662. Ibid.
663. Ibid.
664. Ibid.
665. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Western Port Ramsar site management plan', East Melbourne, Victoria.
666. Ibid.

WP 29: Piscivorous (fish-eating) birds

Region	2021 status	2021 trend	2021 data
Western Port		↙	
Justification for assessment ratings:	Research shows that there were decreasing population trends for terns, cormorants and the Australian pelican at Western Port from 1974 to 2012. Although the data quality to support these assessments is good, the confidence in these assessments is only rated as moderate. This is because there are no clear criteria and thresholds to assess the status and the most recent data are now nearly a decade old.		

Numbers of piscivorous (fish-eating) waterbirds have been documented in Western Port since 1974. A study completed in 2015 analysed data from late summer (February) and parts of winter (June–July) for the 38 years from 1974 to 2012. The researchers found decreasing population trends for terns, cormorants and the Australian pelican at Western Port.[667] Most of the decline in piscivorous birds could be attributed to declines in tern numbers. About 70% of the decline in tern numbers in Western Port was due to a decline in the crested tern, with the remainder mostly due to a decline in fairy tern numbers. The decline in numbers of crested terns in Western Port was most likely due to their reduced use of Western Port for feeding, since breeding numbers increased substantially at the western entrance to Western Port during the period of study.[668]

The results suggest that feeding conditions for terns (and to a lesser extent for cormorants and pelicans) in Western Port have deteriorated in comparison to feeding conditions in West Corner Inlet.[669]

The authors of the study postulated that changes in fish trophic relationships in Western Port have resulted in a reduction in food availability for the crested tern. Specifically, a reduction in the abundance of a predatory fish, Australian salmon (*Arripis trutta*), has reduced the time that schools of small fish spend in surface waters, thereby reducing their accessibility to bird species that capture small fish by shallow plunge diving, such as terns.[670]

Understanding the factors affecting the productivity and availability of species of small, schooling fish, and the population status and ecology of the fairy tern in Western Port and adjacent waters, are key information gaps.[671]

667. Menkhorst P, Loyn R, Liu C, Hansen B, Mackay M and Dann P 2015, 'Trends in numbers of piscivorous birds in Western Port and West Corner Inlet, Victoria, 1987–2012', Arthur Rylah Institute for Environmental Research (ARI), unpublished client report for Melbourne Water, Department of Environment, Land, Water and Planning (DELWP), Heidelberg, Victoria.
668. Ibid.
669. Ibid.
670. Ibid.
671. Ibid.

WP 30: Little penguins

Region	2021 status	2021 trend	2021 data
Western Port	●	↗	●
Justification for assessment ratings:	Extensive conservation work since the 1980s has resulted in an increase in little penguin numbers from 12,000 in the mid-1980s to an estimated 32,000 in 2021. Based on this the status has been rated as good. The trend is improving based on unpublished surveys available for trend analysis across recent years.		

Population studies of Phillip Island's little penguins (*Eudyptula minor*) in the 1980s showed that land-based threats such as habitat destruction from housing development, traffic through the penguin colony at night, fire and domestic pets were having a significant impact on Phillip Island's last remaining penguin colony. Predictions from the impact of such threats suggested the Penguin Parade would be wiped out by the late 1990s.[672]

In response to the research, the Penguin Protection Program was initiated, and the Victorian State Government began buying back homes in the Summerland Estate, located in Phillip Island's last remaining penguin colony on the Summerland Peninsula.[673]

Extensive conservation work since the 1980s has resulted in an increase in little penguin numbers from 12,000 in the mid-1980s to an estimated 32,000 in the present day. Research into little penguin threats continues, including investigating the threat of pests such as foxes, shifts in diet and changes in oceanographic conditions, increased storms and strengthening winds under climate change.[674,675,676,677,678,679,680]

672. Phillip Island Nature Parks, 'Penguin research' https://www.penguins.org.au/conservation/research/penguin-research/ Accessed 9 April 2021.
673. Ibid.
674. Ibid.
675. Amélineau F, Saraux C, Ropert-Coudert Y, Kato A, Hobson KA, Raymond B, Zimmer I and Chiaradia A 2021, 'Intra- and inter-individual changes in little penguin diving and isotopic composition over the breeding season', *Marine Biology*, 168(5), pp. 62.
676. Barreau E, Kato A, Chiaradia A and Ropert-Coudert Y 2021, 'The consequences of chaos: foraging activity of a marine predator remains impacted several days after the end of a storm', *PLOS ONE*, 16(7), e0254269.
677. Chiaradia A, Forero MG, Hobson KA and Cullen JM 2010, 'Changes in diet and trophic position of a top predator ten years after a mass mortality of a key prey', *ICES Journal of Marine Science*, 67, pp. 1710-1720.
678. Chiaradia A, Ramirez F, Forero MG and Hobson KA 2016, 'Stable isotopes (δ13C, δ15N) combined with conventional dietary approaches reveal plasticity in central-place foraging behaviour of little penguins (*Eudyptula minor*)' *Frontiers in Ecology and Evolution*, 3, 154.
679. Ropert-Coudert Y, Kato A and Chiaradia A 2009, 'Impact of small-scale environmental perturbations on local marine food resources: a case study of a predator, the little penguin', *Proceedings of the Royal Society*, B276, pp. 4105-4109.
680. Saraux C, Chiaradia A, Salton M, Dann P and Viblanc VA 2016, 'Negative effects of wind speed on individual foraging performance and breeding success in little penguins', *Ecological Monographs*, 86(1), pp. 61-77.

WP 31: Marine mammals

Region	2021 status	2021 trend	2021 data
Western Port	(dolphins and seals)	(dolphins) (seals)	(seals) (dolphins)
Justification for assessment ratings:	**Dolphins:** The Dolphin Research Institute estimates Western Port has a resident population of 20 dolphins. There is no evidence to suggest there has been a decline of these numbers over the past three decades. The very small population size means the consequences of significant mortality events can be proportionally significant on the dolphin population in Western Port, so the status has been rated as poor to reflect this vulnerability. **Seals:** There are an estimated 20,000 to 30,000 Australian Fur Seals in the Seal Rocks colony at the western entrance to Western Port, including bulls, seals and pups. Phillip Island Nature Parks and collaborators have identified statistically significant declining trends in pup numbers since 2007 at Seal Rocks.		

Although a variety of marine mammal species have been reported in Western Port and the largest Australian fur seal colony in the world is just outside the western entrance, the seals rarely travel there.[681,682] Although many other species of marine mammals have been reported, those that occur more frequently appear to be only passing through the southern part of the bay on their way elsewhere.[683]

Melbourne Water's 2011 synthesis report Understanding the Western Port Environment included narratives on Australian fur seals and bottlenose dolphins. A synthesis of this narrative is provided below.[684]

Australian fur seals

There are an estimated 20,000 to 30,000 Australian fur seals in the Seal Rocks colony at the western entrance to Western Port, including bulls, seals and pups.[685] Of about 70 individuals that have been tracked by satellite over the past 10 years, none have ventured far into the bay.[686]

Seals do occur in small numbers in Western Port, and a study from the mid-1990s found an average of just over two per monthly trip along 81 kilometre transects in Western Port between 1991 and 1994.[687] Most seals were recorded in the western and northern arms of the bay, particularly at the western entrance near the breeding colony. Generally, single and mostly small individuals were seen, presumably juveniles or small females.[688]

The Australian fur seal population was recovering from colonial exploitation until 2007. Current population trends are concerning with statistically significant pup reductions of 20-50% since 2007 at all large colonies except Kanowna Island near Wilsons Promontory, which is stable or increasing (trend not significant).[689,690] Phillip Island Nature Parks and collaborators have identified statistically significant declining trends in pup numbers since 2007 at Seal Rocks near Phillip Island, as well as The Skerries and Deen Maar Island (also known as Lady Julia Percy Island); three of the four largest breeding colonies for the species.[691]

681. Chidgey S and Crockett P 2010, 'Stony Point to Cowes vehicular ferry: marine ecosystem preliminary considerations', CEE Consultants Pty Ltd and Meinhardt Infrastructure and Environment.
682. Kirkwood R, Pemberton D, Gales R, Hoskins A, Mitchell T, Shaughnessy P and Arnould J 2010, 'Continued population recovery by Australian fur seals', *Marine and Freshwater Research*, 61, pp. 695-701.
683. Melbourne Water 2011, 'Understanding the Western Port environment – a summary of current knowledge and priorities for future research', Melbourne, Victoria.
684. Ibid.
685. Kirkwood R, Pemberton D, Gales R, Hoskins A, Mitchell T, Shaughnessy P and Arnould J 2010, 'Continued population recovery by Australian fur seals', *Marine and Freshwater Research*, 61, pp. 695-701.
686. Ibid.
687. Dann P 1996, 'The distribution and abundance of Australian fur seals Arctocephalus pusillus and bottlenose dolphins *Tursiops truncatus* in Western Port, Victoria', *Victorian Naturalist*, 113, pp. 306-310.
688. Ibid.
689. McIntosh RR, Kirkman SP, Thalmann S, Sutherland DR, Mitchell A, Arnould JPY, Salton M, Slip DJ, Dann P and Kirkwood R 2018, 'Understanding meta-population trends of the Australian fur seal, with insights for adaptive monitoring', *PLOS ONE*, 13(9), e0200253.
690. McIntosh RR, Sorrell KJ, Thalmann S, Mitchell T, Gray R, Schnagl H, Arnould JPY, Dann P and Kirkwood R (in review), 'Sustained reduction in numbers of Australian fur seal pups: implications for future population monitoring', *PLOS ONE*.
691. Ibid.

All age classes and both sexes of Australian fur seals travel broadly through Bass Strait to forage, with females and juveniles being more likely to return to the breeding site of origin, most likely to feed young and due to physiological constraints of smaller body size.[692] The seals rely on terrestrial coastal protected areas to rest and use marine national parks when foraging and these may be useful refuges for them with higher levels of human regulation.[693]

Australian fur seals are generalist predators that forage on benthic/demersal fish and cephalopods over the continental shelf, with females typically showing strong site fidelity.[694] Prey availability can be affected by local and large-scale oceanographic processes as well as bathymetry and is expected to be affected by changes in the ocean caused by global warming.[695,696,697]

Threats to the populations include bycatch in the commercial trawl fishery, entanglement in marine debris, toxicants in the environment and human waste exposure, stress from vessel visitation to breeding colonies, ocean inundation and storm surge under climate change, and altered food webs and diet because of climate change.[698,699]

The high per- and poly-fluorinated substances (PFAS) levels identified at Seal Rocks in the mouth of Western Port are of concern. Sources of the contaminant are expected to be local. Considering the role of pinnipeds as sentinels of marine ecosystem health and the potential adverse effects of PFAS on neonatal development, monitoring of temporal changes in concentrations is recommended. It is also critical to identify potential PFAS point sources for possible mitigation, particularly if future investigations reveal significant associations between PFAS concentrations and increased vulnerability of these species to adverse health impacts.[700]

Dolphins

Although Western Port is utilised by many fewer dolphins than Port Phillip Bay, there are some notable resident dolphins that can be reliably found in Western Port.[701] For example, three adult dolphins and a subadult resident were reported to be regularly found off Somers circa 2011.[702]

Dolphins were recorded 46 times as part of monthly transects of likely dolphin locations completed between 1991 and 1994. Usually, the dolphins were seen in small pods at the two entrances, and the maximum recorded in one survey was ten.[703]

The Dolphin Research Institute estimates Western Port has a resident population of 20 dolphins. There is no evidence to suggest there has been a decline of these numbers over the past six decades.

Other species reported:

- New Zealand fur seal (*Arctocephalus forsteri*)
- Subantarctic fur seal (*Arctocephalus tropicalis*)
- Australian sea lion (*Neophoca cinereal*)
- Leopard seal (*Hydrurga leptonyx*)
- Southern elephant seal (*Mirounga leonine*)
- Common dolphin (*Delphinus delphis*)
- Dusky dolphin (*Lagenorhynchus obscurus*)
- Killer whale (*Orcinus orca*)
- Humpback whale (Group V) (*Megaptera novaeangliae*)
- Minke whale (*Balaenoptera acutorostrata*)
- Pygmy right whale (*Caperea marginate*)
- Bryde's whale (*Balaenopointera edeni*)
- Blue whale (*Balaenopointera musculus*)
- Southern right whale (*Eubalaena australis*).[704,705]

This indicator links to the fish indicators, with the high productivity of fish in Western Port of importance for higher order consumers such as marine mammals.[706]

692. Salton M, Kirkwood R, Slip DJ and Harcourt R 2019, 'Mechanisms for sex-based segregation in foraging behaviour by a polygynous marine carnivore', *Marine Ecology Progress Series*, 624, pp. 213-226.
693. Salton M, Carr M, Tarjan LM, Clarke J, Kirkwood R, Slip D and Harcourt R 2021, 'Protected area use by two sympatric marine predators repopulating their historical range', *Endangered Species Research*, 45, pp. 181-194.
694. McIntosh RR 2021, 'Australian sea lion (*Neophoca cinerea*), long-nosed fur seals (LNFS, *Arctocephalus forsteri)*, Australian fur seals (AUFS, *Arctocephalus pusillus doriferus*), state and trend assessment: pinnipeds', State of the Environment 2021, marine expert assessments.
695. Hardy N, Berry T, Kelaher BP, Goldsworthy SD, Bunce M, Coleman MA, Gillanders BM, Connell SD, Blewitt M and Figueira W 2017, 'Assessing the trophic ecology of top predators across a recolonisation frontier using DNA metabarcoding of diets', *Marine Ecology Progress Series*, 573, pp. 237-254.
696. Kliska K 2015, 'Environmental correlates of temporal variation in the diet of Australian fur seals', Master of Science, Department of Biological Sciences, MSc, Macquarie University.
697. Speakman CN, Hoskins AJ, Hindell MA, Costa DP, Hartog JR, Hobday AJ and Arnould JPY 2020, 'Environmental influences on foraging effort, success and efficiency in female Australian fur seals', *Scientific Reports*, 10(17710).
698. 'Australian sea lion (*Neophoca cinerea*), long-nosed fur seals (LNFS, *Arctocephalus forsteri*), Australian fur seals (AUFS, *Arctocephalus pusillus doriferus*), state and trend assessment: pinnipeds', State of the Environment 2021, marine expert assessments.
699. McLean LJ, George S, Ierodiaconou D, Kirkwood RJ, Arnould JPY 2018, 'Impact of rising sea levels on Australian fur seals', PeerJ, 6, e5786.
700. Taylor S, Terkildsen M, Stevenson G, de Araujo J, Yu C, Yates A, McIntosh R and Gray R 2021, 'Per and polyfluoroalkyl substances (PFAS) at high concentrations in neonatal Australian pinnipeds', *Science of the Total Environment*, e147446.
701. The burrunan dolphin's presence as a unique species is disputed. For the purpose of this indicator assessment, the State of the Marine and Coastal Environment 2021 Report is following the listing in the Flora and Fauna Guarantee Act 1998 and referring to the dolphins in Western Port as burrunan dolphins. Further information is provided in the opening summary section for Indicator 31: Marine mammals. Regardless of whether the dolphins in Western Port are classified as burrunan dolphins or common bottlenose dolphins, there is agreement that the population is stable at approximately 20.
702. Melbourne Water 2011, 'Understanding the Western Port environment – a summary of current knowledge and priorities for future research', Melbourne, Victoria.
703. Ibid.
704. Ibid.
705. Note that the pygmy right whale, brydes whale and blue whale are not residents.
706. Melbourne Water 2011, 'Understanding the Western Port environment – a summary of current knowledge and priorities for future research', Melbourne, Victoria.

Corner Inlet and Nooramunga

CIN 15: Conservation of coastal ecosystems in protected areas

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The conservation of coastal ecosystems in protected areas within five km of Corner Inlet and Nooramunga is encompassed within a broad analysis of the entire Victorian coastline in the statewide assessment for this indicator.		

CIN 16: Saltmarsh

Region		2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	Corner Inlet	●	→	●
	Nooramunga	●	→	●
	Nooramunga islands	●	→	●
Justification for assessment ratings:	The status for Corner Inlet has been rated as fair because, although more than half of the saltmarsh cover has been lost since European settlement, the Limit of Acceptable Change (LAC) for saltmarsh in the Corner Inlet Ramsar Site is that total saltmarsh extent will not decline below 2,775 hectares, which is being met. Nooramunga's status is fair with saltmarsh losses less extensive (20%), while the saltmarsh area around the Nooramunga islands is rated as good and estimated to be 6% greater now than in the pre 1750s period.			

Research published in 2012 showed that approximately 60% of Corner Inlet's pre-1750s saltmarsh cover of 1,350 hectares has been lost.[707] This represents some of Victoria's largest losses of saltmarsh. Most of the existing saltmarsh in Corner Inlet is bordered by channels and walls/levees, and the upper marsh has been drained and converted to pasture.

For the Nooramunga coastline, like Corner Inlet, much of the marsh is now bounded inland by sea walls and channels, which provide direct evidence of the extent to which the landscape has changed. About 20% of Nooramunga's pre-1750s saltmarsh cover of 2,820 hectares has been lost.[708]

The Nooramunga islands remain almost entirely uncleared and undeveloped and, as such, probably represent the least disturbed large sector of coastal saltmarsh on the Victorian coast, with the saltmarsh area around the Nooramunga islands estimated to be 6% greater now than in the pre-1750s period.[709]

Habitat mapping for the Corner Inlet Ramsar Site was completed for the West Gippsland Catchment Management Authority during 2020 and found that there was 3,503 hectares of saltmarsh in the Ramsar Site.[710] This saltmarsh extent means the limit of acceptable change (LAC) for the Ramsar Site for saltmarsh extent to remain above 2,775 hectares was met.[711]

707. Sinclair S and Boon P 2012, 'Changes in the area of coastal marsh in Victoria since the mid 19th century', *Cunninghamia*, 12(2), pp. 153–176.
708. Ibid.
709. Ibid.
710. Brooks S and Hale J 2020, 'Corner Inlet Ramsar habitat mapping', report for West Gippsland Catchment Management Authority (WGCMA), Traralgon, Victoria.
711. Ibid.

CIN 17: Mangroves

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga			
Justification for assessment ratings:	There has been minimal loss of mangrove habitat since European settlement, with approximately 80% of the mangrove habitat in Corner Inlet and Nooramunga remaining in 2012. Corner Inlet and Nooramunga has the most extensive stands of mangrove along Victoria's coast. Based on this information, the status for this indicator has been assessed as good. The Limit of Acceptable Change (LAC) for mangroves in the Corner Inlet Ramsar Site is that total mangrove extent will not decline below 1,600 hectares. This is being met, with the most recent assessment estimating there are more than 3,800 hectares of saltmarsh in the Ramsar Site.		

Mangroves are at their southern-most limit in Corner Inlet and Nooramunga, where at least 80% of the pre-1750s cover remains. Corner Inlet and Nooramunga has the most extensive stands of mangrove along Victoria's coast: 846 hectares in Corner Inlet and 2,241 hectares in Nooramunga (compared with 1,230 hectares in Western Port and 84 hectares in the lower Barwon region). The 3,087 hectares of mangroves in Corner Inlet and Nooramunga accounts for 60% of the current mangrove area across Victoria.[712]

The mangrove communities in Corner Inlet are comprised of a single mangrove species, namely white mangrove (*Avicennia marina*), representing the most southerly distribution of this species on a global scale.[713] Corner Inlet's mangroves are important roosting and sheltering sites for a variety of shorebirds, and provide nursery grounds for fish and a diversity of invertebrate fauna.[714]

Habitat mapping for the Corner Inlet Ramsar Site was completed for the West Gippsland Catchment Management Authority during 2020 and found that there was 3,814 hectares of mangroves in the Ramsar Site.[715] This mangrove extent means the Limit of Acceptable Change (LAC) for the Ramsar Site for mangrove extent to remain above 1,600 hectares was met.[716]

712. Sinclair S and Boon P 2012, 'Changes in the area of coastal marsh in Victoria since the mid 19th century', *Cunninghamia*, 12(2), pp. 153–176.
713. Plummer A, Morris L, Blake S and Ball D 2003, 'Marine natural values study, Victorian marine national parks and sanctuaries', Parks Victoria technical series no. 1, Melbourne, Victoria.
714. Department of Sustainability, Environment, Water, Population and Communities (DSEWPC) 2011, 'Corner Inlet Ramsar site ecological character description', Australian Government, Canberra.
715. Brooks S and Hale J 2020, 'Corner Inlet Ramsar habitat mapping', report for West Gippsland Catchment Management Authority (WGCMA), Traralgon, Victoria.
716. Ibid.

CIN 18: Wetland and estuarine vegetation

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga		?	
Justification for assessment ratings:	Through the 2021 Index of Estuary Condition (IEC) assessments, there is high confidence in the status assessment for estuarine flora in this indicator. As part of the IEC, flora assessments for 11 estuaries were completed in the West Gippsland catchment region for those estuaries that flow into Corner Inlet and Nooramunga. One estuary was rated as excellent for flora, three estuaries were rated as good, six as fair, with one rated poor.		

Estuarine flora

Table 19 shows the IEC flora results for estuaries in the West Gippsland catchment region that flow into Corner Inlet and Nooramunga.[717] One estuary received a rating of excellent for flora, three estuaries were rated as good, six estuaries were rated as fair, while one estuary was rated as poor. As this is the first IEC, and IECs are designed to be point-in-time assessments, no time series data are available to assess trends.

The Franklin River estuary on the northern shoreline of Corner Inlet had flora in excellent condition, with large areas of intact mangroves.[718] It should be noted that the condition of flora at the Franklin River estuary is based on fringing vegetation only. No submerged vegetation was detected during field assessments, preventing the application of the submerged vegetation measure that assesses the ratio of macroalgae to total submerged vegetation. Submerged vegetation may have been absent from this system, which is characterised by deep channels, because there was insufficient light for submerged vegetation to grow.[719]

Table 19: IEC results for estuarine flora within the West Gippsland catchment region that flow into Corner Inlet and Nooramunga.[720]

Estuary	Flora	Condition Class
Old Hat Creek	6	Fair
Stockyard Creek	6	Fair
Bennison Creek	6	Fair
Franklin River	10	Excellent
Agnes River	7	Fair
Shady Creek	9	Good
Nine Mile Creek	6	Fair
Albert River	9	Good
Tarra River	7	Fair
Neils Creek	5	Poor
Bruthen Creek	8	Good

Range 1 – 10 (1 poorest condition, 10 best condition). NA = not assessed.

717. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Index of estuary condition', East Melbourne, Victoria.
718. Ibid.
719. Ibid.
720. Ibid.

CIN 19: Species of conservation concern

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	?	●
Justification for assessment ratings:	The data analysed and reported for this indicator provide information on the number of species of conservation concern. The status and trend assessments are unknown and unclear, respectively, because no information is available to ascertain how these species are being tracked and managed, and no trend data are available to assess how these species are tracking over time.		

Publicly accessible data from the Victorian Biodiversity Atlas has been analysed to determine the magnitude of threatened and vulnerable marine and coastal species within Corner Inlet and Nooramunga.

Within the Victorian Biodiversity Atlas there are 552 fauna species and 874 flora species that are mapped to be within the Corner Inlet and Nooramunga marine biounits. Of these, there are 30 fauna species and one flora species that are denoted by the Atlas as being listed within the FFG Act, listed as endangered, threatened or vulnerable within the Environment Protection and Biodiversity Conservation Act 1999, or included as on DELWP's advisory list as endangered, threatened, vulnerable or poorly known.

Given that recent amendments to the FFG Act have removed duplication by establishing a single comprehensive list of threatened flora and fauna species and revoking Advisory Lists,[721] any updates to the Victorian Biodiversity Atlas attribute fields will be incorporated in future State of the Marine and Coastal Environment reports.

Of the combined 31 species of conservation concern that are listed within the Victorian Biodiversity Atlas, 21 (68%) have records within the past 20 years.

There is a lack of published analysis and time series data available to assess how these species are tracking over time and this will be an area of focus for future State of the Marine and Coastal Environment reports.

CIN 20: Mobile invertebrates on intertidal reefs

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The flora and fauna of intertidal reefs within the Corner Inlet Marine National Park and Nooramunga Marine and Coastal Park have not been surveyed.		

CIN 21: Sessile invertebrates on intertidal reefs

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The flora and fauna of intertidal reefs within the Corner Inlet Marine National Park and Nooramunga Marine and Coastal Park have not been surveyed.		

721. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Threatened list and processes list' East Melbourne, Victoria https://www.environment.vic.gov.au/conserving-threatened-species/threatened-list Accessed 17 August 2021.

CIN 22: Invertebrates on subtidal reefs

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The flora and fauna of subtidal reefs within the Corner Inlet Marine National Park and Nooramunga Marine and Coastal Park have not been surveyed.		

CIN 23: Commercially and recreationally important invertebrates

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. This is due to there not being any commercially and recreationally important invertebrate stocks in Corner Inlet and Nooramunga.		

CIN 24: Commercially and recreationally important fish

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	● (King George whiting, rock flathead)	→ (King George whiting) ↙ (rock flathead)	● (King George whiting, rock flathead)
Justification for assessment ratings:	**King George whiting:** The likelihood of recent strong post-larval recruitment based on sampling in Port Phillip Bay is expected to support an increasing CPUE for King George whiting in Corner Inlet over the next few years so the stock should remain sustainable. **Rock flathead:** In recent years a greater commercial effort is being made to catch rock flathead and this is resulting in a greater catch of rock flathead, however, a decreasing CPUE shows that it is becoming more difficult to catch rock flathead in Corner Inlet-Nooramunga. If this combination continues, a further deterioration of rock flathead in Corner Inlet-Nooramunga is expected.		

Each year commercial fishers catch more than $2 million worth of fish from Corner Inlet, with King George whiting, southern calamari, rock flathead, southern sea garfish and gummy shark the most common species. Industry representatives say it relies on a healthy broadleaf seagrass ecosystem for its survival.[722] The Landcare network, in partnership with the commercial fishing industry, is aiming to replant 200 hectares of broadleaf seagrass in Corner Inlet over the coming two years.[723]

King George whiting

During each of the past four years of data (from 2014-15 to 2018-19), Corner Inlet has been the location for the highest commercial landings of King George whiting in Victoria. The catch rates in Corner Inlet are highly variable and likely due to natural fluctuations. There is no recent information on recreational harvest or effort.[724]

722. Australian Broadcasting Corporation (ABC) 2019, 'Sea urchins devastate broadleaf seagrass: industry and environmentalists team up to restore it' https://www.abc.net.au/news/2019-11-01/fighting-urchin-induced-seagrass-devastation/11658504?fbclid=IwAR3g79dZy7FK-lTR-GytnZJFs3q3mqQMH7NR3MCPt7UJU-HT4rTuNmaQ-8s Accessed 13 July 2020.
723. Ibid.
724. Victorian Fisheries Authority (VFA) 2020, 'Review of key Victorian fish stocks — 2019'.

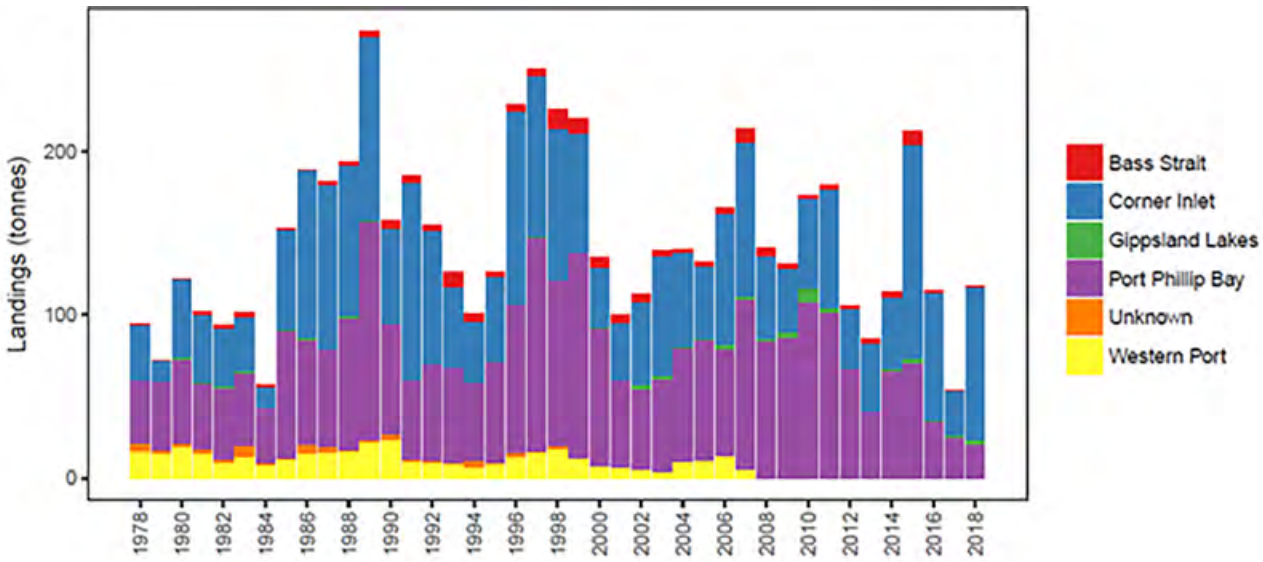
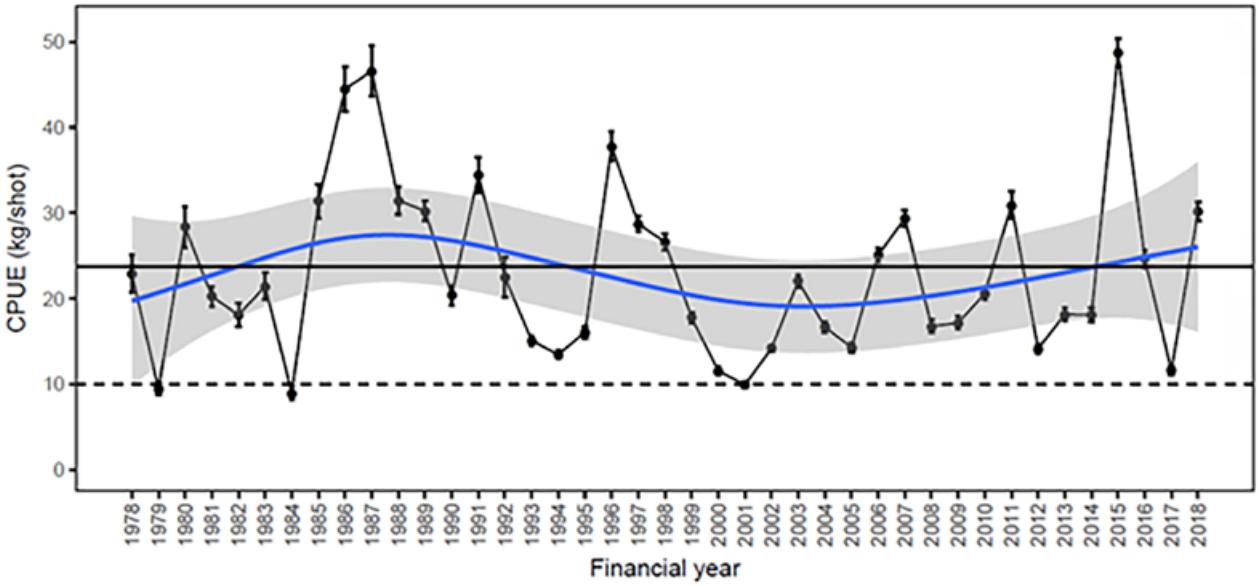


Figure 45: King George whiting commercial catches in Victorian waters by financial years 1978–2018.[725]

Amongst the annual variability, there is a slightly increasing overall trend in CPUE for commercial fishers targeting King George whiting in Corner Inlet.



Horizontal black line is the mean nominal CPUE during the reference period (1985–2015) and the dashed black line is the minimum CPUE within the reference period. The blue line is a generalised additive model GAM of the standardised CPUE trend with the shaded grey area representing the 95% confidence interval of the GAM.

Figure 46: Commercial haul seine catch-per-unit-effort (nominal) for King George whiting in Corner Inlet, 1978–2018.[726]

725. Ibid.
726. Ibid.

There is no data on post-larval King George whiting recruitment to Corner Inlet, however Port Phillip Bay data shows relatively strong recruitment for the three years to 2019 and Port Phillip Bay's King George whiting recruitment patterns are thought to be indicative of post-larval recruitment to other Victorian bays and inlets.[727]

The likelihood of recent strong post-larval recruitment is expected to propel the increasing CPUE for King George whiting in Corner Inlet over the next few years so the stock should remain sustainable.[728]

Rock flathead

The Corner Inlet-Nooramunga fishery was responsible for approximately 70% of the statewide harvest of rock flathead during 2010, which was the year for peak commercial rock flathead harvest in Victoria since records began in 1978. Over the past three years, more than 90% of the commercial harvest of rock flathead has occurred in Corner Inlet-Nooramunga. There was a decline in the commercial catch of rock flathead at Corner Inlet-Nooramunga from the peak in 2010 until 2015, however there has been a steady increase in catches for the three most recent years of data (2016-17 to 2018-19).[729]

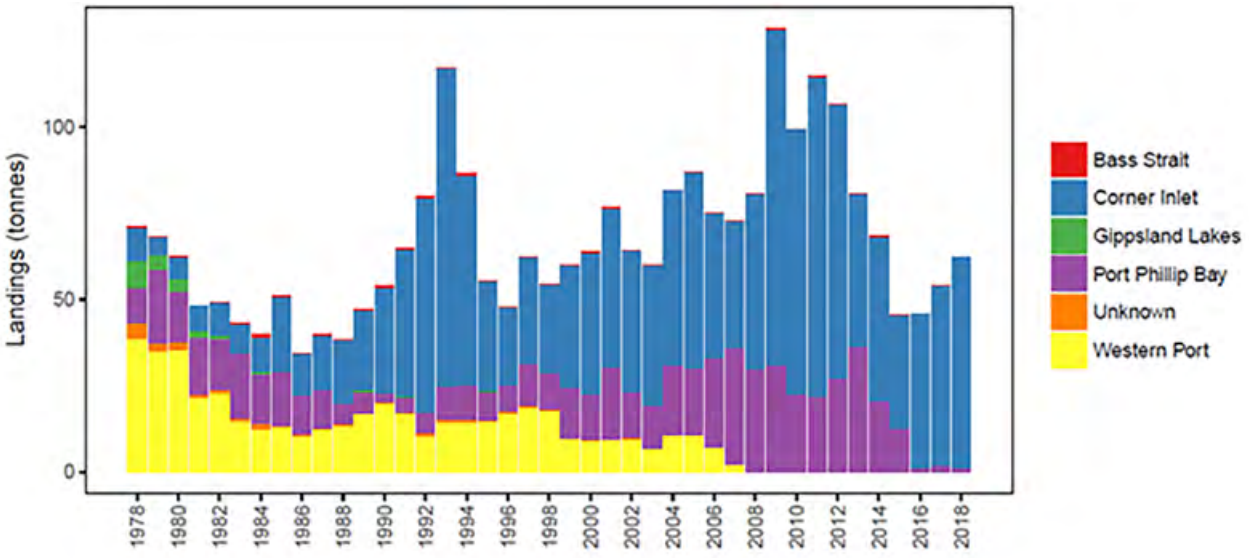


Figure 47: Rock flathead commercial catches in Victorian waters by financial year from 1978–2018.[730]

While the peaks in CPUE likely relate to recruitment variation, the underlying trend is declining for mesh net CPUE and increasing for seine net CPUE. The declining mesh net CPUE is noteworthy because of recent increases in mesh net effort and catch.

There is only a very small recreational catch of rock flathead in Corner Inlet and recreational fishing is unlikely to have a significant impact on stock sustainability.

In recent years a greater commercial effort is being made to catch rock flathead and this is resulting in a greater catch of this species, however, a decreasing CPUE shows that it is becoming more difficult to catch rock flathead in Corner Inlet-Nooramunga. If this combination continues, a further decline of rock flathead in Corner Inlet-Nooramunga is expected.

727. Ibid.
728. Ibid.
729. Ibid.
730. Ibid.

CIN 25: Subtidal reef fish

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The flora and fauna of subtidal reefs within the Corner Inlet Marine National Park and Nooramunga Marine and Coastal Park have not been surveyed.		

CIN 26: Diadromous fish

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. Diadromous fish are assessed in the Statewide chapter.		

CIN 27: Marine and coastal waterbirds

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	→	●
Justification for assessment ratings:	The Limit of Acceptable Change (LAC) assessments from 2020 show that LACs for waterbird abundance and threatened species were being met in the Corner Inlet Ramsar Site for non-migratory birds. There was insufficient information to assess the LAC for waterbird breeding, which has resulted in the indicator confidence assessment of moderate.		

Waterbird abundance and breeding are assessed against Limits of Acceptable Change (LACs) in the in the Corner Inlet Ramsar Site. The LACs are based on five-year data periods; either five-year rolling averages or presence of species recorded in the site for a specified number of seasons during a five-year period.[731]

Four threatened bird species also have limits of acceptable change included within the Corner Inlet Ramsar Site.

Three of these are the migratory species: great knot, greater sand plover and lesser sand plover, with the other being the hooded plover, which is a resident shorebird. The LAC for the hooded plover is that it is recorded within the site in three out of five seasons.[732]

DELWP has advised that the most recent LAC assessment took place in 2020 and the LAC was met for waterbird abundance for all non-migratory species.

731. Hale J 2017, 'Addendum to the ecological character description for the Corner Inlet Ramsar site', Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria.
732. Ibid.

CIN 28: Migratory shorebirds

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga			
Justification for assessment ratings:	A review of 30 years of data (1981–2011) for migratory shorebird numbers in Corner Inlet and Nooramunga revealed a 23% decline in the combined numbers of all species. Despite the deteriorating trend, the status has been rated as fair because the combined population is still estimated to be approximately 25,000-30,000.		

The Corner Inlet Ramsar Site is the most southerly marine embayment and tidal mudflat system of mainland Australia. The site is of international zoological significance as habitat for migratory wading birds.[733]

A review of 30 years of data (1981–2011) for migratory shorebird numbers in Corner Inlet and Nooramunga revealed a 23% decline in the combined numbers of all species, down from 35,000–40,000 to 25,000–30,000.[734] Ten species declined, one increased and five showed no significant change. Although there was uncertainty on the causes, the authors suggested that habitat loss along the birds' flyway could be the main factor.

In addition to the limits of acceptable change for waterbird abundance and breeding that were including in the narrative for Indicator 27: Marine and coastal waterbirds, three threatened migratory shorebird species also have LACs included within the Corner Inlet Ramsar Site. These are the great knot, greater sand plover and lesser sand plover. The LACs are that the great knot, greater sand plover and lesser sand plover are each recorded within the Ramsar site in three out of five seasons.[735] DELWP has advised that the most recent LAC assessment for these migratory species occurred in 2020 and the LAC was exceeded for the great knot and greater sand plover, while it was met for the lesser sand plover.

The exceedance of the waterbird abundance LAC for migratory species is likely due to external factors (for example, habitat loss along the flyway) and the decline in migratory species is consistent with global trends.

733. BirdLife International 2021, 'Important bird areas factsheet: Corner Inlet' http://datazone.birdlife.org/site/factsheet/corner-inlet-iba-australia Accessed 19 May 2021.
734. Minton C, Dann P, Ewing A, Taylor S, Jessop R, Anton P and Clemens R 2012, 'Trends of shorebirds in Corner Inlet, Victoria, 1982–2011', *Stilt*, 61, pp. 3–18.
735. Hale J 2017, 'Addendum to the ecological character description for the Corner Inlet Ramsar site', Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria.

CIN 29: Piscivorous (fish-eating) birds

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	↗	●
Justification for assessment ratings:	A study completed in 2015 analysed data from 1987 to 2012. The researchers found increasing population trends for terns, cormorants and the Australian pelican at West Corner Inlet. The results of this study are the basis of the status and trend assessments of good and improving, respectively.		

Numbers of piscivorous (fish-eating) waterbirds have been documented in West Corner Inlet since 1987. A study completed in 2015 analysed data from late summer (February) and parts of winter (June–July) for the 25 years from 1987 to 2012. The researchers found increasing population trends for terns, cormorants and the Australian pelican at West Corner Inlet.[736]

The results for West Corner Inlet contrasted with decreasing population trends for piscivorous birds that were observed in Western Port.

The authors suggest that feeding conditions for terns, and to a lesser extent for cormorants and pelicans, in Western Port have deteriorated in comparison to feeding conditions in West Corner Inlet.[737] No obvious cause is apparent for the increases in numbers of terns, cormorants and the Australian pelican at West Corner Inlet, but the increasing success of commercial fishing (as measured by catch per unit effort) suggests that fish stocks may have increased there, providing improved foraging conditions.[738]

CIN 30: Little penguins

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. Not a significant fauna species in the region. There is a penguin colony at nearby Rabbit Island, with a brief narrative provided below.		

Foraging studies of little penguins from Rabbit Island showed that sardines (*Sardinops sagax*) and anchovies (*Engraulis australis*) are the most important prey species in the little penguin's diet, making up half of the total biomass.[739] Penguins travelled 18 km on average from Rabbit Island, with most birds spending nearly all their time foraging to the north, around the entrance to Corner Inlet.[740] Sardines are also targeted by commercial fisheries. A decrease in food supply within the penguin foraging range, would likely have adverse ramifications for little penguin breeding success in this area. This highlights the importance of protecting and managing Rabbit Island and surrounding waters to ensure the ongoing viability of the penguin colony.

736. Menkhorst P, Loyn R, Liu C, Hansen B, Mackay M and Dann P 2015, 'Trends in numbers of piscivorous birds in Western Port and West Corner Inlet, Victoria, 1987–2012', Arthur Rylah Institute for Environmental Research (ARI), unpublished client report for Melbourne Water, Department of Environment, Land, Water and Planning (DELWP), Heidelberg, Victoria.
737. Ibid.
738. Ibid.
739. Hoffman J 2006, 'The diet and foraging movements of the little penguin at Rabbit Island, Victoria' Honours thesis, Monash University, Melbourne.
740. Ibid.

CIN 31: Marine mammals

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. No data are currently available to provide status or trend assessments for this indicator, however the federal government's Corner Inlet Ramsar Site Ecological Character Description notes that a wide variety of marine mammals occur in the site including bottlenose dolphins and Australian fur seals, as well as occasional records of common dolphins, New Zealand fur seals, leopard seals and southern right whales.[741]		

Gippsland Lakes

GL 15: Conservation of coastal ecosystems in protected areas

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The conservation of coastal ecosystems in protected areas within five km of the Gippsland Lakes is encompassed within a broad analysis of the entire Victorian coastline in the statewide assessment for this indicator.		

GL 16: Saltmarsh

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	?	●
Justification for assessment ratings:	There has been some loss of saltmarsh cover since European settlement, with approximately 65-100% of the saltmarsh cover remaining in 2012, with the losses occurring variably across the Lakes. The Limit of Acceptable Change (LAC) for saltmarsh in the Gippsland Lakes Ramsar Site is that the total mapped area of salt flat, saltpan and salt meadow habitat at Lake Reeve Reserve extent will not decline below 2,517 hectares. This is being met, with the most recent assessment, completed in 2021, estimating there is more than 5,000 hectares of saltmarsh habitat in the Ramsar site. The status of fair is based on variable losses of saltmarsh cover since European settlement but the LAC for saltmarsh being met in the Gippsland Lakes Ramsar Site.		

Historical mapping of lakes King, Reeve, Victoria and Wellington indicates that between 65% and 100% of pre-1750s saltmarsh has been retained in the Gippsland Lakes.[742]

741. Department of Sustainability, Environment, Water, Population and Communities (DSEWPC) 2011, 'Corner Inlet Ramsar site ecological character description', Australian Government, Canberra.
742. Sinclair S and Boon P 2012, 'Changes in the area of coastal marsh in Victoria since the mid 19th century', *Cunninghamia*, 12(2), pp. 153–176.

Saltmarsh and other areas of saline coastal wetland around the Gippsland Lakes are especially complex spatially and temporally, and this has made it difficult to resolve changes in post-European extent, which is why the confidence for this indicator assessment has been rated as moderate rather than high. Increasing salinisation caused by the 1889 opening of the artificial entrance may see areas of saltmarsh increase and areas of non-halophytic fringing vegetation, such as common reed, decline.[743] Future sea level rise and storm surges, exacerbated by ongoing dredging of the entrance, are expected to reduce saltmarsh extent.[744,745]

Lake Reeve has retained approximately 85% of its former saltmarsh area, with much of the loss due to one large area claimed for pasture at the western end.[746]

The historic record clearly shows that saltmarsh was present and extensive around Lakes Victoria and King in the early 19th century. Like Lakes Victoria and King, Lake Wellington and its fringing wetlands have been strongly influenced by the opening of the artificial entrance to the ocean at Lakes Entrance.

Historical mapping shows that saltmarsh or salt lakes occurred naturally right around the lake. It is likely that saltmarsh has expanded in some places around the Gippsland Lakes, while remaining static or decreasing in others.[747]

DELWP has advised that the most recent LAC assessment for saltmarsh in the Gippsland Lakes Ramsar Site took place in 2021 and the LAC was met. The LAC for saltmarsh in the Gippsland Lakes is that the total mapped area of salt flat, saltpan and salt meadow habitat at Lake Reeve Reserve will not decline below 2,517 hectares.[748] This is being met, with the most recent assessment, completed in 2021, estimating there is more than 5,000 hectares of salt flat, saltpan and salt meadow habitat in the Ramsar site.

The Gippsland Lakes is a hotspot of coastal saltmarsh in Victoria, with more than a third of Victoria's total coastal saltmarsh, and there is a likelihood that it will experience great stress with ongoing sea level rise and associated periods of storm surge, due to climate change.[749,750]

GL 17: Mangroves

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. A brief narrative is provided below for the Gippsland Lakes.		

There are only sporadic occurrences of mangroves in the Gippsland Lakes. Research published in 2015 highlighted that there is a small stand of mangroves at the distal end of Cunninghame Arm in the most eastern part of the Gippsland Lakes, with an isolated specimen occurring near Bullock Island, while it is possible that other specimens occur elsewhere in the most saline parts of the Lakes.[751]

743. Bird E 1966, 'The impact of man on the Gippsland Lakes, Australia', in 'Geography as human ecology. methodology by example', S Eyre and G Jones (eds), Edward Arnold, London, pp. 55–73.
744. Boon P, Cook P and Woodland R 2016, 'The challenges posed by chronic environmental change in the Gippsland Lakes Ramsar site', *Marine and Freshwater Research*, 67(6), pp. 721-737.
745. Boon P, Frood D, Oates A, Reside J and Rosengren N 2019, 'Why has *Phragmites australis* persisted in the increasingly saline Gippsland Lakes? A test of three competing hypotheses', *Marine and Freshwater Research*, 70(4), pp. 469-492
746. Sinclair S and Boon P 2012, 'Changes in the area of coastal marsh in Victoria since the mid 19th century', *Cunninghamia*, 12(2), pp. 153–176.
747. Ibid.
748. BMT WBM 2011, 'Ecological character description of the Gippsland Lakes Ramsar site – final report', prepared for the Department of Sustainability, Environment, Water, Population and Communities (DSEWPC), Australian Government, Canberra.
749. Boon PI, Allen T, Carr G, Frood D, Harty C, McMahon A, Mathews S, Rosengren N, Sinclair S, White M and Yugovic J 2015, 'Coastal wetlands of Victoria, south-eastern Australia: providing the inventory and condition information needed for their effective management and conservation', *Aquatic Conservation: Marine and Freshwater Ecosystems*, 25, pp. 454–479.
750. Rogers K, Boon PI, Branigan S, Duke NC, Field CD, Fitzsimons JA, Kirkman H, MacKenzie JR, and Saintilan N 2016, 'The state of legislation and policy protecting Australia's mangrove and salt marsh and their ecosystem Services', *Marine Policy*, 72, pp. 139–155.
751. Boon P, Rosengren N, Frood D, Oates A and Reside J 2015, 'Shoreline geomorphology and fringing vegetation of the Gippsland Lakes. Volume 1: a literature review', report to Gippsland Lakes Ministerial Advisory Committee, Bairnsdale.

As an expansion of mangroves has been reported for many parts of south-eastern Australia it is perhaps not surprising that they are now also found in the Gippsland Lakes. The 2015 research summarised the opinions of the origins of these mangroves. The specimens in Cunninghame Arm were hypothesised as being planted, probably in the late 1980s or early 1990s, however no evidence was provided to support this hypothesis.[752]

Alternatively, the potential for mangrove propagules to spread from the west (from Corner Inlet-Nooramunga) or from the north (from southern New South Wales) may mean their establishment in the Lakes is a natural phenomenon, occurring in response to the creation of a new and vacant niche in the intertidal zone as a result of chronic salinisation.[753]

GL 18: Wetland and estuarine vegetation

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	(estuarine flora) (wetland habitat extent) (condition of paperbark-dominated wetlands)	?	(estuarine flora) (wetland habitat extent, condition of paperbark-dominated wetlands)
Justification for assessment ratings:	Even though many of the paperbark-dominated wetlands of the Gippsland Lakes are in poor ecological condition, the LAC for freshwater wetland habitat extent was assessed as being met in 2021, while the LAC for brackish wetland habitat extent is likely to be met. Through the 2021 Index of Estuary Condition (IEC) assessments, there is high confidence in the status assessment for estuarine flora in this indicator. As part of the IEC, flora assessments for 14 estuaries were completed in the West and East Gippsland catchment regions for those estuaries that flow into the Gippsland Lakes. Three estuaries were rated as excellent for flora, seven estuaries were rated as good, two as fair, with two rated poor.		

Emergent woody vegetation

A band of woody emergent vegetation frequently occurs behind the saltmarsh zone in the Gippsland Lakes region. In eastern Victoria, this woody emergent, water-dependent vegetation is typically dominated by paperbarks and the dominant coastal paperbark species of the Gippsland Lakes is swamp paperbark, *Melaleuca ericifolia*. As with many wetland taxa of the Gippsland Lakes, this species can tolerate moderate-to-high levels of salinity and can maintain growth under chronically waterlogged conditions, sometimes for decades. Even so, many of the paperbark-dominated wetlands of the Gippsland Lakes are in poor ecological condition because of the combination of high salinity and prolonged inundation.[754]

Emergent non-woody vegetation

Although saltmarsh dominates many of the more elevated intertidal habitats along Australia's south-eastern coastline, a wide range of other non-woody vegetation also occurs along less saline parts of the coast. In estuarine systems, coastal saltmarsh is often juxtaposed with a complex suite of other non-woody wetland types and variously inundated by saline and fresh water over highly variable spatial and temporal scales.[755]

752. Harty C 2011, 'Mangroves of Victoria information kit', Parks Victoria, Melbourne.
753. Boon P, Rosengren N, Frood D, Oates A and Reside J 2015, 'Shoreline geomorphology and fringing vegetation of the Gippsland Lakes. Volume 1: a literature review', report to Gippsland Lakes Ministerial Advisory Committee, Bairnsdale.
754. Ibid.
755. Keith D, Simpson C, Tozer M and Rodoreda S 2007, 'Contemporary and historical descriptions of the vegetation of brundee and saltwater swamps on the lower Shoalhaven River floodplain, southeastern Australia', *Proceedings of the Linnean Society of New South Wales*, 128, pp. 123–153.

The dominant type of non-woody emergent vegetation in the Gippsland Lakes is beds of the common reed, *Phragmites australis*. These commonly form dense bands behind and within swamp paperbark woodlands, commonly close to the water's edge. Reeds and other perennial, emergent rhizomatous taxa also occur around the Gippsland Lakes, including a range of sedges, spike-rushes, and rushes.[756]

Limits of acceptable change for the Ramsar site

Limits of Acceptable Change (LACs) exist for brackish and freshwater wetlands.[757] DELWP has advised that LAC assessments were made in 2021 with the following results:

- Brackish wetlands (habitat extent) – LAC likely to be met
- Freshwater wetlands (habitat extent) – LAC met
- Brackish wetlands (salinity) – LAC met
- Freshwater wetlands – salinity (Sale Common) – insufficient data to assess the LAC.

Estuarine flora

Table 20 shows the IEC flora results for estuaries in the West and East Gippsland catchment regions that flow into the Gippsland Lakes.[758] Three estuaries received a rating of excellent for flora, seven estuaries were rated as good, two estuaries were rated as fair, while two estuaries were rated as poor. As this is the first IEC, and IECs are designed to be point-in-time assessments, no time series data are available to assess trends.

Flora was in excellent condition at the Latrobe and Avon River estuaries where the estuarine fringing vegetation is within the Gippsland Lakes Ramsar Site, the Heart Morass and Dowd Morass Wildlife Reserve (Latrobe), and the Clydebank Morass Wildlife Reserve (Avon). It should be noted that the condition of flora at the Latrobe and Avon River estuaries is based on fringing vegetation only. No submerged vegetation was detected during field assessments, preventing the application of the submerged vegetation measure that assesses the ratio of macroalgae to total submerged vegetation. Submerged vegetation may have been absent from these systems, which are characterised by deep channels, because there was insufficient light for submerged vegetation to grow.[759]

At the Mitchell River, exotic species within the estuary fringe and submerged vegetation dominated by macroalgae (with little seagrass detected) contributed to the poor IEC flora sub-index score. At Tom Creek, submerged vegetation dominated by macroalgae (with little seagrass detected) contributed to the poor IEC flora sub-index score.[760]

756. Boon P, Rosengren N, Frood D, Oates A and Reside J 2015, 'Shoreline geomorphology and fringing vegetation of the Gippsland Lakes. Volume 1: a literature review', report to Gippsland Lakes Ministerial Advisory Committee, Bairnsdale.
757. BMT WBM 2011, 'Ecological character description of the Gippsland Lakes Ramsar site– final report', prepared for the Department of Sustainability, Environment, Water, Population and Communities (DSEWPC), Australian Government, Canberra.
758. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Index of estuary condition', East Melbourne, Victoria.
759. Ibid.
760. Ibid.

Table 20: IEC results for estuarine flora within the West and East Gippsland catchment regions that flow into the Gippsland Lakes.[761]

Estuary	Flora	Condition Class
Latrobe & Thomson Estuary	10	Excellent
Lake Wellington Main Drain	8	Good
Avon River	10	Excellent
Tom Creek	5	Poor
Tom Roberts Creek	7	Fair
Newlands Arms	8	Good
Mitchell River	5	Poor
Nicholson River	8	Good
Slaughterhouse Creek	8	Good
Tambo River	9	Good
Maringa Creek	10	Excellent
Mississippi Creek	7	Fair
Bunga Inlet	8	Good
Lake Tyers	8	Good

Range 1 – 10 (1 poorest condition, 10 best condition). NA = not assessed.

GL 19: Species of conservation concern

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	?	●
Justification for assessment ratings:	The data analysed and reported for this indicator provide information on the number of species of conservation concern. The status and trend assessments are unknown and unclear, respectively, because no information is available to ascertain how these species are being tracked and managed, and no trend data are available to assess how these species are tracking over time.		

Publicly accessible data from the Victorian Biodiversity Atlas has been analysed to determine the magnitude of threatened and vulnerable marine and coastal species within the Gippsland Lakes.

Within the Victorian Biodiversity Atlas there are 1,212 fauna species and 1,234 flora species that are mapped to be within the Gippsland Lakes marine biounit. Of these, there are 67 fauna species and 14 flora species that are denoted by the Atlas as being listed within the FFG Act, listed as endangered, threatened or vulnerable within the *Environment Protection and Biodiversity Conservation Act 1999*, or included as on DELWP's advisory list as endangered, threatened, vulnerable or poorly known. Given that recent amendments to the FFG Act have removed duplication by establishing a single comprehensive list of threatened flora and fauna species and revoking Advisory Lists,[762] any updates to the Victorian Biodiversity Atlas attribute fields will be incorporated in future State of the Marine and Coastal Environment reports.

Of the combined 81 species of conservation concern that are listed within the Victorian Biodiversity Atlas, 48 (59%) have records within the past 20 years.

There is a lack of published analysis and time series data available to assess how these species are tracking over time and this will be an area of focus for future State of the Marine and Coastal Environment reports.

761. Ibid.
762. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Threatened list and processes list' East Melbourne, Victoria https://www.environment.vic.gov.au/conserving-threatened-species/threatened-list Accessed 17 August 2021.

GL 20: Mobile invertebrates on intertidal reefs

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. Intertidal reefs are not a significant component of the Gippsland Lakes.		

GL 21: Sessile invertebrates on intertidal reefs

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. Intertidal reefs are not a significant component of the Gippsland Lakes.		

GL 22: Invertebrates on subtidal reefs

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. Subtidal reefs are not a significant component of the Gippsland Lakes.		

GL 23: Commercially and recreationally important invertebrates

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. This is due to there not being any commercially and recreationally important invertebrate stocks the Gippsland Lakes.		

GL 24: Commercially and recreationally important fish

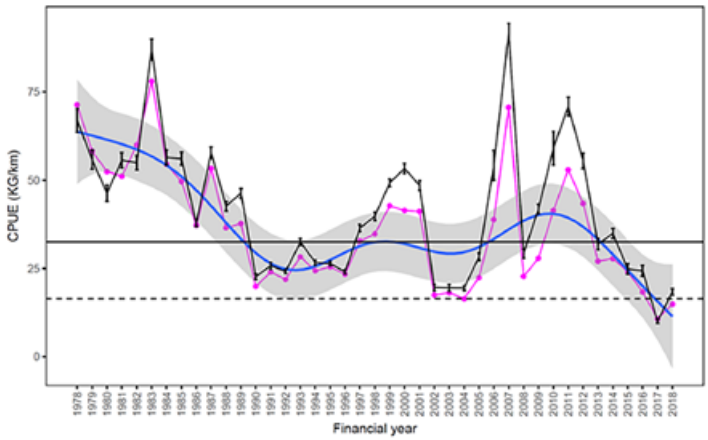
Region	2021 status	2021 trend	2021 data
Gippsland Lakes	(black bream, dusky flathead)	(dusky flathead) (black bream)	(black bream, dusky flathead)

Justification for assessment ratings:	**Black bream:** Due to the recent CPUE data for both commercial and recreational fishers trending near the reference period minimums, and uncertainty in how recruitment replenishes the adult stock, the Gippsland Lakes black bream stock was assessed as depleting in VFA's most recent stock assessment report that was published during 2020. This analysis has been translated into status and trend assessments of poor and deteriorating, respectively, in this report. **Dusky flathead:** Current levels of dusky flathead fishing pressure are well below historic highs yet the catch per unit of effort has remained below average in recent years. Based on this, Victorian Gippsland Lakes dusky flathead stock was described as depleting in the Status of key Victorian Fish stocks report that was published by the VFA in 2020. This analysis has been translated into status and trend assessments of poor and stable, respectively, in this report.

Black bream

Recreational anglers frequent the Gippsland Lakes and the estuarine reaches of the inflowing rivers where they target black bream. There is no recent information about the total recreational catch, however recreational fishery catch-rate and size composition monitoring programs for black bream have been in place for the last 20 years.[763]

Commercial harvests dropped considerably from the 1980s, which was amplified by a declining netting effort due to commercial licence reductions since 2010.[764] As of 1 April 2020, all of the 10 remaining Gippsland Lakes commercial net fishers accepted their compensation packages and exited the fishery.[765] The graph below shows that commercial CPUE for the Gippsland Lakes in 2018 was at its lowest point since estimates began in 1978, which is indicative of a depleting stock.

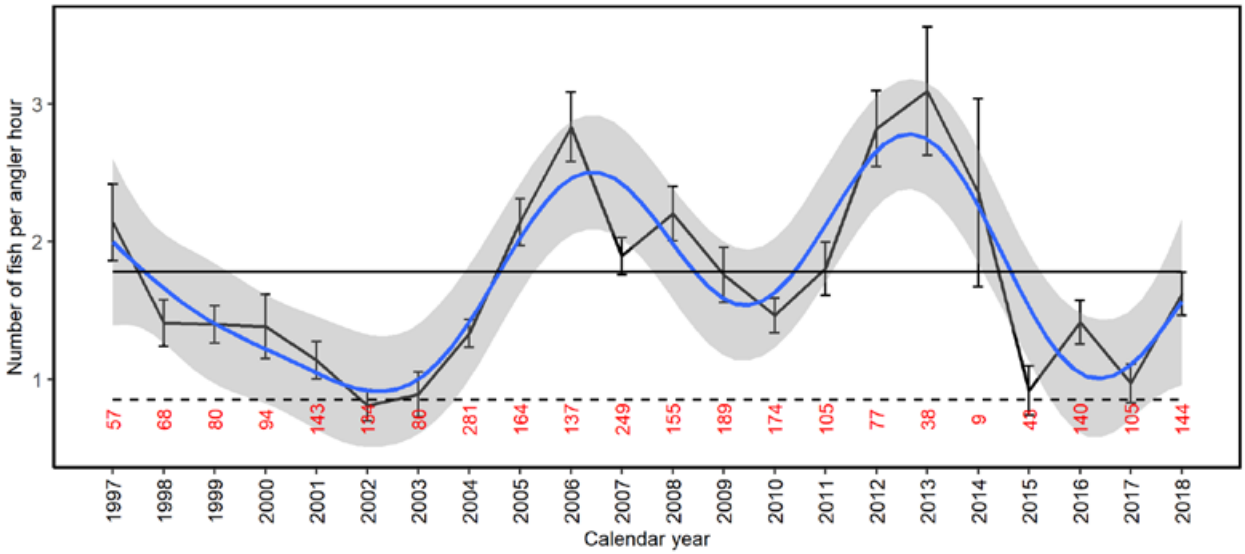


Black line is nominal CPUE (±SE), magenta line is standardised CPUE, blue line is a Generalised Additive Model (GAM) of the standardised CPUE trend with the shaded grey area representing the 95% confidence interval of the GAM. Horizontal black line is the mean standardised CPUE during the reference period (1985–2015) and the dashed black line is the minimum standardised CPUE within the reference period. Note: CPUE is calculated as Kg/km as no soak time data were available prior to 1998 and mesh net fishers in the Gippsland Lakes tend to soak their gear overnight meaning soak time is relatively uniform through time.

Figure 48: Catch-per-unit-effort of black bream by commercial mesh net fishers in the Gippsland Lakes during 1978–2018 financial years.[766]

763. Victorian Fisheries Authority (VFA) 2020, 'Review of key Victorian fish stocks — 2019'.
764. Ibid.
765. Victorian Fisheries Authority (VFA) 2020, 'Gippsland Lakes is now net free' https://vfa.vic.gov.au/recreational-fishing/targetonemillion2/phase-out-of-commercial-netting-in-the-gippsland-lakes Accessed 18 August 2021.
766. Victorian Fisheries Authority (VFA) 2020, 'Review of key Victorian fish stocks — 2019'.

Data for recreational fishers shows two peaks for CPUE. Those peaks occurred in 2006 and 2012–2013 and coincided with peaks in the commercial fishing CPUE. More recently, there was a dip in CPUE from 2013 to 2016 followed by an increase during 2018 – the most recent year with data – and CPUE is now just below the long-term average for recreational fishers.[767]



Horizontal black line is the mean CPUE during the reference period (1997-2015) and the dashed black line is the minimum CPUE within the reference period. Blue line is a (GAM) of the nominal CPUE trend with the shaded grey area representing the 95% confidence interval of the GAM. Red numbers along x-axis are numbers of diary angler trips.

Figure 49: Diary angler mean nominal (± standard error) catch-per-unit-effort of black bream from the Gippsland Lakes, 1997-2018 calendar years.[768]

Black bream recruitment has been relatively strong for the last two years in the Gippsland Lakes. These two cohorts will grow to legal size over the next four to five years. However, because of the short length of the recruitment time series, it remains unclear how strongly recruitment relates to replenishment of adult biomass.[769]

Due to the recent CPUE data for both commercial and recreational fishers trending near the reference period minimums, and uncertainty in how recruitment replenishes the adult stock, the Gippsland Lakes black bream stock was assessed as depleting in VFA's most recent stock assessment report that was published during 2020.[770]

Dusky flathead

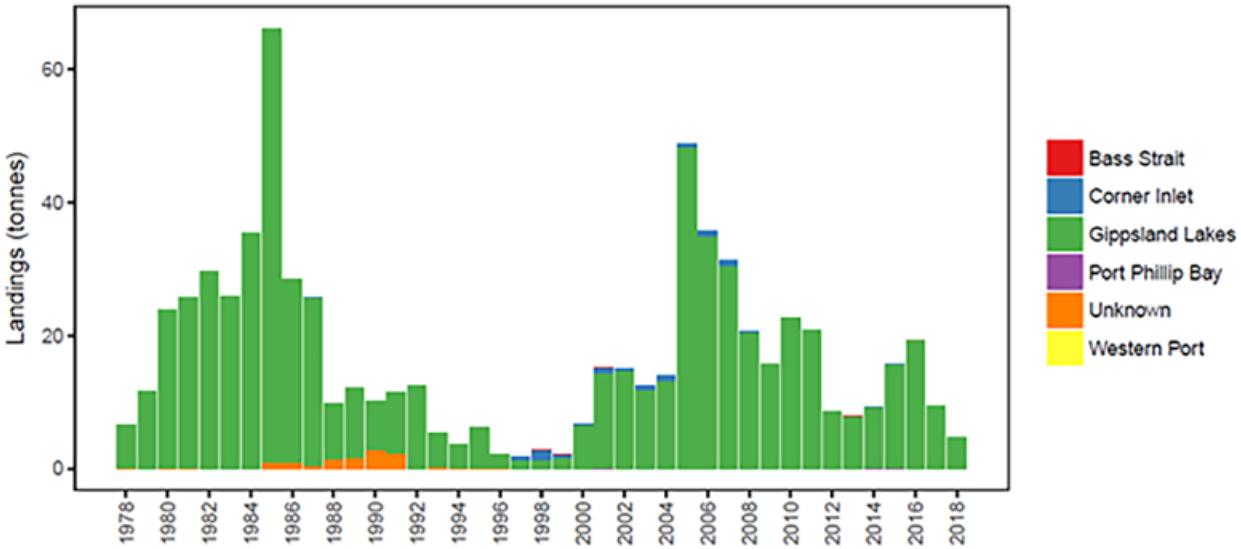
Dusky flathead normally inhabit estuaries, with each estuary likely to support a relatively isolated stock. Considering their isolation, each estuary for which data are available is assessed independently and this is the rationale for providing a specific dusky flathead assessment for Gippsland Lakes in this report.[771]

Commercial harvests had been restricted to Gippsland Lakes since the creation of dedicated fishing reserves for recreational anglers in Lake Tyers in 2007 and Mallacoota Inlet in 2004. As of April 2020, there is no longer commercial net fishing in the Gippsland Lakes.[772]

Historically, commercial fishers in Gippsland Lakes caught dusky flathead as a by-product of targeting more valuable species. However, there has been speculation that dusky flathead has been targeted commercially in Gippsland Lakes since the mid-2000s. This is possibly a response to reduced availability of black bream, with the commercial fishing CPUE for black bream halving during the past decade.

767. Ibid.
768. Ibid.
769. Ibid.
770. Ibid.
771. Ibid.
772. Victorian Fisheries Authority (VFA) 2020, 'Gippsland Lakes is now net free' https://vfa.vic.gov.au/recreational-fishing/targetonemillion2/phase-out-of-commercial-netting-in-the-gippsland-lakes Accessed 18 August 2021.

Landings of dusky flathead have remained in the range of 10–20 tonnes per year for the last few years, although the most recent year of data shows the smallest commercial fishing catch of dusky flathead in the Gippsland Lakes this century. As of 2018, mesh netting effort in Gippsland Lakes was at about half of peak values that occurred in the 1980s and seining effort was at historically low values.[773]



Note: Commercial harvests have been restricted to the Gippsland Lakes since creation of recreational only estuaries in Lake Tyers in 2007 and Mallacoota Inlet in 2004.

Figure 50: Dusky flathead commercial catches in Victorian waters, financial years 1978–2018.[774]

Mesh net commercial CPUE increased during the 2000s, reaching a maximum in the mid-2000s that was well above the long-term average, before declining again to levels similar to the minimum recorded since the start of time series in 1978. CPUE from recreational anglers shows a clearly declining trend over almost two decades.[775]

Current levels of dusky flathead fishing pressure are well below historic highs yet the CPUE has remained below average in recent years. Based on this, Victorian Gippsland Lakes dusky flathead stock was described as depleting in the Status of key Victorian Fish stocks report that was published by the VFA in 2020. In the 2018 SAFS assessment, dusky flathead was rated as sustainable at a Victorian statewide scale.[776]

There is cautious optimism that given the life history characteristics of dusky flathead and an absence of commercial fishing, further recruitment to the stock is likely when environmental conditions are favourable.[777]

773. Victorian Fisheries Authority (VFA) 2020, 'Review of key Victorian fish stocks — 2019'.
774. Ibid.
775. Ibid.
776. Ibid.
777. Ibid.

GL 25: Subtidal reef fish

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. Subtidal reefs are not a significant component of the Gippsland Lakes.		

GL 26: Diadromous fish

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. Diadromous fish are assessed in the Statewide chapter. A brief narrative is provided below for the Gippsland Lakes.		

The Limit of Acceptable Change (LAC) for the Australian grayling in the Gippsland Lakes Ramsar Site is that the Australian grayling continues to be supported in one or more of the catchments draining into the Gippsland Lakes.[778]

DELWP has advised that, based on findings from the Victorian Environmental Flows Monitoring and Assessment Program,[779] the LAC for Australian grayling in the Gippsland Lakes was assessed as being met during 2020. Australian grayling has been recorded annually in the Thomson River from 2005 to 2020.[780]

GL 27: Marine and coastal waterbirds

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	?	●
Justification for assessment ratings:	The Limit of Acceptable Change (LAC) assessments from 2021 show that the LAC for waterbird abundance is being met, while there was insufficient information to assess the LAC for waterbird breeding. This is reflected in a fair status and moderate confidence.		

The Gippsland Lakes supports a diversity and abundance of waterbirds across all the habitats and wetlands. Due to the large area covered by the Lakes, there are very few total waterbird counts. Condition is assessed based on diversity (species richness) and abundance of indicator species that represent different functional groups (for example, fish eating species, ducks, herbivores and waders).

The marine and coastal waterbird assessments for the Gippsland Lakes in this report are based on the Limits of Acceptable Change (LACs) for the Ramsar site.

778. BMT WBM 2011, 'Ecological character description of the Gippsland Lakes Ramsar site – final report', prepared for the Department of Sustainability, Environment, Water, Population and Communities (DSEWPC), Australian Government, Canberra.
779. Tonkin Z, Jones C, Clunie P, Vivian L, Amtstaetter F, Jones M, Koster W, Mole B, O'Connor J, Brooks J, Caffrey L and Lyon J 2020, 'Victorian environmental flows monitoring and assessment program stage 6 synthesis report 2016-2020', technical report series no. 316, Arthur Rylah Institute (ARI), Department of Environment, Land, Water and Planning (DELWP), Heidelberg, Victoria.
780. Ibid.

The LAC for waterbird abundance is that the absence of records in any of the following species in five successive years will represent a change in character: red-necked stint, sharptailed sandpiper, black swan, chestnut teal, fairy tern, little tern, musk duck, Australasian grebe, grey teal, Eurasian coot, great cormorant, red knot, curlew sandpiper.[781,782] DELWP has advised that a 2021 assessment has shown this waterbird abundance LAC to be met.

There is also a LAC for waterbird breeding in the Gippsland Lakes Ramsar Site. The LAC for waterbird breeding requires an assessment of whether there has been abandonment or significant decline (greater than 50%) in the productivity of two or more representative breeding sites (based on two sampling episodes over a 5-year period).[783] DELWP has advised there is no baseline data from the time when the Ramsar site was listed upon which the 50% decline in productivity can be assessed.

GL 28: Migratory shorebirds

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	?	●
Justification for assessment ratings:	The Limit of Acceptable Change (LAC) assessments from 2021 show that the LAC for waterbird abundance is being met for the red-necked stint and sharptailed sandpiper. Both species have been recorded multiple times in the past 5 years (2017 to 2021).		

More than 20 species of migratory birds, including snipe, sandpipers, and tern, visit the Gippsland Lakes as part of their annual breeding and resting cycle in summer. Most travel from breeding grounds in north-east Asia and Alaska as part of the East Asian Australasian Flyway. As the weather turns cold in Victoria, the birds leave their summer getaway and head back north, chasing the sun.

DELWP has advised that a 2021 Limit of Acceptable Change (LAC) assessment for waterbird abundance has shown this waterbird abundance LAC to be met for the following migratory shorebirds: the red-necked stint and sharptailed sandpiper. These species have both been recorded multiple times in the past 5 years (2017 to 2021).

GL 29: Piscivorous (fish-eating) birds

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. Not a significant fauna species in the region.		

GL 30: Little penguins

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. Not a significant fauna species in the region.		

781. BMT WBM 2011, 'Ecological character description of the Gippsland Lakes Ramsar site – final report', prepared for the Department of Sustainability, Environment, Water, Population and Communities (DSEWPC). Australian Government, Canberra.
782. Note that there is duplication with indicator GL 28 (Migratory shorebirds) here, with some species of migratory shorebirds included within the LAC for waterbird abundance.
783. BMT WBM 2011, 'Ecological character description of the Gippsland Lakes Ramsar site – final report', prepared for the Department of Sustainability, Environment, Water, Population and Communities (DSEWPC), Australian Government, Canberra.

GL 31: Marine mammals

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	(dolphins)	(dolphins)	(dolphins)
Justification for assessment ratings:	**Dolphins:** There has been a relatively stable population of between 60 and 100 dolphins living in the Gippsland Lakes, although there was a significant mortality event and skin infections for the resident dolphins during 2020 that have been linked with the 2019-20 bushfires, which is reflected in a deteriorating trend assessment. The small population size means the consequences of significant mortality events can be proportionally significant on the dolphin population in the Lakes, so the status has been rated as poor to reflect this vulnerability.		

Within the Gippsland Lakes there is a stable population of between approximately 60 and 100 dolphins, which are referred to in this indicator assessment as burrunan dolphins (*Tursiops australis*).[784]

Analysis provided by the Marine Mammal Foundation comprised surveys conducted in the Gippsland Lakes between 2014 and 2017. The survey results suggest there is a resident dolphin population that is exposed to a seasonally migratory group of individuals, dominated by males, during late winter and spring. The analysis concluded the resident population most likely comprised 94 individuals, which is subject to seasonal interactions with 28 transient individuals.

The Dolphin Research Institute (DRI) also notes the link between Gippsland Lakes' resident dolphins and the migratory visitors. The DRI estimated there were 65 dolphins residing in the Gippsland Lakes during 2020, with this number generally doubling during winter due to visiting dolphins. It is thought that this is due to migration of males between the Gippsland Lakes and Tasmania in a seasonal pattern, arriving in the Gippsland Lakes in winter to breed, then heading south to Tasmania in summer. By contrast, the female population appears to be more sedentary, remaining in the Lakes throughout the year. Just four calves a year are born on average, and only half of these survive to adulthood. Females form a strong bond with their calves and stay together for around three years (during which they do not breed). This means that the potential for population increases is very low. The DRI advises that the estimated numbers don't seem to have changed since surveys of the dolphin population in the Lakes in the mid-2000s.

The very small population size makes these dolphins vulnerable. The loss of only a few dolphins could affect the viability of a population. In February 2014, the burrunan dolphin *Tursiops australis* species was listed as threatened under the *Flora and Fauna Guarantee Act 1988.* As at June 2021, the burrunan dolphin was listed as a critically endangered species.[785]

An ongoing study of dolphin health by the DRI has found that Port Phillip Bay's resident dolphins show resilience to skin infections and quite severe injuries, however the Gippsland Lakes dolphins do not show the same resilience to skin infections, as demonstrated by mortality events in the 2000s and again in 2020. These events following extreme fires in the catchment might have been expected to result in a decline in resident dolphins in the 2000s but this was not observed, with the DRI estimating the population has stayed at around 50-60.

The Burrunan dolphin population in the Gippsland Lakes is being impacted by what is believed to be freshwater skin disease, most likely caused by freshwater input into the Lakes, a decline in salinity levels, prolonged exposure to freshwater, and complex environmental change with the 2019-20 bushfire event and subsequent run-off into the lakes.

784. The burrunan dolphin's presence as a unique species is disputed. For the purpose of this indicator assessment, the State of the Marine and Coastal Environment 2021 Report is following the listing in the *Flora and Fauna Guarantee Act 1988* and referring to the dolphins in the Gippsland Lakes as burrunan dolphins rather than the common bottlenose dolphin (*Tursiops truncates*). Further information is provided in the opening summary section for Indicator 31: Marine mammals. Regardless of whether the dolphins in Gippsland Lakes are classified as burrunan dolphins or common bottlenose dolphins, there is agreement that the population is between 60 and 100.

785. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Flora and Fauna Guarantee Act 1988 - threatened list June 2021', East Melbourne, Victoria.

The primary visible symptom is ulcerative skin lesions, which can lead to secondary bacterial, algal and fungal infections, organ disfunction, shock, and death. A similar event was observed following the 2006-07 Gippsland bushfires, leading to a number of dolphin deaths.[786] These mortality events were flanked by drought, severe bushfires, subsequent large rainfalls, flooding and inundation, rapid decrease in salinity in the Lakes, and algal blooms.

From September to December 2020, nine dolphins were reported dead in this two-month period, with symptoms consistent with freshwater skin disease. The Marine Mammal Foundation provided information to the Commissioner for Environmental Sustainability stating that all deceased dolphins were documented with severe ulcerative lesions, bacterial and fungal mats across the entire body, with very poor body condition. Of major concern, three of the deceased were breeding females, which has long-term implications to the population viability.

Other Marine Protected Areas

OMPA 15: Conservation of coastal ecosystems in protected areas

Region	2021 status	2021 trend	2021 data
Other marine protected areas	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The conservation of coastal ecosystems in protected areas within five km of the Gippsland Lakes is encompassed within a broad analysis of the entire Victorian coastline in the statewide assessment for this indicator.		

OMPA 16: Saltmarsh

Region	2021 status	2021 trend	2021 data
Other marine protected areas	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. Saltmarsh is covered in the regional indicators.		

OMPA 17: Mangroves

Region	2021 status	2021 trend	2021 data
Other marine protected areas	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. Mangroves are covered in the regional indicators.		

OMPA 18: Wetland and estuarine vegetation

Region	2021 status	2021 trend	2021 data
Other marine protected areas	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. Wetland and estuarine vegetation is covered in the regional indicators.		

786. Duignan PJ, Stephens NS and Robb K 2020, 'Fresh water skin disease in dolphins: a case definition based on pathology and environmental factors in Australia', *Scientific Reports*, 10(21979).

OMPA 19: Species of conservation concern

Region	2021 status	2021 trend	2021 data
Other marine protected areas	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. Species of conservation concern is covered in the regional indicators.		

OMPA 20: Mobile invertebrates on intertidal reefs

Region	2021 status	2021 trend	2021 data
Other marine protected areas	●	→	●
Justification for assessment ratings:	The status assessment of good is based on the available information provided as part of Parks Victoria's long-term Intertidal Reef Monitoring Program. That program ceased in 2014, with the only subsequent information contributing to this status assessment being draft control charts from 2018. Due to the lack of recent evidence, the confidence in the status and trend assessments is low. Parks Victoria is progressing monitoring and assessment with plans to publish Technical Reports within the next couple of years for Port Phillip Heads, Wilsons Promontory, Cape Howe and Discovery Bay Marine National Parks, which will address intertidal reef knowledge gaps in marine protected areas and increase the confidence in this indicator assessment in future State of the Marine and Coastal Environment reports.		

As reported in the Victorian State of the Environment 2018 Report, Parks Victoria draft control charts assess the condition of mobile invertebrates in marine national parks as good.[787]

More information on mobile invertebrates on intertidal reefs in Port Phillip Bay's marine protected areas is available in the Port Phillip Bay regional indicator assessment for mobile invertebrates on intertidal reefs.

Parks Victoria is progressing monitoring and assessment with plans to publish technical reports within the next couple of years for Port Phillip Heads, Wilsons Promontory, Cape Howe and Discovery Bay Marine National Parks, which will address knowledge gaps and increase the confidence in this indicator assessment in future State of the Marine and Coastal Environment reports. A technical report focussing on Point Addis Marine National Park was published in 2020, however mobile invertebrates on intertidal reefs were not covered in that report.

787. Commissioner for Environmental Sustainability (CES) 2018, 'Victorian State of the Environment 2018', Melbourne, Victoria.

OMPA 21: Sessile invertebrates on intertidal reefs

Region	2021 status	2021 trend	2021 data
Other marine protected areas			
Justification for assessment ratings:	The status assessment of good is based on the available information provided as part of Parks Victoria's long-term Intertidal Reef Monitoring Program. That program ceased in 2014, with the only subsequent information contributing to this status assessment being draft control charts from 2018. Due to the lack of recent evidence, the confidence in the status and trend assessments is low. Parks Victoria is progressing monitoring and assessment with plans to publish technical reports within the next couple of years for Port Phillip Heads, Wilsons Promontory, Cape Howe and Discovery Bay Marine National Parks, which will address intertidal reef knowledge gaps in marine protected areas and increase the confidence in this indicator assessment in future State of the Marine and Coastal Environment reports.		

As reported in the Victorian State of the Environment 2018 Report, Parks Victoria has prepared draft control charts for several marine national parks and sanctuaries to track changes in indicators of key natural values and impacts of threats. Sessile invertebrates are a key ecological attribute on intertidal reefs in 12 parks, with their condition assessed as good in nine parks and fair in three. However, there is no data for reefs outside the boundaries of protected areas.[788]

More information on mobile invertebrates on intertidal reefs in Port Phillip Bay's marine protected areas is available in the Port Phillip Bay regional indicator assessment for mobile invertebrates on intertidal reefs.

Parks Victoria is progressing monitoring and assessment with plans to publish technical reports within the next couple of years for Port Phillip Heads, Wilsons Promontory, Cape Howe and Discovery Bay Marine National Parks, which will address intertidal reef knowledge gaps in marine protected areas and increase the confidence in this indicator assessment in future State of the Marine and Coastal Environment reports. A technical report focussing on Point Addis Marine National Park was published in 2020, however sessile invertebrates on intertidal reefs were not covered in that report.

788. Ibid.

OMPA 22: Invertebrates on subtidal reefs

Region	2021 status	2021 trend	2021 data
Other marine protected areas		?	
Justification for assessment ratings:	The status assessment of good is based on the available information available from Parks Victoria's long-term Subtidal Reef Monitoring Program, the more recent Reef Life Survey data and the 2020 Technical Report for Point Addis Marine National Park. Parks Victoria draft control charts assessed mobile megafaunal invertebrates as good in 12 of the parks, fair in one and unknown in one. The Reef Life Survey data shows the trend over the past decade is an increasing number of species in Port Phillip Bay's north, with a decline in the south. Broadly though, across Victoria's marine protected areas, the trend is unclear.		

Data and analysis published before 2014 as part of Parks Victoria's Intertidal Monitoring Program

At Cape Howe Marine National Park, the 2011–2013 survey and review of earlier research found that abundances of the long-spined sea urchin (*Centrostephanus rodgersii*) and blacklip abalone (*Haliotis rubra*) were high, abalone abundance having increased since the park's establishment in 2002, while urchin numbers had remained stable.[789] The density of purple and long-spined sea urchins had increased at Beware Reef Marine Sanctuary towards the end of the survey period, having earlier been in decline. The total number of invertebrates had also declined.[790]

The densities of blacklip abalone and short-spined sea urchin, along with the total numbers of invertebrates (half of baseline levels), had declined at Wilsons Promontory Marine National Park. Invertebrate abundances, again including blacklip abalone and short-spined sea urchin, also declined at Bunurong Marine National Park.[791]

Marengo Reefs Marine Sanctuary experienced fluctuating species richness and diversity, but there was a declining trend for blacklip abalone abundance and total invertebrate abundance was at its lowest at the end of the survey period.[792] Inside the Merri Marine Sanctuary, southern rock lobster (*Jasus edwardsii*) abundance was double that outside the boundaries, while biomass was three to five times greater. Invertebrate abundance was low and stable and blacklip abalone densities were low.[793]

Abalone abundance more generally has been impacted by:

- abalone viral ganglioneuritis
- previous distributions of fishing pressure and overharvesting
- illegal, unreported and unregulated fishing
- possible growth in recreational fishing
- competition from other benthic organisms, particularly sea urchins.[794]

Parks Victoria draft control charts assessed mobile megafaunal invertebrates as good in 12 of the parks, fair in one and unknown in one. There is no data on trends.

Point Addis Marine National Park

Parks Victoria's technical report focussing on Point Addis Marine National Park included results and discussion on macroinvertebrate species found in that marine protected area. Notable macroinvertebrate species included greenlip abalone (*Haliotis laevigata*), blacklip abalone (*Haliotis rubra*) and southern rock lobster (*Jasus edwardsii*).[795]

The 2018 status of *Haliotis laevigata* and *Nectria spp.* (seastars) in Point Addis Marine National Park were found to be in good condition (that is, well above the lower LAC). However, consistent declines over the last 15 years were observed in *Haliotis rubra* and *Lunella undulata* (turban shell). *Haliotis rubra* has been below its lower control limit of 4.6 individuals per 200 m^2 since 2012, and prior to this, from 2003 to 2006, the average abundances inside the marine protected area reduced from 70 to 30. A similar trend was also seen for *Lunella undulata*, with its highest abundances occurring between 2003 and 2006. Since then, it has been below its LAC of 17.5 individuals per 200 m^2.[796]

The 2020 Point Addis Marine National Park technical report also includes a comparison between southern rock lobsters (*Jasus edwardsii*) inside and outside of the Point Addis Marine National Park protected waters. Over 3.5 times the abundance and 4.5 times the number of legal rock lobsters were captured within the Park. The analysis showed abundance and biomass of southern rock lobsters outside the MPA to increase closer to the MPA boundary, suggesting that the Point Addis Marine National Park may be positively affecting the supply of individuals to surrounding waters open to fishing.[797]

789. Edmunds M, Woods B 2017, 'Victorian subtidal reef monitoring program: the reef biota at Cape Howe marine national park, December 2014', Parks Victoria technical series no. 99, Melbourne, Victoria.
790. Edmunds M, Hallein E, Flynn A 2014, 'Victorian subtidal reef monitoring program: the reef biota at Beware Reef marine sanctuary', Parks Victoria technical series no. 88, Melbourne, Victoria.
791. Davis S, Pritchard K and Edmunds M 2011, 'Victorian subtidal reef monitoring program: the reef biota at Bunurong marine national park', Parks Victoria technical series no. 84, Melbourne, Victoria.
792. McArthur M, Smith A, Davis, S, Edmunds M and Pritchard K 2011, 'Victorian subtidal reef monitoring program: the reef biota at Marengo Reefs marine sanctuary, Parks Victoria technical series no. 85, Melbourne, Victoria.
793. Woods B and Edmunds M 2013, 'Victorian subtidal reef monitoring program: the reef biota at Merri marine sanctuary', Parks Victoria technical series no. 87, Melbourne, Victoria.
794. Department of Primary Industries (DPI) 2012, 'Abalone recovery review workshop', Fisheries Victoria Management report series no. 83, Melbourne, Victoria.
795. Ierodiaconou D, Wines S, Carnell P, Tinkler P, Allan B, Carey J, Young M, Howe S, Pocklington J 2020, 'An enhanced signs of healthy parks monitoring program for Victoria's marine national parks and marine sanctuaries: Point Addis marine national park', Parks Victoria technical series no. 114, Melbourne, Victoria.
796. Ibid.
797. Ibid.

Future monitoring, assessment and reporting

Parks Victoria has advised that a technical report focussing on Port Phillip Heads Marine National Park is currently in preparation, with preliminary analysis supplied to the Commissioner for Environmental Sustainability showing a similar effect on southern rock lobsters in the Port Phillip Heads Marine National Park, although populations were lower than expected. Parks Victoria is progressing monitoring and assessment in other marine protected areas with plans to publish Technical Reports within the next couple of years for Port Phillip Heads, Wilsons Promontory, Cape Howe and Discovery Bay Marine National Parks, which will extend the knowledge of subtidal reef invertebrates, including southern rock lobsters, in marine protected areas.

OMPA 23: Commercially and recreationally important invertebrates

Region	2021 status	2021 trend	2021 data
Other marine protected areas	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. Commercially and recreationally important invertebrates are covered in the regional indicators.		

OMPA 24: Commercially and recreationally important fish

Region	2021 status	2021 trend	2021 data
Other marine protected areas	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. Commercially and recreationally important fish are covered in the regional indicators.		

Indicator 25: Subtidal reef fish

Region	2021 status	2021 trend	2021 data
Other marine protected areas	●	→	●
Justification for assessment ratings:	Parks Victoria's integrated dataset and control charts show that the condition of large mobile fish (including sharks and rays) on subtidal reefs in marine national parks and sanctuaries beyond Port Phillip Bay was assessed as good in 14 parks, fair in one and unknown in one. The confidence is rated as moderate rather than high to reflect that the data in some marine protected areas are now several years out of date, however monitoring and assessment programs are underway to provide contemporary data and analysis, which will be incorporated in future State of the Marine and Coastal Environment reports. There have been advances in monitoring via Baited Remote Underwater Videos that are enabling the establishment of time series fish assemblage monitoring for the entire depth range of Marine National Parks.		

Parks Victoria's 2020 publication focussing on Point Addis Marine National Park showed the status of key mobile fish species was healthy (based on both baited remote underwater videos and underwater visual census data).[798] Preliminary analysis supplied to the Commissioner for Environmental Sustainability from draft reports shows similarly good results have been observed at Port Phillip Heads, Wilsons Promontory and Bunurong Marine National Parks.

798. Ibid.

A high diversity of fish species was found in Wilsons Promontory Marine National Park, with the highest species richness occurring in shallow reef areas.

The recently published technical report for Point Addis Marine National Park and the pending reports for Port Phillip Heads, Wilsons Promontory and Bunurong Marine National Parks highlight the advances in monitoring and assessment during the past decade. Fish assemblages within and adjacent to these Marine National Parks were observed using Baited Remote Underwater Videos (BRUVs). These fish assemblages have previously been monitored using subtidal reef monitoring program Underwater Visual Census (UVC) diver survey techniques only. The BRUV studies have enabled the establishment of time series fish assemblage monitoring for the entire depth range of these Marine National Parks, via the use of BRUVs. Whilst UVC techniques are known to sample a different set of species, including cryptic species, better than BRUVs,[799,800] the Point Addis Marine National Park technical report highlighted that, for this region, BRUVs observed 48% more species within the park compared with UVC surveys simultaneously completed in the project.[801]

At Cape Howe Marine National Park, a 2011–13 Parks Victoria long-term Subtidal Reef Monitoring Program survey, and review of earlier research, found that the biomass of fished species had increased, but there was an observed change in their size, with smaller individuals more abundant.[802] Fish species richness and diversity had also increased over the survey period. Beware Reef Marine Sanctuary was characterised by high abundance of butterfly perch, while purple wrasse (*Notolabrus fucicola*) and blue throat wrasse (*Notolabrus tetricus*) had decreased in density. The abundance of banded morwong had declined between 2004 and 2011 (but increased in 2013).[803]

Marine sanctuaries along the west coast – Eagle Rock, Marengo Reefs and Merri – varied in their recorded data. Blue throat wrasse abundance had increased at Eagle Rock, along with total fish abundance, species richness and diversity in the latter half of the survey period.[804] However, at Merri, the three indices had experienced slight declines, while at Marengo Reefs there were no trends in species richness and diversity but a decline in the abundance of larger fish across the species.[805,806] There were no changes in fish abundance, richness and diversity at Point Addis Marine National Park.[807]

In a comment that reflects the data more generally in Victoria's coastal waters, the authors of the report on Marengo Reefs Marine Sanctuary noted that: 'The results in this report present a snapshot in time for community structures and species population trends, which operate over long-time scales. As monitoring continues and longer-term datasets are accumulated (over multiple years to decades) the programme will be able to more adequately reflect the average trends and ecological patterns occurring in the system.'[808]

Within Port Phillip Bay, the marine sanctuaries generally had a low number of fish species and abundance with no consistent trends, with the southern hulafish (*Trachinops caudimaculatus*) dominating the fish assemblages. In southern Port Phillip Bay, the health of reef fish communities was rated as good. Reflecting the improving health of the ecosystem there, western blue groper numbers, which used to be abundant, were increasing at Nepean Bay and Point Lonsdale, and were reported at nearby South Channel Fort, as well as Barwon Bluff and Beware Reef marine sanctuaries along the open coast.[809] In the bay's northern sanctuaries, the health of reef fish communities was rated as unknown in Jawbone and fair in Point Cooke and Ricketts Point.

799. Colton MA, Swearer SE 2010, 'A comparison of two survey methods: differences between underwater visual census and baited remote underwater video', *Marine Ecology Progress Series*, 400, pp. 19-36.
800. Lowry M, Folpp H, Gregson M, Suthers I 2012, 'Comparison of baited remote underwater video (BRUV) and underwater visual census (UVC) for assessment of artificial reefs in estuaries', *Journal of Experimental Marine Biology and Ecology*, 416, pp. 243-253.
801. Ierodiaconou D, Wines S, Carnell P, Tinkler P, Allan B, Carey J, Young M, Howe S, Pocklington J 2020, 'An enhanced signs of healthy parks monitoring program for Victoria's marine national parks and marine sanctuaries: Point Addis marine national park', Parks Victoria technical series no. 114, Melbourne, Victoria.
802. Edmunds M and Woods B 2017, 'Victorian subtidal reef monitoring program: the reef biota at Cape Howe marine national park', Parks Victoria technical series no. 99, Melbourne, Victoria.
803. Edmunds M, Hallein E and Flynn A 2014, 'Victorian subtidal reef monitoring program: the reef biota at Beware Reef marine sanctuary', Parks Victoria technical series no. 88, Melbourne, Victoria.
804. Edmunds M, Brown H and Woods B 2014, 'Victorian subtidal reef monitoring program: the reef biota at Eagle Rock marine sanctuary', Parks Victoria technical series no. 89, Melbourne, Victoria.
805. Woods B and Edmunds M 2013, 'Victorian subtidal reef monitoring program: the reef biota at Merri marine sanctuary', Parks Victoria technical series no. 87, Melbourne, Victoria.
806. McArthur M, Smith A, Davis, S, Edmunds M and Pritchard K 2011, 'Victorian subtidal reef monitoring program: the reef biota at Marengo Reefs marine sanctuary, Parks Victoria technical series no. 85, Melbourne, Victoria.
807. Woods B, Edmunds M and Brown H 2014, 'Victorian subtidal reef monitoring program: The reef biota at Point Addis marine national park, June 2013', Parks Victoria technical series no. 94, Melbourne, Victoria.
808. McArthur M, Smith A, Davis, S, Edmunds M and Pritchard K 2011, 'Victorian subtidal reef monitoring program: the reef biota at Marengo Reefs marine sanctuary, Parks Victoria technical series no. 85, Melbourne, Victoria.
809. Commissioner for Environmental Sustainability (CES) 2016, 'State of the Bays 2016', Melbourne, Victoria.

Theme 3: Biodiversity

Parks Victoria's integrated dataset and control charts show that the condition of large mobile fish (including sharks and rays) on subtidal reefs in marine national parks and sanctuaries beyond Port Phillip Bay was assessed as good in 14 parks, fair in one and unknown in one.

OMPA 26: Diadromous fish

Region	2021 status	2021 trend	2021 data
Other marine protected areas	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. Diadromous fish are covered in the regional indicators.		

OMPA 27: Marine and coastal waterbirds

Region	2021 status	2021 trend	2021 data
Other marine protected areas	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. Marine and coastal waterbirds are covered in the regional indicators.		

OMPA 28: Migratory shorebirds

Region	2021 status	2021 trend	2021 data
Other marine protected areas	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. Migratory shorebirds are covered in the regional indicators.		

OMPA 29: Piscivorous (fish-eating) birds

Region	2021 status	2021 trend	2021 data
Other marine protected areas	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. Piscivorous birds are covered in the regional indicators.		

OMPA 30: Little penguins

Region	2021 status	2021 trend	2021 data
Other marine protected areas	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. Little penguins are covered in the regional indicators.		

OMPA 31: Marine Mammals

Region	2021 status	2021 trend	2021 data
Other marine protected areas	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. Marine mammals are covered in the regional indicators.		

Statewide/broad-scale

SW 15: Conservation of coastal ecosystems in protected areas

Region	2021 status	2021 trend	2021 data
Statewide	●	?	●
Justification for assessment ratings:	This is a broad indicator that covers a range of coastal ecosystems and conservation efforts. There is a variety of protection given to coastal Ecological Vegetation Classes (EVCs) and that some EVCs have been more impacted by changing coastal land use, the status of fair is due to a range of National Parks and other conservation areas having generally having good coverage (that is, extending along approximately 70% of the Victorian coastline), countered by there being some data limitations for threatened and invasive species, while some ecological vegetation classes could be given greater protection. There is no evidence to support a trend assessment. Due to the lack of an existing overarching threshold for conservation of coastal ecosystems, the confidence in this status assessment is low.		

The Port Phillip and Westernport Catchment Management Authority identified that between 2004 and 2007, the conservation status of 10 coastal Ecological Vegetation Classes (EVCs) on the Gippsland Plain bioregion had worsened, and three had improved (see Table 21).[810] Data of this kind is unavailable for other bioregions along the coast.

The protection levels for coastal ecological EVCs vary. Those that occur in the Wilsons Promontory bioregions have 100% of what remains in the bioregion protected within the Wilson's Promontory National Park. However, others on the coastal plains receive far less protection. For example, remaining estuarine wetland has only 7%, 1%, 4% and 0% of its extent in conservation reserves on the Warrnambool Plain, Otway Ranges, Otway Plain and Victorian Volcanic Plain bioregions respectively. Parks Victoria manages around 70% of the Victorian coast as national and state parks or as coastal reserves. However, analysis indicates that several coastal EVCs have limited coverage in protected areas (see Table 22).

Coastal EVCs that are either vulnerable or endangered in two or more bioregions are coast banksia woodland, coastal saltmarsh, estuarine wetland, coastal headland scrub, coastal tussock grassland, coastal saltmarsh/mangrove shrubland mosaic, coastal alkaline scrub and coast banksia woodland/coastal dune scrub mosaic. Those that have experienced substantial declines in their extent, and which are endangered, vulnerable, depleted or rare with limited protection in conservation areas, are coastal dune scrub/coastal dune grassland mosaic, estuarine wetland, mangrove shrubland, coastal dune scrub, coastal headland scrub, coastal tussock grassland, brackish wetland, coastal alkaline scrub and coast banksia woodland/coastal dune scrub mosaic. These are largely the EVCs of the sand dunes and coastal wetlands. However, of the remaining estuarine wetland in those four bioregions, 23%, 40%, 55% and 17% respectively is on public land with the potential for increased protection.

810. Port Phillip and Western Port Catchment Management Authority (PPWCMA) 2008, 'Summary of changes to the bioregional conservation status ratings resulting from updated 2007 native vegetation datasets - Port Phillip and Western Port CMA region'.

Although coast-specific EVCs have been impacted by changing coastal land use, hinterland EVCs such as woodlands and grasslands that range to the coast have also been impacted.[811]

Of the 10 bioregions with coastal boundaries, those where vegetation loss is most pronounced are the Warrnambool Plain (between Portland and Princetown), the Otway Plain (largely from Aireys Inlet to Altona) and the Gippsland Plain (from eastern Melbourne to the Gippsland Lakes).

Table 21: Changes in the conservation status of some Victorian coastal EVCs (in PP&WP CMA).[812]

EVC		Change in conservation status
	Conservation status deteriorated	
1	Coastal dune scrub/coastal dune grassland mosaic	Least concern to depleted
12	Wet swale herbland	Rare to vulnerable
160	Coastal dune scrub	Least concern to depleted
163	Coastal tussock grassland	Least concern to vulnerable
858	Coastal alkaline scrub	Depleted to vulnerable
904	Coast banksia woodland/swamp scrub mosaic	Rare to vulnerable
906	Brackish grassland/swamp scrub mosaic	Rare to endangered
909	Coastal dune scrub/bird colony succulent herbland mosaic	Least concern to depleted
934	Brackish grassland	Rare to endangered
935	Estuarine wetland/estuarine swamp scrub mosaic	Least concern to depleted
	Conservation status improved	
879	Coastal dune grassland	Endangered to depleted
900	Coastal saltmarsh/coastal dune grassland/ coastal dune scrub/coastal headland scrub mosaic	Endangered to vulnerable
922	Coastal alkaline scrub/bird colony succulent herbland mosaic	Endangered to vulnerable

811. Ibid.
812. Ibid.

Table 22: Coastal EVCs and their conservation status by bioregion.[813]

Key: E=Endangered; V=Vulnerable; D=Depleted; R=Rare. Number after conservation status represents: % of pre-1750s cover remaining / % remaining that is protected / % remaining found on other public land / remaining found on private land

Ecological Vegetation Class	Pre-1750s (ha)	Current (ha)	Glenelg Plain	Warrnambool Plain	Otway Ranges	Otway Plain	Victorian Volcanic Plain	Gippsland Plain
1 Coastal Dune Scrub/Coastal Dune Grassland Mosaic	18,255	12,140		V67/51/9/7	D 86/28/50/8	D75/37/31/7	D 91/0/91/0	D 50/32/7/11
2 Coast Banksia Woodland	9,676	6,090						V 41/13/8/20
5 Coastal Sand Heathland	154	145	R 98/0/98/0					
9 Coastal Saltmarsh	15,813	12,471				E 26/4/12/10	V 51/22/10/19	LC 86/53/8/25
10 Estuarine Wetland	10,276	8,484		D 83/7/23/53	E 80/1/40/39	E 89/4/55/30	E 19/0/17/2	LC 81/31/16/34
11 Coastal Lagoon Wetland	863	852						V 93/0/69/24
12 Wet Swale Herbland	4,768	4,768						V 100/100/0/0
140 Mangrove Shrubland	5,387	4,243				V 96/0/72/24	V 59/5/7/47	LC 79/56/6/17
144 Coast Banksia Woodland/Warm Temperate Rainforest Mosaic	244	148						E 100/0/98/1
154 Bird Colony Shrubland	413	411		R 72/72/0/0		R 85/85/0/0		
160 Coastal Dune Scrub	5,320	4,119		D 72/6/35/31				D 20/13/4/3
161 Coastal Headland Scrub	8,218	5,677	E 84/37/29/18	V 61/47/6/8	D 83/32/13/39	V87/57/18/12	V 35/0/27/7	D 59/41/12/8
162 Coastal Headland Scrub/ Coastal Tussock Grassland Mosaic	2,151	1,331		V 88/78/4/7				D 44/14/13/18
163 Coastal Tussock Grassland	2,484	2,087		V 88/78/4/7	V 92/48/4/40	V 72/14/25/33	V 54/13/33/9	V 84/72/3/10
181 Coast Gully Thicket	346	219		E 64/44/8/12				
302 Coastal Saltmarsh/Mangrove Shrubland Mosaic	5,928	4,508				E 81/10/46/25	E 63/11/19/33	V 69/30/2/37
309 Calcareous Swale Grassland	559	559						V 100/100/0/0
311 Berm Grassy Shrubland	191	125				E 58/58/0/0		E 66/2/39/25
656 Brackish Wetland	1,314	662	V 99/0/95/4				E 51/0/3/48	E 17/0/14/3

Table 22: Coastal EVCs and their conservation status by bioregion cont.

Ecological Vegetation Class	Pre-1750s (ha)	Current (ha)	Glenelg Plain	Warrnambool Plain	Otway Ranges	Otway Plain	Victorian Volcanic Plain	Gippsland Plain
665 Coastal Mallee Scrub	597	337	E 56/33/1/22					
858 Coastal Alkaline Scrub	29,910	17,122	E 64/52/2/10			E 31/1/8/22	E 22/11/7/4	
876 Spray-zone Coastal Shrubland	155	141	E 89/77/9/2					
900 Coastal Saltmarsh/Coastal Dune Grassland/Coastal Dune Scrub/ Coastal Headland Scrub Mosaic	153	63					E 9/4/3/2	V 48/1415/20
904 Coast Banksia Woodland/ Swamp Scrub Mosaic	327	65						V 20/2/13/4
906 Brackish Grassland/Swamp Scrub Mosaic	153	15					E 2/0/1/1	E 28/0/6/21
909 Coastal Dune Scrub/Bird Colony Succulent Herbland Mosaic	148	131						D 89/85/0/3
914 Estuarine Flats Grassland	560	157					NS 0/0/0/0	E 28/4/7/17
919 Coastal Headland Scrub/Coast Banksia Woodland Mosaic	357	66						V 19/0/16/3
921 Coast Banksia Woodland/ Coastal Dune Scrub Mosaic	1,288	876					V 27/0/16/11	V 68/3/54/12
922 Coastal Alkaline Scrub/Bird Colony Succulent Herbland Mosaic	120	53						V 44/23/1/20
934 Brackish Grassland	749	59						E 8/0/5/3
935 Estuarine Wetland/Estuarine Swamp Scrub Mosaic	533	160						D 30/15/2/13
TOTAL Pre-1750s cover	127,410		1462	9818	1978	12575	4981	62802
TOTAL current cover		88,384	1083	6921	1657	7384	2486	39971
Remaining (%)		69.4	74.1	70.5	83.8	58.7	49.9	63.6

813. Victorian Environmental Assessment Council (VEAC) 2017, 'Statewide assessment of public land', Melbourne, Victoria.

SW 18: Wetland and estuarine vegetation

Region	2021 status	2021 trend	2021 data
Statewide		?	

Justification for assessment ratings:	As part of the Index of Estuary Condition, flora assessments for 100 estuaries across Victoria were completed. Half of the state's estuaries had flora in excellent or good condition, and only 11% had flora in poor condition. No estuaries had flora in very poor condition.

Fringing vegetation

A pilot study conducted during 2018 tested a method to report on fringing vegetation as part of the Index of Estuary Condition (IEC). The pilot study identified three distinct indicators that allow managers and planners to rapidly understand which issues are affecting each estuary and consider land management interventions accordingly. For example, the pilot study clearly showed that the fringing vegetation on Anglesea estuary has been damaged and restricted by prior building works, but that the remaining vegetation is relatively free from weeds and retains its expected structure.[814]

814. Sinclair S and Kohout M 2018, 'Assessment of fringing vegetation for the index of estuary condition', Arthur Rylah Institute for Environmental Research (ARI), technical report series no. 290, Department of Environment, Land, Water and Planning (DELWP), Heidelberg, Victoria.
815. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Index of estuary condition', East Melbourne, Victoria.
816. Ibid.
817. Ibid.
818. Ibid.

Estuarine flora

Half of the state's estuaries had flora in excellent or good condition, and only 11% had flora in poor condition. No estuaries had flora in very poor condition (Table 23).[815] As this is the first IEC, and IECs are designed to be point-in-time assessments, no time series data are available to assess trends.

The estuaries with flora in poor condition had estuarine floodplains dominated by agriculture (for example, Curdies Inlet, Tarwin River, Neils Creek and Mitchell River) and, to a lesser extent, urbanisation (for example, Mordialloc Creek).[816]

The condition of flora was moderate or better at 89% of Victoria's estuaries. Estuaries with flora in excellent condition were predominantly those within parks and reserves. Estuaries with flora in good condition included some estuaries adjacent to coastal towns (for example, Painkalac Creek, Spring Creek and Thompson Creek).[817]

Table 23: Percentage of estuaries in each flora score category in five catchment regions and all estuaries across Victoria where flora was sampled.[818]

Catchment Region	Excellent	Good	Moderate	Poor	Very poor
Glenelg Hopkins (8)	0	13	75	13	0
Corangamite (17)	0	35	53	12	0
Port Phillip and Western Port (17)	12	35	41	12	0
West Gippsland (29)	31	21	38	10	0
East Gippsland (25)	24	48	16	12	0
All (100)	17	33	39	11	0

Numbers in parentheses next to catchment region names indicate the number of estuaries assessed; note that 100 estuaries were sampled for flora but not all had data from sufficient sub-indices to receive an overall IEC score. Numbers in parentheses under the condition classes indicate the range of scores in that condition class.

SW 19: Species of conservation concern

Region	2021 status	2021 trend	2021 data
Statewide		?	
Justification for assessment ratings:	The data analysed and reported for this indicator provide information on the number of species of conservation concern. The status and trend assessments are unknown and unclear, respectively, because no information is available to ascertain how these species are being tracked and managed, and no trend data are available to assess how these species are tracking over time.		

Publicly accessible data from the Victorian Biodiversity Atlas has been analysed to determine the magnitude of threatened and vulnerable marine and coastal species within Victoria's marine biounits.

Within the Victorian Biodiversity Atlas there are 4,059 fauna species and 3,214 flora species that are mapped to be within Victoria's marine biounits. Of these, there are 153 fauna species and 67 flora species that are denoted by the Atlas as being listed within the FFG Act, listed as endangered, threatened or vulnerable within the *Environment Protection and Biodiversity Conservation Act 1999*, or included as on DELWP's advisory list as endangered, threatened, vulnerable or poorly known.

Given that recent amendments to the FFG Act have removed duplication by establishing a single comprehensive list of threatened flora and fauna species and revoking Advisory Lists,[819] any updates to the Victorian Biodiversity Atlas attribute fields will be incorporated in future State of the Marine and Coastal Environment reports.

Of the combined 220 species of conservation concern that are listed within the Victorian Biodiversity Atlas, 154 (70%) have records within the past 20 years.

There is a lack of published analysis and time series data available to assess how these species are tracking over time and this will be an area of focus for future State of the Marine and Coastal Environment reports.

819. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Threatened list and processes list' East Melbourne, Victoria https://www.environment.vic.gov.au/conserving-threatened-species/threatened-list Accessed 17 August 2021.

SW 23: Commercially and recreationally important invertebrates

Region	2021 status	2021 trend	2021 data
Statewide	(southern calamari, Maori octopus) (southern rock lobster) (blacklip abalone) (pipi, greenlip abalone)	(southern calamari, Maori octopus, southern rock lobster) (blacklip abalone) (pipi, greenlip abalone)	(southern calamari and southern rock lobster) (Maori octopus, blacklip abalone) (pipi, greenlip abalone)
Justification for assessment ratings:	**Southern calamari:** There is no evidence to suggest recruitment impairment and, in the context of their biology and the relatively low level of fishing pressure, the stock is expected to remain sustainable into the future. **Maori octopus:** There is minimal reason to believe that this species is at risk of depletion under current fishing practices. This implies that the Victorian Maori octopus stock is sustainable. **Pipi:** Based on the available information the current status of the Victorian pipi stock is uncertain. **Southern rock lobster:** The southern Australian stock is sustainable, but Victorian CPUE is at very low levels and the abundance of undersize lobsters is at or near record lows in the western and eastern zones of the Victorian fishery. Balancing this information, the status is fair with a stable trend. **Blacklip abalone:** Based on the two fisheries management units with the largest catches in Victoria both being classified as having depleting stocks, this status of this indicator has been assessed as poor, with a deteriorating trend. **Greenlip abalone:** There is insufficient information available to classify the status of this stock.		

Southern calamari

The Victorian southern calamari population supports commercial fisheries in Corner Inlet and Port Phillip Bay, while there are also recreational fisheries in Port Phillip Bay, Corner Inlet, Western Port and coastal waters. Recent assessments by the VFA and Status of Australian Fish Stocks Reports have considered the Victorian calamari population as a statewide stock and it is, therefore, included as a statewide assessment in this report.[820]

Given southern calamari only live for a maximum of one year, the available stock within any given year is reflective of annual spawning success. Interannual changes in catch rate likely reflect this aspect of their population biology.[821]

Statewide commercial catches have declined by over 60% from a peak period during the early 2000s. This decline is related to a decreasing effort from most fisheries that target southern calamari, which is associated with buy outs in Port Phillip Bay and Western Port and a transfer of effort in Corner Inlet from seining to mesh netting. Despite this trend, it is notable that landings have increased at Corner Inlet during the past two years.[822]

820. Victorian Fisheries Authority (VFA) 2020, 'Review of key Victorian fish stocks — 2019'.
821. Ibid.
822. Ibid.

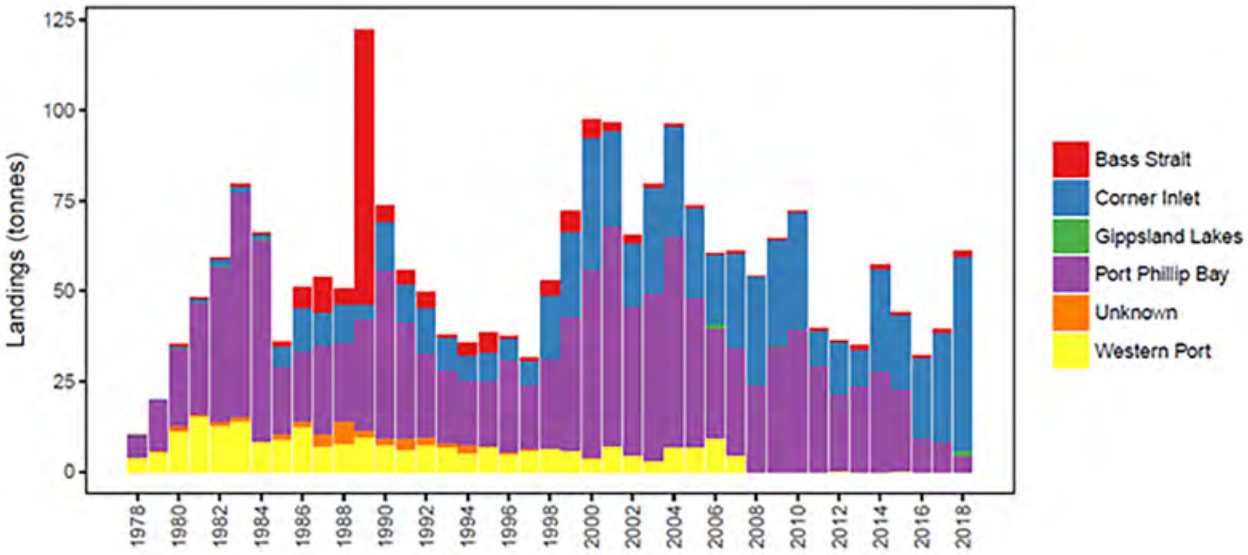
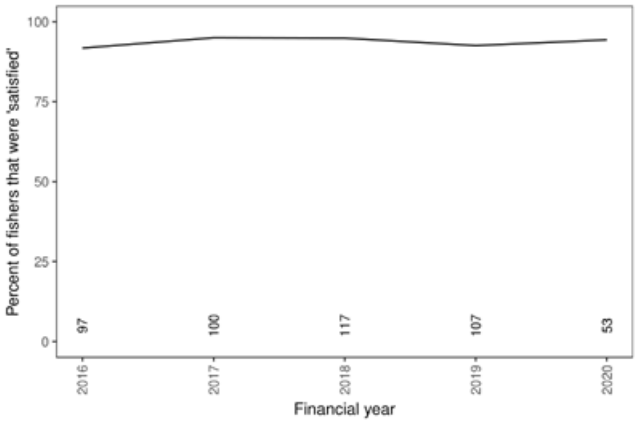


Figure 51: Southern calamari commercial catches in Victorian waters, 1978–2018 financial years.[823]

The CPUE trend of commercial seines in both Corner Inlet-Nooramunga and Port Phillip Bay has been gradually increasing during the 2010s. Likewise, recreational CPUE from creel surveys shows an increasing trend during the past decade.[824]

There is no evidence to suggest recruitment impairment and, in the context of their biology and the relatively low level of fishing pressure, the stock is expected to remain sustainable into the future.[825]

In addition to the data on southern calamari spawning and catch rates, fisher satisfaction can be considered as a supplementary measure that provides indicative information to inform the abundance of fish species at a point in time. The theory of this is that higher satisfaction ratings from fishers are likely to be associated with more plentiful numbers of fish available to be caught. During the five years from 2016 to 2020, in each year nearly 100% of surveyed fishers that were targeting calamari in Victoria reported being satisfied with their fishing experience. This is indicative of there being suitable calamari abundance to ensure most anglers have been enjoying a positive fishing experience.



The numbers above the x-axis represent the number of survey respondents.

Figure 52: Percent of fishers targeting calamari in Victoria that were satisfied with their fishing experience.[826]

823. Ibid.
824. Ibid.
825. Ibid.
826. Image supplied by the Victorian Fisheries Authority (VFA).

Pipi

The overwhelming majority of pipis are landed from Discovery Bay. Infrequent, small, catches of pipi have been reported since 1990, however it was not until 2011 that the fishery was developed and substantial quantities began to be landed. Catches have been reducing since 2013-14, which has been linked to the spatial and catch restrictions imposed from 2013 onwards. Fishing effort increased markedly with the development of the fishery.[827]

During the brief duration of this fishery there have been relatively large shifts in CPUE from greater than 100 kg/hr to approximately 50 kg/hr suggesting that there have either been large changes in the biomass of pipis in Discovery Bay, or that fishing practices have changed.[828]

There is a possibility that effort, and hence CPUE, is inaccurate due to differences over time in what has been reported meaning that there is a possibility that changing fishing practices (for example, additional people catching pipis under a license) could be masking changes in biomass. Now that the number of fishers is reported in ocean access logbooks it will be important to continue to monitor CPUE into the future in conjunction with industry consultation to ascertain whether fishing practices have changed through time. This will assist with determining whether historic CPUE is likely to be biased. Additionally, a significant recreational fishery exists, particularly in Venus Bay, and the landings from this fishery are currently unknown. Based on the available information the current status of the Victorian pipi stock is uncertain.[829]

Maori octopus

Fishing effort in the rock lobster fishery increased from the late 1980s to late 1990s. There has been a consistent decline in effort since then in line with rock lobster quota reductions, meaning there has also been less effort directed at Maori octopus. Landings, however, have remained relatively consistent, which may indicate that a proportion of the octopus by-product have been discarded during earlier years, presumably due to a lack of market demand.[830]

Given the issues with discarding, CPUE trends prior to about 1998 may not be reflective of abundance. Nevertheless, CPUE was very high in the earlier period, decreasing by the early to mid-1980s. Since then, CPUE has been relatively stable and above the reference period average for five out of the last eight years. In 2017, however, CPUE was close to the reference period[831] minimum and it will be important to ensure that it increases soon.[832]

Decreasing trends in effort within the rock lobster sector have resulted in decreasing landings of Maori octopus, despite it being likely that this species is now retained most of the time it is captured. Relative stability in CPUE for more than 30 years suggests there has been no long-term depletion of the stock and - provided the low value in 2017 is established to be within the bounds of natural variation and there is an increase in the near future - there is minimal reason to believe that this species is at risk of depletion under current fishing practices. This implies that the Victorian Maori octopus stock is sustainable.[833]

Southern rock lobster

The VFA publishes annual stock assessment reports for the Victorian Rock Lobster fishery, with the most recent of these occurring for the 2019-20 financial year. The fishery is split into western and eastern Victorian regions for the assessment.

Western zone rock lobster fishery

Overall, the stock indicators in the Western Zone show a marginal improvement. The standardised Catch Per Unit Effort (CPUE) improved from 0.64 kg/pot-lift in 2018-19 to 0.67 kg/pot-lift in 2019-20. The numbers of undersize lobsters have continued to increase from the recent historical low but are still at very low levels. The pre-recruit index has been below the reference point of 1.81 in the previous six seasons.[834]

827. Victorian Fisheries Authority (VFA) 2020, 'Review of key Victorian fish stocks — 2019'.
828. Ibid.
829. Ibid.
830. Ibid.
831. Note that VFA defined the reference period for Maori octopus to be 1998-2015.
832. Victorian Fisheries Authority (VFA) 2020, 'Review of key Victorian fish stocks — 2019'.
833. Ibid.
834. Victorian Fisheries Authority (VFA) 2017, 'Victorian rock lobster fishery stock assessment report – 2019/20 season', Melbourne, Victoria.

Egg production has been relatively consistent at 23-24% in the last seven years, in 2019-20 egg production was at 23.0% which is above the 20% limit reference point. Biomass has been increasing slowly from a recent low in 2008-09 to a level 85% higher than this in 2019-20. Recruitment has been below the long-term average since 2007-08. The 2019-20 assessment report indicated the first sign of a slightly higher level of recruitment since 2010-11, however this higher level was still below the long-term average level of recruitment.[835]

Eastern zone rock lobster fishery

Standardised CPUE has reduced from a recent high of 0.64 kg/pot-lift in 2012-13 to 0.36 kg/pot-lift in 2017-18. Direct application of the harvest strategy would have resulted in a TACC of 32 tonne in 2019-20, however, as a result of industry consultation a lesser reduction to 40 tonne was implemented. The 40 tonne TACC was retained in the 2020-21 season.[836]

The 2018-19 standardised CPUE increased to 0.41 kg/potlift, however it has reduced back to 0.37 kg/potlift in 2019-20. PRI increased to 0.20 undersize/potlift in 2019-20, a significant increase from the 2018-19 level of 0.08 which was the lowest level since 2005-06, however PRI remains well below the reference point of 0.32 undersize/potlift.[837]

Southern Australian stock

Southern rock lobster is considered to be a single biological stock across southern Australia because the species occurs in a continuous distribution across this range and has extensive and protracted pelagic larval dispersal phase.

At the biological stock level (Southern Australia) the southern rock lobster is considered to be sustainable based on a metric of percentage of egg production relative to unfished level.[838]

The 2019-20 assessments for Victoria estimate that egg production in 2019–2020 was 24% of the unfished level for the western stock and 23% for the eastern stock.[839] The limit reference point is 20%. This evidence indicates that the biomass of this stock is unlikely to be depleted and that recruitment is unlikely to be impaired.[840]

While the southern rock lobster stock currently has egg production above the limit reference point of 20% of unfished levels and fishing mortality managed to a level that indicates stock rebuilding will occur, there are aspects of the stock that are of concern.[841] The concerns for Victoria include:

- The abundance of undersize lobsters is at or near record lows in the western and eastern zones of the Victorian fishery.[842,843]
- The estimated level of egg production being close to the limit reference point.[844]

Balancing this information, with the southern Australian stock considered to be sustainable, but with CPUE at very low levels and the abundance of undersize lobsters is at or near record lows in the western and eastern zones of the Victorian fishery, the status is considered to be fair with a stable trend.

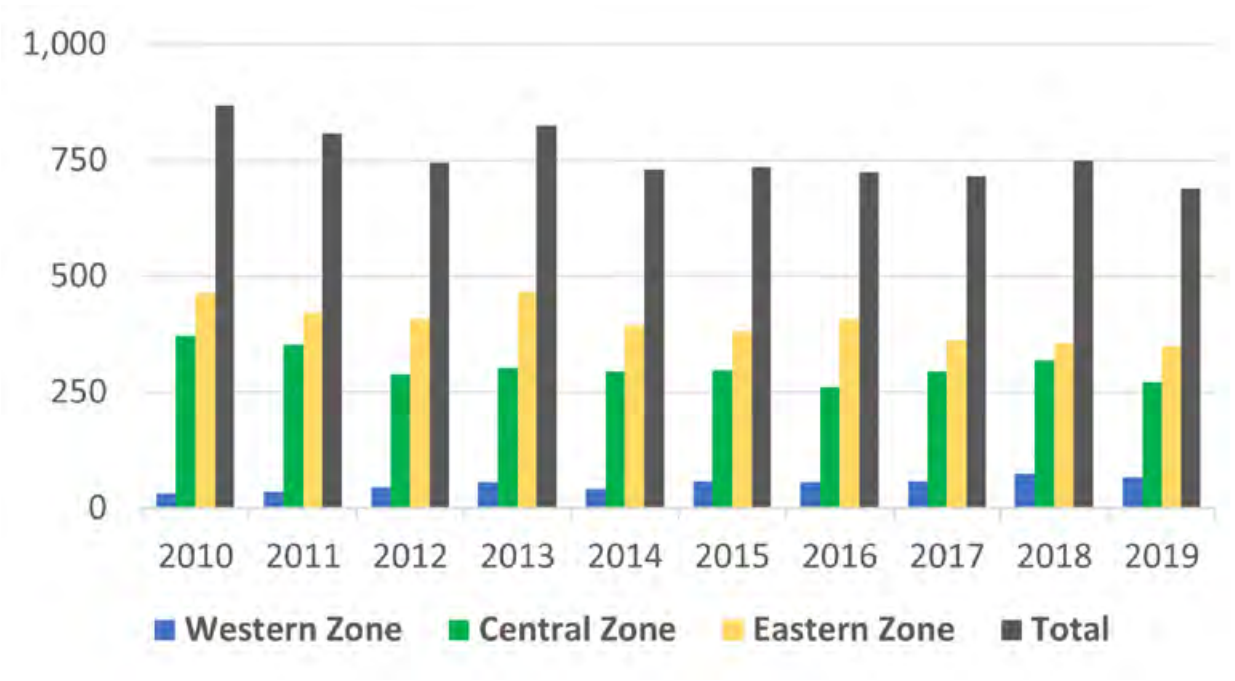
Blacklip abalone

Commercial Catch Per Unit Effort (CPUE) doubled from about 50 kg per hour in the early 1980s to around 100 kg per hour in the early 2000s at the Victorian central zone fishery, a pattern consistent throughout the state.[845] The increase is thought to be at least partly due to changes in fishing practices that improved fishing efficiency.[846] Similar patterns have been observed during the same period in the other Australian blacklip abalone jurisdictions, and have been partially attributed to increased exploitable biomass. The introduction of a Total Allowable Commercial Catch (TACC) in the Victoria Central Zone in 1988 was expected to improve biomass and contribute to CPUE increases to some extent.[847] The TACC was stable for more than a decade prior to the introduction of marine national parks which reduced the available fishing grounds, probably because catch quotas were not linked to biomass trends at that time.[848]

835. Ibid.
836. Ibid.
837. Ibid.
838. Fisheries Research and Development Corporation (FRDC), 'Southern rock lobster (2020)' https://www.fish.gov.au/report/294-Southern-Rock-Lobster-2020 Accessed 30 July 2020.
839. Ibid.
840. Ibid.
841. Ibid.
842. Ibid.
843. Ibid.
844. Ibid.
845. Fisheries Research and Development Corporation (FRDC), 'Blacklip abalone (2020)' https://www.fish.gov.au/report/286-Blacklip-Abalone-2020 Accessed 29 August 2021.
846. Victorian Fisheries Authority (VFA) 2017, '2016/17 Victorian abalone stock assessment – central zone', Victorian Fisheries Authority science report series no. 2, Melbourne, Victoria.
847. Fisheries Research and Development Corporation (FRDC), 'Blacklip abalone (2020)' https://www.fish.gov.au/report/286-Blacklip-Abalone-2020 Accessed 30 July 2020.
848. Department of Natural Resources and Environment (DNRE) 1996, 'Draft abalone management plan', Victorian Fisheries Program, Melbourne, Victoria.

As part of the Fisheries Research and Development Corporation's 2020 stock assessments, and based on catch, CPUE, fishery independent surveys, the Victorian blacklip abalone stock assessments were as follows for each management zone:

- Depleting for the Victoria Central Zone Fishery and Victorian Eastern Zone Fishery.
- Sustainable for the Victoria Western Zone Fishery.[849]



Note: confidential catch not shown.

Figure 53: Commercial catch (tonnes) of blacklip abalone.[850]

Victoria Western Zone Fishery

The Western Zone management unit has undergone significant changes over its recent history. Most notable was the impact of an outbreak of Abalone Viral Ganglioneuritis (AVG) in 2006. Industry has worked with fishery managers since that time to respond to the disease outbreak, including development of a harvest strategy for the fishery that has been applied since 2016. Abalone mortalities due to the disease severely reduced the biomass and resulted in a major reduction in total allowable commercial catch (TACC) for this zone from 280 tonnes in 2001–02 to 20 tonnes in 2008–09. While some fishing occurred on uninfected reefs for a period immediately after the disease was first recognised, by 2008 most areas in the western zone had been impacted and were closed to fishing. These events complicate comparisons between recent and historical fishery-dependent and independent data.[851]

Progression of the disease through the fishery had abated by 2009.[852] This enabled fishers and researchers to conduct a structured fishing program, where divers were assigned precise fishing locations to gather information and assess the capacity of remaining stocks to support a viable commercial fishery.[853] Since SAFS 2016, and in line with the western zone harvest strategy based on simulation modelling by, the TACC has been increased to 70 tonnes reflecting increases in estimates of exploitable biomass of blacklip abalone with shell lengths larger than a conservative Legal Minimum Length (LML) of 130–135 mm.[854]

849. Fisheries Research and Development Corporation (FRDC), 'Blacklip abalone (2020)' https://www.fish.gov.au/report/286-Blacklip-Abalone-2020 Accessed 30 July 2020.
850. Ibid.
851. Ibid.
852. Ibid.
853. Mayfield S, McGarvey R, Gorfine HK, Peeters H, Burch P and Sharma S 2011, 'Survey estimates of fishable biomass following a mass mortality in an Australian molluscan fishery', *Journal of Fish Diseases*, 34, pp. 287–302.
854. Helidoniotis F and Haddon M 2014, 'Modelling the potential for recovery of western victorian abalone stocks: The Crags', interim report to 2012/225, CSIRO, Hobart.

Recent TACCs have been set at around 10% of the estimated biomass of legal-sized abalone to facilitate continued rebuilding.[855]

The fishery-independent survey (FIS) data from 2003 onwards clearly show the impact of the AVG mortalities. Survey abundance indices for both pre-recruits and recruits showed 32% and 8% less abundance respectively in 2018, compared with the pre-disease averages during 1995–2006.[856] Since 2010, pre-recruit abundance has increased more than three-fold and recruit abundance has increased by 75% since 2008.[857] Despite the signs of recovery, the current mature biomass remains below the 2020 target reference point, but above the limit reference point, in the harvest strategy for the fishery but has declined for the last 3 years.[858] Mature biomass is dominated by abalone below the LML, and is also likely to be influenced by variation in year-class strength. Recent declines in mature biomass follow a large increase in the biomass of under-sized abalone to 2016 and are more closely related to declines in legal-sized biomass in recent years whereas mature, but undersize abalone biomass remains more stable.[859]

The above evidence indicates that the biomass of the stock is unlikely to be depleted, and that recruitment is unlikely to be impaired. Abalone viral ganglioneuritis did not disrupt the fundamental breeding and juvenile recruitment processes.[860]

Fishery-dependent and independent information indicate that the management unit has been stable since 2011, although at a lower biomass than pre-AVG.[861] The recent stability of commercial CPUE under the higher LML of 130–135 mm, combined with stability of the fishery-independent pre-recruit and recruit survey indices, and biomass estimates derived from them, indicate that the current management arrangements are constraining fishing pressure sufficiently to avert declines in the productivity of the stock. Signs are now evident of an increase in pre-recruit abundance, indicating that the stock has been rebuilding despite progressive increases in TACC.[862]

Victoria Central Zone Fishery

Since the peak in the early 2000s, CPUE has shown a declining trend, and by 2017–18 was almost one quarter lower at 74 kg per hour.[863] The stable, but relatively low, abundances observed in fishery independent survey indices indicate the decline in biomass observed over two decades may have stabilised, but there is no evidence of recovery and commercial CPUE has decreased by 14% during the past decade.[864] However, pre-recruit abundance levels are similar to those for recruits, implying that reasonable recruitment has been occurring at recent stock levels. The most recent assessment concluded that maintaining the TACC at current levels was likely to meet objectives for stabilising the biomass at its current level but unlikely to recover stocks to previous levels. The above evidence indicates the biomass of this stock is unlikely to be depleted and recruitment is unlikely to be impaired.[865] For the period 2009–2019 the biomass declined, but the stock is not yet considered to be recruitment impaired. Evidence based on the pre-recruit abundance index indicates reasonable recruitment has been occurring at recent stock levels.[866] On the basis of the evidence provided above, the Victoria Central Zone Fishery management unit was classified in 2020 by the Fisheries Research and Development Corporation as a depleting stock.[867]

855. Western Abalone Diver Association 2020, 'Assessment of abalone stocks in western zone Victoria: submission for the TAC setting process for 2020'.
856. Victorian Fisheries Authority (VFA) 2017, '2016/17 Victorian abalone stock assessment – western zone', Victorian Fisheries Authority science report series no. 4, Melbourne, Victoria.
857. Ibid.
858. Fisheries Research and Development Corporation (FRDC), 'Blacklip abalone (2020)' https://www.fish.gov.au/report/286-Blacklip-Abalone-2020 Accessed 30 July 2020.
859. Western Abalone Diver Association 2020, 'Assessment of abalone stocks in western zone Victoria: submission for the TAC setting process for 2020'.
860. Fisheries Research and Development Corporation (FRDC), 'Blacklip abalone (2020)' https://www.fish.gov.au/report/286-Blacklip-Abalone-2020 Accessed 30 July 2020.
861. Ibid.
862. Victorian Fisheries Authority (VFA) 2017, '2016/17 Victorian abalone stock assessment – western zone', Victorian Fisheries Authority science report series no. 4, Melbourne, Victoria.
863. Fisheries Research and Development Corporation (FRDC), 'Blacklip abalone (2020)' https://www.fish.gov.au/report/286-Blacklip-Abalone-2020 Accessed 30 July 2020.
864. Victorian Fisheries Authority (VFA) 2017, '2016/17 Victorian abalone stock assessment – central zone', Victorian Fisheries Authority science report series no. 2, Melbourne, Victoria.
865. Fisheries Research and Development Corporation (FRDC), 'Blacklip abalone (2020)' https://www.fish.gov.au/report/286-Blacklip-Abalone-2020 Accessed 30 July 2020.
866. Dixon CD and Dichmont CM 2019, 'Draft stock assessment for the central zone of the Victorian abalone fishery 2018/19', MRAG Asia Pacific, Brisbane, Australia.
867. Fisheries Research and Development Corporation (FRDC), 'Blacklip abalone (2020)' https://www.fish.gov.au/report/286-Blacklip-Abalone-2020 Accessed 30 July 2020.

Victoria Eastern Zone Fishery

Although the Victorian Eastern Zone Fishery was not impacted by the Abalone Viral Ganglioneuritis (AVG) outbreak west of Cape Otway in 2006 that affected the Victorian central and western zone fisheries, the Victorian eastern zone fishery is being impacted by an increasing abundance of the long-spined sea urchin (*Centrostephanus rodgersii*) in eastern Victorian marine waters.[868] These urchins denude reefs of macroalgae, turning them into 'barrens' that are unsuitable for abalone, with significant areas of reef in the eastern zone affected by urchins in this manner over the past 20 years.[869]

The Eastern Zone catch was relatively stable from 1992 to 2002, ranging from 431 to 445 tonnes per quota year before increasing to 480 tonnes in 2003. Catch was maintained at this level until 2008 and has slowly declined thereafter. The 2018–19 catch quota (TACC) of 346.5 tonnes was the lowest on record. Standardised CPUE significantly increased from 1992 to 2011, before significantly declining over five years from 2011 to 2016, then increasing again from 2016 to 2019. Current CPUE values in 2019 were 89–126 kg per hour among the spatial management units, well above the limit reference point of 50 kg per hour specified throughout the eastern zone.[870] The increases in CPUE are likely to have resulted, at least in part, from ongoing reductions in catch since 2012, as well as from decreases in legal minimum length in some spatial management units in recent years.[871]

For the periods 1995 to 2015 and 2012 to 2017, fishery independent and dependent performance measures respectively indicated that the biomass was declining, but not to the extent that the stock could be considered to have become depleted or recruitment impaired.[872] In the last two years, both CPUE and recruit abundance have increased. Pre-recruit abundance has continued to decline and remains of concern, however it is reasonable to conclude that the status of the resource has stabilised and the likelihood of depletion to a level causing recruitment impairment in the near to medium term is low at the current precautionary TACC of 337.5 tonnes.[873]

On the basis of the evidence provided above, the Victoria eastern zone fishery management unit was classified in 2020 by the Fisheries Research and Development Corporation as a depleting stock.[874]

Greenlip abalone

Greenlip abalone comprises a small, 2% and 1%, component of the total commercial abalone catch in the Victoria western zone fishery management unit and Victoria central zone fishery management units, respectively.[875]

The current TACC supports the collection of some data on the Victoria Western Zone Fishery, but these data are insufficient to support a formal assessment, particularly because there has been a spatial shift in fishing operations.[876] Fishing for greenlip abalone in the Victoria Western Zone Fishery management unit is less profitable than fishing for blacklip abalone.[877]

The low catches and resulting limited data on greenlip abalone in the mixed species Victoria western and central zone fishery management units makes CPUE unreliable for this species and prevents direct (or by proxy) assessment of current stock size or fishing pressure.[878] In addition, there is little information about recruitment, no survey data during the past decade and the Victorian Wild Harvest Abalone Fishery Management Plan does not identify a performance indicator or a reference point below which the fishery would be defined as depleted.[879] Consequently, there is insufficient information available to classify the status of this stock.[880]

868. Ibid.
869. Gorfine H, Bell J, Mills K, Lewis Z 2012, 'Removing sea urchins (*Centrostephanus rodgersii*) to recover abalone (*Haliotis rubra*) habitat', Department of Primary Industries (DPI), Queenscliff, Victoria.
870. Fisheries Research and Development Corporation (FRDC), 'Blacklip abalone (2020)' https://www.fish.gov.au/report/286-Blacklip-Abalone-2020 Accessed 30 July 2020.
871. Dixon CD and Dichmont CM 2019, 'Draft stock assessment for the eastern zone of the Victorian abalone fishery 2018/19', MRAG Asia Pacific, Brisbane, Australia.
872. Fisheries Research and Development Corporation (FRDC), 'Blacklip abalone (2020)' https://www.fish.gov.au/report/286-Blacklip-Abalone-2020 Accessed 30 July 2020.
873. Dixon CD and Dichmont CM 2019, 'Draft stock assessment for the eastern zone of the Victorian abalone fishery 2018/19', MRAG Asia Pacific, Brisbane, Australia.
874. Fisheries Research and Development Corporation (FRDC), 'Blacklip abalone (2020)' https://www.fish.gov.au/report/286-Blacklip-Abalone-2020 Accessed 30 July 2020.
875. Fisheries Research and Development Corporation (FRDC), 'Greenlip abalone (2020)' https://www.fish.gov.au/report/286-Blacklip-Abalone-2020 Accessed 30 July 2020.
876. Western Abalone Diver Association 2020, 'Assessment of abalone stocks in western zone Victoria: submission for the TAC setting process for 2020'.
877. Fisheries Research and Development Corporation (FRDC), 'Greenlip abalone (2020)' https://www.fish.gov.au/report/286-Blacklip-Abalone-2020 Accessed 30 July 2020.
878. Ibid.
879. Department of Economic Development, Jobs, Transport and Resources (DEDJTR) 2015, 'Victorian wild harvest abalone fishery management plan', Melbourne, Victoria.
880. Fisheries Research and Development Corporation (FRDC), 'Greenlip abalone (2020)' https://www.fish.gov.au/report/286-Blacklip-Abalone-2020 Accessed 30 July 2020.

SW 24: Commercially and recreationally important fish			
Region	**2021 status**	**2021 trend**	**2021 data**
Statewide	(bluethroat, purple wrasse)	(bluethroat, purple wrasse)	(bluethroat, purple wrasse)
Justification for assessment ratings:	The current harvest and effort appear to present a low risk for the stock becoming recruitment overfished at a statewide scale, bearing in mind a depleting trend in the east which was occurring prior to licence transferability. Statewide, fishing for blue throat and purple wrasse appears to be sustainable.		

Bluethroat and purple wrasse

Recent assessments by the VFA and Status of Australian Fish Stocks Reports have considered the Victorian wrasse populations as a coastal waters stock and it is, therefore, included as a statewide assessment in this report.[881]

Harvests of wrasse increased rapidly to around 90 tonnes per year when a market for wrasse became established in the early 1990s. However, the challenging nature of wrasse fishing, and the market preference for live fish, saw many fishers with offshore fishery access licences cease to target them. By 2010, statewide harvest had declined to the current levels of 20–30 tonnes per year. The harvest in 2017-18, immediately after 22 transferable 'Ocean Wrasse' licences were issued in April 2017, was the highest since 2009. Over the last two years, 10-15% of the wrasse harvest has been by pots and most of the catch has been taken in the central zone.[882]

Overall, the CPUE variation and trends would appear to indicate relative stability of biomass rather than clear increases or decreases. One caveat is that the relationship between CPUE and stock wide biomass is unclear, as CPUE for this fishery may be prone to hyper-stability due to the highly resident behaviour of wrasse on reef areas, while fishers regularly move between different reef areas to maintain acceptable catch rates.[883]

The limited licences (22) and limited number of fishing days per year due to swell and weather impose constraints on harvest for most areas. However, there is significant potential for increased effort and catch because most of the 22 licences are not yet fully utilised and the catch is unconstrained. The main risk for the fishery has been identified as a potential for localised depletion on individual reefs, which is linked to wrasse territorially inhabiting specific reefs.[884]

The current harvest and effort appear to present a low risk for the stock becoming recruitment overfished at a statewide scale, bearing in mind a depleting trend in the east which was occurring prior to licence transferability. Statewide, fishing for blue throat and purple wrasse appears to be sustainable.[885]

881. Victorian Fisheries Authority (VFA) 2020, 'Review of key Victorian fish stocks — 2019'.
882. Ibid.
883. Ibid.
884. Ibid.
885. Ibid.

SW 26: Diadromous fish

Region	2021 status	2021 trend	2021 data
Statewide		?	
Justification for assessment ratings:	There is no routine monitoring or assessments of diadromous fish in Victoria, so status and trend assessments cannot be made for this indicator. However, the narrative highlights the research that has been done to understand migration habits and to enable waterway managers to optimise environmental water delivery to enhance immigration by diadromous fishes in Victorian coastal rivers.		

Diadromous fish were assessed as part of the Victorian Government's Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP) that was established to help understand how to maximise the benefits of environmental watering. Stage 6 of VEFMAP occurred from 2016 to 2020, with one of the research priorities focussing on determining whether environmental flows promote immigration by diadromous fishes in Victorian coastal rivers.[886]

The research team investigated whether the abundance of four species of diadromous fish species (climbing galaxias *Galaxias brevipinnis*, common galaxias, spotted galaxias *Galaxias truttaceous* and Australian grayling, *Protroctes maraena*) was affected by discharge when moving into the lower freshwater reaches of rivers.[887]

A positive association was discovered between spring river discharge and catches of juvenile diadromous fishes, which is believed to be the first research to demonstrate such links. Increasing discharge had a linear correlation with increasing immigration of juvenile fishes. The results indicate the greatest benefit of environmental water for enhancing the immigration of diadromous fishes into rivers would be to target systems and years when spring discharge rates have been low. When there are large spring discharge volumes driven by extensive rainfall events, very large numbers of fish are attracted into coastal rivers; during these times environmental flows will provide little additional benefit in promoting immigration. Instead, the research team suggest this water is best used to enhance the dispersal and survival of recruits during the following summer.[888]

Scientists from the Arthur Rylah Institute, in collaboration with the Gunditjmara Traditional Owners, the Glenelg Hopkins CMA and Melbourne Water, have been leading the research effort to fill knowledge gaps for the two species of anguillid eels found in Victoria; the long-finned eel (*Anguilla reinhardtii*) and short-finned eel (*Anguilla australis*).[889] As part of the research that commenced in 2018, eel migration routes and spawning areas were tracked via satellite tags that were attached to adult migratory stage eels (called 'silver eels'). Migrating adult eels were tagged in western Victoria and tracked for up to five months, with many eels travelling about 3,000 km from where they were released. Tagged eels were tracked migrating to an area in the Coral Sea near New Caledonia, a presumed spawning area in the south Pacific Ocean. The information on migratory routes provides an important basis to inform future efforts to assess and mitigate interactions between eels and human activities in the marine environment.[890]

886. Tonkin Z, Jones C, Clunie P, Vivian L, Amtstaetter F, Jones M, Koster W, Mole B, O'Connor J, Brooks J, Caffrey L and Lyon J 2020, 'Victorian environmental flows monitoring and assessment program stage 6 synthesis report 2016-2020', technical report series no. 316, Arthur Rylah Institute (ARI), Department of Environment, Land, Water and Planning (DELWP), Heidelberg, Victoria.
887. Ibid.
888. Ibid.
889. Department of Environment, Land, Water and Planning (DELWP), 'Tracking eel migration using satellites' https://www.ari.vic.gov.au/research/field-techniques-and-monitoring/tracking-eel-migration-using-satellites Accessed 14 July 2021.
890. Ibid.

Figure 54: Eel migration from Victoria to the Coral Sea.[891]

There is no routine monitoring or assessments of diadromous fish in Victoria, so status and trend assessments cannot be made for this indicator. However, the narrative highlights the research that has been done to understand migration habits and to enable waterway managers to optimise environmental water delivery to enhance immigration by diadromous fishes in Victorian coastal rivers.

891. Ibid.

Theme 4
Seafloor Integrity and Health

Commissioner *for* Environmental Sustainability Victoria

Port Phillip Heads Marine National Park
© Parks Victoria

Theme 4: Seafloor Integrity and Health

Background

The indicators in this theme contain assessments on the conservation of marine ecosystems in protected areas, and – more broadly across the assessed regions - seagrass, nitrogen cycling, macroalgae and shellfish reefs.

Seagrass meadows are a critical habitat for many marine species, including fish targeted by commercial and recreational fishers, provide shoreline protection and store significant amounts of carbon. Changes in their condition can have environmental, social and economic effects. Considerable losses in seagrass have been observed in Port Phillip Bay (in conjunction with the millennium drought from 1997 to 2009), Western Port (in the mid-1970s and early 1980s) and Corner Inlet (a slow decline from 1965 to 2013).

Macroalgae on intertidal and subtidal reefs has been monitored and reported on by Parks Victoria, with technical reports periodically published and generally focussing on individual marine protected areas. The condition and extent of macroalgae on subtidal reefs in Port Phillip Bay has been assessed as poor for Point Cooke and Jawbone Marine Sanctuaries, fair for Ricketts Point Marine Sanctuary and good for Port Phillip Heads Marine National Park.

In 2020, a Parks Victoria study in Point Addis Marine National Park revealed that the previously dominant species golden kelp (*Ecklonia radiata*) has shown an alarming decline since 2012. While some increases in other canopy-forming brown algae have occurred since then, canopy-forming algae has now fallen below the lower control limit.[892] On the east coast of Victoria (Cape Howe Marine National Park and Beware Reef Marine National Parks), macroalgal beds have been under threat and Parks Victoria advises there has been a dramatic increase in urchin barrens.

Substantial losses of giant kelp (*Macrocystis pyrifera*) have been observed this century in marine areas off the coast of south-eastern Australia, with these losses not restricted to Victoria's marine protected areas. Broad-scale temporal patterns in giant kelp canopy cover are correlated with El Niño–Southern Oscillation events, while regional patterns are related to warming sea surface temperatures, raising concerns for the future of this species as a major habitat-forming kelp in Australia.[893]

Shellfish reef ecosystems support unique assemblages of associated fauna and valuable ecosystem services, including fish production, coastal protection, erosion mitigation and nutrient cycling. Historically, there were large areas of native flat oyster (*Ostrea angasi*) reefs in Port Phillip Bay, Western Port and Corner Inlet, with large areas of blue mussel (*Mytilus edulis galloprovincialis*) reefs also present in Port Phillip Bay. The extent of these shellfish reefs is now minimal and the status of the shellfish reefs indicator has been rated as poor for these regions. Large mussel reefs can still be found in the entrance region of the Gippsland Lakes, which is why the status is fair in this region despite the extent of shellfish reefs being noted to decline during the 20th century.

Comparison with insights from State of the Bays 2016 Report and the State of the Environment 2018 Report

Since the SotB 2016 Report and SoE 2018 Report, significant new research has been published and incorporated in this theme. Most notably, Parks Victoria technical reports, specifically for Point Addis Marine National Park, contain a comprehensive update to the macroalgae indicators. Additionally, there is a new indicator inclusion - shellfish reefs.

The conservation of marine ecosystems in protected areas indicator includes fresh Parks Victoria data that states the condition of natural values is good or very good in 93% of marine parks. This indicator status assessment remains at fair, as it was in the SoE 2018 Report.

892. Ierodiaconou D, Wines S, Carnell P, Tinkler P, Allan B, Carey J, Young M, Howe S, and Pocklington J 2020, 'An enhanced signs of healthy parks monitoring program for Victoria's marine national parks and marine sanctuaries: Point Addis marine national park', Parks Victoria technical series no. 114, Melbourne, Victoria.
893. Butler CL, Lucieer VL, Wotherspoon SJ, Johnson CR 2020, 'Multi-decadal decline in cover of giant kelp *Macrocystis pyrifera* at the southern limit of its Australian range', *Marine Ecology Progress Series*, 653, pp. 1-18.

Indicator 32: Conservation of marine ecosystems in protected areas

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Other marine protected areas				(Victoria's five marine bioregions)	(seals)	(seals)
Gippsland Lakes						

Data source:	Parks Victoria
Measures:	Percentage of Victoria's state waters that are protected | Percentage of Victoria's marine protected areas that are no-take | Zones where removing animals and plants is banned | Percentage of marine parks reported to be in good condition

Why this indicator?

By assessing the area and type of marine ecosystems with formal protection, and the degree of protection, it is possible to then determine whether Victoria is meeting international benchmarks for protection.

By assessing the area and type of marine ecosystems with formal protection, and the degree of protection, it is possible to determine whether Victoria is meeting international benchmarks for protection.

The final report of VEAC's Statewide Assessment of Public Land noted in 2017 that it is evident from preliminary assessments based on available information that the existing system of no-take marine protected areas has some gaps in representation, and individual marine protected areas may not meet the adequacy criterion.

The State of the Environment 2018 Report demonstrated that marine protected areas are relevant for this indicator. Therefore, this indicator is largely confined to the narrative and assessment provided within the 'Other Marine Protected Areas' region. The Victorian Environmental Assessment Council provides a map of marine protected areas in Victoria, which is useful to understand geographical distribution of these areas.

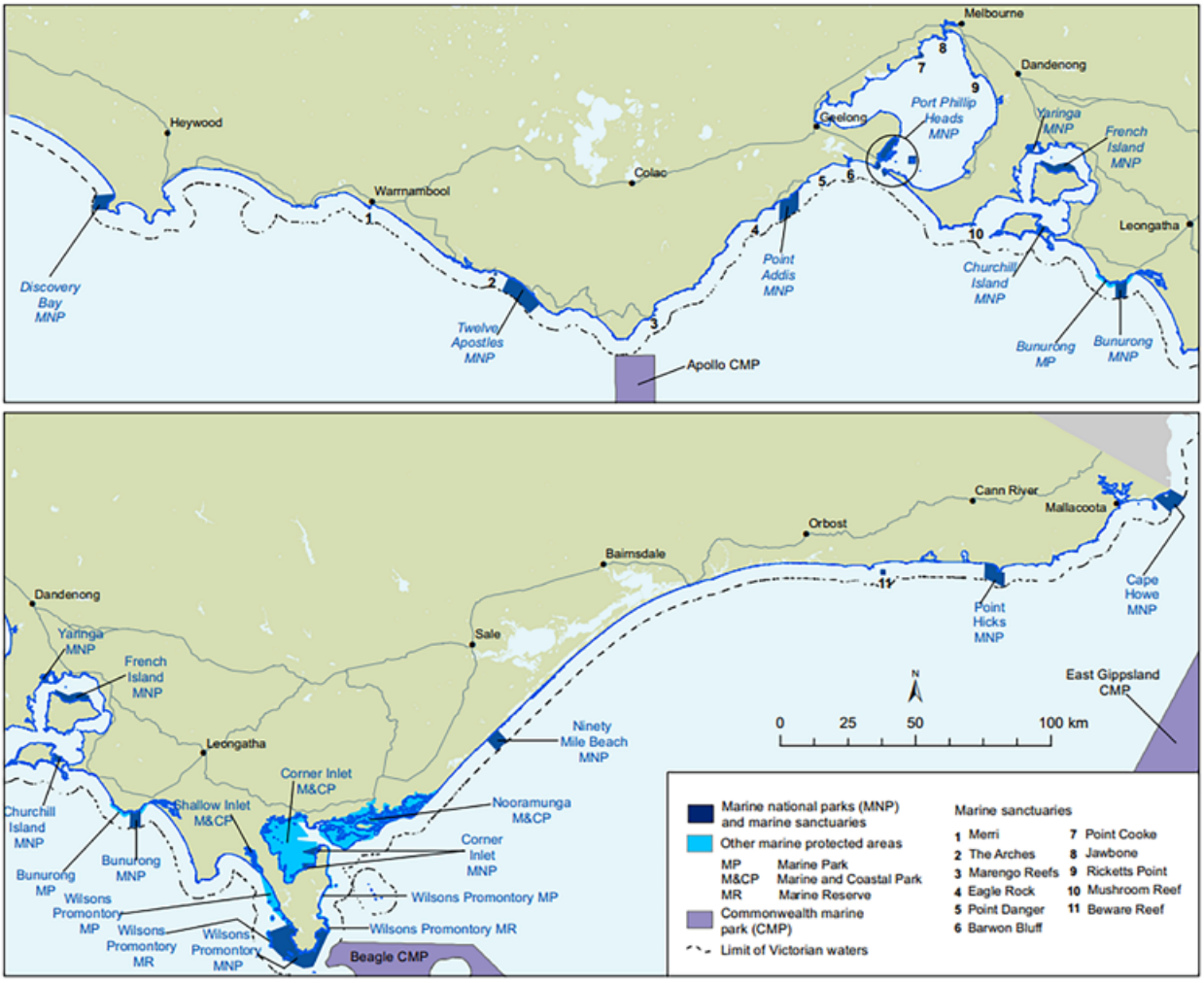


Figure 55: Marine protected areas in Victoria and adjacent Commonwealth waters.[894]

894. Victorian Environmental Assessment Council (VEAC) 2019, 'Assessment of the values of Victoria's marine environment' Melbourne, Victoria.

Indicator 33: Nitrogen cycle

Region		2021 status	2021 trend	2021 data	2016 status	2016 trend	2016 data
Port Phillip Bay			→			→	
Western Port			→			?	
Gippsland Lakes	Lake King		→			N/A	N/A
	Lake Victoria		→			N/A	N/A
	Lake Wellington		→			N/A	N/A

Data source:	DELWP, Melbourne Water, academic researchers
Measures:	Denitrification efficiency | The ratio of nitrogen fixation to denitrification | Dissolved inorganic nitrogen concentrations

Why this indicator?

Denitrification maintains water quality by removing nitrogen from the system and releasing it into the atmosphere. How efficiently this is done is described as Denitrification Efficiency (DE). When DE is high, less nitrogen recycles and phytoplankton growth is limited. When DE is low, phytoplankton can proliferate, which may lead to decreased water quality and the threat of algal blooms. Port Phillip Bay is estimated to process over 5,000 tonnes of nitrogen per year. The value of this service is estimated at around $11 billion per year, which represents the costs that would be incurred to achieve equivalent denitrification through alternative means, such as upgrading infrastructure or wetland enhancement.

Denitrification maintains water quality by removing nitrogen from the system and releasing it into the atmosphere. How efficiently this is done is described as Denitrification Efficiency (DE). When DE is high, less nitrogen is recycled and phytoplankton growth is limited. When DE is low, phytoplankton can proliferate, which may lead to decreased water quality and the threat of algal blooms. Port Phillip Bay is estimated to process over 5,000 tonnes of nitrogen per year.

The value of this service is estimated at around $11 billion per year, which represents the costs that would be incurred to achieve equivalent denitrification through alternative means, such as upgrading infrastructure or wetland enhancement.

Reporting of this indicator is nuanced across the geographic regions. For example, Port Phillip Bay has high nitrogen loads and monitoring denitrification is important but for other systems, it is more important to understand the nitrogen cycle through targeted science.

Theme 4: Seafloor Integrity and Health

Indicator 34: Seagrass

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	Fair	?	Poor	Good	↗	Fair
Western Port	Poor	↗	Fair	Unknown	?	Fair
Corner Inlet-Nooramunga	Fair	↗	Fair	Fair	↙	Fair
Gippsland Lakes	Fair	?	Fair	Fair	?	Fair
Other marine protected areas	Fair	→	Fair	Not applicable	N/A	N/A

Data source:	Academic researchers, Melbourne Water
Measures:	Seagrass extent | Seagrass condition (includes a range of variables such as shoot length, density and biomass along with epiphyte cover, epifauna, water temperature and light)

Why this indicator?

Seagrass meadows are critical habitat for many marine species, including fish targeted by commercial and recreational fishers, provide shoreline protection and store significant amounts of carbon. Changes in their condition can have environmental, social and economic effects.

Seagrass meadows are critical habitats for many marine species, including fish targeted by commercial and recreational fishers. Seagrasses provide shoreline protection and store significant amounts of carbon. Changes in seagrass extent, percentage cover, density and epiphytes can have environmental, social and economic effects. Human activities threaten seagrass meadows in many areas, via habitat loss and reductions to water quality.[895,896]

Seagrasses are closely related to land plants and share many of their attributes. Therefore, seagrasses are typically restricted to shallow coastal waters where there is ample light to support growth, and sandy/muddy bottoms where seagrass roots can acquire sufficient nutrients without being uprooted and washed away by waves and currents.[897]

895. Orth R, Carruthers T, Dennison W, Duarte C, Fourqurean J, Heck K, Hughes A, Kendrick G, Kenworthy W, Olyarnik S, Short F, Waycott M and Williams SL 2006, 'A global crisis for seagrass ecosystems', *BioScience*, 56, pp. 987–96.
896. Waycott M, Duarte C, Carruthers T, Orth R, Dennison W, Olyarnik S, Calladine A, Fourqurean J, Heck K, Hughes A, Kendrick G, Kenworthy W, Short F and Williams S 2009, 'Accelerating loss of seagrasses across the globe threatens coastal ecosystems', *Proceedings of the National Academy of Science USA*, 106, pp. 12377–81.
897. Hirst AJ, Giri K, Ball D and Lee RS 2017, 'Determination of the physical drivers of Zostera seagrass distribution using a spatial autoregressive lag model', *Marine and Freshwater Research*, 68, 1752-1763.

Indicator 35: Shellfish reefs

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay					N/A	N/A
Western Port					N/A	N/A
Corner Inlet-Nooramunga					N/A	N/A
Gippsland Lakes					N/A	N/A

Data source:	Academic researchers
Measures:	Extent of shellfish reefs

Why this indicator?

Shellfish reef ecosystems support unique assemblages of associated fauna and valuable ecosystem services, including fish production, coastal protection, erosion mitigation and nutrient cycling.

Shellfish reef ecosystems support unique assemblages of associated fauna and valuable ecosystem services, including fish production, coastal protection, erosion mitigation and nutrient cycling.

Key reef building species of Victoria include the blue mussel (*Mytilus edulis galloprovincialis*) and the flat oyster (*Ostrea angasi*).

Shellfish reefs are one of the most threatened coastal habitats. Victoria has lost more than 95% of reefs from estuarine and coastal waters since European settlement, leading scientists to classify this habitat as functionally extinct.[898] Destructive dredge fishing practices and long periods of large-scale removal of biomass (that is, overharvesting) have been determined as playing a major role in the decline of flat oyster and blue mussel reefs from Victoria's major bays and estuaries.[899]

While the large-scale removal and destructive fishing practices that drove the rapid declines in shellfish reefs have not occurred since the mid-1990s, a natural recovery has not occurred.[900] Recovery has likely been hampered by a host of factors, including water quality and sedimentation, lack of shell substrate for settlement, chemical pollution impacts, disease of native flat oysters (notably *Bonamia*), and more recently introduced species that compete with or prey on shellfish.[901] While a long-term sustained and structured approach is required, there is potential to re-establish shellfish reefs as a functioning ecological community in Victoria's coastal environment.[902]

Practical work is happening to restore Victoria's shellfish reefs. During 2019, The Nature Conservancy published Restoration Guidelines for Shellfish Reefs. The guidelines provide a high-level checklist for practitioners to help guide the establishment and delivery of shellfish restoration projects. The guidelines illustrated the beneficiaries of shellfish reef ecosystems (Figure 56) and the ecosystem services provided by shellfish reef ecosystems (Figure 57).

898. Ford J and Hamer P 2016, 'The forgotten shellfish reefs of coastal Victoria: documenting the loss of marine ecosystem over 200 years since European settlement', *Proceedings of the Royal Society of Victoria*, 128, pp. 87-105.
899. Ibid.
900. Ibid.
901. Ibid.
902. Ibid.

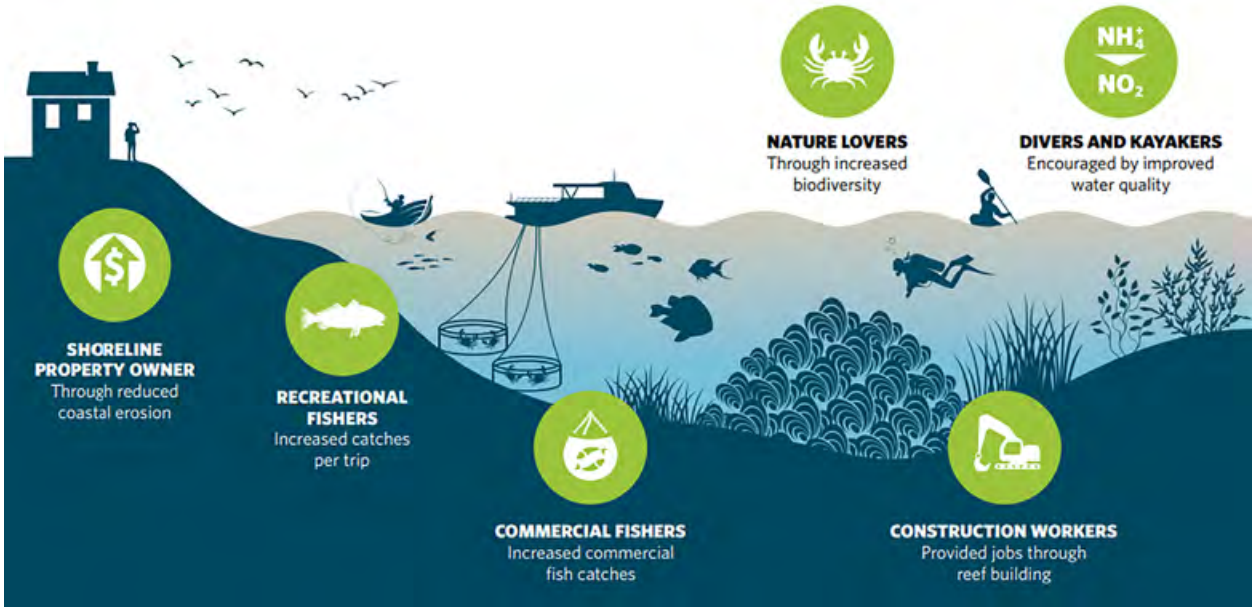


Figure 56: Beneficiaries of shellfish reef ecosystems.[903]

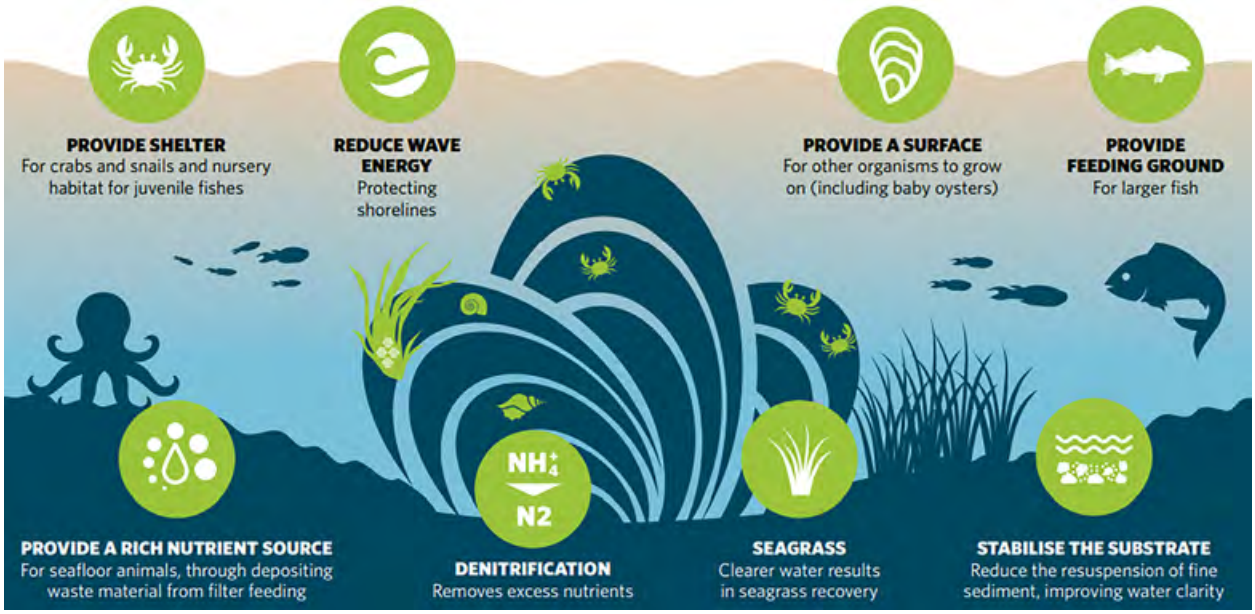


Figure 57: Ecosystem services provided by shellfish reef ecosystems.[904]

903. Fitzsimons, J, Branigan S, Brumbaugh R, McDonald T and zu Ermgassen P 2019, 'Restoration guidelines for shellfish reefs', The Nature Conservancy, Arlington VA, USA.
904. Ibid.

Indicator 36: Macroalgae on intertidal reefs

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	Good	→	Fair	Good	→	Good
Other marine protected areas	Fair	?	Fair	Good	→	Good

Data source:	Parks Victoria
Measures:	Parks Victoria's control charts for the condition of brown algae communities on intertidal reefs

Why this indicator?

Macroalgae are an important source of food and habitat for many marine species and provide shoreline protection. Changes in this intertidal community (for example, changes in macroalgal cover) may be a sign of other changes occurring in the marine environment that require management action.

Macroalgae are an important source of food and habitat for many marine species and provide shoreline protection. Changes in this intertidal community (for example, changes in macroalgal cover) may be a sign of other changes occurring in the marine environment that require management action.

Intertidal reefs are the most accessible component of marine environments and consequently these habitats have important social and cultural values. Due to their accessibility, intertidal reefs are sometimes subject to human pressures, including collection of animals for food and fishing bait, trampling, and pollution from catchment discharges. To help effectively manage and conserve these habitats, the Victorian Government, through Parks Victoria, established the Intertidal Reef Monitoring Program (IRMP), which ceased in 2014.[905] The IRMP has been superseded by Signs of Healthy Parks, which, as stated by Parks Victoria, provides a framework for systematic and integrated ecological monitoring of the health of the state's ecosystems.[906] A draft state-wide monitoring plan based on conservation, management and monitoring priorities identified for each park through the conservation planning process, has been developed.[907]

The new monitoring program will focus on key ecological attributes and threats in at least one of the large marine national parks within each bioregion, currently identified as Discovery Bay Marine National Park (Otway bioregion), Point Addis Marine National Park (Central Victoria bioregion), Port Phillip Heads Marine National Park (Victorian Embayments bioregion), Wilsons Promontory Marine National Park (Flinders bioregion) and Cape Howe Marine National Park (Twofold Shelf bioregion).[908]

Parks Victoria is progressing monitoring and assessment with plans to publish technical reports within the next couple of years for Port Phillip Heads, Wilsons Promontory, Cape Howe and Discovery Bay Marine National Parks, which will address intertidal reef knowledge gaps in marine protected areas and increase the confidence in this indicator assessment in future State of the Marine and Coastal Environment reports. A technical report focussing on Point Addis Marine National Park was published in 2020.

905. Edmunds M, Woods B and Donnelly D 2014, 'Intertidal reef monitoring program: central Victoria marine protected areas March 2014', Parks Victoria technical series no. 97, Melbourne, Victoria.
906. Parks Victoria, 'Signs of healthy parks', https://www.parks.vic.gov.au/get-into-nature/conservation-and-science/science-and-research/signs-of-healthy-parks Accessed 25 July 2021.
907. Ierodiaconou D, Wines S, Carnell P, Tinkler P, Allan B, Carey J, Young M, Howe S, Pocklington J 2020, 'An enhanced signs of healthy parks monitoring program for Victoria's marine national parks and marine sanctuaries: Point Addis marine national park', Parks Victoria technical series no. 114, Melbourne, Victoria.
908. Ibid.

Common algae on intertidal reefs include the mat forming brown algae Neptune's Necklace *Hormosira banksii* and the green algae *Ulva spp*. Other small turfing species are also often present. Less conspicuous is a thin layer of microscopic algae growing directly on the surface of the reef, which is an important food source for species of grazing molluscs.[909]

Historically, reef monitoring has required teams of two or more people manually counting the algae or invertebrates that make up the intertidal community. Victorian research published during 2017 highlighted the applications of Unmanned Aerial Vehicles (UAVs) in intertidal reef monitoring. The findings of the study demonstrated the benefits of low-cost UAVs for intertidal monitoring through rapid data collection, full coverage census, identification of dominant canopy habitat and generation of geomorphic derivatives for explaining biological variation.[910] This monitoring method has now been integrated in Parks Victoria's monitoring, with results from UAVs a key component of the 2020 technical report focussing on Point Addis Marine National Park.[911]

White-faced heron (*Egretta novaehollandiae*) and Neptune's necklace (*Hormosira banksii*) at Bunurong Marine National Park
© Museums Victoria

909. Edmunds M, Woods B and Donnelly D 2014, 'Intertidal reef monitoring program: central Victoria marine protected areas March 2014', Parks Victoria technical series no. 97, Melbourne, Victoria.
910. Murfitt, S, Allan B, Bellgrove A, Rattray A, Young M, Ierodiaconou D 2017, 'Applications of unmanned aerial vehicles in intertidal reef monitoring', *Scientific Reports*, 7(10259) https://doi.org/10.1038/s41598-017-10818-9 Accessed 9 April 2021.
911. Ierodiaconou D, Wines S, Carnell P, Tinkler P, Allan B, Carey J, Young M, Howe S, Pocklington J 2020, 'An enhanced signs of healthy parks monitoring program for Victoria's marine national parks and marine sanctuaries: Point Addis marine national park', Parks Victoria technical series no. 114, Melbourne, Victoria.

Indicator 37: Macroalgae-dominated subtidal reefs

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	(Port Phillip Heads Marine National Park) (Ricketts Point Marine Sanctuary) (Point Cooke and Jawbone marine sanctuaries)	→		(north) (south)	? (north) ↙ (south)	(north) (south)
Other marine protected areas		?			?	
Data source:	Parks Victoria					
Measures:	Parks Victoria control charts					

Why this indicator?

Macroalgal communities on subtidal reefs provide shelter, nursery and feeding areas for reef fish and other marine species. Broken stems washed ashore form beach wrack that is used as food for invertebrates living on beaches and mudflats, which in turn become food for migratory and resident shorebirds. Changes in the condition of macroalgal beds can have broad implications for marine and coastal species.

Macroalgae form important subtidal habitats by colonising subtidal rock substrate. Brown algae, including kelps and fucoids, form complex habitats that promote marine biodiversity and productivity.[912] Kelp (*Ecklonia radiata*) and the fucoid *Phyllospora comosa* form forest canopies that largely occupy the coastal zone within Victorian State Waters. Giant kelp forests (*Macrocystis pyrifera*) are threatened ecological communities under Commonwealth legislation (the *Environment Protection and Biodiversity Conservation Act 1999*).

Temperature increases associated with climate change impact macroalgae on temperate reefs, specifically local extinction of species that have northern range limits along the southern coastline (no poleward range shift possible) and changes in species' life cycle events that are influenced by seasonal and interannual variations in climate.[913] Research published during 2009 suggested that the combined effects of increased temperature and non-climate stresses (for example, pollution and reduced water quality) will make Australian temperate reef communities more vulnerable to perturbations (for example, storms, diseases and invasive species), many of which are projected to increase in frequency and/or severity in response to climate change.

912. Bennett S, Wernberg T, Connell S, Hobday A, Johnson C and Poloczanska E 2015, 'The 'Great Southern Reef': social, ecological and economic value of Australia's neglected kelp forests', *Marine and Freshwater Research*, 67, pp. 47-56.
913. Wernberg T, Campbell A, Coleman M, Connell S, Kendrick G, Moore P, Russell B, Smale D and Steinberg P 2009, 'Macroalgae and temperate rocky reefs', in CSIRO, 'Marine climate change in Australia. Impacts and adaptation responses. 2009 report card'.

Reduced resilience is predicted to lead to the loss or alteration of algal habitats and associated ecological function – changes which will happen progressively from 2030 to 2100.[914] A decrease in the resilience of temperate species is a likely consequence of physiological adjustment to elevated temperatures. Cold-water species of algae, such as kelps (*Macrocystis*), are likely to become less abundant as ocean temperatures increase towards their tolerance limit.[915]

In temperate waters, kelps and fucoids form macroalgal canopies that provide habitat and form the basis of subtidal reef food webs. *Macrocystis* prefer cool, nutrient-rich waters and are threatened by warming ocean temperatures. Current projections are that *Macrocystis* is predicted to retreat more than 500 km south in eastern Australia by 2100, due to warming alone.[916] Generally, the kelp story is one of concern driven by warming ocean temperatures and changes to ocean currents that deliver nutrients to coastal waters, as well as the increasing proliferation of urchins that feed on the kelp.

Port Phillip Bay

PPB 32: Conservation of marine ecosystems in protected areas

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The conservation of marine ecosystems in Port Phillip Bay's protected areas is covered in the Other Marine Protected Areas region.		

PPB 33: Nitrogen cycle

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	●	→	●
Justification for assessment ratings:	The Denitrification Efficiency (DE) process generally maintains the nutrients in Port Phillip Bay at a suitable level for biodiversity. No event since 1994 has been large enough to reduce DE for more than a month. A status assessment of good has been made on the basis that a threshold of denitrification efficiency lower than 60% in Port Phillip Bay (40% for Hobsons Bay) indicates the denitrification process is disrupted. The confidence in the assessment is only moderate because no data since 2014 is available.		

As reported in the State of the Bays 2016, nutrients entering Port Phillip Bay can have a positive effect when conditions are nutrient-poor. Or, they can have a negative effect when levels are too high leading to algal blooms, particularly after heavy rainfall events. In the marine environment, nitrogen is a more important contributor to algal blooms than phosphorus. Denitrification removes nitrogen from the system and is the critical nutrient cycle process occurring in the bay. The denitrification efficiency process generally maintains the nutrients in Port Phillip Bay at a suitable level for biodiversity.

Denitrification efficiency lower than 60% in Port Phillip Bay (40% for Hobsons Bay) indicates the denitrification process is disrupted.[917]

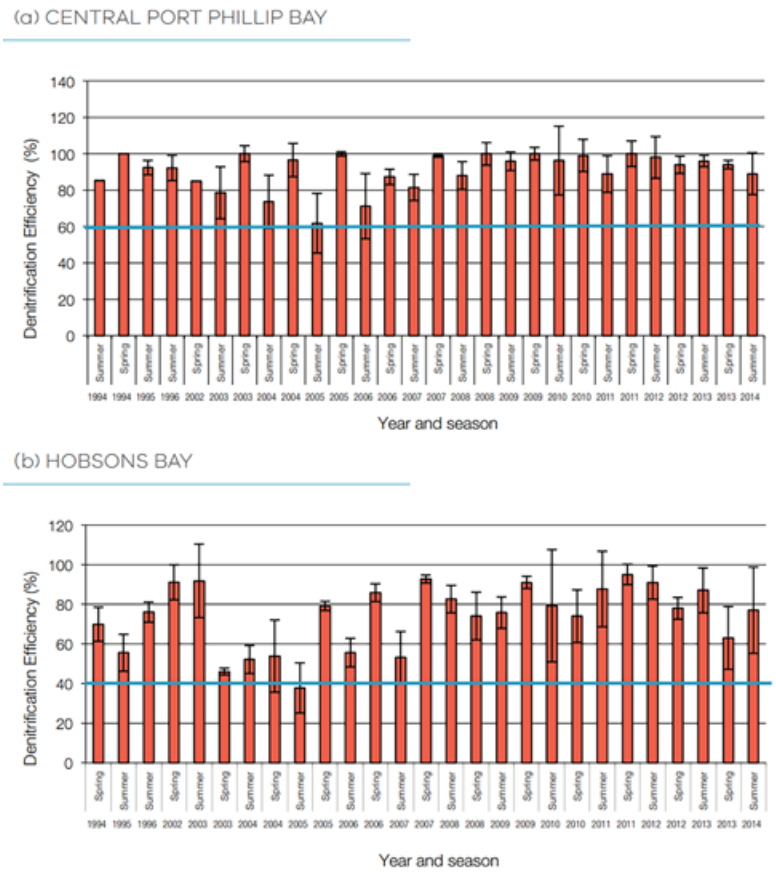
914. Ibid.
915. Wernberg T, Thomsen M, Tuya F, Kendrick G, Staehr P and Toohey B 2010, 'Decreasing resilience of kelp beds along a latitudinal temperature gradient: potential implications for a warmer future', *Ecology Letters*, 13, pp. 685-694.
916. Castro L, Cetina-Heredia P, Roughan M, Dworjanyn S, Thibaut L, Chamberlain M, Feng M and Verges A 2020, 'Combined mechanistic modelling predicts changes in species distribution and increased co-occurrence of a tropical urchin herbivore and a habitat-forming temperate kelp', *Diversity and Distributions*, 26, pp. 1211–1226 https://doi.org/10.1111/ddi.13073 Accessed 30 March 2021.
917. Commissioner for Environmental Sustainability (CES) 2016, 'State of the Bays 2016', Melbourne, Victoria.

Denitrification is the key nitrogen cycling process in the muddy sediments that dominate the large central basin in Port Phillip Bay, and where phytoplankton is the key primary producer. However, denitrification may be less important in near-shore sandy sediments, where microphytobenthos, macroalgae or seagrass dominate. Some signs of stress in reefs and seagrass beds in the north and west of Port Phillip Bay could be associated with nutrient inputs (most likely from the Western Treatment Plant (WTP) and the Werribee, Yarra and Maribyrnong rivers) and poor light conditions.[918]

The Port Phillip Bay Environmental Study was directed by the CSIRO and funded by Melbourne Water. The $12 million study was completed in 1996 and investigated the ecology of the Bay, its physical processes, nutrient levels and toxicant levels.

As part of this work, CSIRO recommended an annual target for nitrogen in the bay, to keep the load well below levels that could risk eutrophication, but still support productivity for fisheries. Specifically, the CSIRO recommended keeping annual gross nitrogen loads to the bay below 6,000 tonnes of nitrogen each year, split between the WTP (3,100 t) and catchments (2,900 t).[919] As reported in the State of the Bays 2016 Report, there is high confidence that these targets have been met. Further discussion and analysis on nitrogen loads is discussed in Indicator 08: Total nutrient loads, within the Water Quality and Catchment Inputs chapter.

The notional DE trigger lines – 60% in Port Phillip Bay and 40% in Hobsons Bay – illustrates the resilience of DE in Port Phillip Bay to disruptive events such as storms and drought.



Note: Error bars indicate standard error of the mean. Blue lines indicate notional trigger values.

Figure 58: Denitrification efficiency (DE) in spring and summer in (a) central Port Phillip Bay and (b) Hobsons Bay, 2002–15.[920]

918. Ibid.
919. Murray A and Parslow J 1999, 'Modelling of nutrient impacts in Port Phillip Bay – a semi-enclosed marine Australian ecosystem', *Marine and Freshwater Research*, 50, pp. 597–611.
920. Commissioner for Environmental Sustainability (CES) 2016, 'State of the Bays 2016', Melbourne, Victoria.

Denitrification remains an ecosystem service critical to maintaining high water quality in Port Phillip Bay. No event since 1994 has been large enough to reduce DE for more than a month and, even then, only in a restricted area (Hobsons Bay). Observations since 1994 and modelling of storm flood impacts suggest denitrification is resilient to loads from the WTP and the catchments expected over the next 20 years. However, localised reductions in DE are likely following storm events (for example, in Hobsons Bay). These events are likely to create acute short-term impacts (for example, algal blooms, beach closures).

In the Port Phillip Bay Environmental Management Plan 2017–2027, the government committed to improving the understanding of ecological processes, threats and pressures for Port Phillip Bay, which included an action to increase the understanding of impacts of catchment discharges on denitrification processes.[921] The 2019-20 Annual Report and Delivery Plan Update as part of the Port Phillip Bay Environmental Management Plan 2017-2027 did not provide any discussion on denitrification in the bay.[922]

PPB 34: Seagrass

Region	2021 status	2021 trend	2021 data
Port Phillip Bay		?	
Justification for assessment ratings:	During the last major drought (1997–2009), Port Phillip Bay lost considerable areas of seagrass. There is insufficient information to measure the extent of recovery, if any, since the drought ended in 2010. The Limit of Acceptable Change (LAC) for seagrass in the Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar Site is that total seagrass extent will not decline below 1,500 hectares for a period of greater than 20 continuous years. This is being met, although the data used to make this assessment are mostly based on data that are now more than 20 years old. The condition of seagrass in Port Phillip Bay are good but based on only four years of data (2008–11). This information on seagrass extent and condition has been combined into a status assessment of fair. Due to the short-time series and lack of recent data from the past decade, the trend is unclear and the confidence in the assessments is low.		

Seagrass in Port Phillip Bay is dominated by the eelgrass, *Zostera nigricaulis*, which occurs around the margin of the bay from the shallow subtidal zone to depths of up to 8 metres. *Zostera* provides crucial ecosystem services such as stabilising sediments and improving water quality, reducing coastal erosion, increasing biological productivity via marine food webs, and providing nursery habitats for key recreational and commercial fish species. *Zostera muelleri* tends to be restricted to the intertidal zone or very shallow subtidal habitats.[923]

The distribution of seagrass in Port Phillip Bay is principally constrained by the influence of two physical processes: wave exposure and light/depth.[924] The former excludes seagrasses from colonising wave-exposed coastlines, while the latter directly determines the depth profile of seagrasses via its influence on the availability of light at depth.

The maximum *Zostera nigricaulis* depth in Port Phillip Bay, at about 8 m, broadly corresponds with the minimum light requirements for this species at 10–20% of surface irradiance.[925,926]

921. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Port Phillip Bay environmental management plan 2017-2027', East Melbourne, Victoria.
922. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Port Phillip Bay environmental management plan 2017-2027. 2019-2020 annual report and 2020 delivery plan update', East Melbourne, Victoria.
923. Commissioner for Environmental Sustainability (CES) 2016, 'State of the Bays 2016', Melbourne, Victoria.
924. Hirst A, Giri K, Ball D and Lee R 2017, 'Determination of the physical drivers of Zostera seagrass distribution using a spatial autoregressive lag model', *Marine and Freshwater Research*, 68, pp. 1752-1763.
925. Bulthuis D 1983, 'Effects of in situ light reduction on density and growth of the seagrass *Heterozostera tasmanica* (Martens ex Aschers.) den Hartog in Western Port Victoria Australia', *Journal of Experimental Marine Biology and Ecology*, 67, pp. 91–103.
926. Hirst A, Giri K, Ball D and Lee R 2017, 'Determination of the physical drivers of Zostera seagrass distribution using a spatial autoregressive lag model', *Marine and Freshwater Research*, 68, pp. 1752-1763.

In Port Phillip Bay, the largest expanses of seagrass are in shallow waters (that is, depths of less than four metres) protected from prevailing westerly winds (and hence waves) such as Swan Bay, Corio Bay and parts of the southern shore of the Geelong Arm and western shore of the Bellarine Peninsula.[927] By contrast, there is little seagrass on the eastern shore of Port Phillip Bay – the coastline most exposed to prevailing winds and waves.[928]

Seagrass area is not constant in Port Phillip Bay and changes considerably in some regions. For example, in regional areas such as Blairgowrie, St Leonards and Bellarine Bank there had been a long-term increase in seagrass cover from the 1950s to the late 1990s but then a dramatic decline in the 2000s.[929] During the millennium drought, there was a large reduction in seagrass extent in Port Phillip Bay, where the Bellarine Bank reduced by more than 90% from 2000 to 2011.[930] Seagrasses in sheltered areas (Corio Bay, Point Henry, Swan Bay) were relatively stable or 'persistent', whereas those in exposed areas (southern bay, Bellarine Bank) were 'ephemeral' and heavily influenced by nutrient loadings.[931]

Mapping from aerial photography over at least 50 years shows the most extensive areas of seagrass are in the south-western quadrant of Port Phillip Bay. Reconstructed historical trends using aerial photography found reductions in seagrass area over the past 70 years matched drier periods in Victoria's climate.[932,933,934] Seagrass area was lowest following the World War II drought in the 1940s and during the recent millennium drought (1997–2009).

A review of aerial photos of the Bellarine Bank from 2009 to 2014, concluded that the rapid decline in seagrass since the onset of the millennium drought was consistent with a decline in nutrient loadings to the bay, while it may also have reflected changes in other pressures such as prevailing winds and bay circulation patterns.[935]

Given this result, climatic variability may be important in controlling total seagrass area in Port Phillip Bay via its influence on the availability of nutrients to seagrasses.[936] During the millennium drought (1997–2009), the greatest seagrass losses occurred on the Bellarine Bank on the southern coast of the Geelong Arm and in the southern part of Port Phillip Bay. Seagrass area was lost in regions of the bay most dependant on nitrogen from the catchment; this contribution declined significantly during the millennium drought.[937,938]

The health of seagrass was assessed at three sites in Port Phillip Bay from 2004–05 to 2006–07 (as well as sites in Western Port and Corner Inlet), establishing a baseline dataset for future monitoring and comparison.[939] Along with aerial mapping to determine changes in percentage cover, the researchers monitored a large range of seagrass variables including shoot length, density and biomass, along with epiphyte cover, epifauna, water temperature and light. Aerial mapping for Port Phillip Bay showed reductions in seagrass cover at Point Richards and Blairgowrie, an increase at Kirk Point and no change at Swan Bay.

927. Jenkins G, Keough M, Ball D, Cook P, Ferguson A, Gay J, Hirst A, Lee R, Longmore A, Macreadie P, Nayar S, Sherman C, Smith T, Ross D and York P 2015, 'Seagrass resilience in Port Phillip Bay', final report to the seagrass and reefs program for Port Phillip Bay, University of Melbourne, Melbourne.
928. Commissioner for Environmental Sustainability (CES) 2016, 'State of the Bays 2016', Melbourne, Victoria.
929. Jenkins G, Keough M, Ball D, Cook P, Ferguson A, Gay J, Hirst A, Lee R, Longmore A, Macreadie P, Nayar S, Sherman C, Smith T, Ross D and York P 2015, 'Seagrass resilience in Port Phillip Bay', final report to the seagrass and reefs program for Port Phillip Bay, University of Melbourne, Melbourne.
930. Ibid.
931. Ibid.
932. Ball D, Soto-Berelov M, Young P and Coots A. 2009, 'Baywide seagrass monitoring program – historical seagrass mapping', Fisheries Victoria technical report series no. 70, Department of Primary Industries (DPI), Queenscliff, Victoria.
933. Ball D, Soto-Berelov M and Young P 2014, 'Historical seagrass mapping in Port Phillip Bay', *Journal of Coastal Conservation*, 18, pp. 257–72.
934. Hirst A, Longmore A, Ball D, Cook P and Jenkins G 2016, 'Linking nitrogen sources utilised by seagrass in a temperate marine embayment to patterns of seagrass change during drought', *Marine Ecology Progress Series*, 549, pp. 79–88.
935. Jenkins G, Keough M, Ball D, Cook P, Ferguson A, Gay J, Hirst A, Lee R, Longmore A, Macreadie P, Nayar S, Sherman C, Smith T, Ross D and York P 2015, 'Seagrass resilience in Port Phillip Bay', final report to the Seagrass and Reefs Program for Port Phillip Bay, University of Melbourne, Melbourne.
936. Commissioner for Environmental Sustainability (CES) 2016, 'State of the Bays 2016', Melbourne, Victoria.
937. Hirst A, Longmore A, Ball D, Cook P and Jenkins G 2016, 'Linking nitrogen sources utilised by seagrass in a temperate marine embayment to patterns of seagrass change during drought', *Marine Ecology Progress Series*, 549, pp. 79–88.
938. Jenkins G, Keough M, Ball D, Cook P, Ferguson A, Gay J, Hirst A, Lee R, Longmore A, Macreadie P, Nayar S, Sherman C, Smith T, Ross D and York P 2015, 'Seagrass resilience in Port Phillip Bay', final report to the Seagrass and Reefs Program for Port Phillip Bay, University of Melbourne, Melbourne.
939. Ball D, Hirst A, Parry G, Heislers S, Blake S, Werner G, Young P and Coots A 2010, 'Victorian multi-regional seagrass health assessment 2004–07', Fisheries Victoria technical report no. 66, Department of Primary Industries (DPI), Queenscliff, Victoria.

Zostera meadows in Port Phillip Bay obtain nutrients from several sources. These nutrients principally come from the catchments (riverine inputs), treated sewage (WTP), seasonal influxes from Bass Strait and the atmospheric inputs (primarily nitrogen fixation).[940] Nitrogen fixation provides varying amounts of the nitrogen used by seagrasses, but it appears to be the dominant source only in Swan Bay.[941,942]

A significant proportion of nutrients entering seagrass ecosystems are subsequently recycled via decomposition of leaf (seagrass and epiphytes) material which regenerates nutrients, returning them to a soluble form. Nutrients released in dissolved forms can be reused by seagrasses or other primary producers. Much of this primary productivity is exported to other locations as leaf detritus, transported by waves and currents, to support coastal foods adjacent to seagrass beds.

The Limit of Acceptable Change (LAC) for seagrass in the Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar Site is that total seagrass extent will not decline below 1,500 hectares for a period of greater than 20 continuous years.[943]

DELWP advises that this is being met, although the data used to make this assessment are mostly based on data that are now more than 20 years old that shows a total of 2,900 hectares of seagrass within the Ramsar site boundary in 2000.[944] The assessments of seagrass cover in Swan Bay from 2008 to 2012 showed little change in seagrass cover, however that is only a small sample of data within the past 20 years and there is no recent information.

The seagrass data sets used in this indicator assessment were compiled over specific periods, the most recent of which is now ten years old. There is no ongoing mapping of seagrass extent, or monitoring of seagrass condition, which is a critical knowledge gap in our understanding of the drivers of seagrass health in Port Phillip Bay.

940. Hirst A, Longmore A, Ball D, Cook P and Jenkins G 2016, 'Linking nitrogen sources utilised by seagrass in a temperate marine embayment to patterns of seagrass change during drought', *Marine Ecology Progress Series*, 549, pp. 79–88.
941. Cook P, Evrard V and Woodland R 2015, 'Factors controlling nitrogen fixation in temperate seagrass beds', *Marine Ecology Progress Series*, 525, pp. 41–51.
942. Hirst A, Longmore A, Ball D, Cook P and Jenkins G 2016, 'Linking nitrogen sources utilised by seagrass in a temperate marine embayment to patterns of seagrass change during drought', *Marine Ecology Progress Series*, 549, pp. 79–88.
943. Hale J 2020, 'Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar site ecological character description, for catchments, waterways cities and towns', Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria.
944. Ibid.

PPB 35: Shellfish reefs

Region	2021 status	2021 trend	2021 data
Port Phillip Bay			
Justification for assessment ratings:	Historically, there were large areas of blue mussel (*Mytilus edulis galloprovincialis*) and native flat oyster (*Ostrea angasi*) reefs in Port Phillip Bay. While flat oysters and blue mussel can still be found throughout Port Phillip Bay, there are currently no known areas of extensive mussel or flat oyster reefs occurring on the bay sediments. The trend has been rated as improving because of a current shellfish reef restoration project that has built 5.5 hectares of shellfish reef in Port Phillip Bay since 2015. The confidence is rated as moderate rather than high because it is unknown whether the conditions that support the ongoing enhancement and maintenance of these oyster reefs improving.		

As part of a research project published by the Royal Society of Victoria in 2016, the history of coastal Victoria's shellfish reefs since the early 1800s was documented.[945]

The earliest European reference to shellfish in Port Phillip Bay is reported to be in the journal of Matthew Flinders, who remarked in 1802, upon exploring the coast of eastern Port Phillip Bay near Mornington, 'Quantities of fine oysters were lying upon the beaches between high and low water marks'.[946]

Historical references, fisheries catch records since 1950 and contemporary observations indicate that the predominant reef- or bed-forming shellfish species in Port Phillip Bay have been the blue mussel and native flat oyster. An approximation of historic major areas of blue mussel (*Mytilus edulis galloprovincialis*) and native flat oyster (*Ostrea angasi*) reefs in Port Phillip Bay is shown in Figure 59.

A bay-wide survey of benthic communities in the early 1980s identified mussel aggregations throughout the bay.[947] The northern and eastern sections of the bay supported large areas of mixed mussel and oyster reef between 6 and 10 metres depth, with mussel the dominant species. The large reefs were scattered with a range of other suspension-feeding and habitat-forming macroinvertebrate species, such as *Pyura stolonifera*, sponges (*Porifera*) and macroalgae. While large mussel and oyster reefs did not appear to occur in the central muddy basin of the bay, recent surveys suggest that they would have been present in these areas, perhaps as dispersed small clumps.[948] Data on mussel densities suggest a decline of over 80% in abundance of mussels in north-east Port Phillip Bay since 1980.[949,950]

Based on recent observations of large oyster-shell aggregations in the Geelong Arm, the numerous lime kilns and related placenames (for example, Limeburners Bay and Limeburners Lagoon on the south and north sides of Geelong), it is likely there were historical oyster reefs in these regions.[951] Prior to limestone mining, oyster shells were burnt for lime to supply mortar for the colonial building industry during the mid-19th century. This process would have required a large and consistent supply of oyster shells.[952] The importance of the Geelong Arm as an area for oyster reefs is further confirmed by earlier fisheries reports, while oyster dredge fishing is reported to have occurred at least up until the late 1950s or early 1960s in the Geelong Outer Harbour.[953]

While flat oysters and blue mussel can still be found throughout Port Phillip Bay, there are currently no known areas of extensive mussel or flat oyster reefs occurring on the bay sediments.[954]

945. Ford J and Hamer P 2016, 'The forgotten shellfish reefs of coastal Victoria: documenting the loss of a marine ecosystem over 200 years since European settlement', *Proceedings of the Royal Society of Victoria*, 128, pp. 87-105 https://doi.org/10.1071/RS16008 Accessed 31 March 2021.
946. Ibid.
947. Winstanley R 1982, 'The fishery and stocks of blue mussel *Mytilis edulis planulatus* in Port Phillip Bay', Fisheries and Wildlife Victoria Division of Commercial Fisheries, report no. 5.
948. Cohen B, Currie D and Mcarthur M 2000, 'Epibenthic community structure in Port Phillip Bay, Victoria, Australia', *Marine and Freshwater Research*, 51, pp. 689–702.
949. Winstanley R 1982, 'The fishery and stocks of blue mussel *Mytilis edulis planulatus* in Port Phillip Bay', Fisheries and Wildlife Victoria Division of Commercial Fisheries report no. 5.
950. Cohen B, Currie D and Mcarthur M 2000, 'Epibenthic community structure in Port Phillip Bay, Victoria, Australia', *Marine and Freshwater Research*, 51, pp. 689–702.
951. Ford J and Hamer P 2016, 'The forgotten shellfish reefs of coastal Victoria: documenting the loss of a marine ecosystem over 200 years since European settlement', *Proceedings of the Royal Society of Victoria*, 128, pp. 87-105 https://doi.org/10.1071/RS16008 Accessed 31 March 2021.
952. Harrison A 1996, 'The fisheries savant: William Saville-Kent in Victoria, 1887–8', Historical Records of Australian Science, 11(3), pp. 419–429.
953. Lynch D 1966, 'Port Phillip survey 1957–63 - the fisheries', *Memoirs of the National Museum of Victoria*, 27, pp. 7–18.
954. Cohen B, Currie D and Mcarthur M 2000, 'Epibenthic community structure in Port Phillip Bay, Victoria, Australia', *Marine and Freshwater Research*, 51, pp. 689–702.

Flat oysters now only occur in occasional and small isolated groups attached to hard structures or as solitary or a few individuals attached to old scallop, mussel or oyster shells, and are much more abundant in the outer reaches of the Geelong/Corio Arm than any other location.[955]

Mussels are generally found on raised hard surfaces, particularly on fringing rocky reefs, on top of boulders on subtidal reefs and on most manmade structures (for example, pier, jetties and navigation marks).

As part of a shellfish reef restoration project delivered by The Nature Conservancy, the Victorian Government, The Thomas Foundation and the Albert Park Yachting and Angling Club to rebuild Port Phillip Bay's shellfish reefs, 5.5 hectares of shellfish reef has been built in Port Phillip Bay since 2015. Figure 59 shows that the shellfish reef restoration has occurred at Margaret's Reef, Dromana, 9ft Bank and Wilson Spit.

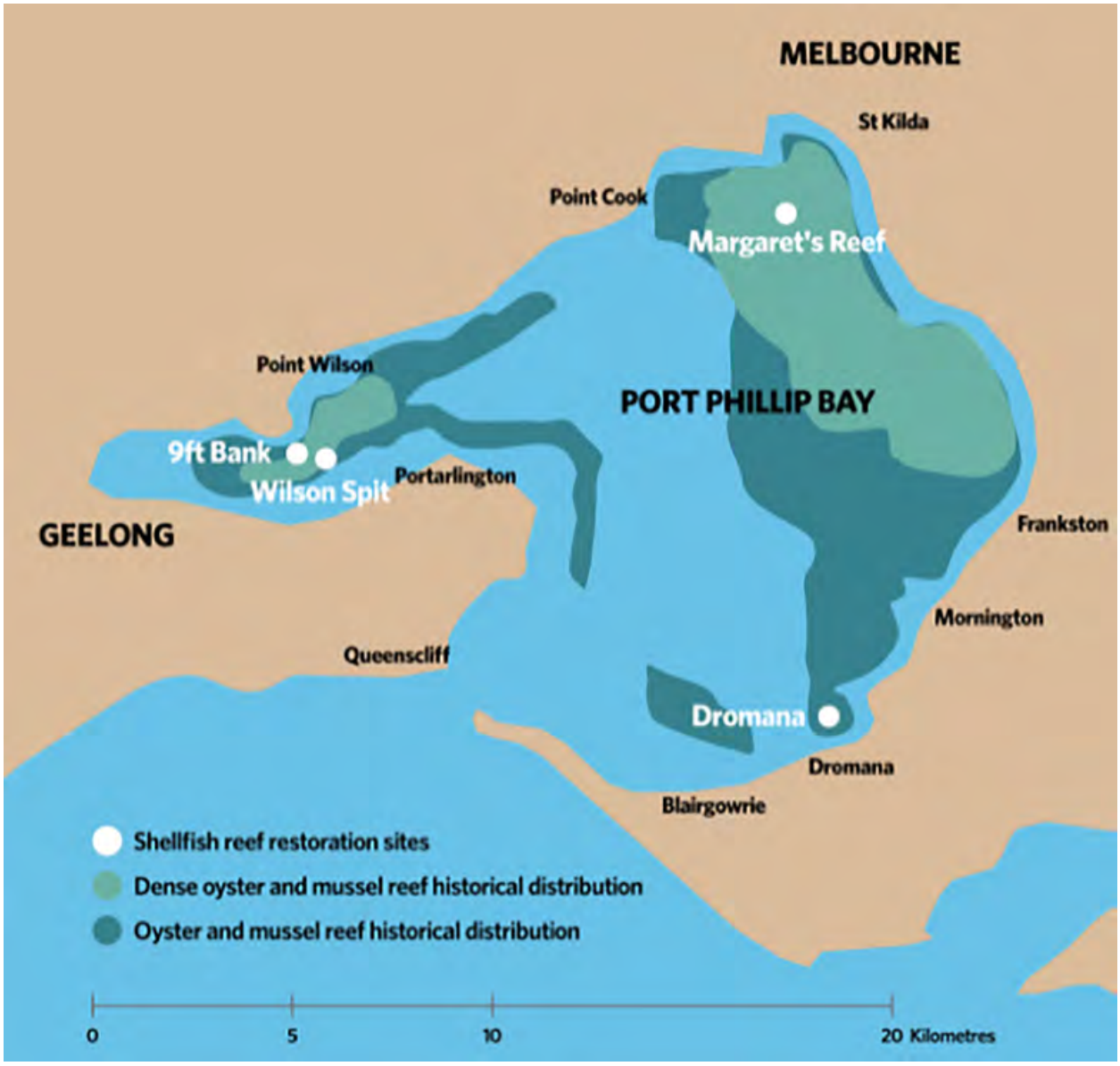


Figure 59: Areas where remnant or degraded shellfish reefs may exist and locations where shellfish reef restoration has been occurring.[956]

955. Ford J and Hamer P 2016, 'The forgotten shellfish reefs of coastal Victoria: documenting the loss of a marine ecosystem over 200 years since European settlement', *Proceedings of the Royal Society of Victoria*, 128, pp. 87-105 https://doi.org/10.1071/RS16008 Accessed 31 March 2021.
956. The Nature Conservancy, 'Victoria's lost reefs rediscovered' https://www.natureaustralia.org.au/what-we-do/our-priorities/oceans/ocean-stories/restoring-shellfish-reefs/port-phillip-bay/ Accessed 19 May 2021.

PPB 36: Macroalgae on intertidal reefs

Region	2021 status	2021 trend	2021 data
Port Phillip Bay			
Justification for assessment ratings:	The status assessment of good is based on the available information provided as part of Parks Victoria's long-term Intertidal Reef Monitoring Program. No reports have been published since 2014, however Parks Victoria advises that monitoring and assessment is ongoing and the most recent findings are consistent with those previously published – an updated technical report is in preparation by Parks Victoria.		

Parks Victoria's data and reporting was relied upon for this regional indicator assessment. This means the assessment for this indicator is mostly confined to marine protected areas within Port Phillip Bay, with Parks Victoria's reporting also including some reference sites outside the marine protected area boundaries.

As part of Parks Victoria's long-term Intertidal Reef Monitoring Program (IRMP), information has been collected at Victoria's Marine Protected Areas on the status of Victorian intertidal reef flora and fauna, as well as the nature and magnitude of trends in species populations and species diversity through time.[957] No data for Port Phillip Bay's marine protected areas has been published since 2014, limiting analysis for this indicator to data collected up to that time. However, Parks Victoria advises that monitoring and assessment is ongoing, and the most recent findings are consistent with those previously published. Parks Victoria has advised that a technical report focussing on Port Phillip Heads Marine National Park is currently in preparation.

Within Port Phillip Bay, intertidal survey sites were established on reefs in the northern Port Phillip Bay marine sanctuaries at Point Cooke, Jawbone and Ricketts Point. Reference sites were also surveyed in association with each of these sanctuaries. An intertidal survey site and reference site was also established at Port Phillip Heads Marine National Park. The IRMP used standardised visual census methods for surveying macroalgae on intertidal reefs.[958]

Neptune's necklace (*Hormosira banksii*) is an intertidal algae that forms large beds and habitats for macroinvertebrate grazers, predators, scavengers and microfauna. Data for macroalgae, sessile and mobile invertebrate indicators from the IRMP indicate these reef communities within Port Phillip Bay have remained in good condition since 2003, with *Hormosira banksii* cover increasing steadily since 2009.[959] However, water quality is an issue for intertidal habitats near Point Cooke Marine Sanctuary and Boags Rocks, close to the Eastern and Western treatment plants, in Hobsons Bay (affecting Jawbone Marine Sanctuary), along the bay's north-eastern shoreline (affecting Ricketts Point Marine Sanctuary) and stormwater inflows.[960]

Point Cooke Marine Sanctuary

At Point Cooke there was a trend of increasing green algal *Ulva spp.* cover since 2011. The reference site at Altona had far less macroalgal cover than Point Cooke. The cover of *Ulva spp*. at Altona was generally low, and *Ulva spp*. (*Enteromorpha* form) was detected only in 2005 and 2012. Coralline algal species were intermittently detected at very low coverages throughout the monitoring period.[961]

Jawbone Marine Sanctuary

The cover of Neptune's necklace (*Hormosira banksii*) at Williamstown, the reference site for Jawbone Marine Sanctuary, has been increasing continuously since the start of the monitoring period in 2003.[962]

957. Edmunds M, Woods B and Donnelly D 2014, 'Intertidal reef monitoring program: central Victoria marine protected areas March 2014', Parks Victoria technical series no. 97, Melbourne, Victoria.
958. Ibid.
959. Commissioner for Environmental Sustainability (CES) 2016, 'State of the Bays 2016', Melbourne, Victoria.
960. Commissioner for Environmental Sustainability (CES) 2018, 'Victorian State of the Environment 2018', Melbourne, Victoria.
961. Edmunds M, Woods B and Donnelly D 2014, 'Intertidal reef monitoring program: central Victoria marine protected areas March 2014', Parks Victoria technical series no. 97, Melbourne, Victoria.
962. Ibid.

Ricketts Point Marine Sanctuary

Macroalgal cover along the seaward edge of the Ricketts Point platform was predominantly the brown alga Neptune's Necklace (*Hormosira banksia).* *Hormosira banksii* coverage at Ricketts Point generally followed an upward trend from 2009. The highest abundances were recorded in 2013 and 2014. At the reference site at Halfmoon Bay, coverage was always consistently close to zero. There was a consistent pattern emerging in the cover of green algal species, with spikes in abundance at Ricketts Point and the reference site at Halfmoon Bay which were increasing in both amplitude and frequency over the monitoring period.[963]

Port Phillip Heads Marine National Park

Parks Victoria is progressing monitoring and assessment with plans to publish technical reports within the next couple of years for Port Phillip Heads, Wilsons Promontory, Cape Howe and Discovery Bay Marine National Parks, which will address knowledge gaps in marine protected areas and increase the confidence in this indicator assessment in future State of the Marine and Coastal Environment reports. Preliminary analysis supplied to the Commissioner for Environmental Sustainability shows that that *Hormosira banksii* cover was maintained well above the lower limit of acceptable change of 48%. Cover has increased from 62% in 2013, to an all-time high of 87% in 2018 and 2019. No surveys were conducted at the reference site (Cheviot Beach) in 2018 or 2019, so it is difficult to understand if this is representative of a broader pattern (for example, due to environmental conditions) or as a result of park management.

PPB 37: Macroalgae-dominated subtidal reefs

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	(Port Phillip Heads Marine National Park) (Ricketts Point Marine Sanctuary) (Point Cooke and Jawbone marine sanctuaries)	→	
Justification for assessment ratings:	A range of evidence from research studies and Parks Victoria's long-term Subtidal Reef Monitoring Program shows that the condition and extent of macroalgae on subtidal reefs in Port Phillip Bay is poor for Point Cooke and Jawbone Marine Sanctuaries, fair for Ricketts Point Marine Sanctuary and good for Port Phillip Heads Marine National Park. The recent trend is stable although it is worth noting that there was a significant deterioration in kelp loss during the early 2000s in association with the millennium drought.		

The sheltered, subtidal, shallow reefs of Port Phillip Bay generally cover depths of 2.5–20 metres. Shallow reef habitats cover extensive areas along the Victorian coast and most reefs are exposed to strong winds, currents and large swell. Shallow reefs in Victoria are predominantly composed of kelp and a high diversity of smaller seaweeds.[964] Seaweeds provide important habitat structure for other organisms on the reef.

Parks Victoria's Subtidal Reef Monitoring Program provides information on macroalgae. At Point Cook Marine Sanctuary, a macroalgal cover of giant kelp (*Macrocystis pyrifera*) has been replaced by short-spined sea urchin (*Heliocidaris erythrogramma*)

963. Ibid.
964. Edmunds M 2017, 'Victorian subtidal reef monitoring program: Popes Eye – Port Phillip Heads, January 2015', Parks Victoria technical series no. 103, Melbourne, Victoria.

barrens, coralline algae and filamentous brown algae, possibly due to changes in water quality and catchment inputs that have led to reduced nutrients and restrictions on kelp growth. However, at Jawbone Marine Sanctuary, there are no significant trends in species abundance richness and diversity, although giant kelp (*Macrocystis pyrifera*) cover has declined. Along the bay's east coast, species richness and diversity have fluctuated at Ricketts Point Marine Sanctuary, but algal cover has declined.[965]

Parks Victoria has advised that a technical report focussing on Port Phillip Heads Marine National Park is currently in preparation. Preliminary analysis supplied to the Commissioner for Environmental Sustainability shows that some subtidal reef macroalgal communities of the Port Phillip Heads Marine National Park, such as the brown macroalgae dominated beds (*Ecklonia radiata* and *Phyllospora comosa*), declined from the early 2000s to 2017, before recovering during 2018 and 2019 to be above the Limit of Acceptable Change. Note that Parks Victoria, in collaboration with the University of Melbourne and Deakin University, have developed a series of control charts to provide timely, accurate, and reliable information on the condition of natural assets, level of threats and management effectiveness. These charts form part of Parks Victoria's State of the Parks evaluation. The charts depict a simple line graph tracking an indicator through time, with a zone of acceptable change identified, plus upper and/or lower control limits to flag values where a management response should be considered.[966]

Most reefs in the north are low-wave energy and have been permanently changed by short-spined sea urchins (*Heliocidaris erythrogramma*) and the highly invasive Japanese kelp (*Undaria pinnatifida*), which exploits the disturbance caused by the urchins. Their ecological status is highly variable, and trends are currently unknown. The Victorian species of white sea urchin (*Heliocidaris erythrogramma*) has also been increasing in abundance and forming barrens, especially in the northern parts of Port Phillip Bay.[967]

The density of native sea urchins is a critical pressure on subtidal reefs in Port Phillip Bay. Overgrazing by urchins leads to loss of the larger macroalgae cover and density that is critical for fish mortality, while creating intense competition for abalone. Removal of fish grazers and predators by fishing has also altered the trophic balance, which reduces urchin control.[968]

In Port Phillip Bay, since the 1930s, kelp has declined up to 98% in some areas, potentially related to a warmer, drier climate and increasing urchin barrens.[969] This research involved creating a historical time series of kelp (*Ecklonia radiata*) and sea urchin (*Heliocidaris erythrogramma*) populations of Port Phillip Bay using various field-collected datasets, with aerial photographs part of the data set used to calculate the extent of algal beds, going back to the 1930s. Between the 1930s and the 1980s, kelp is estimated to have occurred as dense (21–58% cover) beds over large sections of reef at all surveyed sites. However, by the early 2000s, kelp cover had declined by between 59% and 98%. From 2005 to 2012, sea urchins became 250–420% more abundant and were observed to be directly consuming large areas of macroalgae, creating sea urchin barrens. Analysis of reef algal cover between the 1930s and 2014 indicates that increases in temperature and declines in rainfall—which, in Port Phillip Bay, influences salinity, nutrient inputs and algal productivity—are correlated with the declines in kelp abundance.

965. Woods B, Donnelly D and Edmunds M 2013, 'Victorian subtidal reef monitoring program: the reef biota at Point Cooke marine sanctuary', Parks Victoria technical series no. 99, Melbourne, Victoria.
966. Ierodiaconou D, Wines S, Carnell P, Tinkler P, Allan B, Carey J, Young M, Howe S, Pocklington J 2020, 'An enhanced signs of healthy parks monitoring program for Victoria's marine national parks and marine sanctuaries: Point Addis marine national park', Parks Victoria technical series no. 114, Melbourne, Victoria.
967. Parks Victoria 2012, 'Marine natural values study summary', Melbourne, Victoria.
968. Johnson C, Swearer S, Ling S, Reeves S, Kriegisch N, Treml E, Ford J, Fobert E, Black K, Weston K and Sherman C 2015, 'The Reef Ecosystem Evaluation Framework (REEF): managing resilience in temperate environments, seagrass and reefs program for Port Phillip Bay (draft final report)', Melbourne, Victoria.
969. Carnell P and Keough M 2019, 'Reconstructing historical marine populations reveals major decline of a kelp forest ecosystem in Australia', *Estuaries and Coasts*, 42, pp. 765–778 https://doi.org/10.1007/s12237-019-00525-1

The millennium drought (1997-2009) is a particularly important case study for kelp and sea urchins in Port Phillip Bay. During this period there was a one degree increase in average daily maximum temperature. With the changes in the environment as part of the millennium drought, researchers observed a decline in kelp, but when kelp started declining the bay's urchins began to run out of a key food source and were forced to move around to find food, which drove further kelp losses.[970]

The northern part of the bay where kelp forests once predominated, are now mostly covered by urchin barrens. While there were urchin barren areas in the bay in the 1970s and 1980s, researchers noted their rapid expansion towards the end of the drought.[971] Despite kelp being now nearly completely absent in the Point Cook and Williamstown regions, Beaumaris has started to show some recovery.[972] The impact of the millennium drought on kelp in Port Phillip Bay is particularly salient when considered in the context that more considerable temperature increases are projected for the rest of the 21st century.

Western Port

WP 32: Conservation of marine ecosystems in protected areas

Region	2021 status	2021 trend	2021 data
Western Port	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The conservation of marine ecosystems in Western Port's protected areas is covered in the Other Marine Protected Areas region.		

WP 33: Nitrogen cycle

Region	2021 status	2021 trend	2021 data
Western Port	●	→	●
Justification for assessment ratings:	In most parts of Western Port, the ratio of nitrogen fixation to denitrification is high (that is, nitrogen fixation is more common than denitrification). Low denitrification indicates the water column is starved of nutrients because the vegetation is processing it. This ratio is inverted in less vegetated areas of Western Port (that is, denitrification is higher than nitrogen fixation). There is only a small number of research studies that have investigated this, so confidence in the status assessment is low.		

In contrast to Port Phillip Bay, there is very little denitrification in Western Port, which is dominated by vegetated, shallow areas. Rather, nitrogen fixation governs its nitrogen cycle. For a healthy Western Port, a higher ratio of nitrogen fixation to denitrification is better.

Western Port is generally considered to have low nutrient inputs relative to other bays such as Port Phillip Bay. It does not receive a direct sewage discharge, and the catchment inputs are comparatively small.

The most significant catchment inputs are in the Upper North Arm (for example, Watsons Creek) and Corinella segments – and these are relatively small.[973] The Bass River is also an important source, but it discharges into well-flushed parts of Western Port.[974]

970. Blue Carbon Lab 2019, 'Scientists find historical declines in kelp forest of southeast Australia' https://www.bluecarbonlab.org/kelp-forest-declines/ Accessed 6 April 2021.
971. Ibid.
972. Ibid.
973. Melbourne Water 2011, 'Understanding the Western Port environment – a summary of current knowledge and priorities for future research'.
974. Ibid.

Analysis published in 2016 estimated that Western Port receives around 650 tonnes of nitrogen a year from the catchments, around 430 tonnes a year from nitrogen fixation and loses around 230 tonnes a year though denitrification. Therefore, approximately 40% of the total nitrogen input to Western Port resulted from nitrogen fixation.[975]

Western Port is dominated by tidal flats that are highly productive environments due to their large surface area, exposure to high light intensities and the presence of benthic vegetation (seagrass) and/or microphytobenthos.[976,977] The intertidal areas of Western Port represent a major habitat type, yet prior to 2013 there had previously been limited data on nutrient transformation in this system. This knowledge gap was addressed by a research study that indicated the nutrient exchange between the tidal flats and the water column in Western Port was very low compared to catchment inputs.[978]

Seagrasses are known to be important factories for nitrogen fixation.[979] Seagrass meadows were found to contribute 320 tonnes of nitrogen each year to the Western Port ecosystem compared to approximately 110 tonnes a year in unvegetated soft sediments. Nitrogen fixation by seagrass contributed approximately 40% of the nitrogen inputs compared to the catchments inputs from small rivers and streams (~50-60%) and atmospheric deposition associated with rainfall (less than 10%), confirming the importance of seagrass habitats as a key component to nutrient cycling in Western Port.[980] Because seagrass can stimulate nitrogen fixation activity, seagrass death will likely lower nitrogen fixation rates. Therefore, it is important to understand how the balance of denitrification and nitrogen fixation in coastal ecosystems will respond to further reductions in seagrass coverage, and to investigate how site-specific controls affect the relative importance of the major nitrogen transformations.[981]

WP 34: Seagrass

Region	2021 status	2021 trend	2021 data
Western Port		↗	
Justification for assessment ratings:	In the mid-1970s to early 1980s extensive loss (up to 75%) of intertidal seagrasses was observed. Seagrass recovery has been observed since then, although coverage is still less than during the 1970s. The Limit of Acceptable Change (LAC) for seagrass in the Western Port Ramsar Site is that total seagrass extent will not decline below 5,400 hectares. This is being met. Even though the LAC for seagrass is being met, because of the documented and extensive historical seagrass losses and the lack of a major recovery in recent years, the status has been rated as poor but the trend is improving.		

Seagrass meadows are a critical habitat for a broad range of aquatic life within Western Port and play a vital role in coastal and estuarine ecosystem functions including:

- regulation of nutrients
- stabilisation of sediments
- nursery grounds for recreationally/commercially important fisheries
- as an essential food source for a range of marine animals.[982,983]

975. Russell D, Warry F and Cook P 2016, 'The balance between nitrogen fixation and denitrification on vegetated and non-vegetated intertidal sediments', *Limnology and Oceanography*, 61, pp. 2058-2075 https://doi.org/10.1002/lno.10353 Accessed 31 March 2021.
976. Perillo G, Wolanski E, Cahoon D and Hopkinson C 2019, 'Coastal wetlands: an integrated ecosystem approach', Elsevier, Amsterdam, Netherlands.
977. Evrard V, Huettel M, Cook P, Soetaert K, Heip C and Middelburg J 2012, 'Importance of phytodetritus and microphytobenthos for heterotrophs in a shallow subtidal sandy sediment', *Marine Ecology Progress Series*, 455, pp. 13–31.
978. Evrard V, Eate V, Woodland R, Ross D, O'Brien A, Keough M, Longmore A, Wilson R, and Cook P 2013, 'Nutrient processing on tidal flats in Western Port: interactions with ecology and implications for bay-wide nutrient budgets', report prepared for Melbourne Water, Water Studies Centre, Monash University.
979. Melbourne Water 2018, 'Understanding the Western Port environment 2018'.
980. Ibid.
981. Commissioner for Environmental Sustainability (CES) 2016, 'State of the Bays 2016', Melbourne, Victoria.
982. Collier C, Waycott M and McKenzie L 2012, 'Light thresholds derived from seagrass loss in the coastal zone of the northern Great Barrier Reef, Australia', *Ecological Indicators*, 23, pp. 211-219.
983. Connolly R 2009, 'Seagrass', in E Poloczanska, A Hobday and A Richardson (eds), 'Marine climate change impacts and adaptation report card for Australia', National Climate Change Adaptation Research Facility (NCCARF) Publication 2009, Southport, Queensland.

In Western Port, the dominant intertidal species is *Zostera muelleri* but historically was *Zostera nigricaulis*. In the mid-1970s to early 1980s extensive loss (up to 75%) of intertidal seagrasses was observed, with increased sediment inputs from human activities and associated changes in water quality a likely, but unconfirmed, cause. Seagrass recovery has been observed since then, although coverage is still less than during the 1970s. As such, the need for research-based approaches was recognised to not only prevent further declines, but also assist in recovery.[984]

The Limit of Acceptable Change (LAC) for seagrass in the Western Port Ramsar Site is that total seagrass extent will not decline below 5,400 hectares for a period of greater than 10 continuous years.[985] DELWP advises that this is being met, with researchers measuring 15,000 hectares in 2011.[986] However, this research is now a decade old.

Melbourne Water's 2018 synthesis report Understanding the Western Port Environment, summarised the latest scientific research on seagrass in Western Port and noted the following key findings:

- Current nutrient loads to Western Port are not posing a significant risk to seagrass cover on a bay-wide scale, although there may be some localised problem areas.
- Physical factors, especially light availability, exert a strong influence over seagrass cover and health.
- At some sites, seagrass is growing in (suboptimal) light-limited conditions for most of the year.
- Although it has been demonstrated that seagrass has some ability to cope with short-term (up to five weeks) increases in turbidity, persistent turbidity is likely to be detrimental to survival (for example, exhausted carbohydrate stores).
- Genetic analysis shows there are two common species of seagrass in Western Port – *Zostera muelleri* (intertidal-shallow subtidal) and *Zostera nigricaulis* (shallow-deep subtidal).
- Analysis of genotypic diversity in *Zostera muelleri* shows there is a high level of gene flow and connectivity between sites except for the northeast of the bay, with possible implications for seagrass resilience and population persistence in this region.
- Seagrass beds provide an important source of nitrogen through nitrogen fixation in their root zone.
- Overall, seagrass meadows were found to contribute 320 tonnes of nitrogen each year to the Western Port ecosystem compared to approximately 110 tonnes a year in unvegetated soft sediments. Nitrogen fixation by seagrass contributed approximately 40% of the nitrogen inputs compared to the catchments (small rivers and streams (~50-60%) and atmospheric deposition (rainfall less than 10%)), confirming the importance of seagrass habitats as a key component to nutrient cycling in Western Port.
- Seagrasses throughout Victorian estuaries become overgrown with epiphytes when nitrogen inputs exceed 10 tonnes per km^2 of estuarine area.[987] By comparison, the rates of nitrogen input to Western Port are less than 1 tonne per km^2, suggesting that, with the possible exception of some sites adjacent to agricultural drains, nitrogen inputs are not a major issue in Western Port.[988]

Poor water quality in Western Port has adverse impacts on the condition and extent of seagrass as well as the sustainability of fish stocks.

As reported in Melbourne Water's 2018 Report Understanding the Western Port Environment 2018, a key action to improve water quality in Western Port to levels suitable for seagrass maintenance and restoration is to restrict sediment loads from the catchment and coastline to current levels of around 28 kt per year.[989] Restricting sediment loads is likely to result in suitable water quality for seagrass once existing legacy sediments have been flushed out of the bay in the coming decades.

984. Melbourne Water 2011, 'Understanding the Western Port environment – a summary of current knowledge and priorities for future research'.
985. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Western Port Ramsar site management plan', East Melbourne, Victoria.
986. Holland D, Cook P, Mac Nally R, Thomson J, Womersley B, Ball D, Longmore A, Keough M, Lee R, Martinez G, Greer D 2013, 'Preliminary assessment of water quality requirements of seagrasses in Western Port', report prepared for Melbourne Water.
987. Woodland R, Thomson J, Mac Nally R, Reich P, Evrard V, Walker J and Cook P 2015, 'Nitrogen loads explain primary productivity in estuaries at the ecosystem scale', *Limnology and Oceanography*, 60, pp. 1751-1762.
988. Melbourne Water 2018, 'Understanding the Western Port environment 2018'.
989. Ibid.

Seagrass extent is strongly correlated with light availability in Western Port. Thus, increased turbidity caused by high sediment loads plays a major role in seagrass decline or growth. Turbidity is a measure of water clarity and water clarity has been one of the more variable and poorest performing indicators measured by EPA Victoria in Western Port during recent years. It was rated as poor from 2000 to 2005 before ratings ceased for three years while there was an insufficient number of monitoring stations to enable an overall water clarity assessment for Western Port. Since 2009, water clarity has been rated as being of good quality for five years, fair quality for three years, poor quality for three years and very poor water quality for one year.

The effects of climate change are highly likely to exacerbate the challenges poor water quality poses for seagrass in Western Port. A projected sea level rise of one metre during the next 100 years and/or an increase in water temperature may cause a substantial reduction in seagrass extent within existing seagrass beds. This and other changes in seagrass distribution will need to be taken into consideration in future seagrass restoration strategies.[990,991]

Recent research has developed our understanding of the links between sediment inputs to the bay and seagrass. However, the effect of specific catchment management actions on Western Port water quality and seagrass extent are less-well understood and this is a current research focus.[992]

Water quality strongly influences fish stocks and catch rates in regions of Western Port, including the popular fishing area off the coast near Rhyll. Water quality in this region is affected by sedimentation entering the northeast of the bay – primarily from the catchment and coastal erosion. Catchment management, aimed at maintaining water quality entering the bay, is therefore likely to be critical to maintaining fish biodiversity and sustaining recreational fishing in Western Port.[993]

WP 35: Shellfish reefs

Region	2021 status	2021 trend	2021 data
Western Port			
Justification for assessment ratings:	Historically, there were large areas of native flat oyster (*Ostrea angasi*) reefs in Western Port. Anecdotal evidence reported as part of a 2016 research project indicates that sporadic oyster harvesting has not occurred since the mid-20th century, which indicates the extent of native flat oyster reefs is now minimal. However, the lack of recent quantitative analysis means confidence in this indicator assessment is low.		

As part of a research project published by the Royal Society of Victoria in 2016, the history of coastal Victoria's shellfish reefs since the early 1800s was documented.[994] The researchers relied on accounts from the early colonial fishing days to assess the historical distribution and abundance of native flat oyster and mussel in Western Port. The native flat oyster appears to have been very abundant in Western Port when Europeans arrived, forming large reef areas. While there have been no recent surveys of subtidal benthic invertebrates in Western Port and the current status of native flat oyster reefs in Western Port is unclear, sporadic oyster harvesting is reported to have occurred at least until the mid-twentieth century.[995,996]

The 2016 study found that the blue mussel did not appear to have historically been a major reef building shellfish in Western Port.[997]

990. Wilkinson S, Anstee J, Joehnk K, Karim F, Lorenz Z, Glover M and Coleman R 2016, 'Western Port sediment supply and resuspension dynamics', report to Melbourne Water, CSIRO, Australia.
991. Melbourne Water 2018, 'Understanding the Western Port environment 2018'.
992. Ibid.
993. Ibid.
994. Ford J and Hamer P 2016, 'The forgotten shellfish reefs of coastal Victoria: documenting the loss of a marine ecosystem over 200 years since European settlement', *Proceedings of the Royal Society of Victoria*, 128, pp. 87-105 https://doi.org/10.1071/RS16008 Accessed 31 March 2021.
995. Hannan H and Bennett B 2010, 'Western Port fishermen', published by Hannan and Bennett, Melbourne Victoria.
996. Ford J and Hamer P 2016, 'The forgotten shellfish reefs of coastal Victoria: documenting the loss of a marine ecosystem over 200 years since European settlement', *Proceedings of the Royal Society of Victoria*, 128, pp. 87-105 https://doi.org/10.1071/RS16008 Accessed 31 March 2021.
997. Ibid.

Native flat oyster and blue mussels were not detected by sampling that took place during the 1970s. Fisherman accounts suggests that smaller commercial harvests of oyster were obtained until the early 1970s but that the few patches of oyster remaining at that time died out about the same time as a major seagrass die-off in the 1970s.[998,999]

Historical newspaper archives and government gazettes related to the oyster dredge fishery closures in 1886 were used to derive a map of the general areas of Western Port's historic flat oyster reefs (Figure 60). The map provides a general representation of the distribution of oyster reefs, but also shows that the main oyster reefs were along the channel banks and subtidal shoal areas, where shingle and shell were abundant, rather than the intertidal zones/mud flats.[1000] Historical accounts suggest the banks and channels along the southern fringe of French Island were particularly productive, although the locations of individual reefs were not widely communicated as fishers tried to protect their finds for their own personal gain, and newly discovered reefs were a closely guarded secret.[1001,1002]

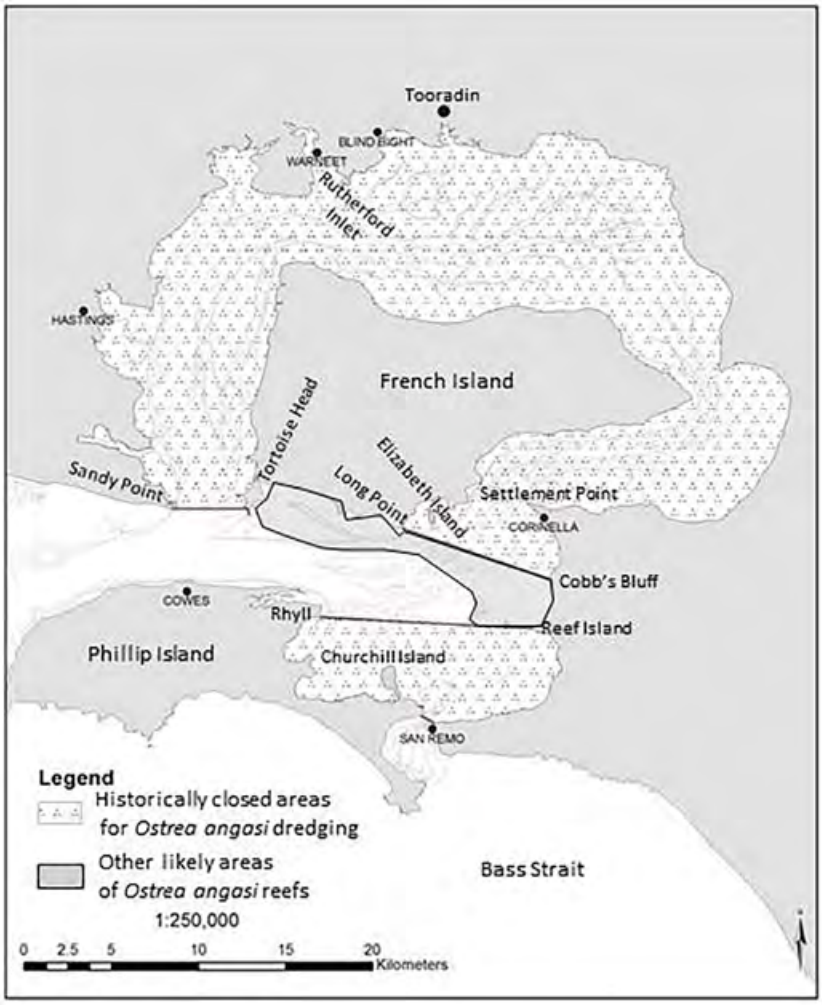


Figure 60: Approximation of broad regions of Western Port that encompassed the distribution of the bay's major native flat oyster reefs at European settlement.[1003]

There is no current information about the distribution of shellfish reefs in Western Port.

998. Hannan H and Bennett B 2010, 'Western Port fishermen', published by Hannan and Bennett, Melbourne Victoria.
999. Jenkins G, Edgar G, May H and Shaw C 1993, 'Ecological basis for parallel declines in seagrass habitat and catches of commercial fish in Western Port Bay, Victoria', in DA Hancock (ed) 'Sustainable fisheries through sustaining fish habitat', Australian Society for Fish Biology Workshop Proceedings, Victor Harbour, South Australia, 12–13 August, Bureau of Resource Sciences (BRS), Canberra.
1000. Hannan H and Bennett B 2010, 'Western Port fishermen', published by Hannan and Bennett, Melbourne Victoria.
1001. Ibid.
1002. Ford J and Hamer P 2016, 'The forgotten shellfish reefs of coastal Victoria: documenting the loss of a marine ecosystem over 200 years since European settlement', *Proceedings of the Royal Society of Victoria*, 128, pp. 87-105 https://doi.org/10.1071/RS16008 Accessed 31 March 2021.
1003. Ibid.

WP 36: Macroalgae on intertidal reefs

Region	2021 status	2021 trend	2021 data
Western Port	●	N/A	N/A
Justification for assessment ratings:	Not assessed. The flora and fauna of intertidal reefs within the marine protected areas of Western Port have not been surveyed.		

WP 37: Macroalgae-dominated subtidal reefs

Region	2021 status	2021 trend	2021 data
Western Port	●	N/A	N/A
Justification for assessment ratings:	Not assessed. The flora and fauna of subtidal reefs within the marine protected areas of Western Port have not been surveyed.		

Corner Inlet and Nooramunga

CIN 32: Conservation of marine ecosystems in protected areas

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The conservation of marine ecosystems in Corner Inlet and Nooramunga's protected areas is covered in the Other Marine Protected Areas region.		

CIN 33: Nitrogen cycle

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. No routine monitoring is done to inform the condition and impacts associated with the nitrogen cycle in Corner Inlet and Nooramunga, and no focused research has been published.		

CIN 34: Seagrass

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	↗	●
Justification for assessment ratings:	Despite a long history of slow seagrass decline in Corner Inlet, where seagrass extent had declined on average by 0.5 km^2 per year between 1965 and 2013, the cover of seagrass appears to have stabilised in the period of 2013-2018, and then increased from 2018-2020.[1004,1005] Based on this information, the status has been assessed as fair and the trend as improving.		

1004. Ford J 2018, '2018 Seagrass mapping of the Corner Inlet basin (preliminary report)', report to West Gippsland Catchment Management Authority (WGCMA), Traralgon, Victoria.
1005. Brooks S and Hale J 2020, 'Corner Inlet Ramsar habitat mapping', report to West Gippsland Catchment Management Authority (WGCMA), Traralgon, Victoria.

Seagrass in Corner Inlet has been mapped several times during the past 60 years, with the mapping often covering different areas of the site. As noted during habitat mapping for the Corner Inlet Ramsar Site completed during 2020, these different methods and areas make comparisons across time periods difficult, and mean trend evaluations should be treated with a degree of caution.[1006]

Seagrass in Corner Inlet was mapped for 2013 and 2018 using satellite imagery. This represented the first time that two seagrass maps of Corner Inlet were produced using the same methodology and provided useful information on total change in seagrass cover, species-specific change, and geographic areas of seagrass decline and growth. Seagrass beds were classified as being dominant with *Posidonia australis* or *Zostera nigricaulis*. Nearshore *Zostera Muelleri* beds were not mapped due to their intermittent nature and difficulty in identification.[1007]

More recently, during 2020, seagrass in Corner Inlet was again mapped using satellite imagery, but this time over a larger area (approximately 81% of the total Ramsar site area). As part of this work, completed for the West Gippsland Catchment Management Authority, a dramatic increase in seagrass was estimated to have occurred in Corner Inlet between 2018 and 2020.[1008] Parks Victoria also mapped seagrass over a large area across Corner Inlet during 2020, with similar mapped outputs to the West Gippsland Catchment Management Authority's results.[1009]

Despite the different methods and the likely errors and uncertainties, the following summary was provided in the habitat mapping report for the Corner Inlet Ramsar Site completed during 2020.

The extent of *Posidonia australis*:

- declined between 1965 and 1998
- that was followed by an increase by 2011
- then another decline in 2016 that persisted through 2018
- before increasing again by 2020.[1010]

The extent of *Zostera nigricaulis*:

- was relatively stable in Corner Inlet from 1998 through 2011
- declined by 2016 that persisted through to 2018
- before increasing by 2020.[1011]

Even though there was a long period of slow seagrass decline in Corner Inlet, where seagrass extent had declined on average by 0.5 km^2 per year between 1965 and 2013, the cover of seagrass was found to increase by a total of 0.43 km^2 or 0.5% between 2013 (84.9 km^2) and 2018 (85.4 km^2).[1012,1013] A link between poor water quality from the catchment and declines in seagrass has previously been established, so the stabilisation of seagrass cover may be attributed to improvements in water quality in Corner Inlet.[1014] However, without a water quality monitoring program it is difficult to establish a conclusive link.[1015] Corner Inlet's water quality is analysed in more detail in the Water Quality and Catchment Inputs chapter.

In the period from 2013 to 2018, *Posidonia australis* declined slightly by 0.32 km^2 or 0.5%, which was offset by a 0.76 km^2 or 4.4% increase in *Zostera nigricaulis*.[1016]

Zostera nigricaulis beds showed great variability in location and extent between 2013 and 2018, which characterises its role as a dynamic and rapidly colonising species. Whilst there were declines in seagrass bed extent in areas such as Golden Creek channel (NW), Chinaman's beach (SE), and between Yanakie and Middle Bank, these were offset by large new beds establishing along the shoreline in the northwest, southwest and northeast of the Inlet. *Posidonia australis* beds remained mostly unchanged between 2013 and 2018. The only major exceptions were declines in areas around Doughboy Island, between Yanakie basin and Middle Bank, and below Bennison Island. Increasing 'patchiness' or the formation of sand hollows within beds, is of concern in almost all major *Posidonia australis* banks.[1017]

1006. Ibid.
1007. Ford J 2018, '2018 Seagrass mapping of the Corner Inlet basin (preliminary report)', report to West Gippsland Catchment Management Authority (WGCMA), Traralgon, Victoria.
1008. Brooks S and Hale J 2020, 'Corner Inlet Ramsar habitat mapping', report to West Gippsland Catchment Management Authority (WGCMA), Traralgon, Victoria.
1009. Herpich D 2020, 'Corner Inlet and Nooramunga marine and coastal parks – seagrass change detection and urchin barren assessment', Parks Victoria, Melbourne.
1010. Brooks S and Hale J 2020, 'Corner Inlet Ramsar habitat mapping', report to West Gippsland Catchment Management Authority (WGCMA), Traralgon, Victoria.
1011. Ibid.
1012. Ford J, Barclay K and Day R 2016, 'Using local knowledge to understand and manage ecosystem-related decline in fisheries productivity', Fisheries Research and Development Corporation (FRDC), final project report, no. 2013-021, Melbourne, Victoria.
1013. Ford J 2018, '2018 Seagrass mapping of the Corner Inlet basin (preliminary report)', report to West Gippsland Catchment Management Authority (WGCMA), Traralgon, Victoria.
1014. Ford J, Barclay K and Day R 2016, 'Using local knowledge to understand and manage ecosystem-related decline in fisheries productivity', Fisheries Research and Development Corporation (FRDC), final project report, no. 2013-021, Melbourne, Victoria.
1015. Ford J 2018, '2018 Seagrass mapping of the Corner Inlet basin (preliminary report)', report to West Gippsland Catchment Management Authority (WGCMA), Traralgon, Victoria.
1016. Ibid.
1017. Ibid.

The Limit of Acceptable Change (LAC) for seagrass in the Corner Inlet Ramsar Site was defined in 2011 as:

- Total mapped extent of dense *Posidonia* will not decline by greater than 10% of the baseline value of 3,050 hectares (LAC = mapped area less than 2,745 hectares) on any occasion.
- Total mapped extent of the dense and medium density *Zosteraceae* will not decline by greater than 25% of the baseline values at a whole of site scale on two sampling occasions within any decade.
- Dense *Zostera* - baseline = 5,743 hectares (LAC = mapped area less than 4307 hectares).
- Medium *Zostera* - baseline = 1,077 hectares (LAC = mapped area less than 807 hectares).[1018]

In 2016 an addendum to the ecological character description for the Corner Inlet Ramsar Site was produced.[1019] The LAC was updated to account for the high variability in above ground biomass of seagrass in the system and to reflect the proposed future monitoring of a smaller area of the site (approximately 50% of the Corner Inlet Marine and Coastal Park):

- Seagrass extent will not decline below 900 hectares for *Posidonia* and 3,500 hectares for *Zosteraceae* (within the study area)[1020] for a period of greater than 20 continuous years.[1021]

Based on the habitat mapping completed for the West Gippsland Management Authority in 2020, seagrass in Corner Inlet has remained within the LAC.[1022] The extent of *Posidonia australis* has not dropped below the thresholds of 3,050 hectares for the whole site (old LAC) and 900 hectares for the smaller area of the revised LAC. Similarly, *Zostera* has remained above the thresholds of 5,114 (combined dense and medium) for the entire site and although it did drop below 3,500 in the smaller area, this did not persist for more than 20 continuous years.[1023] Table 24 shows the significant increase in seagrass extent from 2018 to 2020.

Table 24: Areas of seagrass in Corner Inlet from March 2018 and November 2020.[1024]

Seagrass type	2018 (ha)	2020 (ha)
Posidonia	6,774	11,146
Zostera	5,870	13,389

The local community has been helping to monitor changes as part of the Corner Inlet Community Seagrass Monitoring Project (CICSMP), which was established through Sea Search – Parks Victoria's citizen science program that was set up to engage communities near the state's marine protected areas. CICSMP was formed with the joint aims of collecting long term data on the health of *Posidonia australis* in Corner Inlet and connecting the community to the Inlet's diverse marine values.[1025]

A report on CICSMP, published during 2017, describes the 11 years of data collection up to 2016. The project monitored *Posidonia australis* at 12 sites and collected data on substrate type, seagrass cover, epiphyte cover, leaf length, shoot density, faunal groups and reproduction success. The data reported showed that *Posidonia australis* was relatively stable over time and all sites retained seagrass for the duration of the study.

1018. Brooks S and Hale J 2020, 'Corner Inlet Ramsar habitat mapping', report for West Gippsland Catchment Management Authority (WGCMA), Traralgon, Victoria.
1019. Hale J 2016, 'Ecological character description addendum - Corner Inlet Ramsar site', Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria.
1020. Study area defined in: Pope A, Monk J and Ierodiaconou D 2013, 'Corner Inlet and Nooramunga marine habitat mapping project: part II', Deakin University, Warrnambool, Victoria.
1021. Brooks S and Hale J 2020, 'Corner Inlet Ramsar habitat mapping', report for West Gippsland Catchment Management Authority (WGCMA), Traralgon, Victoria.
1022. Ibid.
1023. Ibid.
1024. Ibid.
1025. Stevenson J 2017, 'Sea searching in seagrass: 10 years of citizen science seagrass monitoring in Corner Inlet, Victoria, Australia', Parks Victoria, Melbourne.

Water quality is not routinely measured in Corner Inlet however researchers note the health and extent of Corner Inlet's important habitats (such as seagrass meadows, sand flats, mangroves and saltmarsh) can be affected by nutrient and sediment pollution. This pollution has an impact on the delicate balance of organisms that rely on these habitats. During this century, changes in local seagrass health and distribution (and the presence of algae) have been of concern to local fishers, recreational users and local community members.[1026]

Research on the link between seagrass decline and fisheries productivity in Corner Inlet stated that there was a clear link between catchment nutrients/sediment, algal blooms and seagrass decline.[1027] Prior to this research, there was limited documentation on the type and extent of algal blooms in Corner Inlet. Research has identified two types of blooms, one which appears to be fuelled by nutrients coming from the natural breakdown of seagrass and has been occurring for many decades, and the other fuelled by nutrients originating in the catchment and which is increasing in impact over the past decade. These findings inform the ongoing nutrient/sediment reduction work in the catchment and the associated monitoring requirements.[1028]

Thousands of native short-spined sea urchins (*Heliocidaris erythrogramma*) have invaded *Posidonia australis* seagrass in Corner Inlet and created large areas of bare sand. This overabundance of native short-spined sea urchins has decreased the broadleaf seagrass in the area by thousands of hectares.[1029] The urchin eats the seagrass, reducing much of the seagrass beds to a marine desert. This has resulted in the loss of feeding and shelter habitat for fish in the region which is an important fishing ground for Victoria's commercial and recreational fishers. Parks Victoria staff, officers from the Victorian Fisheries Authority and volunteers culled 57,000 urchins by hand in 2017.[1030] The Yarram Yarram Landcare Network, in partnership with the local Corner Inlet fishing community, is undertaking a project to locate, harvest and replant areas of the seagrass meadows.[1031]

CIN 35: Shellfish reefs

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga			
Justification for assessment ratings:	The past distribution of native flat oyster (Ostrea angasi) in Corner Inlet and Nooramunga is estimated to be almost the entire enclosed waterway and some sandy stretches on the open coast. *Ostrea angasi* is still present in many locations in Corner Inlet and Nooramunga but consists mainly of isolated clumps or individuals and no longer forms a continuous reef matrix.		

As part of a research project published by the Royal Society of Victoria in 2016, the history of coastal Victoria's shellfish reefs since the early 1800s was documented.[1032] The researchers did not identify any historical maps or detailed accounts of the locations of shellfish beds in Corner Inlet–Nooramunga.[1033] However, the area supported a dredge fishery that ran intensively from around 1840-1860, with numerous short revivals in the following 50 years.[1034] Historical newspaper articles all referred to the fishery as targeting oysters, with no evidence that mussels were caught and sold from the region.[1035] Research carried out during 2002 identified remnant *Ostrea angasi* beds (dead shell) in channels at 10-15 metres.[1036]

1026. Ford J, Barclay K and Day R 2016, 'Using local knowledge to understand and manage ecosystem-related decline in fisheries productivity', Fisheries Research and Development Corporation (FRDC), final project report, no. 2013-021, Melbourne, Victoria.
1027. Ibid.
1028. Ibid.
1029. Landcare Victoria 2020, 'Community leads restoration of seagrass at Corner Inlet', *Victorian Landcare and Catchment Management Magazine*, 77, pp. 20-21.
1030. Parks Victoria 2017, 'Seagrass meadows saved from sea urchin attack', media release 28 July 2017, Melbourne, Victoria.
1031. Victorian Marine and Coastal Council (VMaCC), 'Corner Inlet broadleaf seagrass restoration project' https://www.marineandcoastalcouncil.vic.gov.au/news-and-events/victorian-marine-and-coastal-awards/2020/corner-inlet-broadleaf-seagrass-restoration-project Accessed 14 August 2021.
1032. Ford J and Hamer P 2016, 'The forgotten shellfish reefs of coastal Victoria: documenting the loss of a marine ecosystem over 200 years since European settlement', *Proceedings of the Royal Society of Victoria*, 128, pp. 87-105 https://doi.org/10.1071/RS16008 Accessed 31 March 2021.
1033. Ibid.
1034. Bowen A 2012, 'Archaeology of the Chinese fishing industry in colonial Victoria', Studies in Australian Historical Archaeology, *Australasian Society for Historical Archaeology*, Sydney.
1035. Ford J and Hamer P 2016, 'The forgotten shellfish reefs of coastal Victoria: documenting the loss of a marine ecosystem over 200 years since European settlement', *Proceedings of the Royal Society of Victoria*, 128, pp. 87-105 https://doi.org/10.1071/RS16008 Accessed 31 March 2021.
1036. O'Hara T, Norman M and Staples D 2002, 'Baseline monitoring of Posidonia seagrass beds in Corner Inlet, Victoria', *Museum Victoria Science Reports*, 1, pp. 1–44.

The 2016 study concluded that Corner Inlet – Nooramunga supported large beds of *Ostrea angasi* in the many tidal channels, as well as it also being likely on the shallow banks co-existing with seagrass (Figure 61). Historical accounts of extensive oyster beds co-existing with scallops in 15–24 metres of water off the coast of Corner Inlet provide the only evidence of commercially fished oyster beds in the coastal waters of Victoria.[1037] Based on this information, the presumed past distribution of *Ostrea angasi* in Corner Inlet – Nooramunga is almost the entire enclosed waterway and some sandy stretches on the open coast.[1038]

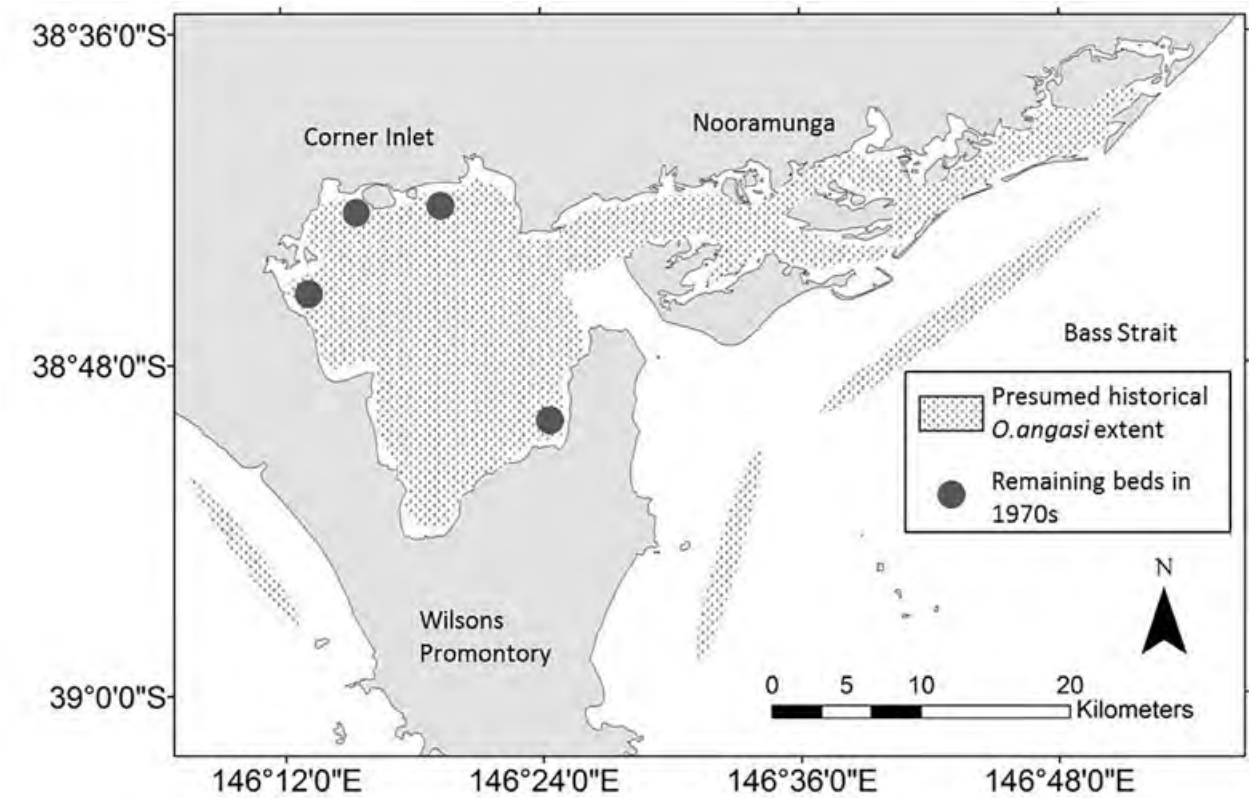


Figure 61: Approximate distribution of flat oyster in Corner Inlet–Nooramunga at European arrival derived from historical records and location of remaining beds in 1970s derived from fishermen's local knowledge.[1039]

Ostrea angasi is still present in many locations in Corner Inlet – Nooramunga but consists mainly of isolated clumps or individuals and no longer forms a continuous reef matrix. While oysters are likely still present in the areas recreationally fished during the 1960s and 1970s, they are not considered to be in abundances worthwhile for collection. A comprehensive study of the macrobenthos of Corner Inlet in 1986 did not record *Ostrea angasi* in either seagrass beds or mud flats, and they were similarly absent in a 2002 survey of seagrass associated fauna.[1040,1041]

1037. Ford J and Hamer P 2016, 'The forgotten shellfish reefs of coastal Victoria: documenting the loss of a marine ecosystem over 200 years since European settlement', *Proceedings of the Royal Society of Victoria*, 128, pp. 87-105 https://doi.org/10.1071/RS16008 Accessed 31 March 2021.
1038. Ibid.
1039. Ibid.
1040. Morgan G 1986, 'A survey of macrobenthos in the waters of Corner Inlet and the Nooramunga, southern Victoria, with an assessment of the extent of Posidonia seagrass', Victorian Fisheries and Wildlife paper no. 31, Museum of Victoria.
1041. O'Hara T, Norman M and Staples D 2002, 'Baseline monitoring of Posidonia seagrass beds in Corner Inlet, Victoria', *Museum Victoria Science Reports*, 1, pp. 1–44.

Theme 4: Seafloor Integrity and Health

CIN 36: Macroalgae on intertidal reefs

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The flora and fauna of intertidal reefs within the Corner Inlet Marine National Park and Nooramunga Marine and Coastal Park have not been surveyed.		

CIN 37: Macroalgae dominated subtidal reefs

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. Subtidal reefs have a minimal extent within the Corner Inlet Marine National Park and Nooramunga Marine and Coastal Park. The flora and fauna of these subtidal reefs have not been surveyed.		

Mud oyster (*Ostrea angasi*) on a reef
© Julian Finn, Museums Victoria/ CC BY-NC 4.0

Gippsland Lakes

GL 32: Conservation of marine ecosystems in protected areas

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The conservation of marine ecosystems in Gippsland Lakes' protected areas is covered in the Other Marine Protected Areas region.		

GL 33: Nitrogen cycle

Region		2021 status	2021 trend	2021 data
Gippsland Lakes	**Lake King**	●	→	●
	Lake Victoria	●	→	●
	Lake Wellington	●	→	●
Justification for assessment ratings:	These status and trend ratings for the Gippsland Lakes are based on dissolved inorganic nitrogen concentration assessments for the Lakes using thresholds derived from the framework established in the Australian and New Zealand Water Quality Guidelines. Dissolved inorganic nitrogen concentrations in Lake King are rated as good, but Lakes Victoria and Wellington were above the threshold for all five years from 2010 to 2015. Although there is a pattern of increased concentrations in high rainfall years, there are no sustained trends.			

The shallow, well-oxygenated environment of Lake Wellington provides ideal conditions for nitrification/denitrification within the lake sediments, which results in large losses of nitrogen to the atmosphere as nitrogen gas.[1042] The marine stratified environments of Lakes Victoria and King have more complex nitrogen cycles. Dissolved inorganic nitrogen comprises nitrate, nitrite and ammonium - all are readily available for plant (including algal) uptake and have been combined as a measure for this indicator.

Dissolved inorganic nitrogen concentration assessments for Gippsland Lakes in this report use thresholds derived from the framework established in the Australian and New Zealand Water Quality Guidelines (ANZECC and ARMCANZ 2000).[1043]

Water quality data for the Gippsland Lakes was interrogated to find a period that could be considered to represent good conditions – a period without algal blooms and with average rainfall conditions. The first two years of available data (1986–1988) was selected and thresholds have been calculated as 80th percentiles for each indicator for this period. In accordance with the prescribed method, annual 50th percentile (median) values of current conditions were compared with the thresholds.

1042. Longmore A and Roberts S 2006, 'Importance of sediment nutrients in the Gippsland Lakes', Gippsland Lakes Task Force.
1043. Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000, 'Australian and New Zealand guidelines for fresh and marine water quality'.

The criteria for the status assessments are provided below:

- Good = annual median values for the past five years were consistently better than the 80th percentiles of reference years (1986-1988).
- Fair = the annual median for one year in the past five years was worse than the 80th percentiles of reference years (1986-1988).
- Poor = the annual median for two or more of the past five years was worse than the 80th percentiles of reference years (1986-1988).

Trends have been assessed using a visual assessment of indicators over the complete timeframe data are available (1986-2015). The Exponentially Weighted Moving Average control charting technique has been used, which smooths the data and allows trends to be more easily detected.[1044]

Dissolved inorganic nitrogen concentrations in Lake King are rated as good, but in Lakes Victoria and Wellington were above the threshold for all five years from 2010 to 2015. Although there is a pattern of increased concentrations in high rainfall years, there are no sustained trends.

GL 34: Seagrass

Region	2021 status	2021 trend	2021 data
Gippsland Lakes		?	
Justification for assessment ratings:	The Limit of Acceptable Change (LAC) for seagrass in the Gippsland Lakes Ramsar site is being met for one of the two components of the LAC, with the other unable to be assessed. No trend can be determined for seagrass in the Gippsland Lakes as there are only two points in time upon which extent and condition can be compared. Seagrass extent can be highly variable. The decline from 1997 to 2016 does not provide any indication of variability over time or whether seagrass extent expanded and contracted several times over that period or is on a trajectory of decline.		

Seagrass in the Gippsland Lakes is an important habitat for fish and waterbirds and important to the local community. Seagrass extent and condition can be influenced by a wide variety of factors, but in the Gippsland Lakes light availability, salinity, nutrients and disturbance are likely to play significant roles.[1045]

Within the Gippsland Lakes, seagrass is only a feature in the more marine environment of Lakes Victoria and King. Three species of seagrass occur in Lakes Victoria and King: *Zostera nigricaulis* in deeper areas, *Zostera muelleri* in shallower, often intertidal, areas where the seagrass may be exposed at low tide, and *Ruppia spiralis*.

The limit of acceptable (LAC) change for seagrass in the Gippsland Lakes Ramsar Site is that:

- Total seagrass extent will not decline by greater than 50% of the baseline value (that is, by more than 2,165 ha) in two successive decades at a whole of site scale.
- Total mapped extent of dense and moderate *Zostera* will not decline by greater than 80% of the baseline values in two successive decades at any of the following locations:
    - Fraser Island
    - Point Fullerton, Lake King
    - Point King, Raymond Island, Lake King
    - Gorcrow Point – Steel Bay, Lake Victoria
    - Waddy Island, Lake Victoria.[1046]

1044. Emphron Informatics 2008, 'Channel deeping project: bay-wide monitoring programme - water quality', CSIRO Mathematical and Information Sciences, Melbourne.
1045. Roob R and Ball D 1997, 'Victorian marine habitat database, seagrass, Gippsland Lakes', report for Fisheries Victoria, and the Victorian Department of Natural Resources and the Environment (DNRE), The Marine and Freshwater Resources Institute, Queenscliff, Victoria.
1046. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Western Port Ramsar site management plan', East Melbourne, Victoria.

DELWP advises that the first component of the LAC is being met, with total seagrass extent ranging from 2,235 hectares in 2021 to 2,854 hectares in 2019. This data are yet to be published. It is worth noting that the value of 2,235 is within 100 hectares of exceeding the LAC as a 50% decline in seagrass extent from the 1997 baseline value.

Seagrass has been mapped and published at two points in time: 1997 and 2016. The 1997 mapping assessed the seagrass extent across the entirety of the main lakes, while the 2016 investigation covered a smaller area.[1047,1048] To compare the two assessments, the 1997 map was clipped to the extent of mapping in 2016.

Within the matching areas, seagrass extent declined from 2,600 hectares in 1997 to 1,600 hectares in 2016. In contrast to the decline in seagrass extent, seagrass condition was improved in 2016 with 63% of seagrass considered to be in dense patches, which was up from 50% in 1997.

No trend can be determined for seagrass in the Gippsland Lakes as there are only two points in time upon which extent and condition can be compared. Seagrass extent can be highly variable. The decline from 1997 to 2016 does not provide any indication of variability over time or whether seagrass extent expanded and contracted several times over that period or is on a trajectory of decline.

Most of the seagrass in the Gippsland Lakes is intertidal or shallow sub-tidal, growing in water less than two metres deep.[1049] These communities will be highly susceptible to increased temperatures and temperature extremes that are expected based on climate projections. Several studies in Australia and internationally have reported loss of seagrass following extreme heatwaves.[1050,1051,1052,1053] In several instances, there was a loss in root mass and carbon stores, which also limit seagrass recovery. In addition, sea level rise is likely to impact on seagrass in the Gippsland Lakes, as water depths increase, there will be less light available in deeper waters and limited capacity for landward migration.

GL 35: Shellfish reefs

Region	2021 status	2021 trend	2021 data
Gippsland Lakes			
Justification for assessment ratings:	Large mussel reefs can still be found in the entrance region of the Gippsland Lakes, which is why the status is fair despite the extent of shellfish reefs being noted to decline during the 20th century. No significant changes to shellfish reefs have been noted this century, so the trend has been assessed as stable.		

As part of a research project published by the Royal Society of Victoria in 2016, the history of coastal Victoria's shellfish reefs since the early 1800s was documented.[1054] The researchers concluded that, although there is no indication that a significant flat oyster fishery occurred in Gippsland Lakes during colonial times, they were likely to have been present in the Lakes, like they were in other nearby inlets such as Corner Inlet. Blue mussel may have been common in large beds throughout the lakes system for many years, although their abundance at the time of European arrival, and prior to the creation of the artificial entrance in 1889 is unclear. These large beds were most significant in the region from Metung to Lakes Entrances and were exploited by a dive fishery during the latter half of the twentieth century.[1055]

1047. Roob R and Ball D 1997, 'Victorian marine habitat database, seagrass, Gippsland Lakes', report for Fisheries Victoria and the Victorian Department of Natural Resources and the Environment (DNRE), the Marine and Freshwater Resources Institute, Queenscliff, Victoria.
1048. Kitchingman A 2016, 'Gippsland Lakes seagrass mapping', Arthur Rylah Institute for Environmental Research (ARI), Department of Environment, Land, Water and Planning (DELWP), Heidelberg, Victoria.
1049. Roob R and Ball D 1997, 'Victorian marine habitat database, seagrass, Gippsland Lakes', report for Fisheries Victoria, and the Victorian Department of Natural Resources and the Environment (DNRE), the Marine and Freshwater Resources Institute, Queenscliff, Victoria.
1050. Collier C and Waycott M 2014, 'Temperature extremes reduce seagrass growth and induce mortality', *Marine Pollution Bulletin*, 83(2), pp. 483–490.
1051. Fraser M, Kendrick, G, Statton J, Hovey R, Zavala-Perez A and Walker D 2014, 'Extreme climate events lower resilience of foundation seagrass at edge of biogeographical range', *Journal of Ecology*, 102(6), pp. 1528–1536.
1052. Thomson J, Burkholder D, Heithaus M, Fourqurean J, Fraser M, Statton J and Kendrick G 2015, 'Extreme temperatures, foundation species, and abrupt ecosystem change: an example from an iconic seagrass ecosystem', *Global Change Biology*, 21(4), pp. 1463–1474.
1053. Nowicki R, Thomson J, Burkholder D, Fourqurean J and Heithaus M 2017, 'Predicting seagrass recovery times and their implications following an extreme climate event,' *Marine Ecology Progress Series*, 567, pp. 79–93.
1054. Ford J and Hamer P 2016, 'The forgotten shellfish reefs of coastal Victoria: documenting the loss of a marine ecosystem over 200 years since European settlement', *Proceedings of the Royal Society of Victoria*, 128, pp. 87-105 https://doi.org/10.1071/RS16008 Accessed 31 March 2021.
1055. Ibid.

Theme 4: Seafloor Integrity and Health

Large mussel reefs can still be found in the entrance region of the Gippsland Lakes. Little is known of the shellfish community before the permanent opening of the Lakes in 1880s, but it is likely to have fluctuated significantly between freshwater and saltwater periods. Evidence of historical mussel and oyster presence at Mallacoota Inlet comes from middens and early historical accounts, but no fishery information is available.[1056]

GL 36: Macroalgae on intertidal reefs

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. Intertidal reefs are not a significant component of the Gippsland Lakes.		

GL 37: Macroalgae-dominated subtidal reefs

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. Subtidal reefs are not a significant component of the Gippsland Lakes.		

1056. Ibid.

Other Marine Protected Areas

OMPA 32: Conservation of marine ecosystems in protected areas

Region	2021 status	2021 trend	2021 data
Other marine protected areas			
Justification for assessment ratings:	This is a broad indicator that covers a range of marine protected areas and conservation efforts. In total, Victoria's marine protected areas cover 106,106 hectares or 10.4% of state waters. Based on 10.4% of all Victoria's marine coastal waters being covered by marine protected areas, Victoria does satisfy an international target for at least 10% marine protected area coverage. However, only 5.2% of Victoria's state waters are no-take zones where removing animals and plants is banned – Victoria has the second smallest proportion of no-take areas of any Australian state or territory. Parks Victoria reports that the condition of natural values is good or very good in 93% of marine parks. Based on this broad range of evidence, with Victoria's marine protected areas generally in good condition and meeting international target to conserve at least 10% of coastal and marine areas, but with a smaller spatial coverage of no-take zones relative to most other Australian jurisdictions, the status of this indicator is rated as fair. The trend is rated as stable because the area protected in marine parks has remained unchanged since 2002, while the condition of marine protected areas remains generally good.		

By assessing the area and type of marine ecosystems with formal protection, it is possible to determine whether Victoria is meeting international benchmarks for marine protection.

Parks Victoria manages 24 marine national parks and sanctuaries that were established in 2002. Extractive resource use is not permitted in these parks, which cover 53,076 hectares or 5.2% of Victoria's marine waters. Another six marine protected areas, established in 1986 and 1991 in South and West Gippsland, allow extractive commercial and recreational use and cover 53,030 hectares, or 5.2% of marine waters, and provide only partial protection.[1057] In total, Victoria's marine protected areas cover 106,106 hectares or 10.4% of state waters.

The final report of VEAC's Statewide Assessment of Public Land noted in 2017 that it is evident from preliminary assessments based on available information that the existing system of no-take marine protected areas has some gaps in representation, and individual marine protected areas may not meet the adequacy criterion.[1058] The report recommended that Victoria's marine environment be reviewed for the comprehensiveness, adequacy and representativeness of its marine protected areas when current work on marine habitat mapping and classification is completed and available.[1059]

The status of marine conservation can be assessed in several ways. One common way is to measure the extent of marine protected areas against international benchmarks for levels of protection, such as the Convention on Biological Diversity's (CBD) Aichi targets or the United Nations (UN) Sustainable Development Goals (SDGs). Both Aichi Target 11 and SDG Target 14.5 aim for at least 10% of coastal and marine areas to be conserved. The Aichi Target 11 in the CBD Strategic Plan for Biodiversity 2011–2020 is:

By 2020, at least 17 percent of terrestrial and inland water areas and 10 percent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape and seascape.[1060]

1057. This figure excludes the terrestrial areas in the Corner Inlet, Shallow Inlet and Nooramunga marine and coastal parks which comprise 10%, 20% and 40% of each, respectively. Data from Victorian Environmental Assessment Council (VEAC) 2014, 'Marine investigation final report', Melbourne, Victoria, p.99.
1058. Victorian Environmental Assessment Council (VEAC) 2017, 'Statewide assessment of public land', Melbourne, Victoria.
1059. Ibid.
1060. Convention on Biological Diversity, 'Quick guide to the Aichi biodiversity targets'.

The rationale for the Aichi Target 11 was: 'Well governed and effectively managed protected areas are a proven method for safeguarding both habitats and populations of species and for delivering important ecosystem services'.[1061] The UN SDGs reaffirmed the Aichi Target 11 in SDG Target 14.5: 'By 2020, conserve at least 10% of coastal and marine areas, consistent with national and international law and based on the best available scientific information'[1062]

Based on 10.4% of all Victoria's marine coastal waters being covered by marine protected areas, Victoria does satisfy the 10% international target for marine protected areas. However, this provides only part of the picture and consideration should then be given to the type of protection. 'No-take' zones are where removing animals and plants is banned. Fish populations within these areas can grow with limited human interference and potentially replenish fished populations outside the protected area.[1063] A 2019 report by the Victorian National Parks Association highlighted that Victoria has the second smallest proportion of no-take areas of any Australian state or territory.[1064] Australian research published in 2019 found that the benefits of marine protected areas for the replenishment of fished populations is likely to have been previously underestimated for most species of fish.[1065] The results of the 2019 research suggest that marine protected areas are not in conflict with the interests of fishers, as is often argued. While marine protected areas restrict access to local populations of fish, fishers still benefit from their disproportionate effect on fish numbers, with the researchers positing marine protected areas as a win-win strategy in this instance.[1066]

Analysis of where the protection is located is also useful to investigate the efficacy of current marine protection. This analysis requires a review of the percentage of each marine bioregion covered by marine protected areas and can verify whether the network comprises 'ecologically representative and well-connected systems of protected areas', a key aim of the Aichi Target. Of the five marine bioregions off Victoria's coastline, the Victorian Embayments bioregion is the most well represented in parks, with more than 60% of its area protected. Central Victoria, Flinders, Twofold Shelf and Otway have 2% or less of their area protected in parks. This means that only one of the five marine bioregions satisfies the Aichi target.

The Victorian State of the Environment 2018 Report found that Victoria's 24 marine national parks and sanctuaries 'cover only 5.2% of Victoria's marine and coastal waters, compared to the protection of 18% of Victoria's land in parks and reserves. The area protected in marine national parks has remained unchanged since 2002'.[1067,1068]

Australia's Marine Protected Areas were set up with a primary goal to 'establish and manage a comprehensive, adequate and representative system of MPAs to contribute to the long-term ecological viability of marine and estuarine systems, to maintain ecological processes and systems, and to protect Australia's biological diversity at all levels'.[1069] Parks Victoria's Signs of Healthy Parks has been initiated to provide a framework for systematic and integrated ecological monitoring of the health of the state's ecosystems.[1070] A draft state-wide monitoring plan based on conservation, management and monitoring priorities identified for each park through the Conservation Planning process, has been developed.[1071]

Signs of Healthy Parks is focusing on key ecological attributes and threats in at least one of the large marine national parks within each bioregion, currently identified as Discovery Bay Marine National Park (Otway bioregion), Point Addis Marine National Park (Central Victoria bioregion), Port Phillip Heads Marine National Park (Victorian Embayments bioregion), Wilsons Promontory Marine National Park (Flinders bioregion) and Cape Howe Marine National Park (Twofold Shelf bioregion).[1072]

1061. Ibid.
1062. United Nations, 'Sustainable Development Goal 14' https://sustainabledevelopment.un.org/sdg14 Accessed 19 May 2021.
1063. The Conversation 2019, 'No-take marine areas help fishers (and fish) far more than we thought' https://theconversation.com/no-take-marine-areas-help-fishers-and-fish-far-more-than-we-thought-119659 Accessed 6 April 2021.
1064. Victorian National Parks Association (VNPA) 2019, 'Marine protected area review June 2019', Carlton, Victoria.
1065. Marshall D, Gaines S, Warner R, Barneche D and Bode M 2019, 'Underestimating the benefits of marine protected areas for the replenishment of fished populations', *Frontiers in Ecology and the Environment*, 17, pp. 407–413.
1066. The Conversation 2019, 'No-take marine areas help fishers (and fish) far more than we thought' https://theconversation.com/no-take-marine-areas-help-fishers-and-fish-far-more-than-we-thought-119659 Accessed 6 April 2021.
1067. Commissioner for Environmental Sustainability (CES) 2018, 'Victorian State of the Environment 2018', Melbourne, Victoria.
1068. Parks Victoria 2020, 'Annual report 2019-20', Melbourne, Victoria https://www.parks.vic.gov.au/-/media/f0f4aa2dfacd43948158493c6d0b7855.pdf?la=en&hash=6E3FC66C70DE08527982AE1D9653B5C821B2B44E Accessed 5 April 2021.
1069. Australian and New Zealand Environment and Conservation Council (ANZECC) Task Force on Marine Protected Areas 1998, 'Guidelines for establishing the national representative system of marine protected areas', Canberra, Australia.
1070. Parks Victoria, 'Signs of healthy parks' https://www.parks.vic.gov.au/get-into-nature/conservation-and-science/science-and-research/signs-of-healthy-parks Accessed 25 July 2021.
1071. Ierodiaconou D, Wines S, Carnell P, Tinkler P, Allan B, Carey J, Young M, Howe S, Pocklington J 2020, 'An enhanced signs of healthy parks monitoring program for Victoria's marine national parks and marine sanctuaries: Point Addis marine national park', Parks Victoria technical series no. 114, Melbourne, Victoria.
1072. Ibid.

Parks Victoria is progressing monitoring and assessment with plans to publish Technical Reports within the next couple of years for Port Phillip Heads, Wilsons Promontory, Cape Howe and Discovery Bay Marine National Parks. The completion of these technical reports will enable a more confident status assessment to be made for this indicator in future State of the Marine and Coastal Environment reports. A technical report focussing on Point Addis Marine National Park was published in 2020.

In the State of the Parks reports, Parks Victoria periodically reports on the management effectiveness for, and the condition of, the marine protected areas that it manages. The State of the Parks 2018 is the most recent State of the Parks Report; it was published during 2020 and based on data collected up to and including 2018.[1073] Data included in the State of the Parks 2018 shows the condition of natural values was reported to be good or very good in 93% of marine parks (75% by marine park area).

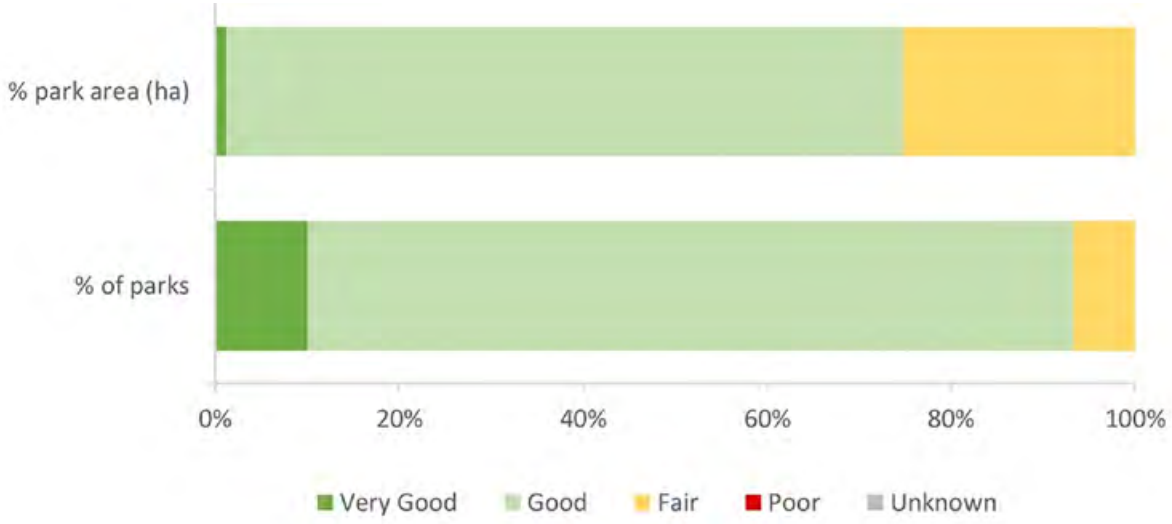


Figure 62: Condition of natural values for marine parks (n=30) in 2018.[1074]

However, despite this very positive rating, management objectives for marine pests and nature conservation were fully or substantially met for fewer than half of marine parks.[1075]

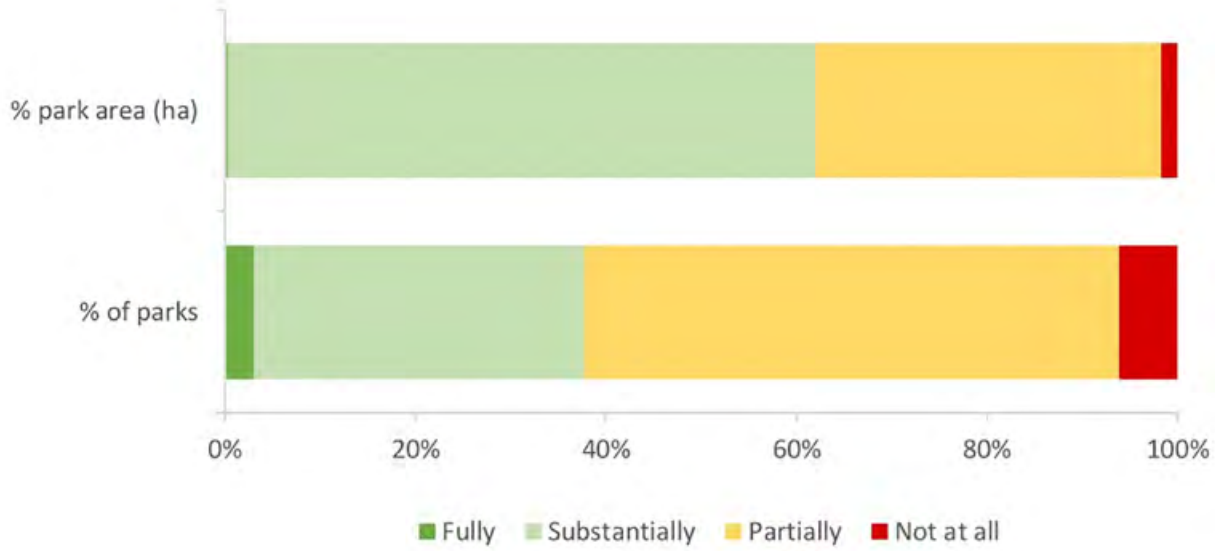


Figure 63: Extent that management objectives were met for nature conservation in marine protected areas (n=30) in 2018.[1076]

1073. Parks Victoria 2020, 'State of the parks 2018', Melbourne, Victoria.
1074. Ibid.
1075. Ibid.
1076. Ibid.

A particularly noteworthy item was the reporting of the impact of key threats on conservation values. Marine pests, pathogens and over-abundant natives were listed as a major, extreme or unknown threat in nearly 60% of parks. A knowledge gap on the the impact of marine pests, pathogens and over-abundant natives is highlighted by it being rated as an unknown threat for nearly 40% of marine parks.[1077]

Counts of a selection of marine flora and fauna species were reported for 13 marine national parks and sanctuaries as part of State of the Parks 2018.[1078] The number of marine flora and algae species in each park ranged from 231 in Port Phillip Heads Marine National Park to 34 in Bunurong Marine National Park. Unfortunately, a change in methodology for the data sets contributing to the species counts means data cannot be compared with those reported in previous State of the Parks reports. Similarly, the number of marine fauna species was also reported for many marine national parks, marine sanctuaries, coastal parks, coastal reserves and heritage parks, with a maximum number of marine fauna species (260) counted at Port Phillip Heads Marine National Park and a minimum (16) at Point Gellibrand Heritage Park.[1079]

OMPA 33: Nitrogen cycle

Region	2021 status	2021 trend	2021 data
Other marine protected areas	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The nitrogen cycle is covered in the regional indicators.		

OMPA 34: Seagrass

Region	2021 status	2021 trend	2021 data
Other marine protected areas	●	→	●
Justification for assessment ratings:	Parks Victoria data shows a 9% decline in seagrass extent occurred within marine protected areas during a three-year period from 2015. The change in seagrass extent is variable across the state's marine protected areas and is small enough in magnitude for the trend to be rated as stable. For example, there have been increases during the past decade in Corner Inlet and Nooramunga Marine and Coastal Parks, while there has been a decrease of *Amphibolis antartica* seagrass extent in the Port Phillip Heads Marine National Park from a high of 12% cover in 2003 to a low of 4% in 2019. The most recent estimate is that there are 18,287 hectares of seagrass habitat within Victorian marine protected areas.		

Victoria's State of the Parks 2018 publication reported there was 18,287 hectares of seagrass habitat within Victorian marine protected areas. This represents a decline of 1,877 hectares (9%) in seagrass extent within marine protected areas during a three year period from 2015 when 20,164 hectares of seagrass was reported in the Valuing Victoria's Parks document.

Parks Victoria runs Sea Search, a marine citizen science project that was set up to engage communities near the state's marine protected areas. The local community has been helping to monitor changes as part of the Corner Inlet Community Seagrass Monitoring Project (CICSMP), which was established through Sea Search.

1077. Ibid.
1078. Ibid.
1079. Ibid.

As reported in the Corner Inlet and Nooramunga regional indicator assessment, CICSMP was formed with the joint aims of collecting long term data on the health of *Posidonia australis* in Corner Inlet and connecting the community to the Inlet's diverse marine values.[1080] A report on CICSMP, published during 2017, describes the 11 years of data collection up to 2016. The project monitored *Posidonia australis* at 12 sites and collected data on substrate type, seagrass cover, epiphyte cover, leaf length, shoot density, faunal groups and reproduction success. The data reported showed that *Posidonia australis* was relatively stable over time and all sites retained seagrass for the duration of the study.

During 2020, Parks Victoria published research on the progress made developing a low-cost and repeatable methodology to identify seagrass change within Corner Inlet and Nooramunga Marine and Coastal Parks. This study utilised Sentinel 2 satellite imagery and supervised classification techniques to develop habitat maps comprising the seagrass classes of *Zostera* and *Posidonia*. The study showed an increase in seagrass and a decrease in substrate between 2011 and 2020, consistent with other habitat mapping efforts detailed in the Corner Inlet and Nooramunga regional indicator assessment.

Preliminary analysis supplied to the Commissioner for Environmental Sustainability shows that cover of the *Amphibolis antartica* seagrass in the Port Phillip Heads Marine National Park has slowly declined from a high of 12% cover in 2003 to a low of 4% in 2019. However, prior to declaration of the marine park, cover was as low as 1% in the autumn of 1998, which makes both the lower control limit and the lower limit of acceptable change below this.

OMPA 35: Shellfish reefs

Region	2021 status	2021 trend	2021 data
Other marine protected areas	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. Shellfish reefs are covered in the regional indicators.		

OMPA 36: Macroalgae on intertidal reefs

Region	2021 status	2021 trend	2021 data
Other marine protected areas	●	?	●
Justification for assessment ratings:	The status assessment of fair is based on the available information provided as part of Parks Victoria's long-term Intertidal Reef Monitoring Program to 2014, draft control charts from 2018 and a 2020 publication focussing on Point Addis Marine National Park. The absence of regular published reporting for many marine protected areas is reflected in an unclear trend and a confidence assessment of moderate rather than high.		

As reported in the Victorian State of the Environment 2018 Report, the condition of brown algae communities on intertidal reefs has been assessed in Parks Victoria draft control charts for marine national parks and sanctuaries. The communities were assessed as being in good condition in five parks, fair in six parks and poor in one park.

Point Addis Marine National Park

Neptune's necklace (*Hormosira banksii*) is an intertidal algae that forms large beds and habitats for macroinvertebrate grazers, predators, scavengers and microfauna.

1080. Stevenson J 2017, 'Sea searching in seagrass: 10 years of citizen science seagrass monitoring in Corner Inlet, Victoria, Australia', Parks Victoria, Melbourne.

In 2020, Parks Victoria published a technical report that focused on monitoring results in Point Addis Marine National Park. The technical report showcased new approaches for intertidal reef community assessments, such as using unmanned aerial vehicles (UAVs) for high-resolution remote sensing to successfully identify dominant algal canopy cover.[1081]

Within Point Addis Marine National Park, *Hormosira banksii* cover was maintained above the lower limit of acceptable change of 42% between 2005 and 2012. In 2013 coverage dropped below this threshold and was very close to exceeding the lower control limit. In the latest surveys in 2018 and 2019, *Hormosira* has now increased back above the lower limit of acceptable change.[1082]

Links to other indicator assessments

More information on macroalgae on intertidal reefs in Port Phillip Bay's marine protected areas is available in the Port Phillip Bay regional indicator assessment and narrative (indicator PPB 36: Macroalgae on intertidal reefs).

OMPA 37: Macroalgae-dominated subtidal reefs

Region	2021 status	2021 trend	2021 data
Other marine protected areas	●	?	●
Justification for assessment ratings:	The status assessment of fair is based on the available information provided as part of Parks Victoria's long-term Subtidal Reef Monitoring Program to 2014, draft control charts from 2018 and a 2020 publication focussing on Point Addis. The absence of regular published reporting for many marine protected areas is reflected in a confidence assessment of moderate rather than high. Parks Victoria is progressing monitoring and assessment with plans to publish Technical Reports within the next couple of years for Port Phillip Heads, Wilsons Promontory, Cape Howe and Discovery Bay Marine National Parks, which will address intertidal reef knowledge gaps in marine protected areas and increase the confidence in this indicator assessment in future State of the Marine and Coastal Environment reports.		

In 2020, Parks Victoria published a technical report that focused on monitoring results in Point Addis Marine National Park.[1083] While overall control charts showed that macroalgal indicators are in fair condition, the previously dominant species *Ecklonia radiata* has shown an alarming decline since 2012. While some increases in other canopy-forming brown algae have occurred since then, in the 2018 survey, canopy-forming algae has now fallen below the lower control limit.[1084] Shallow Reef Monitoring Program surveys previously revealed that coverage of *Ecklonia radiata* declined from a regional average of 29% cover in 2012 to 6% cover in 2013.[1085] There were bare stipes present in 2013 which indicated the loss was from some form of dieback disease.[1086] These were not identified in the photo quadrat analyses in the recent surveys. Coverage estimates for *Ecklonia radiata* for these sites have indicated a further decline to a regional average of 0.75% coverage in 2017 and complete absence in the 2018 Reef Life Survey.[1087]

These results indicate that *Ecklonia radiata* is being replaced by other species and the implications of this are unclear at this stage. It is also unclear whether this is a widespread issue on the west coast of Victoria or localised to Point Addis Marine National Park. Parks Victoria is progressing monitoring and assessment with plans to publish technical reports within the next couple of years for Port Phillip Heads, Wilsons Promontory, Cape Howe and Discovery Bay Marine National Parks, which will address knowledge gaps in marine protected areas and increase the confidence in this indicator

1081. Ierodiaconou D, Wines S, Carnell P, Tinkler P, Allan B, Carey J, Young M, Howe S, Pocklington J 2020, 'An enhanced signs of healthy parks monitoring program for Victoria's marine national parks and marine sanctuaries: Point Addis marine national park', Parks Victoria technical series no. 114, Melbourne, Victoria.
1082. Ibid.
1083. Ibid.
1084. Ibid.
1085. Ibid.
1086. Woods B, Edmunds M and Brown H 2014, 'Victorian subtidal reef monitoring program: the reef biota at Point Addis marine national park', June 2013. Parks Victoria technical series no. 94, Melbourne, Victoria.
1087. Ierodiaconou D, Wines S, Carnell P, Tinkler P, Allan B, Carey J, Young M, Howe S, Pocklington J 2020, 'An enhanced signs of healthy parks monitoring program for Victoria's marine national parks and marine sanctuaries: Point Addis marine national park', Parks Victoria technical series no. 114, Melbourne, Victoria.

assessment in future State of the Marine and Coastal Environment reports. Preliminary analysis supplied to the Commissioner for Environmental Sustainability shows that some subtidal reef macroalgal communities of the Port Phillip Heads Marine National Park, such as the brown macroalgae dominated beds (*Ecklonia radiata* and *Phyllospora comosa*), declined from the early 2000s to 2017, before recovering during 2018 and 2019 to be above the LAC. On the east coast (for example, Cape Howe Marine National Park and Beware Reef Marine National Parks), macroalgal beds have been under threat and Parks Victoria advises there has been a dramatic increase in urchin barrens.

Substantial losses of giant kelp (*Macrocystis pyrifera*) have been observed this century in marine areas off the coast of south-eastern Australia, with these losses not restricted to Victoria's marine protected areas. Broad-scale temporal patterns in giant kelp canopy cover are correlated with El Niño–Southern Oscillation events, while regional patterns are related to warming sea surface temperatures, raising concerns for the future of this species as a major habitat-forming kelp in Australia.[1088] A specific example of this in Victorian marine waters is the overgrazing by the overabundant black sea urchins (*Centrostephanus rodgersii*), which has extended its historical range from New South Wales into eastern Victoria due to warming waters. By overgrazing the seaweed on a reef, the urchins create extensive barrens leaving nothing but bare rock, which supports far less marine life. This has been occurring for more than a decade in Beware Reef Marine Sanctuary off the coast from East Gippsland. Since March 2019, more than 25,000 black sea urchins in the marine sanctuary have been culled to protect the reef and the species that call it home. In April 2021, Parks Victoria dive crews revisited sites where black sea urchins have been culled over the past two years and kelp forest regrowth was observed and few urchins were present in treated areas.[1089]

As reported in the State of the Environment 2018 Report, the condition of brown algae communities on subtidal reefs has been assessed in Parks Victoria draft control charts for marine national parks and sanctuaries. On subtidal reefs, the assessment revealed them to be in good condition in 14 parks and fair in 30.

The subtidal reef biota (macroalgae, invertebrates and fish) for a number of marine national parks and sanctuaries (and reference sites outside) were surveyed between 2011 and 2013, with the results compared with earlier surveys and published in Park's Victoria's technical report series.

Although the cover of crayweed (*Phyllospora comosa*) had declined in Cape Howe Marine National Park, algal species richness and diversity had increased with greater abundance of smaller understorey species.[1090] Algal species richness fluctuated at Beware Reef, while algal assemblages were generally stable. However, giant kelp (*Macrocystis pyrifera*) abundance declined, while bull kelp (*Durvillaea potatorum*) cover increased.[1091]

Macroalgae abundance remained high in Wilsons Promontory[1092] and Bunurong[1093] Marine National Parks. The abundance, richness and diversity of macroalgal species was stable throughout the survey period in Eagle Rock Marine Sanctuary,[1094] while there were no clear trends in Marengo Reefs[1095] and Merri[1096] Marine Sanctuaries.

1088. Butler CL, Lucieer VL, Wotherspoon SJ, Johnson CR 2020, 'Multi-decadal decline in cover of giant kelp Macrocystis pyrifera at the southern limit of its Australian range', *Marine Ecology Progress Series*, 653, pp. 1-18.
1089. Parks Victoria, 'Kelp forests recovering after urchin culls' https://www.parks.vic.gov.au/news/2021/05/21/00/23/kelp-forests-recovering-after-urchin-culls Accessed 14 August 2021.
1090. Edmunds M and Woods B 2014, 'Victorian subtidal reef monitoring program: the reef biota at Cape Howe marine national park', Parks Victoria technical series no. 99, Melbourne, Victoria.
1091. Edmunds M, Hallein E and Flynn A 2014, 'Victorian subtidal reef monitoring program: the reef biota at Beware Reef marine sanctuary', Parks Victoria technical series no. 88, Melbourne, Victoria.
1092. Woods B, Donnelly D and Edmunds M 2014, 'Victorian subtidal reef monitoring program: the reef biota at Point Cooke marine sanctuary', Parks Victoria technical paper series no. 93, Melbourne, Victoria.
1093. Davis S, Pritchard K and Edmunds M 2011, 'Victorian subtidal reef monitoring program: the reef biota at Bunurong marine national park', Parks Victoria technical series no. 84, Melbourne, Victoria.
1094. Edmunds M, Brown H and Woods B 2014, 'Victorian subtidal reef monitoring program: the reef biota at Eagle Rock marine sanctuary', Parks Victoria technical series no. 89, Melbourne, Victoria.
1095. McArthur M, Smith A, Davis, S, Edmunds M and Pritchard K 2011, 'Victorian subtidal reef monitoring program: the reef biota at Marengo Reefs marine sanctuary, Parks Victoria technical series no. 85, Melbourne, Victoria.
1096. Woods B and Edmunds M 2013, 'Victorian subtidal reef monitoring program: the reef biota at Merri marine sanctuary', Parks Victoria technical series no. 87, Melbourne, Victoria.

Commissioner *for* Environmental Sustainability Victoria

Theme 5
Pests and Invasive Species

Northern Pacific seastar (*Asterias amurensis*)

Background

The establishment and subsequent spread of invasive species is widely recognised as one of the most threatening processes contributing to global biodiversity loss. Monitoring is critical to determine whether their range is expanding, with new incursions requiring rapid management responses.

There are now more than 160 invasive marine species present in Port Phillip Bay. The impacts of some of these invasive species is significant, notably the northern Pacific seastar (*Asterias amurensis*) that has been shown to cause changes in fish populations in Port Phillip Bay. New invasive species continue to arrive in Port Phillip Bay, most recently the Asian shore crab (*Hemigrapsus sanguineus*) that was first detected at Mount Martha in late 2020. There are several known invasive marine species in Western Port, although the size and number of infestations is significantly less than in Port Phillip Bay.[1097]

Corner Inlet has remained relatively free of invasive marine species. Japanese kelp (*Undaria pinnatifida*) has been detected at Port Welshpool and the northern Pacific seastar has previously been detected at nearby Tidal River. The northern Pacific seastar was first detected in the Gippsland Lakes in 2015 and was spotted again in 2019.[1098] Both detections resulted in surveillance and removal activities. The species is extremely difficult to eradicate and can rapidly establish large populations in new areas. To demonstrate the risk posed to Gippsland Lakes, estimates indicated the population of northern Pacific seastars in Port Phillip Bay had reached 165 million, five years after they were first detected.[1099]

The detection, monitoring and management of invasive plants is a complex and important process to ensure the adverse effects of invasive plants are minimised. The State of the Parks 2018 reported on impacts from weeds and pest animals along the Victorian coastline.

The management and coordination of marine pest management across agencies remains a challenge - especially once they become established in the state and are no longer a biosecurity issue managed by the Department of Jobs, Precincts and Regions (DJPR). An end-to-end pest management plan is required to cover the full invasion curve from prevention and preparedness through to on-ground asset-based management.

Comparison with insights from State of the Bays 2016 Report and the State of the Environment 2018 Report

New invasive species continue to arrive in Victoria's marine environments as well as continuing to spread to new areas within Victoria, and this is reflected in the trend of invasive marine species being rated as deteriorating for each geographic region in this report. The following invasive marine species have recently been detected in new areas:

- The Asian shore crab (*Hemigrapsus sanguineus*) was first detected at Mount Martha in Port Phillip Bay in late 2020.
- *Undaria pinnatifida*, also known as Wakame, has been observed in Corner Inlet since 2018.
- The northern Pacific seastar (*Asterias amurensis*) was first recorded in the Gippsland Lakes in 2015 and has since been found in several locations within the Lakes.

The SotB 2016 report did not contain any pests or invasive species indicator assessments but a marine pests narrative was provided in the 'Threats to the bays' and 'Habitats and their dependent species' chapters. For the SoE 2018 report, the status of the invasive marine species indicator was rated as poor for Port Phillip Bay, with that status assessment retained for this report.

1097. DELWP 2017, 'Western Port Ramsar site management plan', East Melbourne, Victoria.
1098. Australian Government Inspector-General of Biosecurity 2019, 'Pest and disease interceptions and incursions in Australia', p. 53, Mascot, NSW https://www.igb.gov.au/sites/default/files/documents/qid52819_igb_interceptions_and_incursions_report_-_final.docx Accessed 8 October 2021..
1099. Parry G, Heislers S and Werner G 2004, 'Changes in distribution and abundance of Asterias amurensis in Port Phillip Bay 1999-2003',

Theme 5: Pests and Invasive Species

Indicator 38: Invasive marine species

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay						
Western Port					N/A	N/A
Corner Inlet-Nooramunga					N/A	N/A
Gippsland Lakes					N/A	N/A
Other marine protected areas		?			N/A	N/A

Data source:	DJPR
Measures:	Number of invasive marine species | Change in the number of marine species Abundance of invasive marine species | Impact of invasive marine species

Why this indicator?

The establishment and subsequent spread of invasive species is widely recognised as one of the most threatening processes contributing to global biodiversity loss. Monitoring is critical to determine whether their range is expanding, with new incursions requiring rapid management responses.

The establishment and subsequent spread of invasive species is widely recognised as one of the most threatening processes contributing to global biodiversity loss. This is especially true for marine and estuarine ecosystems, which have experienced significant increases in the number of invasive species with the increase in global maritime trade.[1100]

The *Fisheries Act 1995* provides the legislative framework for the regulation and management of fishing and aquaculture activities. It also supports the protection and conservation of fisheries resources including the declaration of marine species as noxious aquatic species.

The *Flora and Fauna Guarantee Act 1988* formally lists the introduction of exotic organisms into Victorian marine waters as a threatening process.

Invasive marine species can impact habitats and ecological processes.[1101] Approximately 100 introduced marine species are now resident in Port Phillip Bay and can prey on – or outcompete – native species for space, food and light. Monitoring is critical to determine whether their range is expanding, with new incursions requiring rapid management responses.

1100. Richardson MF, Sherman CDH, Lee RS, Bott NJ, Hirst AJ 2016, 'Multiple dispersal vectors drive range expansion in an invasive marine species', *Molecular Ecology*, 25, pp. 5001–5014.
1101. Barbee N, Longmore A, Townsend K, Pettigrove V and Swearer S 2016, 'Technical knowledge synthesis for nutrient cycling, marine pests and pollutants in Port Phillip Bay: informing the development of the new Port Phillip Bay environmental management plan', Centre for Aquatic Pollution Identification and Management (CAPIM) technical report no. 60, University of Melbourne, Parkville, Victoria.

In Australia, biofouling (that is, the growth of marine plants and animals on the submerged parts of a vessel or infrastructure) has been estimated to contribute to 60% of invasive species translocations, and ballast water 24%.[1102] The figures for Port Phillip Bay are similar with contributions of biofouling and ballast water estimated to contribute to 65% and 18% of invasive species translocations.

All users of the marine environment have a role to play in preventing the introduction and spread of marine pests. Invasive marine species are often microscopic in size at early growth stages and can be transported on boats or equipment without the user being aware. At local and regional scales, the movement of fishing equipment and activities associated with aquaculture are potential pathways for the introduction of invasive marine species.[1103] Recreational activities are also potential pathways, through transport on recreational vessels and possibly recreational equipment. To help stop the spread of invasive marine species, Parks Victoria and other supporting agencies have been encouraging boat users to practice good vessel hygiene through the 'Check, Clean, Dry' method.[1104]

Non-indigenous species can also spread by non-human mediated mechanisms. For example, the cordgrass Spartina has been established in Gippsland and has encroached into the eastern end of Western Port through natural dispersal. Similarly, the seastar *Asterias amurensis* is well established in Port Phillip Bay, and incursions have been recorded in Gippsland at Andersons Inlet and Tidal River, which is consistent with natural range expansion via larval dispersal from Port Phillip Bay.[1105]

In addition to the introduction of species from outside Australia, climate change provides another pathway for the introduction of marine species to Victorian waters. Warmer water may result in Victorian waters becoming suitable for species from more northern latitudes. Some New South Wales species have already extended their range to Tasmania and Victoria and are capable of breeding there, notably the urchin *Centrostephanus* and various fish.[1106,1107]

These temperature-tolerant invasive species could out-compete and exclude native species from coastal waters.[1108]

The eradication of invasive marine species is only possible in very limited circumstances, and so the primary management focus is the prevention of their introduction and spread. But the growing number of vessels operating in Victorian waters could undermine these efforts. For example, wakame (*Undaria pinnatifida*) was initially confined to northern Port Phillip Bay, but its range has expanded beyond Port Philip Bay to the Apollo Bay Harbour, Portland Harbour and more recently to Port Welshpool in 2018 where it is now considered established.

To minimise the risks associated with marine pests, the Australian government, in conjunction with state and territory governments, industry, research organisations and non-government organisations, has released MarinePestPlan 2018-2023.[1109] The five objectives of the plan are to:

- minimise the risk of marine pest introductions, establishment and spread
- strengthen the national marine pest surveillance system
- enhance Australia's preparedness and response capability for marine pest introductions
- support marine pest biosecurity research and development
- engage stakeholders to better manage marine pest biosecurity.

1102. Department of Agriculture, Fisheries and Forestry (DAFF) 2010, 'The relative contribution of vectors to the introduction and translocation of invasive marine species', Australian Government, Canberra.
1103. Melbourne Water 2011, 'Understanding the Western Port environment – a summary of current knowledge and priorities for future research'.
1104. Parks Victoria 2018, 'Check clean dry', Melbourne, Victoria https://www.parks.vic.gov.au/-/media/project/pv/main/parks/documents/get-into-nature/conservation-and-science/marine-docs/check-clean-dry_stop-the-spread-marine-pests.pdf?la=en&hash=91C478C9982B8EAE17326AEFB7C52C2772920441 Accessed 03 July 2020.
1105. Richardson MF, Sherman CDH, Lee RS, Bott NJ, Hirst AJ 2016, 'Multiple dispersal vectors drive range expansion in an invasive marine species', *Molecular Ecology*, 25, pp. 5001–5014.
1106. Ling S 2008, 'Range expansion of a habitat-modifying species leads to loss of taxonomic diversity: a new and impoverished reef state', *Oecologia*, 156, pp. 883-894.
1107. Last P, White W, Gledhill D, Hobday A, Brown R, Edgar G and Pecl G 2011, 'Long-term shifts in abundance and distribution of a temperate fish fauna: a response to climate change and fishing practices', *Global Ecology and Biogeography*, 20, pp. 58-72.
1108. Sorte C, Williams S and Zerebecki R 2010, 'Ocean warming increases threat of invasive species in a marine fouling community', *Ecology*, 91(8), pp. 2198-2204.
1109. Department of Agriculture and Water Resources (DAWR) 2018, 'MarinePestPlan 2018-2023: the national strategic plan for marine pest biosecurity', Canberra, Australia.

Theme 5: Pests and Invasive Species

Indicator 39: Coastal invasive plants

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		?			N/A	N/A

Data source:	DELWP, DJPR, PV
Measures:	Area of treatment works to control weeds on land within 5 km of the Victorian coastline The impact of weeds | Threat of transformer weeds | Benefit minus cost of weed control Number of locations where invasive plants have been detected within 5 km of the Victorian coastline

Why this indicator?

Invasive coastal plants are a threat to Australia's biodiversity because they can displace native plant species, disrupt ecological processes such as fire and soil erosion patterns, and alter the genetic composition of native plant populations.

This indicator looks at invasive freshwater and terrestrial plants within five km of the Victorian coastline and encompasses the following terrestrial pest plant categories:

- Naturalised flora taxa – naturalised taxa originate from either outside Australia or interstate, or they are Victorian natives that have established long-term self-sustaining populations outside their pre-European range. Examples of Victorian natives that have become naturalised taxa include spotted gum (*Corymbia maculata*) and coastal umbrella-bush (*Acacia cupularis*), used as ornamental plantings.[1110] Naturalised flora taxa may not adversely impact native plants and/or animals or functioning ecosystems.
- Environmental weeds – environmental weeds are a subset of naturalised taxa. These plants invade native ecosystems and have the potential to adversely affect the survival of native plants, animals and functioning ecosystems. They include plant species that have been introduced to Australia from other countries, as well as native plant species that have spread beyond their previous natural range due to changed land management or practices (examples include sallow wattle, coastal wattle and coastal tea tree).[1111] Environmental weeds are a threat to Australia's biodiversity because they can displace native plant species, disrupt ecological processes such as fire and soil erosion patterns, and alter the genetic composition of native plant populations.[1112]

Transformer weeds are a subset of environmental weeds used in the Strategic Management Prospects (SMP) tool.[1113] A transformer weed is an invasive plant species that has the capacity to change the character, condition, form or nature of one or more ecosystems over substantial areas relative to the extent of that ecosystem. Transformer weed invasion can also alter the three-dimensional arrangement, nature and abundance of food resources within an ecosystem and as such can have a profound impact on animals.[1114] This indicator includes analysis of transformer weeds along the Victorian coastline.

SMP is a tool to help biodiversity managers identify and prioritise management options in a transparent, objective and repeatable way. SMP uses a spatially-explicit, landscape-scale approach to identify the most effective and efficient management actions to benefit biodiversity across Victoria.[1115]

1110. White M, Cheal D, Carr GW, Adair R, Blood K and Meagher D 2018, 'Advisory list of environmental weeds in Victoria', Arthur Rylah Institute for Environmental Research (ARI), technical report series no. 287, Department of Environment, Land, Water and Planning (DELWP), Heidelberg, Victoria.
1111. Ibid.
1112. Ibid.
1113. Department of Environment, Land, Water and Planning (DELWP) 2019, 'NaturePrint's strategic management prospects - transformer weeds', East Melbourne, Victoria.
1114. Ibid.
1115. Ibid.

Freshwater invasive plant species can form dense infestations that reduce the diversity of freshwater plant communities and have secondary impacts on freshwater animals such as invertebrates and fish.[1116] These impacts can alter freshwater habitats and threaten their long-term function if not managed.[1117] Freshwater invasive plants can also impact on recreational values such as swimming, fishing and boat navigation. Some dense plant populations can produce unpleasant odours that can affect those living near the water body or interacting with it.[1118] In irrigation channels, invasive plant species can limit water flow, and, in some cases of excessive plant growth, cause channels to overflow.[1119]

The SoE 2018 found the costs of the impact that freshwater invasive species have on waterways in Victoria had not been fully estimated.[1120] In addition to the direct costs of freshwater invasive species management, invasive species can undermine the outcomes of previous investment into waterway management activities.[1121]

Indicator 40: Coastal invasive animals

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		?			N/A	N/A

Data source:	DELWP, DJPR, PV
Measures:	Area of treatment works to control cats, deer, foxes, goats, pigs and rabbits within 5 km of the Victorian coastline | The impact of pest animals | Benefit minus cost of fox control Number of locations where invasive animals have been detected within 5 km of the Victorian coastline

Why this indicator?

Pest animals that have established populations in Victoria include foxes, rabbits, feral pigs, feral goats, feral horses, deer and feral cats, with their impacts recognised through several listings under the *Flora and Fauna Guarantee Act 1988*.

This indicator looks at invasive freshwater and terrestrial animals within five km of the Victorian coastline.

Invasive animals are those that originate from outside Australia and establish long-term self-sustaining populations here. Overabundant native animal populations (for example, koalas, kangaroos and possums) can also have localised negative impacts also require specific management.

Pest animals that have established populations in Victoria include foxes, rabbits, feral pigs, feral goats, feral horses, deer and feral cats, with their impacts recognised through several listings under the *Flora and Fauna Guarantee Act 1988*. Statewide pest animal population numbers in Victoria are currently not well described for all species, however, it is thought that populations, and their distribution, are expanding across Victoria.[1122]

Aside from carp (*Cyprinus carpio*), the SoE 2018 was unable to report on invasive freshwater animals.[1123] There was a lack of comprehensive and accurate statewide data on population numbers and trends of invasive freshwater pest plants and animals, and their threatening processes.

1116. Dugdale TM, Hunt TD and Clements D 2013, 'Aquatic weeds in Victoria: where and why are they a problem, and how are they being controlled?' *Plant Protection Quarterly*, 28(2), pp. 35-40.
1117. Ibid.
1118. Ibid.
1119. Ibid.
1120. Commissioner for Environmental Sustainability (CES) 2018, 'Victorian State of the Environment 2018, scientific assessments', Melbourne, Victoria.
1121. Department of Environment and Primary Industries (DEPI) 2013, 'Improving our waterways: Victorian waterway management strategy', Melbourne, Victoria.
1122. Environment, Natural Resources and Regional Development Committee 2017, 'Inquiry into the control of invasive animals on Crown land', Parliament of Victoria, Melbourne, Victoria.
1123. Commissioner for Environmental Sustainability (CES) 2018, 'Victorian State of the Environment 2018, scientific assessments', Melbourne, Victoria.

Port Phillip Bay

PPB 38: Invasive marine species

Region	2021 status	2021 trend	2021 data
Port Phillip Bay			
Justification for assessment ratings:	There are now more than 160 invasive marine species present in Port Phillip Bay. The impacts of some of these invasive species is significant, notably the northern Pacific seastar (*Asterias amurensis*) that has been shown to cause changes in fish populations in Port Phillip Bay. New invasive species continue to arrive in Port Phillip Bay, most recently the Asian shore crab (*Hemigrapsus sanguineus*) that was first detected at Mount Martha in late 2020.		

The Port of Melbourne, within Port Phillip Bay, is the largest container port in Australasia and an entry point for new marine species into Victoria.[1124] Consequently, there are many exotic species found in the bay.[1125] The Port of Geelong is also located within Port Phillip Bay.

With the Asian shore crab (*Hemigrapsus sanguineus*) being detected in late 2020, Port Phillip Bay has approximately 100 confirmed records of introduced and 61 cryptogenic (unknown origin) marine pests, although some estimates put the number at more than 300.[1126,1127] The pests of greatest concern are the northern Pacific seastar (*Asterias amurensis*), Asian shore crab (*Hemigrapsus sanguineus*), European fan worm (*Sabella spallanzanii*), European green crab (*Carcinus maenas* - also known as the European shore crab), wakame (*Undaria pinnatifida*), New Zealand screw shell (*Maoricolpus roseus*) and the Pacific oyster (*Magallana gigas*).

The northern Pacific seastar has been shown to have caused changes in fish populations in Port Phillip Bay, principally among fish species that feed on molluscs and polychaetes in areas where northern Pacific seastar densities were highest.[1128] The fish species impacted were the eastern shovelnose stingaree (*Trygonoptera imitata*), southern eagle ray (*Myliobatis australis*) and globefish (*Diodon nicthemerus*). The Northern Pacific seastar was first detected in Port Phillip Bay in 1995, and by 2000 a significant population of the seastar had established. It is a widespread and well-established marine pest in Port Phillip Bay and cannot be eradicated. Following rapid increases in numbers, competition between individuals for remaining food can lead to significant numbers of seastars dying and washing up on shore. There have been large numbers of dead seastars reported from around the bay at various times, including under Mornington Pier, where many thousands were seen by divers in 2010, and more recently there was a significant die-off at Carrum during 2019 when about 1,000 northern Pacific seastars washed ashore.[1129]

The Asian shore crab was first detected in Mount Martha in late 2020. Originally from the waters around Japan, Russia, North China and Korea, the species can spread rapidly and may consume and outcompete our native species including important scallops, mussels and oysters.[1130] The detection in late 2020 led to significant surveillance effort by government and the local community to attempt to delimit the population. The species has now been detected at ten sites from Point Cooke to Mount Martha with more than 200 individuals removed, including many reproductive females. The species is now considered established in Port Phillip Bay. Agriculture Victoria is working with research providers to determine the full distribution, potential impacts and means of rapid in-field detection of the species.

1124. Port of Melbourne Corporation, 'Port of Melbourne – facts and figures' https://www.portofmelbourne.com/about-us/factsandfigures/ Accessed 13 July 2021.
1125. Parks Victoria, 'Marine pests' https://www.parks.vic.gov.au/get-into-nature/conservation-and-science/conserving-our-parks/marine-pests Accessed 26 March 2021.
1126. Agriculture Victoria, 'Asian shore crab suspected in Mount Martha and Rickett's Point' https://agriculture.vic.gov.au/about/media-centre/media-releases/asian-shore-crab-suspected-in-mount-martha-and-ricketts-point Accessed 13 July 2021.
1127. Agriculture Victoria, 'Marine pests in Victoria' https://agriculture.vic.gov.au/biosecurity/marine-pests/marine-pests-in-victoria Accessed 26 March 2021.
1128. Parry G and Hirst A 2015, 'Decadal decline in demersal fish biomass coincident with a prolonged drought and the introduction of an exotic starfish', *Marine Ecology Progress Series*, 544, pp. 37–52.
1129. Agriculture Victoria, 'Northern pacific seastar die-off detected at Carrum', https://agriculture.vic.gov.au/about/media-centre/media-releases/northern-pacific-seastar-die-off-detected-at-carrum Accessed 29 March 2021.
1130. Agriculture Victoria, 'Asian shore crab suspected in Mount Martha and Rickett's Point' https://agriculture.vic.gov.au/about/media-centre/media-releases/asian-shore-crab-suspected-in-mount-martha-and-ricketts-point Accessed 13 July 2021.

The European fan worm is native to the Mediterranean Sea and the east Atlantic coast. The species was introduced to Port Phillip Bay, most likely via ballast water in the 1980s and had become abundant in Corio Bay by 1991. Researchers investigating the ecological impacts of the European fan worm noted concern with the species' indirect impact on nutrient cycling. The researchers found the efficiency of denitrification, the key ecosystem process that permanently removes nitrogen from the system, fell by 37-53% in the presence of the European fan worm.[1131] When denitrification efficiency is low, phytoplankton can proliferate, which may lead to decreased water quality and the threat of algal blooms. Further information on denitrification is provided in Indicator PPB 33: Nitrogen cycle.

Wakame is an introduced kelp. It was first detected in 1996 near Point Wilson and has progressively become established in all three of Port Phillip Bay's marine sanctuaries (Point Cooke, Jawbone and Ricketts Point) and at the Pope's Eye, Swan Bay, Point Lonsdale, Point Nepean sectors of the Port Phillip Heads Marine National Park.[1132,1133]

Parks Victoria has studied wakame in the marine sanctuaries of Port Phillip Bay and in 2017 reported that eradication efforts have had little impact on the kelp's overall abundance. The analysis also concluded there was little evidence the kelp had an ecological effect.[1134] The influences on wakame abundance included urchin-grazing levels, the cover of canopy-forming algae, and wave and nutrient regimes. The species has also been detected in Apollo Bay, Port Welshpool and Portland.[1135] There is substantial concern about the spread of the species outside of its known distribution.[1136] Native kelp can generally outcompete wakame.[1137] However, when native kelp forests are defoliated (for example, through processes such as urchin overgrazing) faster-growing invasive kelps can take over.[1138] Once established, wakame is challenging to eradicate and management efforts should therefore focus on preventing the spread and establishment of wakame in new locations. Once wakame is established, urchin grazing can help reduce the population.[1139,1140,1141]

PPB 39: Coastal invasive plants

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. More detail is provided in the statewide assessment. This reflects that information on coastal invasive plants is available at the statewide scale part of DELWP's NaturePrint package, Parks Victoria's Environmental Information System and Agriculture Victoria's databases.		

1131. Ross J, Longmore A and Keough M 2013, 'Spatially variable effects of a marine pest on ecosystem function', *Oecologia*, 172(2), pp. 525-538.
1132. Campbell S and Burridge T 1998, 'Occurrence of *Undaria pinnatifida* (Phaeophyta: Laminariales) in Port Phillip Bay', Victoria, Australia. *Marine and Freshwater Research*, 49, pp. 379-381.
1133. Victorian Environmental Assessment Council (VEAC) 2019, 'Assessment of the values of Victoria's marine environment' Melbourne, Victoria.
1134. Crockett P, Johnson K, Brenker M, Ierodiacanou D and Carnell P 2017, '*Undaria pinnatifida* in Port Phillip Bay marine sanctuaries: removal strategies and interactions with the native algal canopy', Parks Victoria technical series no. 113, Melbourne, Victoria.
1135. Ibid.
1136. Casas G, Scrosati R and Luz Piriz M 2004, 'The invasive kelp *Undaria pinnatifida* (Phaeophyceae, Laminariales) reduces native seaweed diversity in Nuevo Gulf (Patagonia, Argentina)', *Biological Invasions*, 6, pp. 411-416.
1137. Victorian Environmental Assessment Council (VEAC) 2019, 'Assessment of the values of Victoria's marine environment'.
1138. Valentine J, and Johnson C 2004, 'Establishment of the introduced kelp *Undaria pinnatifida* following dieback of the native macroalga *Phyllospora comosa* in Tasmania, Australia', *Marine and Freshwater Research*, 55, pp. 223-230.
1139. Primo C, Hewitt C, and Campbell M 2010, 'Reproductive phenology of the introduced kelp *Undaria pinnatifida* (Phaeophyceae, Laminariales) in Port Phillip Bay (Victoria, Australia)', *Biological Invasions*, 12, pp. 3081-3092.
1140. Crockett P, Johnson K, Brenker M, Ierodiaconou D and Carnell P 2017, '*Undaria pinnatifida* in Port Phillip Bay marine sanctuaries: removal strategies and interactions with the native algal canopy', Parks Victoria technical series no. 113, Melbourne, Victoria.
1141. Hewitt C, Campbell M, McEnnulty F, Moore K, Murfet N, Robertson B and Schaffelke B 2005, 'Efficacy of physical removal of a marine pest: the introduced kelp *Undaria pinnatifida* in a Tasmanian marine reserve', *Biological Invasions*, 7, pp. 251-263.

PPB 40: Coastal invasive animals

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. More detail is provided in the statewide assessment. This reflects that information on coastal invasive animals is available at the statewide scale as part of DELWP's NaturePrint package, Parks Victoria's Environmental Information System and Agriculture Victoria's databases.		

Western Port

WP 38: Invasive marine species

Region	2021 status	2021 trend	2021 data
Western Port	●	↙	●
Justification for assessment ratings:	The status assessment of fair reflects that there are several invasive marine species in Western Port, although the size and number of infestations is significantly less than in Port Phillip Bay.		

There are several known invasive marine species in Western Port, although the size and number of infestations is significantly less than in Port Phillip Bay.[1142] Researchers in the 1990s suggested the strong tidal currents in Western Port might be why there is a relative lack of pest species around the Port of Hastings, compared to those now common in Port Phillip Bay.[1143]

Many of the invasive marine species in Western Port occupy the marine habitats at Hastings.[1144,1145,1146] These introductions presumably occurred as the result of a range of shipping and boating activities.[1147] The potential for further introductions will increase if risks from international and domestic shipping are not managed effectively and population growth places more demands on boating facilities in Western Port.[1148]

Recreational and commercial marine watercraft can also contribute to the spread of pest and invasive marine species. To help stop their spread, Parks Victoria and other supporting agencies have been encouraging boat users to practice good vessel hygiene through the 'Check, Clean, Dry' method.[1149] It is also possible for invasive marine species to spread from established populations in Port Phillip Bay without human intervention. Modelling of Bass Strait water circulation indicates that larvae can be transported from Port Phillip Heads to the entrance of Western Port in less than four days under favourable wind conditions.[1150]

Many species of concern have planktonic larval stages that are longer than four days and could survive such a trip.

High priority marine pest species in Western Port include Pacific oysters (*Magallana gigas*) and the Asian bag mussel (*Arcuatula senhousia*), with confirmed detection and successful control activities for wakame (*Undaria pinnatifida*) and northern Pacific seastar (*Asterias amurensis*).

Another species of concern, the European fanworm (*Sabella spallanzanii*), has been recorded on mussel ropes in an aquaculture zone in the south-west of Western Port.[1151] Improved treatment of mussel ropes is expected to prevent further translocations of this species to Western Port.[1152]

1142. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Western Port Ramsar site management plan', East Melbourne, Victoria.
1143. Currie D and Crookes D 1997, 'Exotic marine pests in the Port of Hastings, Victoria', Marine and Freshwater Resources Institute, Queenscliff, Victoria.
1144. Ibid.
1145. Parry G and Cohen B 2001, 'Exotic species established in Western Port, including an assessment of the status of the exotic species *Corbula gibba, Alexandrium spp, Gymnodinium spp* and *Undaria pinnatifida*', report no. 45, Marine and Freshwater Resources Institute, Queenscliff, Victoria.
1146. Webb J and Keough M 2002, 'Measurement of environmental trace-metal levels with transplanted mussels and diffusive gradients in thin films (DGT): a comparison of techniques', *Marine Pollution Bulletin*, 44, pp. 222-229.
1147. Melbourne Water 2011, 'Understanding the Western Port environment – a summary of current knowledge and priorities for future research'.
1148. Ibid.
1149. Parks Victoria 2018, 'Check clean dry', Melbourne, Victoria https://www.parks.vic.gov.au/-/media/project/pv/main/parks/documents/get-into-nature/conservation-and-science/marine-docs/check-clean-dry_stop-the-spread-marine-pests.pdf?la=en&hash=91C478C9982B8EAE17326AEFB7C52C2772920441 Accessed 03 July 220.
1150. Jenkins G, Black K and Hamer P 2000, 'Determination of spawning areas and larval advection pathways for King George whiting in southeastern Australia using otolith microstructure and hydrodynamic modelling', *Marine Ecology Progress Series*, 199, pp. 231-242.
1151. Cohen B, McArthur M and Parry G 2000, 'Exotic marine pests in Westernport', Marine and Freshwater Resources Institute, Queenscliff, Victoria.
1152. Melbourne Water 2011, 'Understanding the Western Port environment – a summary of current knowledge and priorities for future research'.

WP 39: Coastal invasive plants

Region	2021 status	2021 trend	2021 data
Western Port	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. More detail is provided in the statewide assessment. This reflects that information on coastal invasive plants is available at the statewide scale as part of DELWP's NaturePrint package, Parks Victoria's Environmental Information System and Agriculture Victoria's databases. An indicator narrative is provided for the Western Port region because contextual information from specific studies is available.		

A 2018 study led by Melbourne Water noted that *Spartina anglica* (spartina or common cord grass) has been recognised as a significant threat to intertidal habitats and recent mapping across Western Port has shown a significantly reduced extent of spartina following recent management efforts.[1153] The same Melbourne Water study summarised field trials that showed a selective herbicide was not effective at controlling invasive tall wheat grass (*Lophopyrum ponticum*), while a broad-spectrum herbicide produced undesirable side-effects. Alternative control options need to be explored such as manual removal, burning, biological control and grazing. These two invasive plants are discussed further below.

Spartina anglica (spartina or common cord grass)

In Western Port, *Spartina anglica* (spartina or common cord grass) has been recognised as a significant threat to intertidal habitats.[1154] Melbourne Water and Parks Victoria have been managing the weed since the early 2000s and recent mapping has shown that the extent of spartina has been significantly reduced. Melbourne Water commissioned a ten-year management plan with the aim of eradicating the species from Western Port.[1155] The management plan has emphasised the importance of collecting robust baseline data on the extent of spartina and the health of infested saltmarsh to ensure that appropriate analysis and adaptation of management activities can be undertaken. The results of the eradication program may assist coastal managers in other regions, as well as managers dealing with nearby Spartina infestations at Andersons Inlet, Corner Inlet and Lake Connewarre.

Spartina is a rapidly-spreading grass species introduced from Europe in the 1920s to prevent shoreline erosion. Its strong, matt-like growth stabilises banks, but also out-competes native saltmarsh plants. Having taken over several of the region's saltmarsh areas, it is now known to be a major environmental threat to estuaries by:

- destroying native saltmarsh and seagrass
- affecting the habitat of migratory bird species and near-shore marine animals
- creating unnaturally deep and narrow intertidal canals that impact tidal flows.[1156]

A control program is helping re-establish indigenous saltmarsh, which provides habitat for the critically-endangered orange-bellied parrot and other animals.[1157]

This indicator links with the mangroves and saltmarsh indicators because the Victorian Saltmarsh Study identified 118 exotic species in Victorian saltmarshes.[1158] Of these, only two species – both from the genus *Spartina* - invade the lower intertidal areas occupied by mangroves in Western Port while the rest invade the drier middle and upper saltmarsh. As discussed above, spartina is a well-known weed in Western Port and has been subject to intensive control programs by Melbourne Water and Parks Victoria for several years. The remaining invasive species have received far less attention since the Victorian Saltmarsh Study was completed except for a recent control trial of *Lophopyrum ponticum* (tall wheat grass).

1153. Melbourne Water 2018, 'Understanding the Western Port environment 2018', Melbourne, Victoria.
1154. Department of Sustainability and Environment (DSE) 2003, 'Western Port Ramsar site strategic management plan', East Melbourne, Victoria.
1155. Ecology Australia 2014, 'Western Port (Bass River and the inlets): 10 year Spartina anglica (common cordgrass) management plan', Fairfield, Victoria.
1156. *Melbourne Water*, 'Spartina management in Western Port estuaries' https://www.melbournewater.com.au/building-and-works/projects/spartina-management-western-port-estuaries Accessed 29 March 2021.
1157. Ibid.
1158. Boon PI, Allen T, Brook J, Carr G, Frood D, Harty C, Hoye J, McMahon A, Mathews S, Rosengren N, Sinclair S, White M and Yugovic J 2011, 'Mangroves and coastal saltmarsh of Victoria: distribution, condition, threats and management', Institute for Sustainability and Innovation, Victoria University, Melbourne, VictoriaAllen R.

Lophopyrum ponticum (tall wheat grass)

Lophopyrum ponticum is a large tussock grass that is indigenous to Eastern Europe and Southern Russia and is one of the most serious invaders of coastal saltmarsh communities because of its robust lifeform and tolerance to saline conditions.[1159] Its salt tolerance led to its introduction to Australia in the 1940s as an alternate pasture species for salinity affected soils. While it is still recommended for use by Agriculture Victoria, it has recently been listed as a 'Potentially Threatening Process' under the Victorian *Flora and Fauna Guarantee Act 1988*, so its use in agricultural settings should be re-evaluated.[1160]

Lophopyrum ponticum is currently restricted to just a few locations in Western Port, including the lower Lang Lang River and Fisher's Wetland on Phillip Island.

A trial to examine the effects of two different weed control techniques was established at the lower Lang Lang River site in 2012, with the results published in 2016.[1161] One of the herbicides, Glyphosate, was found to be very effective at controlling *Lophopyrum ponticum* but was also responsible for severe adverse effects on most of the indigenous saltmarsh species found at the site. The other herbicide, Fluazifop-P, did not have a significant impact on *Lophopyrum ponticum*. The lack of success with a selective herbicide and the undesirable side effects of the broad-spectrum herbicide indicates that alternative invasive species control options need to be explored.[1162]

Melbourne Water's 2018 report Understanding the Western Port Environment summarised this research and the implications for management by noting there are a range of potential options including manual removal, burning, biological control and grazing. The report also discussed that, although the ecological impact of these techniques is reasonably well understood in terrestrial and riparian settings, there is very little information on how these techniques may affect the integrity of coastal saltmarsh communities.[1163] The 2016 study that investigated the effect of two herbicides on tall wheat grass focused largely on a single invasive species, but there are many more potentially harmful invasive species for saltmarsh environments. A good understanding of the magnitude of adverse ecological impacts for the most potentially threatening species is required to help coastal managers prioritise their control efforts.[1164]

WP 40: Coastal invasive animals

Region	2021 status	2021 trend	2021 data
Western Port	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. More detail is provided in the statewide assessment. This reflects that information on coastal invasive animals is available at the statewide scale as part of DELWP's NaturePrint package, Parks Victoria's Environmental Information System and Agriculture Victoria's databases.		

1159. Ibid.
1160. Melbourne Water 2018, 'Understanding the Western Port environment 2018', Melbourne, Victoria.
1161. Hurst T and Boon P 2016, 'Agricultural weeds and coastal saltmarsh in south-eastern Australia: an insurmountable problem?', *Australian Journal of Botany*, 64, pp. 308-324.
1162. Ibid.
1163. Melbourne Water 2018, 'Understanding the Western Port environment 2018', Melbourne, Victoria.
1164. Ibid.

Corner Inlet and Nooramunga

CIN 38: Invasive marine species

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga			
Justification for assessment ratings:	The status assessment of good reflects that Corner Inlet has remained relatively free of invasive marine species. The deteriorating trend is based on *Undaria pinnatifida*, also known as wakame being observed in the region since 2018.		

Corner Inlet has remained relatively free of invasive marine species. Wakame (*Undaria pinnatifida*) has been detected at Port Welshpool and the northern Pacific seastar (*Asterias amurensis*) has previously been detected at nearby Tidal River.

Wakame was detected at Port Welshpool in 2018, making it the first incursion to become established outside of Por Phillip Bay and Apollo Bay harbour.[1165] The introduction and spread of wakame is often associated with human activity and it is likely that it was introduced to Port Welshpool on the hulls of vessels coming from Port Phillip Bay.

The complete removal of the infestation from Port Welshpool is not feasible, however it is important to stop it from spreading to other areas such as the largely pristine waters of Wilsons Promontory Marine National Park. Many boats launch from Port Welshpool and travel to locations such as Refuge Cove but also further out to Lakes Entrance.[1166]

Detail on the short-spined sea urchin (*Heliocidaris erythrogramma*), an over-abundant native species in Corner Inlet, is provided for Indicator CIN 34: Seagrass.

CIN 39: Coastal invasive plants

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga		N/A	N/A
Justification for assessment ratings:	Not assessed for this region. More detail is provided in the statewide assessment. This reflects that information on coastal invasive plants is available at the statewide scale as part of DELWP's NaturePrint package, Parks Victoria's Environmental Information System and Agriculture Victoria's databases.		

CIN 40: Coastal invasive animals

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga		N/A	N/A
Justification for assessment ratings:	Not assessed for this region. More detail is provided in the statewide assessment. This reflects that information on coastal invasive animals is available at the statewide scale as part of DELWP's NaturePrint package, Parks Victoria's Environmental Information System and Agriculture Victoria's databases.		

1165. Gippsland Ports, 'Marine pest found at Port Welshpool' https://www.gippslandports.vic.gov.au/news/marine-pest-found-port-welshpool/ Accessed 29 March 2021.
1166. Ibid.

Gippsland Lakes

GL 38: Invasive marine species

Region	2021 status	2021 trend	2021 data
Gippsland Lakes			
Justification for assessment ratings:	The status assessment of fair reflects research published in 2016 that determined the Gippsland Lakes invasive marine species risk profile is lower than many other major ports along the Australian coast. The deteriorating trend is based on the arrival of the Northern Pacific seastar (*Asterias amurensis*) and Pacific oyster (*Magallana gigas*), with both species being spotted in the Lakes in recent years.		

Research published in 2016 analysed the invasive marine species risk profile for the Gippsland Lakes and found it to be lower than many other major ports along the Australian coast.[1167] This is because there is less vessel traffic from other domestic ports and far fewer international arrivals than most other Australian ports. International shipping visits to the Lakes are rare and, for commercial shipping, highly regulated. Nevertheless, fishing vessels move between ports within the south-eastern Australian region and marine pest species, such as the European green crab (*Carcinus maenas* – also known as the European shore crab), are known to occur with the lakes.[1168]

Other invasive marine species in the Gippsland Lakes include the Pacific oyster (*Magallana gigas*), the Asian bag mussel (*Arcuatula senhousia*) and the green macroalgae, dead man's fingers (*Codium fragile subspecies fragile*).[1169] Also recorded were three species listed on the National Introduced Marine Pest Information System database: pleated sea squirt (*Styela plicata*), stalked ascidian (*Styela clava*) and sea vase (*Ciona intestinalis*).[1170]

Except for the European green crab, which has been in the Gippsland Lakes since the early 1900s, all other target species in the 2016 study appear to have arrived in the Gippsland Lakes in the past 25 years. The Asian bag mussel and the introduced green macroalgae, dead man's fingers, are abundant and occur throughout the lower reaches of the Gippsland Lakes from Paynesville to Lakes Entrance. By comparison, the Pacific oyster has a restricted distribution within the Gippsland Lakes, and occurred at low densities, suggesting this species may be a relatively recent introduction.[1171]

The Gippsland Lakes contained fewer target marine pest species than the Port of Melbourne or Port of Geelong, but comparable numbers to that recorded in the ports of Hasting and Portland. In general, the Gippsland Lakes has target species that are widely distributed amongst Victorian ports and this pattern of introductions suggests the Gippsland Lakes is at further risk of future introductions, primarily via domestic marine traffic.[1172]

1167. Hirst A and Bott N 2016, 'Marine pests in the Gippsland Lakes: existing threats and future monitoring', Centre for Environmental Sustainability and Remediation, RMIT, Melbourne, Victoria.
1168. Ibid.
1169. Ibid.
1170. Department of Agriculture, Water and the Environment (DAWE), 'National introduced marine pest information system', Australian Government, Canberra https://www.marinepests.gov.au/pests/nimpis Accessed 29 March 2021.
1171. Hirst A and Bott N 2016, 'Marine pests in the Gippsland Lakes: existing threats and future monitoring', Centre for Environmental Sustainability and Remediation, RMIT, Melbourne, Victoria.
1172. Ibid.

The northern Pacific seastar (*Asterias amurensis*) is an invasive pest that can have an adverse effect on marine ecosystems, notably its consumption of the native shellfish that are an important part of the food chain.[1173] It was first detected in the Gippsland Lakes in 2015 and was spotted again in 2019.[1174] Both detections resulted in surveillance and removal activities. The species is extremely difficult to eradicate and can rapidly establish large populations in new areas. To demonstrate the risk posed to Gippsland Lakes, estimates indicate the population of the northern Pacific seastar in Port Phillip Bay had reached 165 million, five years after they were first detected.[1175] Shortly after this peak, the population crashed to roughly 36 million individuals. Since then, localised removal works have focused on key sites within Port Phillip Bay, but with little effect on overall population numbers.

GL 39: Coastal invasive plants

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. More detail is provided in the statewide assessment. This reflects that information on coastal invasive plants is available at the statewide scale as part of DELWP's NaturePrint package, Parks Victoria's Environmental Information System and Agriculture Victoria's databases.		

GL 40: Coastal invasive animals

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. More detail is provided in the statewide assessment. This reflects that information on coastal invasive animals is available at the statewide scale as part of DELWP's NaturePrint package, Parks Victoria's Environmental Information System and Agriculture Victoria's databases.		

1173. Gippsland Times 2015, 'Pacific seastar found in Gippsland Lakes' https://www.gippslandtimes.com.au/story/3283646/pacific-seastar-found-in-gippsland-lakes/ Accessed 29 March 2021.
1174. Australian Government Inspector-General of Biosecurity 2019, 'Pest and disease interceptions and incursions in Australia', p. 53, Mascot, NSW https://www.igb.gov.au/sites/default/files/documents/qid52819_igb_interceptions_and_incursions_report_-_final.docx Accessed 8 October 2021.
1175. Parry G, Heislers S and Werner G 2004, 'Changes in distribution and abundance of Asterias amurensis in Port Phillip Bay 1999-2003', Primary Industries Re*search Victoria, Mar*ine and Freshwater Systems report series no. 1, Victorian Department of Primary Industries (DPI), Queenscliff, Victoria.

Other marine protected areas

OMPA 38: Invasive marine species

Region	2021 status	2021 trend	2021 data
Other marine protected areas		?	
Justification for assessment ratings:	The status assessment of fair reflects research that highlights the risks invasive marine species pose to marine protected areas. For example, *Undaria pinnatifida*, also known as wakame, is an introduced kelp that was first detected in 1996 near Point Wilson and has progressively become established in all three of Port Phillip Bay's marine sanctuaries (Point Cooke, Jawbone and Ricketts Point) and Portsea Hole in the Port Phillip Heads Marine National Park. Not enough information is available to determine the trend and the confidence in the status and trend indicator assessments is rated as moderate.		

The introduction of invasive marine species threatens the integrity of marine biodiversity and may reduce the social and economic benefits derived from the marine environment.[1176]

Wakame (*Undaria pinnatifida*), is an introduced kelp. It was first detected in 1996 near Point Wilson and has progressively become established in all three of Port Phillip Bay's marine sanctuaries (Point Cooke, Jawbone and Ricketts Point) and Portsea Hole in the Port Phillip Heads Marine National Park.[1177,1178] Parks Victoria has studied wakame in the marine sanctuaries of Port Phillip Bay and reported that eradication efforts have little impact on the kelp's overall abundance. The analysis also concluded there was little evidence that the kelp had an ecological effect.[1179]

Parks Victoria listed introduced species of concern within marine national parks and sanctuaries as part of their marine natural values studies that were published during 2012.[1180]

As part of the State of the Parks Report preparation, park manager assessments are made for a range of metrics for each marine protected area. One part of the park manager assessments is a specific rating of the extent of the threat of marine pest invasion within each marine protected area. Parks Victoria supplied the Commissioner for Environmental Sustainability for with marine protected area assessments conducted for the 2018 State of the Parks Report. The threat of marine pest invasion was listed as widespread for several marine protected areas.

Introduced plants of concern include the wakame and three other algal species (*Grateloupia turuturu, Caulerpa racemosa var. cylindracea* and *Codium fragile subspecies fragile*). Introduced animals of concern include two echinoderms (northern Pacific seastar *Asterias amurensis*, New Zealand seastar *Astrostole scabra*), one arthropod (European green crab *Carcinus maenas* – also known as the European shore crab), one annelid (European fan worm *Sabella spallanzanii*), three molluscs (Asian bag mussel *Arcuatula senhousia*, New Zealand screw shell *Maoricolpus roseus*, Pacific oyster *Magallana gigas*), and one bryozoan (*Bugula neritina*). These species have all been identified in Victoria, some within marine protected areas, and have potential to spread to further marine protected areas.[1181]

A 2020 technical report for Point Addis Marine National Park that was published by Parks Victoria reported that no invasive or overabundant native species were found in Point Addis Marine National Park.[1182]

1176. Parks Victoria 2003, 'Victoria's system of marine national parks and marine sanctuaries management strategy 2003 – 2010', Parks Victoria and the Department of Sustainability and Environment (DSE), Melbourne
1177. Campbell S and Burridge T 1998, 'Occurrence of *Undaria pinnatifida* (Phaeophyta: Laminariales) in Port Phillip Bay', Victoria, Australia, *Marine and Freshwater Research*, 49, pp. 379-381.
1178. Victorian Environmental Assessment Council (VEAC) 2019, 'Assessment of the values of Victoria's marine environment', Melbourne, Victoria.
1179. Crockett P, Johnson K, Brenker M, Ierodiacanou D and Carnell P 2017, '*Undaria pinnatifida* in Port Phillip Bay marine sanctuaries: removal strategies and interactions with the native algal canopy', Parks Victoria technical series no. 113, Melbourne, Victoria.
1180. Parks Victoria 2012, 'Marine natural values study summary', Victoria, Melbourne.
1181. Ibid.
1182. Ierodiaconou D, Wines S, Carnell P, Tinkler P, Allan B, Carey J, Young M, Howe S, Pocklington J 2020, 'An enhanced signs of healthy parks monitoring program for Victoria's marine national parks and marine sanctuaries: Point Addis marine national park', Parks Victoria technical series no. 114, Melbourne, Victoria.

Statewide/broad-scale

SW 39: Coastal invasive plants

Region	2021 status	2021 trend	2021 data
Statewide		?	
Justification for assessment ratings:	Only limited time series data exists to track the impact of coastal invasive plants over time. The status of fair is due to varying impacts of invasive plants along the Victorian coastline.		

The detection, monitoring and management of invasive plants is a complex and important process to ensure the adverse effects of invasive plants are minimised.

Information supplied by DELWP shows that funded treatment works to control weeds took place on 64,299 hectares of land within five km of the Victorian coastline during 2019-20. This means that treatment works to control weeds occurred on 6% of land within five km of the Victorian coastline during 2019-20.

In the State of the Parks 2018 Report, which was published in 2020, the impact of weeds was included as a map, which has been duplicated in Figure 64.[1183]

The map shows the whole of Victoria, however the impacts from weeds along the Victorian coastline can be inferred as follows:

- major impacts in the far east (Croajingolong National Park) and the far west (much of the coastline from Portland to Nelson)
- moderate impacts along much of the coastline from Cape Otway to Anglesea, parts of French Island, coastal areas of Port Phillip Bay, Wilsons Promontory National Park and coastal areas surrounding Corner Inlet Marine National Park and Nooramunga Marine and Coastal Park
- sporadic areas with minor impacts
- large areas with unknown impacts, including most of the coastline from Portland to Cape Otway, and much of the coastal region between Western Port and Wilsons Promontory.

Wilsons Promontory National Park – Friends of the Prom volunteers
© Parks Victoria

1183. Parks Victoria 2020, 'State of the parks 2018', Melbourne, Victoria.

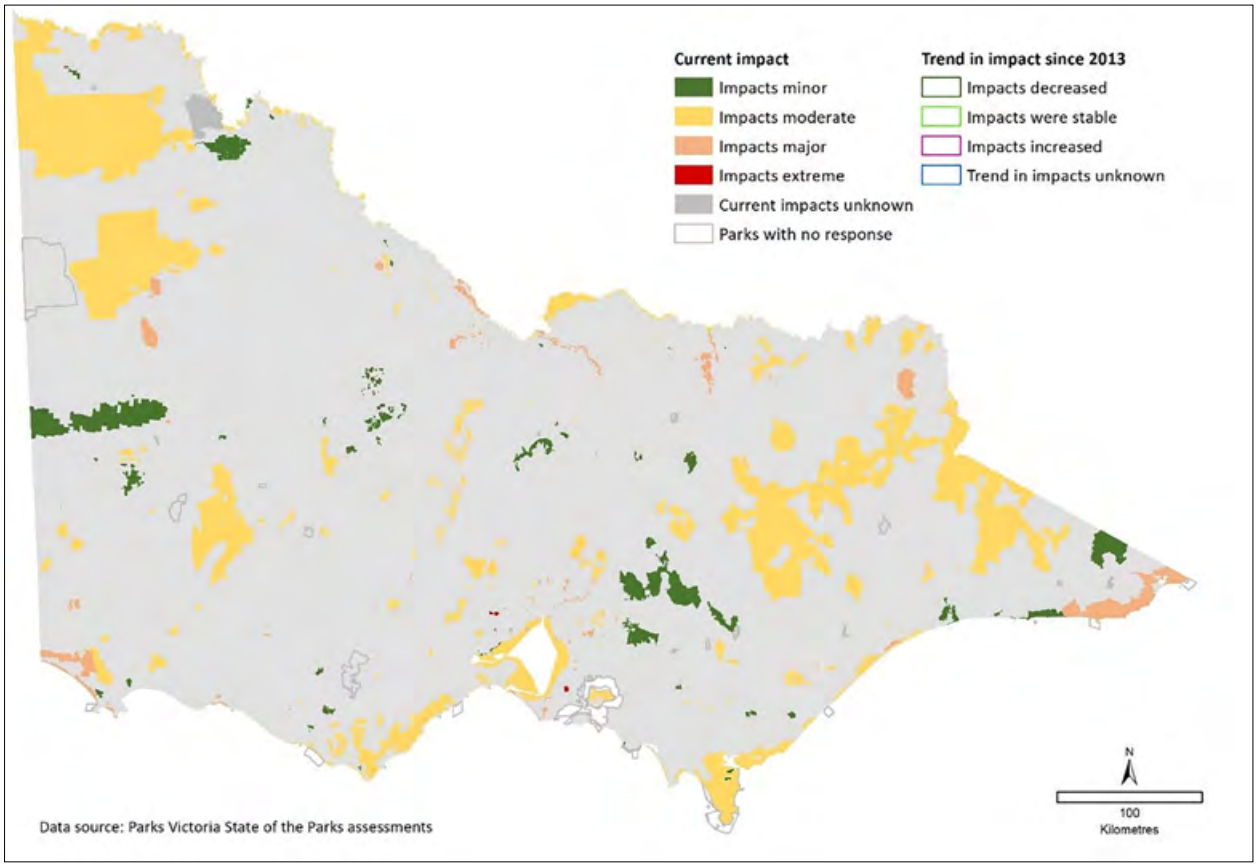


Figure 64: Impact of weeds in Victoria.[1184]

DELWP's Strategic Management Prospects (SMP) tool enables biodiversity managers to identify and prioritise management options in a transparent, objective and repeatable way. SMP uses a spatially-explicit, landscape-scale approach to identify the most effective and efficient management actions to benefit biodiversity across Victoria.[1185]

Threats, benefits and cost of action are mapped across Victoria as part of SMP. Figure 65 shows the threat of transformer weeds – those invasive plant species that have the capacity to change the character, condition, form or nature of one or more ecosystems over substantial areas relative to the extent of that ecosystem. In SMP, threat mapping shows where action-related landscape-scale threats are likely to occur across Victoria, represented through spatial models of threat likelihood and expressed on a scale of 1 to 100.[1186] As published on NatureKit during August 2021, there is generally a greater threat from transformer weeds along the western Victorian coastline.

1184. Ibid.
1185. Department of Environment, Land, Water and Planning (DELWP) 2019, 'NaturePrint's strategic management prospects - transformer weeds', East Melbourne, Victoria.
1186. Department of Environment, Land, Water and Planning (DELWP), 'NatureKit layers and datasets' https://www.environment.vic.gov.au/biodiversity/naturekit/nk-datalists#toc__id_1_biodiversity Accessed 2 August 2021.

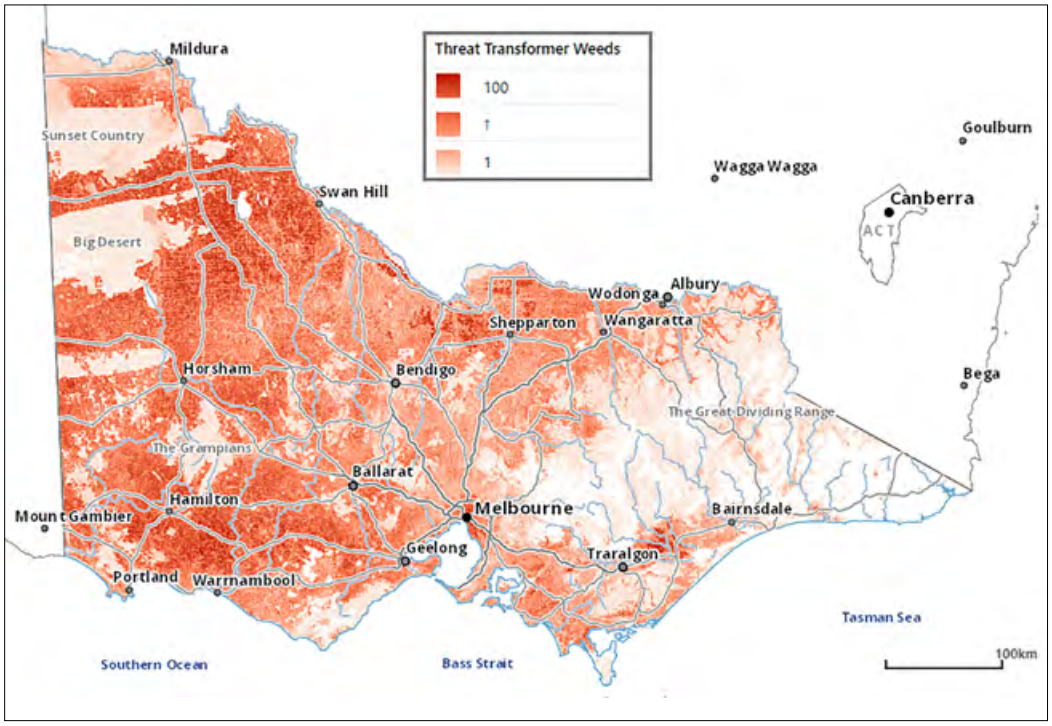


Figure 65: Threat of transformer weeds in Victoria.[1187]

A benefit minus cost analysis is also calculated as part of SMP and published by DELWP on NatureKit. It shows where biodiversity management actions will achieve the highest benefit to the most species across Victoria on a scale of 0 to 100. The weeds component of that analysis is shown below in Figure 66. It shows that the far western and eastern coastline, as well as French Island rank strongly as areas where biodiversity management actions are expected to provide high biodiversity benefits.

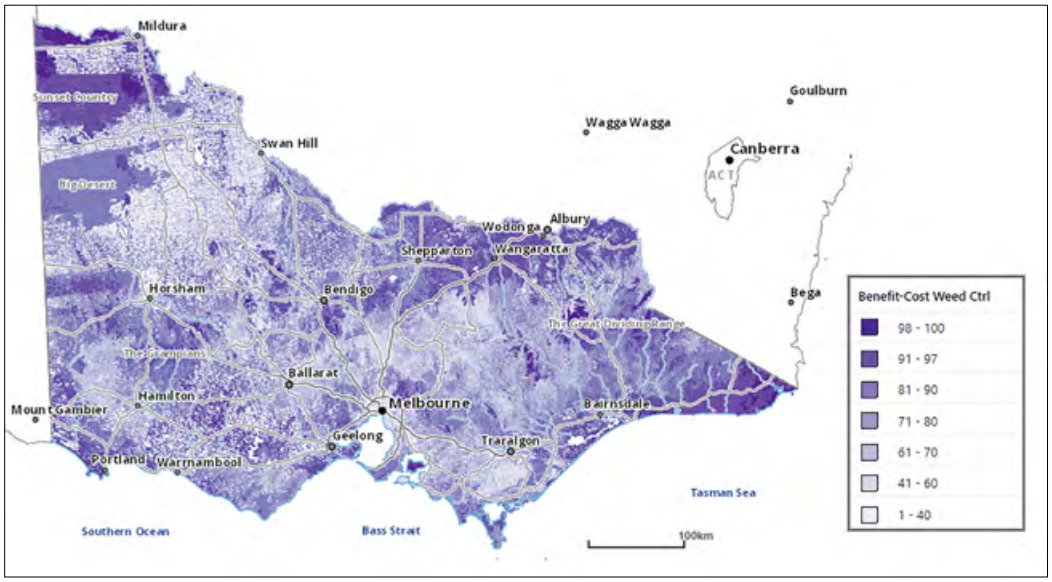


Figure 66: Benefit minus cost (weed control) in Victoria.[1188]

1187. Department of Environment, Land, Water and Planning (DELWP), 'NatureKit' https://maps2.biodiversity.vic.gov.au/Html5viewer/index.html?viewer=NatureKit Accessed 2 August 2021.
1188. Ibid.

Theme 5: Pests and Invasive Species

Under the *Catchment and Land Protection Act 1994* (CaLP Act) certain plants are declared as noxious weeds in Victoria.[1189] These plants cause environmental or economic harm or have the potential to cause such harm. They can also present risks to human health. Agriculture Victoria supplied data on these plants, with the records filtered to include only those located within five km of the Victorian coastline. The supplied data was categorised by management, control and enforcement activities.

There have been 40 species of coastal invasive plants listed in the CaLP Act that have been detected within five km of the Victorian coastline. Of the 1,403 localised sites where coastal invasive plants have been detected near Port Phillip Bay, the coastal invasive plant has been eradicated from 219 (16%) of these specific locations. Note that eradication in this sense means eradication of the invasive plant from a localised area rather than eradication of every individual of a particular species. Table 25 shows the breakdown of the invasive plants along the Victorian coastline categorised by risk and management activity.

Table 25: Number of locations where invasive plants have been detected within five km of the Victorian coastline.[1190]

	Eradicated from a specific location	Nominated for eradication from a specific location	Active Treatment at a specific location	Monitoring (current or planned) at a specific location	Surveillance at a specific location	No current action at a specific location	Total locations where invasive plants detected
High Risk invasive plants[1191]	214	70	14	57	0	0	355
Other established invasive plants[1192]	5	0	0	0	259	784	1048
Total	219	70	14	0	259	780	806

This indicator links to the Biodiversity 2037 Monitoring, Evaluation, Reporting and Improvement Framework that was published by DELWP in 2019 to help achieve Victoria's twenty-year plan for the future of Victoria's biodiversity as outlined in Protecting Victoria's Environment – Biodiversity 2037.[1193,1194] Chapter 3 of the Monitoring, Evaluation, Reporting and Improvement Framework contains the problem statement that 'Victoria's biodiversity continues to decline, and the current level of remedial effort is not sufficient or well enough targeted to make up for these losses in the face of climate change'. This problem statement is linked to outputs such as 'enable everyone to provide the right data to measure their contributions', 'provide information on how to make better on-ground decisions to maximise biodiversity outcomes' and 'integrate decision support tools into our processes', with an outcome that 'everyone has maximised their contribution to delivering the greatest overall benefit for biodiversity by undertaking the most beneficial actions in the relevant places'. The utility of tools embedded within Strategic Management Prospects demonstrate the increasing sophistication in the tools that map the threats, benefits and cost of management actions across Victoria, including the coastal areas. Therefore, the current confidence in the indicator assessment of moderate is expected to increase in future reports.

1189. Agriculture Victoria, 'Invasive plant classifications' https://agriculture.vic.gov.au/biosecurity/weeds/invasive-plant-classifications Accessed 2 August 2021.
1190. Data supplied by Agriculture Victoria.
1191. Contains emerging weed data collected during enforcement and administration of the *Catchment and Land Protection Act 1994* for weed species listed on the State Prohibited Weeds list.
1192. Contains invasive plant data collected during enforcement and administration of the *Catchment and Land Protection Act 1994* for weeds not listed as State Prohibited Weeds
1193. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Biodiversity 2037 monitoring, evaluation, reporting and improvements framework (MERF) Version 2.0', East Melbourne, Victoria.
1194. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Protecting Victoria's environment – biodiversity 2037', East Melbourne, Victoria.

SW 40: Coastal invasive animals

Region	2021 status	2021 trend	2021 data
Statewide		?	
Justification for assessment ratings:	Only limited time series data exists to track the impact of coastal invasive animals over time. The status of fair is due to varying impacts of invasive animals along the Victorian coastline.		

The detection, monitoring and management of invasive animals is a complex and important process to ensure the adverse effects of invasive animals are minimised.

Information supplied by DELWP shows that funded treatment works took place to control cats, deer, foxes, goats, pigs and rabbits on 354,608 hectares of land within five km of the Victorian coastline during 2019-20. This means that treatment works to control pest animals occurred on approximately one third of land within five km of the Victorian coastline during 2019-20. The majority of these treatment actions were focused on areas to control foxes (225,590 ha or 64% of the treatment area).

In the State of the Parks 2018 Report, which was published in 2020, the impact of pest animals was included as a map, which has been duplicated in Figure 67.[1195] The map shows the whole of Victoria, however the impacts from pest animals along the Victorian coastline can be inferred as follows:

- major impacts in the far east (Croajingolong National Park) and the far west (much of the coastline from Portland to Nelson), as well as Wilsons Promontory National Park and along much of the coastline from Cape Otway to Anglesea (the impacts in the far east and west were noted to be increasing from 2013)
- moderate impacts along the coastal areas surrounding Corner Inlet Marine National Park and Nooramunga Marine and Coastal Park
- sporadic areas with minor impacts
- some areas with unknown impacts, including most of the coastline from Portland to Warrnambool.

1195. Parks Victoria 2020, 'State of the parks 2018', Melbourne, Victoria.

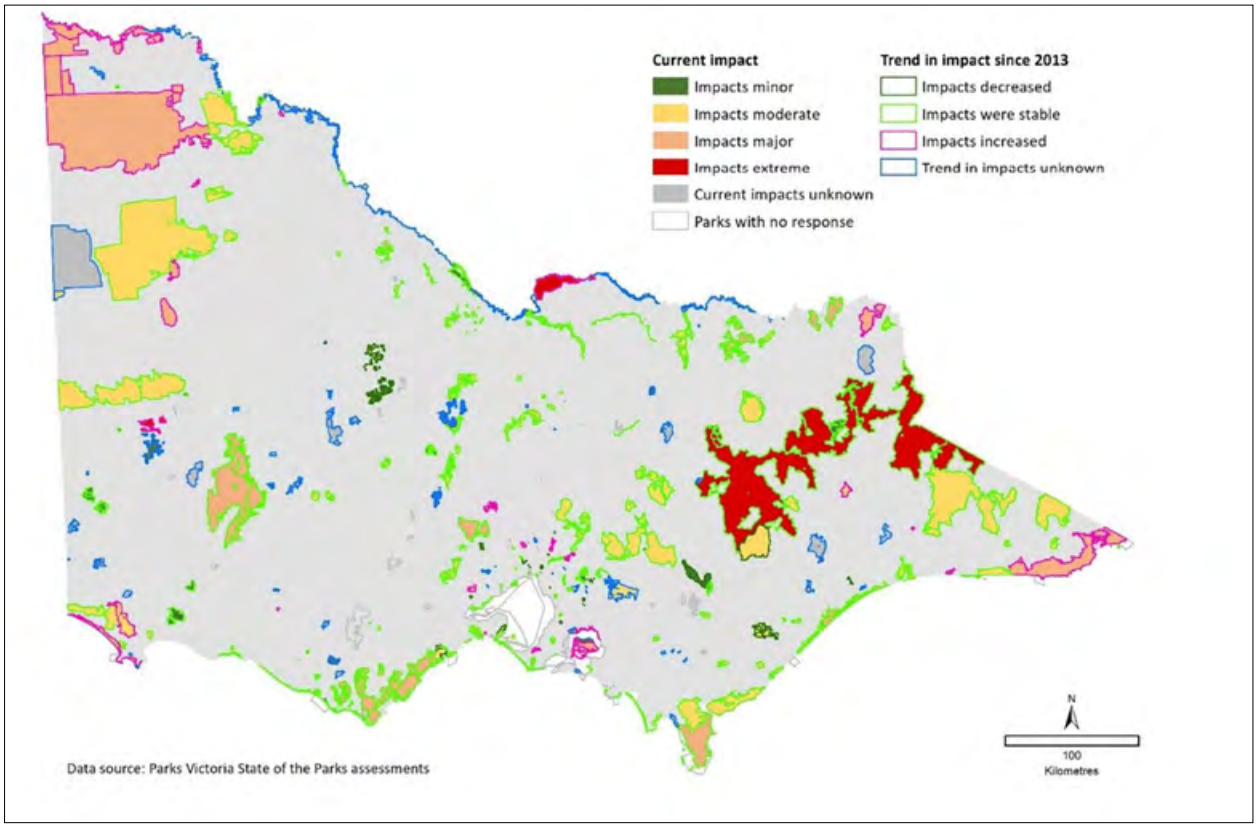


Figure 67: Impact of pest animals Victoria.[1196]

DELWP's Strategic Management Prospects (SMP) tool enables biodiversity managers to identify and prioritise management options in a transparent, objective and repeatable way. SMP uses a spatially-explicit, landscape-scale approach to identify the most effective and efficient management actions to benefit biodiversity across Victoria.[1197]

Threats, benefits and cost of action are mapped across Victoria as part of SMP for many pest animals. One facet of this is a benefit minus cost analysis that is published by DELWP on NatureKit. It shows where biodiversity management actions will achieve the highest benefit to the most species across Victoria on a scale of 0 to 100. The foxes component of that analysis is shown below in Figure 68 – foxes have been chosen to be displayed in the figure because the majority of treatment area along the coast is for foxes. The far western and eastern coastline, as well as the areas surrounding Wilsons Promontory National Park, rank strongly as areas where biodiversity management actions are expected to provide high biodiversity benefits.

1196. Ibid.
1197. Department of Environment, Land, Water and Planning (DELWP) 2019, 'NaturePrint's strategic management prospects - transformer weeds', East Melbourne, Victoria.

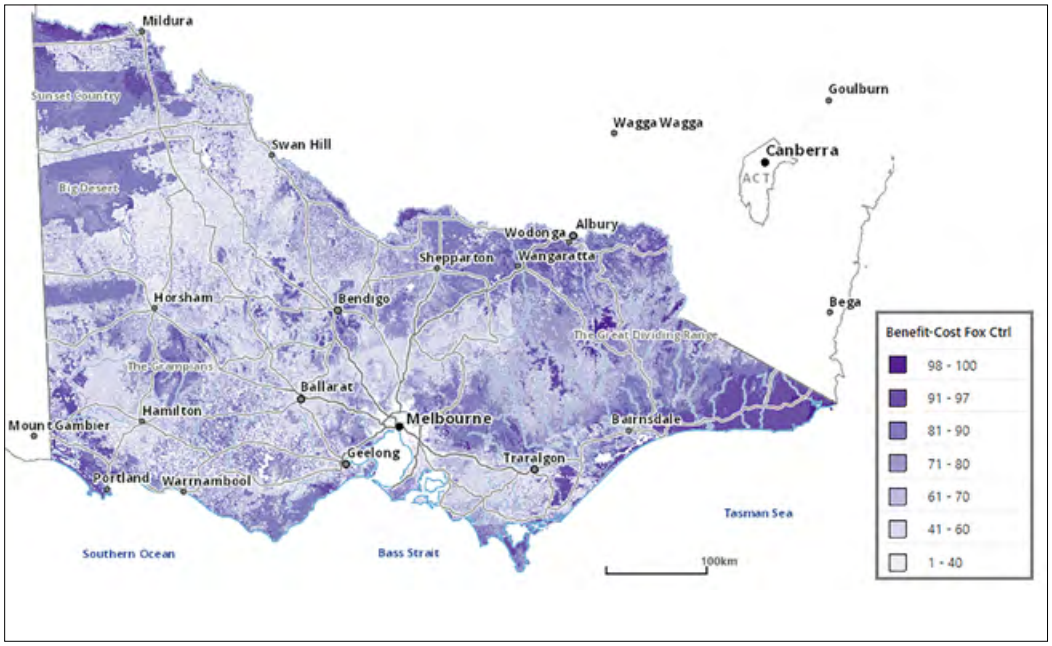


Figure 68: Benefit minus cost (fox control) in Victoria.[1198]

Under the *Catchment and Land Protection Act 1994* (CaLP Act) certain animals are declared as pest animals in Victoria.[1199] These animals are, or have the potential to become, a serious threat to primary production, Crown land, the environment or community health in Victoria.

Agriculture Victoria supplied data on these animals, with the records filtered to include only those located within five km of the Victorian coastline. Table 26 shows the breakdown of invasive animals categorised by the level of surveillance response.

Two species of coastal invasive animals were detected across 261 locations near the Victorian coastline and included in the Agriculture Victoria database. The two species were rabbits and feral pigs, with the infested area estimated to be 22,376 hectares. It is unclear whether the infested area is increasing or decreasing over time.

Table 26: Number of locations where invasive animals have been detected within five km of the Victorian coastline.[1200]

Established invasive animals[1201]	Under surveillance	Not under surveillance	Infested area (ha)
Rabbits	59	181	2,518
Feral pigs	0	21	19,859
Total	59	202	22,376

1198. Department of Environment, Land, Water and Planning (DELWP), 'NatureKit' https://maps2.biodiversity.vic.gov.au/Html5viewer/index.html?viewer=NatureKit Accessed 2 August 2021.
1199. Agriculture Victoria, 'Invasive animal classifications' https://agriculture.vic.gov.au/biosecurity/pest-animals/invasive-animal-classifications Accessed 2 August 2021.
1200. Data supplied by Agriculture Victoria.

Theme 5: Pests and Invasive Species

This indicator links to the Biodiversity 2037 Monitoring, Evaluation, Reporting and Improvement Framework that was published by DELWP in 2019 to help achieve Victoria's twenty-year plan for the future of Victoria's biodiversity as outlined in Protecting Victoria's Environment – Biodiversity 2037.[1202,1203] Chapter 3 of the Monitoring, Evaluation, Reporting and Improvement Framework contains the problem statement that 'Victoria's biodiversity continues to decline, and the current level of remedial effort is not sufficient or well enough targeted to make up for these losses in the face of climate change'. This problem statement is linked to outputs such as 'enable everyone to provide the right data to measure their contributions provide information on how to make better on-ground decisions to maximise biodiversity outcomes' and 'integrate decision support tools into our processes', with an outcome that 'everyone has maximised their contribution to delivering the greatest overall benefit for biodiversity by undertaking the most beneficial actions in the relevant places'. The utility of tools embedded within Strategic Management Prospects demonstrate the increasing sophistication in the tools that map the threats, benefits and cost of management actions across Victoria, including the coastal areas. Therefore, the current confidence in the indicator assessment of moderate is expected to increase in future reports.

Wildlife trapping at Wilsons Promontory National Park
© Parks Victoria

1201. Contains vertebrate pest data collected during enforcement and administration of the *Catchment and Land Protection Act 1994*.
1202. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Biodiversity 2037 monitoring, evaluation, reporting and improvements framework (MERF) Version 2.0', East Melbourne, Victoria.
1203. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Protecting Victoria's environment – biodiversity 2037', East Melbourne, Victoria.

Theme 6
Climate and Climate Change Impacts

Commissioner *for* Environmental Sustainability Victoria

Sea urchin (*Heliocidaris erythrogramma*)

Theme 6: Climate and Climate Change Impacts

Background

This theme includes assessments of how Victoria's climate is changing and the associated impacts of those changes. None of the Climate and Climate Change Impacts Indicators in this report were assessed as having a good status and deteriorating trends were observed for 21 of the 22 regional indicators where the trend was assessed.

Tidal gauge measurements show that sea levels have been rising by approximately 1.8 cms per decade at Williamstown since 1981 and 3.5 cms per decade at Stony Point from 1981. Future rises in sea level are projected with high confidence.[1204] Research published in 2020 found significant change in shoreline position was experienced by 13% of the Victorian coast between 1986 and 2017.[1205] The researchers estimated that erosion hotspots extend over 76.6 km of the coastline, equivalent to approximately 6.2% of the Victorian coast. Progradation hotspots (sediment deposits shifting the shoreline seaward) were estimated to extend over 72.7 km of coast, equivalent to approximately 5.9% of the coast. The results of a 2017 erosion vulnerability assessment show that more than 100 km of the Gippsland coastline is rated as having a very high vulnerability to coastal erosion. This means that more than a quarter of the entire Victorian coastline most at risk to erosion is located along the Gippsland Lakes.

By the 2050s, average temperatures in Victoria are projected to be 1.4 to 2.4°C warmer under a high emissions scenario (RCP 8.5) or 0.9 to 1.8°C warmer under a medium emissions scenario (RCP 4.5) compared to 1986–2005. By the 2090s, average temperatures in Victoria are projected to be 2.8 to 4.3°C warmer under a high emissions scenario (RCP 8.5) or 1.3 to 2.2°C warmer under a medium emissions scenario (RCP 4.5) compared to 1986–2005 (high confidence).

If the world succeeds in matching aspirations under the Paris Agreement to limit global warming to 2°C relative to a pre-industrial era baseline, then Victoria is also expected to warm by around 2°C in line with the global average.[1206] The analysis provided within the specific regional assessments of air temperature highlights that Victoria's coastal regions are likely to have already warmed by more than 1°C, with areas of the Port Phillip Bay coastline now regularly experiencing years with temperatures approximately 1.5 degrees warmer than an indicative pre-industrial era baseline.

The increasing frequency of marine heatwaves around Australia in recent years has caused permanent impacts on marine ecosystem health, marine habitats and species. These impacts include depleting kelp forests and seagrasses, a poleward shift in some marine species, and increased occurrence of disease. A 2019 international study found the ocean off southeast Australia was identified as being particularly vulnerable to marine heatwaves.[1207]

There is a fluctuating pressure being exerted on the water resources and agricultural sectors by wetter years interspersing a predominately drying climate. Rainfall reduction during the cool seasons is particularly important given the adverse impacts rainfall reductions can have on streamflows and the reduced reliability for water storage filling seasons. A 7-12% reduction in annual rainfall has been observed along the Port Phillip Bay coastline during the first two decades of the 21st century (compared to the final two decades of the 20th century), while a 13-20% reduction in cool-season rainfall has been observed. Notably, the biggest percentage rainfall reductions have occurred on the western side of Port Phillip Bay, which is also projected to have faster population growth in coming decades,[1208] placing increasing pressure on water resources.

1204. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019', East Melbourne, Victoria.
1205. Konlechner TM, Kennedy DM, O'Grady JJ, Leach C, Ranasinghe R, Carvalho RC and Ierodiaconou D 2020, 'Mapping spatial variability in shoreline change hotspots from satellite data; a case study in southeast Australia', *Estuarine, Coastal and Shelf Science*, 246, 107018.
1206. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019'.
1207. Smale DA, Wernberg T, Oliver ECJ, Thomsen M, Harvey BP, Straub SC, Burrows MT, Alexander LV, Benthuysen JA, Donat MG, Feng M, Hobday AJ, Holbrook NJ, Perkins-Kirkpatrick SE, Scannell HA, Gupta AS, Payne BL and Moore PJ. 2019, 'Marine heatwaves threaten global biodiversity and the provision of ecosystem services', *Nature Climate Change*, 9, pp. 306–312.
1208. DELWP 2019, 'Victoria in future 2019: population projections 2016 to 2056', East Melbourne, Victoria.

Comparison with insights from State of the Bays 2016 Report and the State of the Environment 2018 Report

The SotB 2016 Report did not contain any climate change indicator assessments but a climate change narrative was provided in the 'Threats to the bays' chapter. The SotB 2016 Report stated:

Climate change impacts are likely to include peak rainfall events that transport high loads of nutrients and pollutants to the bays in short time periods, and sea level rise that encroaches on important habitat. Water chemistry, water temperature, wind and storm patterns also contribute to a complex mix of potential impacts.

For the SoE 2018 Report, there were indicators assessing temperature, rainfall, sea level and sea-surface temperature, with the status of these indicators rated as fair to poor and the trends all rated as deteriorating.

Data available for the three most recent years generally shows further deteriorations in climatic indicators, however it is worth noting that, for many climatic variables, change is often only detected over longer time periods than the five-yearly state of environment reporting time scale. Furthermore, minimal changes in climatic variables can have significant impacts on environmental condition.

To complement the indicators previously reported, this report also includes new climate change indicators on ocean acidification, wave climate, coastal erosion, seawater intrusion into coastal aquifers and climate change impact on built infrastructure.

Point Nepean National Park
© Parks Victoria

Theme 6: Climate and Climate Change Impacts

Indicator 41: Rainfall

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		↙			N/A	N/A
Western Port		→			N/A	N/A
Corner Inlet-Nooramunga		↙			N/A	N/A
Gippsland Lakes		↙			N/A	N/A
Statewide					↙	

Data source:	BoM, CSIRO, DELWP
Measures:	Rolling 10-year average of annual rainfall | Rolling 10-year average of cool-season (April to October) rainfall | Percentage change in rainfall from 1980–99 to 2000–19

Why this indicator?

Rainfall is an important factor in plant growth. The timing and intensity of rainfall can influence the severity of pluvial and riverine floods which have social and community impacts, as well as environmental impacts for sediment and pollutants entering bays.

Rainfall over Victoria is highly variable from year to year, due to large-scale climate drivers such as the El Niño–Southern Oscillation. But beyond this variability, a drying trend is emerging. Below average rainfall has been recorded most years since the late 1990s. The main exceptions are 2010 and 2011 (influenced by strong La Niña events) and 2016 (influenced by a strong negative Indian Ocean Dipole) The rainfall projections suggest there is roughly an equal chance of wetter or drier conditions in the warm season.

Rainfall is an important factor in plant growth. The timing and intensity of rainfall can influence the severity of pluvial and riverine floods which have social and community impacts, as well as environmental impacts for sediment and pollutants entering bays.

Indicator 42: Air temperature

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		↙			N/A	N/A
Western Port		↙			N/A	N/A
Corner Inlet-Nooramunga		↙			N/A	N/A
Gippsland Lakes		↙			N/A	N/A
Statewide	N	N	N		↙	

Data source:	BoM, CSIRO, DELWP
Measures:	Rolling 10-year average of annual mean maximum temperature | Rolling 10-year average of summer mean maximum temperature | Temperature change (average daily maximum temperature in °C) per decade from the 1980s to the 2010s | Number of days when the daily maximum temperature exceeds 35°C

Why this indicator?

Temperature is an important factor in beach usage – when it is warmer people tend to head to the beach and this affects the utility and social and economic value of a beach, but also potentially accelerates degradation of the coastal environment if not properly managed. Temperature is also a factor in staffing for surf-lifesaving. Temperature increases the risk of heatstroke episodes and extreme heat can preclude many marine and coastal recreational activities.

Temperature is an important factor in beach usage. When it is warmer people tend to head to the beach and this affects the utility and social and economic value of a beach, but also potentially accelerates degradation of the coastal environment if not properly managed. Temperature is also a factor in staffing for surf-lifesaving. Temperature increases the risk of heatstroke episodes and extreme heat can preclude many marine and coastal recreational activities.

Victoria's climate has been warming since the 1950s, with the scale of the warming more pronounced this century – each year since 1997 has been warmer than the long-term average.

Temperatures are expected to be an average of 0.4 to 1.3°C warmer across Victoria by 2030, relative to the 1986 to 2005 baseline. Warming is projected to increase further by 2090, in proportion to the scale of emissions from human activity. From the 1986 to 2005 baseline, Victorian temperatures are expected to increase by 2.5 to 4.5°C in 2090 under a high ongoing emissions scenario, by 1.1 to 2.4°C under an intermediate emissions scenario, and by 0.4 to 1.5°C under a lower emissions scenario. The latter aligns most closely with the Paris Agreement targets. The magnitude of the warming is projected to be slightly greater in the Murray Basin region of Victoria than across the Southern Slopes.

Physical evidence, past trends and various models all suggest Victoria will continue warming this century, so an ongoing warming is projected with very high confidence, with the full range of projected change considered plausible.

The Australian Climate Observations Reference Network – Surface Air Temperature (ACORN-SAT) is the dataset used by the Bureau of Meteorology to monitor long-term temperature trends in Australia. ACORN-SAT uses observations from 112 weather stations in all corners of Australia, selected for the quality and length of their available temperature data.[1209]

1209. Bureau of Meteorology (BoM) 2021, 'Long-term temperature record' http://www.bom.gov.au/climate/data/acorn-sat/ Accessed 25 January 2021.

Theme 6: Climate and Climate Change Impacts

Lake Tyers Beach
© Visit Victoria

Australia is a signatory to the Paris Agreement, which has a central aim of strengthening the global response to the threat of climate change by keeping a global temperature rise this century well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5°C.[1210]

The definition of 'pre-industrial levels' is a critical part of determining how well Victoria's coastal areas are tracking to limit temperature increase to the 2°C threshold. An Intergovernmental Panel on Climate Change (IPCC) report in 2014 used a reference period of 1850–1900 to represent pre-industrial temperature, with the same period again used in an IPCC special report in 2018.[1211,1212]

The ACORN-SAT data set starts in 1910. One reason for this is that equipment was not standardised across Australia until after the Bureau of Meteorology was formed as a federal institution in 1908, while there was also a lack of data collected prior to 1910, especially before 1890. Current Australian research is defining an 1850-1900 pre-industrial era temperature baseline for Australia, however there is uncertainty associated with constructing an 1850-1900 baseline and such a baseline is not currently being developed at the Victorian scale.

An indicative analysis is provided in the regional air temperature assessments to provide an update on how the Paris Agreement targets are tracking in a Victorian context.

1210. United Nations 2015, 'Paris agreement'.
1211. Intergovernmental Panel on Climate Change (IPCC) 2014, 'Climate change 2014: synthesis report', contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) by RK Pachauri and LA Meyer (eds), Geneva, Switzerland.
1212. Intergovernmental Panel on Climate Change (IPCC) 2018, 'Global warming of 1.5°c. An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty', by V Masson-Delmotte, P Zhai, HO Pörtner, D Roberts, J Skea, PR Shukla, A Pirani, W Moufouma-Okia, C Péan, R Pidcock, S Connors, JBR Matthews, Y Chen, X Zhou, MI Gomis, E Lonnoy, T Maycock, M Tignor, and T Waterfield (eds), in press.

Indicator 43: Water temperature

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide						

Data source:	BoM, CSIRO, DELWP
Measures:	Trends in sea-surface temperatures (°C per decade)

Why this indicator?

Oceans play an important role in the global climate system, absorbing more than 90% of the excess heat trapped by greenhouse gases. Water temperature is important for all marine life, which serve environmental (for example, biodiversity), economic (for example, commercial fisheries) and social (for example, recreational fishing) functions.

Oceans play an important role in the global climate system, absorbing more than 90% of the excess heat trapped by greenhouse gases.[1213] Water temperature is important for all marine life, which serve environmental (for example, biodiversity), economic (for example, commercial fisheries) and social (for example, recreational fishing) functions.

Extreme ocean water temperatures (persistence and intensity) are referred to as marine heatwaves. They can have devastating and long-term impacts on Australia's coastal ecosystems, economy and communities, including industries such as fisheries, aquaculture and tourism.[1214]

Ocean temperature monitoring programs are crucial for identifying marine heatwaves. Australia's Integrated Marine Observing System (IMOS) incorporates ocean data systems from multiple data streams to provide near real-time summaries of many parameters, including sea-surface temperature. The IMOS data offers region-specific information for monitoring marine heatwaves. This information can be valuable for the public, aquaculture industries and tourism operators in the marine environment.

1213. Intergovernmental Panel on Climate Change (IPCC) 2013, 'Climate change 2013: the physical science basis', Working Group I contribution to the IPCC Fifth Assessment Report, Cambridge University Press, Cambridge, United Kingdom.
1214. National Environmental Science Programme (NESP), 'Marine heatwaves: changes, causes and impacts' http://nespclimate.com.au/marine-heatwaves-changes-causes-and-impacts/ Accessed 2 February 2021.

Theme 6: Climate and Climate Change Impacts

Indicator 44: Ocean acidification

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		↙	Low (status), High (trend)		N/A	N/A
Data source:	BoM, CSIRO, DELWP					
Measures:	Change in pH of surface waters					

Why this indicator?

The uptake of atmospheric CO_2 by the oceans affects the carbonate chemistry and decreases pH, a process known as ocean acidification. Ocean acidification is the consequence of rising atmospheric CO_2 levels and impacts the entire marine ecosystem—from plankton at the base through to the top of the food chain.

The impacts of ocean acidification on Victoria's coast include:

- impacts on early life stages of species, particularly larvae and plankton
- loss of plankton base for food webs
- changes to ecological cycles
- damage to reef-building communities, such as molluscs, polychaetes (worms), corals and sponges
- damage to infrastructure.

The uptake of atmospheric CO_2 by the oceans affects the carbonate chemistry and decreases pH, a process known as ocean acidification. Ocean acidification is the consequence of rising atmospheric CO_2 levels and impacts the entire marine ecosystem—from plankton at the base through to the top of the food chain.[1215]

The impacts of ocean acidification on Victoria's coast include:

- impacts on early life stages of species, particularly larvae and plankton
- loss of plankton base for food webs
- changes to ecological cycles
- damage to reef-building communities, such as molluscs, polychaetes (worms), corals and sponges
- damage to infrastructure.[1216]

Ocean acidification impedes the ability of calcifying organisms to form their skeletons. Formation of shells or skeletons of calcium carbonate by organisms such as shelled plankton, polychaetes (worms), coralline algae, corals and molluscs will decrease. Many reef-building/forming organisms will take longer to build reefs, which are likely to be more fragile and vulnerable to erosion.[1217]

Increased ocean acidity impairs the ability of some reef fish to avoid predators. Conversely, other species such as non-calcifying algae may benefit from increased oceanic carbon dioxide concentrations. The ability of reef-forming organisms to provide ecosystem habitats, protect coastal regions from storms and support tourism and fisheries is likely to decline.[1218]

Victorian waters are home to many reef-forming organisms, including many inside marine national parks and sanctuaries. Acidification is already affecting reef-forming organisms and other marine organisms. Impacts are likely across the entire marine food web.[1219]

1215. Bureau of Meteorology (BoM) and CSIRO 2020, 'State of the Climate 2020'.
1216. Victorian Coastal Council (VCC) 2018, 'Victoria's coast and marine environments under projected climate change: impacts, research gaps and priorities'.
1217. Ibid.
1218. Ibid.
1219. Ibid.

Indicator 45: Areas of coastal vulnerability

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	●	?	●	●	N/A	N/A
Western Port	●	?	●	●	N/A	N/A
Corner Inlet-Nooramunga	●	↙	●	●	N/A	N/A
Gippsland Lakes	●	↙	●	●	N/A	N/A
Statewide	N	N	N	●	N/A	N/A

Data source:	DELWP, academic researchers
Measures:	This indicator is designed to describe the types of hazards, report on where these hazards are, and how much area they cover.

Why this indicator?

When marine and coastal processes have the potential to negatively affect environmental, social, cultural or economic values, they pose coastal hazard risks (such as flooding of coastal settlements, storms damaging coastal habitats and erosion of midden sites).

When marine and coastal processes have the potential to negatively affect environmental, social, cultural or economic values, they pose coastal hazard risks (such as flooding of coastal settlements, storms damaging coastal habitats and erosion of midden sites).

This indicator is designed to have a broad scope describing the types of hazards, report on where these hazards are, and how much area they cover. The following indicators in this chapter provide further detail and assessments on specific climatic hazards and impacts.

The concept of risk involves the interplay of hazard, exposure and vulnerability.[1220] Vulnerability refers to the degree to which individuals and communities may be impacted by the hazard. While general analysis of vulnerability is valuable for climate change assessment, it should be noted that individuals will vary in how they prepare for, respond to, and recover from, an emergency event. Vulnerability assessment, therefore, is only indicative of the potential impacts.[1221]

1220. Canterford S 2011, 'Locating people spatially: 2006, 2010 and 2.36pm on Friday', *Australasian Journal of Regional Studies*, 17(1), pp. 46-59.
1221. McKenzie F and Canterford S 2018, 'Demographics for bushfire risk analysis', Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria.

Theme 6: Climate and Climate Change Impacts

Indicator 46: Sea-level and coastal inundation

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		↙			N/A	N/A
Western Port		↙			N/A	N/A
Corner Inlet-Nooramunga		?			N/A	N/A
Gippsland Lakes		?			N/A	N/A
Statewide		↙			↙	

Data source:	BoM
Measures:	Annual mean sea level | Annual maximum sea level

Why this indicator?

Sea level rise is one of the biggest threats associated with climate change to coastal areas. Coastal communities in Victoria are already experiencing some of the impacts associated with sea level rise. These impacts are expected to intensify this century and include:

- more frequent and extensive inundation of low-lying areas, with the impacts exacerbated by storm surges
- loss of coastal habitat, such as roosting and nesting sites for shorebirds and seabirds
- accelerated cliff retreat and shoreline recession
- altered saltmarsh and mangrove habitats.

Sea level rise is one of the biggest threats associated with climate change to coastal areas. Coastal communities in Victoria are already experiencing some of the impacts associated with sea level rise. These impacts are expected to intensify this century and include:

- more frequent and extensive inundation of low-lying areas, with the impacts exacerbated by storm surges
- loss of coastal habitat, such as roosting and nesting sites for shorebirds and seabirds
- accelerated cliff retreat and shoreline recession
- altered saltmarsh and mangrove habitats.[1222]

Global mean sea level has risen by around 25 cms since 1880. Half of this rise occurring since 1970, providing confirmation that global mean sea level rise is accelerating.

Tide gauge and satellite altimetry observations show that the rate of global mean sea level rise increased from 1.5 ± 0.2 cms per decade (1901–2000) to 3.5 ± 0.4 cms per decade (1993–2019). The dominant cause of global mean sea level rise since 1970 is anthropogenic climate change.[1223]

As the ocean warms it expands and sea level rises. This thermal expansion has contributed about one third of the sea level rise observed globally. Ice loss from glaciers and polar ice sheets, together with changes in the amount of water stored on the land, contribute the remaining two thirds of the observed global sea level rise. Ice loss from Greenland, Antarctica and glaciers has been the dominant contributor to global sea level rise since 1993.[1224]

1222. Victorian Coastal Council (VCC) 2018, 'Victoria's coast and marine environments under projected climate change: impacts, research gaps and priorities'.
1223. Bureau of Meteorology (BoM) and CSIRO 2020, 'State of the Climate 2020'.
1224. Ibid.

Confidence in assessing changes in mean global sea level has continuously improved because there has been more analysis of satellite altimetry and longer records. Efforts to reliably quantify the various contributions to sea level rise have also led to greater confidence and process understanding.[1225]

Australia, like other nations, is already experiencing sea level rise. Sea level varies from year to year and from place to place, partly due to the natural variability of the climate system from the effect of climate drivers such as El Niño and La Niña. Based on satellite altimetry observations since 1993, the rates of sea level rise to the north and southeast of Australia (Figure 69) have been significantly higher than the global average of 3.5 cms per decade.[1226]

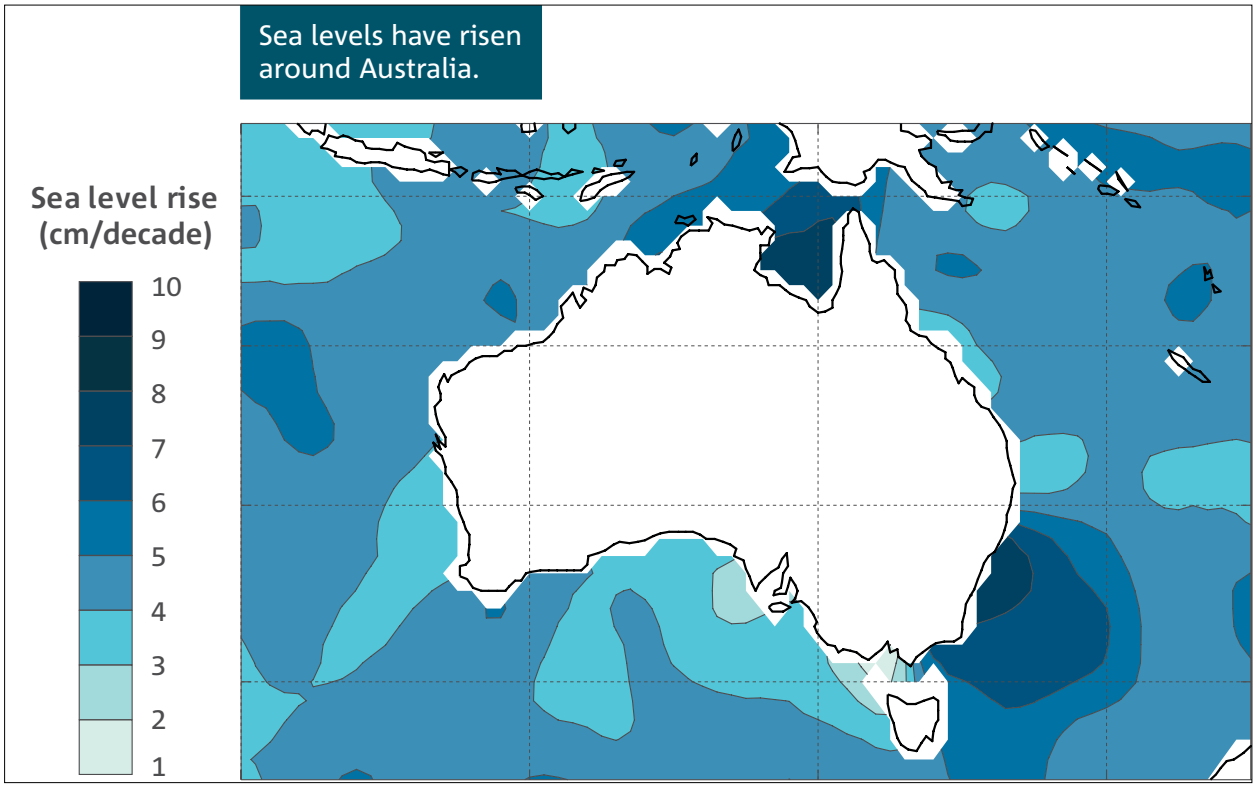


Figure 69: Rate of sea level rise around Australia measured using satellite altimetry, from 1993 to 2019.[1227]

Australian sea levels are projected to rise for the rest of this century, most likely at a faster rate than for the past four decades.[1228] Sea level rise is also expected to continue rising beyond 2100.

1225. Ibid.
1226. Ibid.
1227. Ibid.
1228. CSIRO and Bureau of Meteorology (BoM) 2015, 'Climate change in Australia: information for Australia's natural resource management regions: technical report', Australia https://apo.org.au/sites/default/files/resource-files/2015-01/apo-nid52475.pdf Accessed 15 November 2021

Indicator 47: Wave climate

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay		?			N/A	N/A
Statewide		?			N/A	N/A

Data source:	Academic researchers
Measures:	Percentage of load on structures from meteorological and oceanographic forcing (that is, the combined wind, wave and climate conditions)

Why this indicator?

Waves are a dominant process along Victoria's coastline and near-shore regions. Understanding their characteristics and impacts is an important consideration for ecologically sustainable development of coastal and offshore infrastructure, and management of coastal resources and ecosystems.

Waves are a dominant process along Victoria's coastline and near-shore regions. Understanding their characteristics and impacts is an important consideration for ecologically sustainable development of coastal and offshore infrastructure, and management of coastal resources and ecosystems.[1229]

Ocean waves are generated by surface winds. Our changing climate will drive changes in wind patterns around the globe, which will in turn alter ocean wave conditions. Changes in wave height, frequency, duration and direction have the potential to alter coastal systems, impact coastal infrastructure and change sand transportation processes, which affect beach morphology.[1230]

Even slight changes in wave direction can result in significant hazards to infrastructure as beaches can rotate due to the amount of sand being shunted around. Climate-driven variations in average wave directions can cause erosion on the down-drift side and comparable accretion on the up-drift side of embayed beaches. Changes in the frequency or intensity of storm systems can cause significant changes in the size of the beach envelope.[1231]

Infrastructure built on the coast, or offshore, is sensitive to the many characteristics of waves. And, while each of these wave characteristics is important on its own, about 40% of the world's coastlines are likely to see changes in wave height, period and direction happening simultaneously, which is likely to exacerbate their impacts.[1232]

A current research project is aiming to better understand how Victoria's wave climate will change in the future. The study is using global climate models to generate the wind data that is used as an input to global wave models, which are then nested into regional wave models. Two emission scenarios will be used to determine the sensitivity of the projections to GHG emissions. The aim of the research project is to determine how Victoria's wave climate is expected to change between now and 2100. This research will be incorporated into the next State of the Marine and Coastal Environment Report.

1229. CSIRO 2021, 'Waves' https://research.csiro.au/slrwavescoast/waves/ Accessed 22 January 2021.
1230. National Environmental Science Programme (NESP) 2020, 'Science webinar: impacts of climate change and variability on ocean waves' http://nespclimate.com.au/impacts-of-climate-change-and-variability-on-ocean-waves/ Accessed 22 January 2021.
1231. Kennedy M, McInness K and Ierodiaconou D 2019, 'Understanding coastal erosion on beaches', Earth Systems and Climate Change Hub.
1232. Morim J, Hemer MA, Wang XL, Cartwright N, Trenham C, Semedo A, et al. 2019, 'Robustness and uncertainties in global multivariate wind-wave climate projections', *Nature Climate Change*, 9, pp. 711-718. https://doi.org/10.1038/s41558-019-0542-5 Accessed 5 February 2021.

Indicator 48: Coastal erosion

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	Yellow	?	Yellow	Black	N/A	N/A
Western Port	Yellow	↙	Yellow	Black	N/A	N/A
Corner Inlet-Nooramunga	Yellow	↙	Yellow	Black	N/A	N/A
Gippsland Lakes	Red	↙	Yellow	Black	N/A	N/A
Statewide	Yellow	?	Yellow	Black	N/A	N/A

Data source:	DELWP
Measures:	Area of coast defined as an erosion hotspot (that is, where there has been a landward shift in shoreline position between 1986 and 2017 at a rate greater than 0.5 m per year) | Area of coastline defined as highly or very highly vulnerable to erosion

Why this indicator?

Rising sea levels due to climate change are likely to cause accelerated erosion of many Australian coastlines. This is based on the expectation that many shorefaces will shift up and onshore to maintain an equilibrium with the waves and changing water level. This may result in tens of metres of erosion on many beaches – narrow beaches in front of cliffs and seawalls have the potential to erode entirely. This erosion has broad reaching consequences for coastal infrastructure, communities, ecosystems and coastal leisure activities.

Beaches are dynamic landform systems which are in a constant state of flux as they interact with waves breaking on the shore. It is their ability to respond to each wave event that allows beaches to survive in high energy environments.[1233]

Erosion on a beach occurs when sand is moved from one location to another. It is a natural process. Sand is generally not lost from the coastal system; it is simply moved to another location to balance the energy that impacts the coast.

Beaches operate over annual to decadal cycles. Each year there can be a lot of natural movement – commonly there is tens of metres of lateral movements and over five metres vertically.

The beach envelope is the range from the most eroded state of the beach (for example, after a series of big storms) to the most accreted state of the beach (for example, after a mild summer). The subaerial beach (the part above low tide) and backing dunes are part of the beach envelope and are the principal store of sand for storm events.

Understanding the size and dynamics of the beach envelope is critical for sustainable environmental management on the coast. Increasing population at the coast, coupled with climate change, will put increasing amounts of infrastructure into the existing coastal hazard zone. This coastal hazard zone already overlaps with many communities.

1233. Kennedy M, McInness K and Ierodiaconou D 2019, 'Understanding coastal erosion on beaches', Earth Systems and Climate Change Hub.

Theme 6: Climate and Climate Change Impacts

Rising sea levels due to climate change are likely to cause accelerated erosion of many Australian coastlines. This is based on the expectation that many shorefaces will shift up and onshore to maintain an equilibrium with the waves and changing water level.

This may result in tens of metres of erosion on many beaches – narrow beaches in front of cliffs and seawalls have the potential to erode entirely. This erosion has broad consequences for coastal infrastructure, communities, ecosystems and coastal leisure activities. Knowledge gaps remain around the amount of long-term shoreline retreat that may occur under climate change. Greater understanding is therefore required of historical shoreline dynamics over decadal time frames and the influence of sediment supply, vegetation and human infrastructure on this process.[1234]

A 2017 project commissioned by the Victorian Government included the development of an erosion vulnerability rating that was a combination of potential impact and adaptive capacity.[1235,1236,1237] This vulnerability rating was assigned to each 50-metre section of the coast. Vulnerability ratings were given from 1 (very low vulnerability) to 5 (very high vulnerability).

Seaspray erosion
© Blake Allan

1234. Earth Systems and Climate Change Hub, 'Coastal erosion under a changing climate'.
1235. Spatial Vision 2017, 'Victorian coastal hazard assessment 2017 technical report 1'.
1236. Impact was determined through combining sensitivity and exposure.
1237. Adaptive capacity was a measure of the resilience of the coastal strip to given impacts. This capacity could either come in the form of man-made structures, natural structures or natural vegetative cover.

Indicator 49: Seawater intrusion into coastal aquifers

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		?			N/A	N/A

Data source:	Academic researchers
Measures:	Vulnerability ratings for seawater intrusion into coastal aquifers

Why this indicator?

Sea water intrusion into aquifers presents a risk to future freshwater supply in coastal areas.

Seawater intrusion causes degradation of groundwater resources in coastal areas.

Sea water intrusion into aquifers presents a risk to future freshwater supply in coastal areas.

Seawater intrusion causes degradation of groundwater resources in coastal areas. The characterisation of seawater intrusion is difficult and expensive, highlighting a need to develop methods for rapid assessment of seawater intrusion as part of large-scale screening studies to guide future investment.[1238]

Fresh groundwater stored in coastal aquifers has many beneficial values including town and domestic water supply, irrigation of crops and pastures, ecological services, industrial usage, even as a fluid for heating and cooling.[1239] On Australia's coastal fringe, continuing population expansion allied with significant reductions in rainfall have led to an increasing dependency on coastal groundwater resources.[1240]

Research into coastal groundwater that was completed in 2017 found that estimates of the economic value of coastal groundwater in Australia are yet to be reported or compiled to support an economic assessment of the impacts of climate change on coastal groundwater resources.[1241] While previously, a 2013 study estimated the economic contribution of groundwater use to Gross Domestic Product (GDP) across the Australian economy to be between $3.0 – $11.1 billion.[1242]

Despite reports of seawater intrusion in most states and evidence that some Australian coastal aquifers are seriously depleted, comprehensive seawater intrusion investigations are lacking for Victoria.[1243]

1238. Morgan LK and Werner AD 2015, 'A national inventory of seawater intrusion vulnerability for Australia,' *Journal of Hydrology: Regional Studies*, 4, pp. 686-698 http://dx.doi.org/10.1016/j.ejrh.2015.10.005 Accessed 07 July 2020.
1239. Anderson DJ 2017, 'Coastal groundwater and climate change', WRL technical report 2017/04, technical monograph prepared for the National Climate Change Adaptation Research Facility (NCCARF), Water Research Laboratory of the School of Civil and Environmental Engineering, UNSW, Sydney.
1240. Geoscience Australia, 'Seawater intrusion', Canberra, Australia http://www.ga.gov.au/scientific-topics/water/groundwater/understanding-groundwater-resources/seawater-intrusion Accessed 07 July 2020.
1241. Anderson DJ, 2017, 'Coastal groundwater and climate change', WRL technical report 2017/04, technical monograph prepared for the National Climate Change Adaptation Research Facility, Water Research Laboratory of the School of Civil and Environmental Engineering, UNSW, Sydney.
1242. Deloitte Access Economics 2013, 'Economic Value of Groundwater in Australia'.
1243. Werner AD 2010, 'A review of seawater intrusion and its management in Australia', *Hydrogeology Journal*, 18, pp. 281–285.

Indicator 50: Frequency and impact of fire on marine and coastal ecosystems

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Gippsland Lakes		?			N/A	N/A

Data source:	Academic researchers
Measures:	Change in water quality, algal bloom frequency and nutrient loads before, during and after significant fire activity

Why this indicator?

Research has shown that when the nutrients, ash, debris, sediments and metals released by bushfires are washed into waterways, they can remove the feeding and breeding areas of aquatic animals, clog the gills of fish, and undermine the breathing of filter feeding animals such as mussels. The bushfire impacts on estuaries and other coastal waterways could take months or longer to materialise, therefore it is important for programs to monitor, assess and report on this issue.

Research has shown that when the nutrients, ash, debris, sediments and metals released by bushfires are washed into waterways, they can remove the feeding and breeding areas of aquatic animals, clog the gills of fish, and undermine the breathing of filter feeding animals such as mussels. The contaminated sediment slug can slowly work its way downstream to the coast, harming aquatic life along the way.[1244]

Metals such as copper, zinc, lead and mercury, and other contaminants released by bushfires, could change the physiology and behaviours of marine animals and work their way up the food chain. Harmful algal blooms caused by nutrient enrichment can kill fish and contaminate oyster farms.[1245]

Fire retardants used in fire suppression activities can be harmful to aquatic animals when directly or indirectly applied to waterways, while increased or repeated hazard reduction burning could cause local impacts on coastal environments, such as increased erosion and longer recovery times.[1246]

The bushfire impacts on estuaries and other coastal waterways could take months or longer to materialise, therefore it is important for programs to monitor, assess and report on this issue.

1244. Australian Marine Conservation Society 2020, 'The impacts of bushfires on coastal and marine environments'.
1245. Ibid.
1246. Ibid.

Indicator 51: Climate change impact on marine and coastal infrastructure

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Port Phillip Bay	●	?	●	●	N/A	N/A
Western Port	●	↙	●	●	N/A	N/A
Gippsland Lakes	●	↙	●	●	N/A	N/A
Statewide	●	↙	●	●	N/A	N/A

Data source:	DELWP, AURIN (Australian Urban Research Infrastructure Network)
Measures:	Number and proportion of buildings expected to be inundated by 2100 under a high-emissions scenario with an expected sea-level rise of 82 cm and a one-in-100-year storm tide, by coastal local government area | Total capital improved value of properties vulnerable to flooding

Why this indicator?

Buildings and structures in the marine and coastal environment help communities and industries to function. They include port facilities, transport docks, jetties, boat ramps, paths, toilet blocks, picnic facilities, structures to maintain public safety, and buildings to enhance recreation opportunities such as clubs and cafes. Sea level rise, coastal erosion and storm surge will also affect seaside housing.

Buildings and structures in the marine and coastal environment help communities and industries to function. They include port facilities, transport docks, jetties, boat ramps, paths, toilet blocks, picnic facilities, structures to maintain public safety, and buildings to enhance recreation opportunities such as clubs and cafes. Sea level rise, coastal erosion and storm surge will also affect seaside housing.[1247] New and improved buildings and structures that are well designed, appropriately located and properly maintained are necessary to enable a diversity of uses in the marine and coastal environment, and to accommodate increasing demand as the population grows.[1248]

Victoria has a vast inventory of coastal assets (sea walls, groynes, piers and jetties), particularly in its bays and estuaries (Port Phillip Bay, Western Port Bay, Gippsland Lakes and Corner Inlet), that have been constructed over the past 100 years. Many of these assets are ageing and, without regular maintenance or upgrading, will no longer be able to provide the services for which they were built. In 2018 the Victorian Auditor General's Office estimated that between 20% and 30% of coastal assets were in poor condition, and between 30% and 50% were estimated to have less than ten years' useful life remaining.[1249]

Increasing storms and erosion under climate change will further undermine the integrity of many assets, forcing decisions to be made about their future existence.[1250]

1247. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Climate change risks to local government', East Melbourne, Victoria.
1248. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Marine and coastal policy', East Melbourne, Victoria.
1249. Victorian Auditor General's Office (VAGO) 2018,'Protecting Victoria's coastal assets', Melbourne, Victoria.
1250. Ibid.

A 2020 global research study led by Victorian researchers estimated the economic cost of coastal inundation.[1251] The results of the research study show that if there is no coastal protection or adaptation, and a high emissions scenario prevails, there will be an increase of 48% of the world's land area, 52% of the global population and 46% of global assets at risk of flooding by 2100.[1252] The same research found the total assets potentially exposed to episodic coastal flooding will increase to up to 20% of global Gross Domestic Product by 2100.[1253] Without a dramatic reduction in greenhouse gas emissions, or a huge investment in sea walls and other structures, it is clear coastal erosion will have a profoundly adverse impact on the global economy and much of the world's population.

Port Phillip Bay

PPB 41: Rainfall

Region	2021 status	2021 trend	2021 data
Port Phillip Bay		↙	
Justification for assessment ratings:	The status and trend assessments of fair and deteriorating respectively reflect the fluctuating pressure being exerted on the water resources and agricultural sectors by wetter years interspersing a predominately drying climate. The enhanced rainfall reduction during the cool seasons is particularly important given the adverse impacts this can have on streamflows and the reduced reliability for water storage filling seasons. The confidence in the status and trend assessments is rated as moderate rather than high because even though the data quality on rainfall is good, knowledge on the impacts of rainfall on coastal settlements is constantly evolving.		

The Bureau of Meteorology has been measuring rainfall along the Port Phillip Bay coastline since the 1850s. The longest continuously operating rainfall measurements are at Laverton, which began measuring rainfall in 1941. The Melbourne Regional Office, located in Melbourne's CBD, measured rainfall from 1855 but recently closed in 2015. This analysis of observed rainfall for Port Phillip Bay has been limited to weather stations located within five km of the Port Phillip Bay coastline that currently measure rainfall and have been measuring rainfall for more than 20 years.[1254] The Melbourne Regional Office and Geelong (Moolap) weather stations have also been included due to the length of those data sets and their closure only occurring recently.

To account for the year-to-year variability associated with rainfall, a rolling ten-year average of annual rainfall has been assessed and shows there was not a distinctive long-term trend in annual rainfall along the Port Phillip Bay coastline across the last 140 years. The data reveal that the eastern side of the bay generally receives the most rainfall, with the western side receiving significantly less rain.

1251. Kirezci E, Young IR, Ranasinghe R, Muis S, Nicholls RJ, Lincke D and Hinkel J 2020, 'Projections of global-scale extreme sea levels and resulting episodic coastal flooding over the 21st century', *Scientific Reports*, 10, 11629 https://doi.org/10.1038/s41598-020-67736-6 Accessed 9 March 2021.
1252. Ibid.
1253. Ibid.
1254. Five km has been used as the threshold for analysis due to the Marine and Coastal Act 2018 definition of the marine and coastal environment being the outer limit of Victorian coastal waters and five km inland of the high-water mark of the sea.

The driest ten-year rolling average rainfall amounts were measured during the millennium drought early in the 21st century and, although some relatively wetter years have been recorded during the 2010s, the ten-year rolling average of annual rainfall for the 2010s is still drier than most historical ten-year rolling average periods.

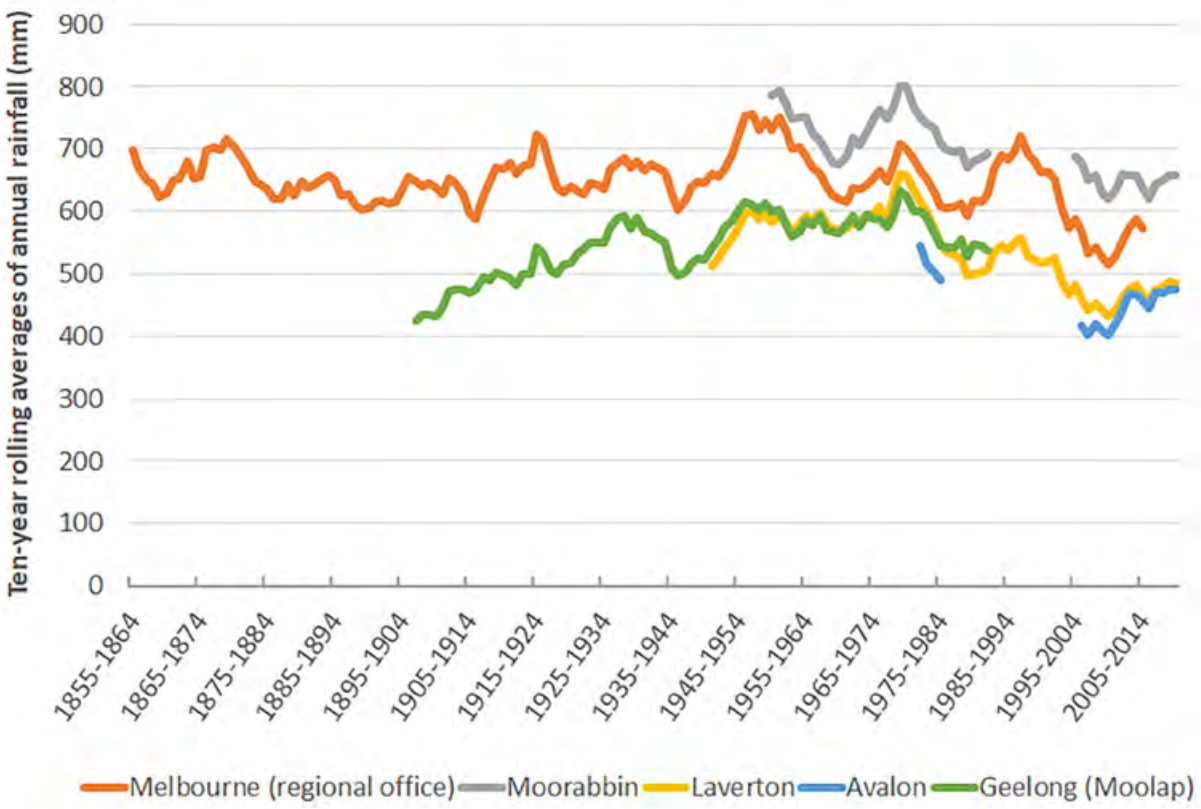


Figure 70: Observed rainfall measurements (presented as ten-year rolling averages) at the Bureau of Meteorology weather stations located along the Port Phillip Bay coastline, 1855-1864 to 2010-2019.[1255]

The rainfall graph for cool-season rainfall (April to October) shows a similarly stable pattern of rainfall over a long-term trend period, with a shift towards a drier climate during the 21st century. Given there is high confidence that natural climate variability will remain the major driver of rainfall changes in the short term (until 2030), this recent decline in cool season rainfall along the Port Phillip Bay coastline is unlikely to become significantly more pronounced in the next decade. This window of opportunity for climate change adaptation action should be utilised by the agriculture and water resources sectors that are likely to be increasingly impacted by reduced water availability as the 21st century progresses.

1255. Prepared using Bureau of Meteorology (BoM), 'Climate data online' http://www.bom.gov.au/climate/data

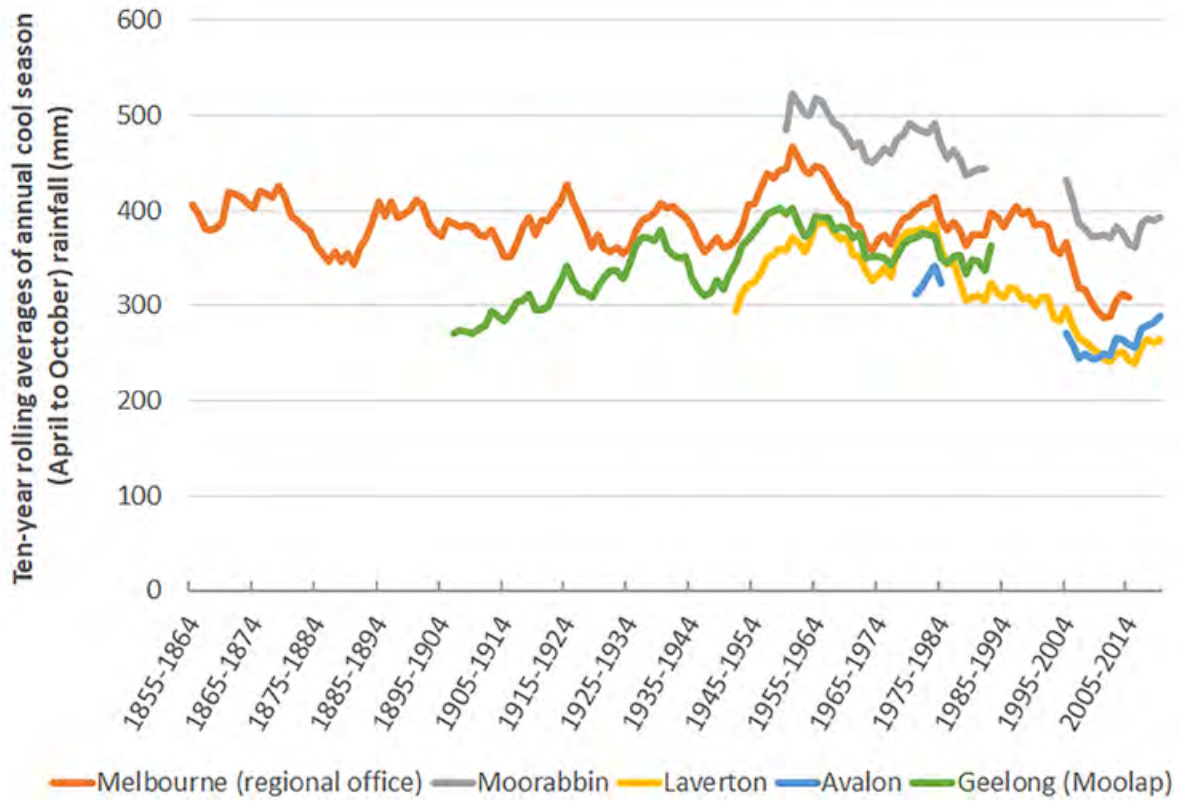


Figure 71: Observed rainfall measurements (presented as ten-year rolling averages) for the cool season (April to October) at Bureau of Meteorology weather stations located along the Port Phillip Bay coastline, 1855-1864 to 2010-2019.[1256]

Table 27 and Table 28 show rainfall reductions observed during the 21st century, comparing the 20 years from 2000 to 2019 to the preceding 20 years (1980-1999). A 7-12% reduction in annual rainfall has been observed along the Port Phillip Bay coastline during the 21st century, while a 13-20% reduction in cool-season rainfall has been observed. Notably, the biggest percentage rainfall reductions have occurred on the western side of Port Phillip Bay, which is the area with the least rainfall.

In other words, that side of the bay is historically drier and its rate of drying has been faster than elsewhere along the bay. The western side of the bay is also projected to have faster population growth in coming decades,[1257] which will place increasing pressure on water resources and require a robust water delivery network to service those communities.

1256. Ibid.
1257. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria in future 2019: population projections 2016 to 2056', East Melbourne, Victoria.

Table 27: Observed rainfall measurements at the Bureau of Meteorology weather stations located along the Port Phillip Bay coastline.[1258]

* Note that this value is based on an average from 2000 to 2014 due to the Melbourne Regional Office weather station closing in 2015.

Weather Station	Average annual rainfall (mm) from 1980-1999	Average annual rainfall (mm) from 2000-2019	Change in rainfall from 1980-1999 to 2000-2019
Laverton RAAF	511.2	456.6	11% reduction
Melbourne Regional Office	640.0	564. 4*	12% reduction*
Moorabbin Airport	683.5	634.7	7% reduction

Table 28: Observed cool-season (April to October) rainfall measurements at the Bureau of Meteorology weather stations located along the Port Phillip Bay coastline.[1259]

* Note that this value is based on an average from 2000 to 2014 due to the Melbourne Regional Office weather station closing in 2015.

Weather Station	Average annual rainfall (mm) from 1980-1999	Average annual rainfall (mm) from 2000-2019	Change in rainfall from 1980-1999 to 2000-2019
Laverton RAAF	328.7	263.6	20% reduction
Melbourne Regional Office	389.7	328.5*	16% reduction*
Moorabbin Airport	441.9	384.9	13% reduction

Rainfall will continue to be variable over time, but over the long term it is expected to continue to decline in winter and spring (medium to high confidence), and autumn (low to medium confidence). Annual rainfall for Melbourne and Geelong is expected to decline by 8 and 11%, respectively, for the 2050s under a high emissions scenario (RCP 8.5) compared to 1986–2005.[1260]

Extreme rainfall events are expected to become more intense on average through the rest of the 21st century (high confidence).[1261]

1258. Prepared using Bureau of Meteorology (BoM), 'Climate data online' http://www.bom.gov.au/climate/data
1259. Ibid.
1260. Clarke JM, Grose M, Thatcher M, Round V and Heady C 2019, 'Greater Melbourne climate projections 2019', CSIRO, Melbourne Australia.
1261. Ibid.

PPB 42: Air temperature

Region	2021 status	2021 trend	2021 data
Port Phillip Bay			
Justification for assessment ratings:	The status and trend assessments of fair and deteriorating respectively reflect the increasing pressure being exerted on human health, biodiversity and coastal infrastructure. Melbourne was 0.96°C warmer during the 2010s than the 1990s, highlighting the rapid rate of recent warming. The confidence in the status and trend assessments is rated as moderate rather than high because even though the data quality on temperature is good, knowledge on the impacts of increasing temperatures is constantly evolving.		

The Australian Climate Observations Reference Network – Surface Air Temperature (ACORN-SAT) is the dataset used by the Bureau of Meteorology to monitor long-term temperature trends in Australia. ACORN-SAT uses observations from 112 weather stations across Australia, selected for the quality and length of their available temperature data.[1262] Via the ACORN-SAT network, temperature data are available for Laverton and Melbourne since 1910. Additionally, the Bureau of Meteorology has operated a range of weather stations along the Port Phillip Bay coastline for more than 150 years and any data available prior to 1910 has been included in this assessment to provide an indicative guide of temperature in the pre-industrial era.

The rolling ten-year average of annual mean maximum temperatures for Melbourne remained reasonably stable within a temperature range of 18.77 to 19.32°C for the first 50 years of the ACORN-SAT database (1910-1960). The rolling ten-year average has increased significantly, by 1.43°C, from the 1950s to the 2010s, with the rate of increase being most pronounced during the past 20 years, with the 2010s being 0.96°C warmer than the 1990s.

The temperature trend for Laverton, along the western Port Phillip Bay coastline, is similar to the pattern observed in Melbourne, although the rate of warming at Laverton has been slightly faster this century, with Laverton's temperatures during the 2010s being 1.24°C warmer than the 1990s and 1.81°C warmer than the 1950s.

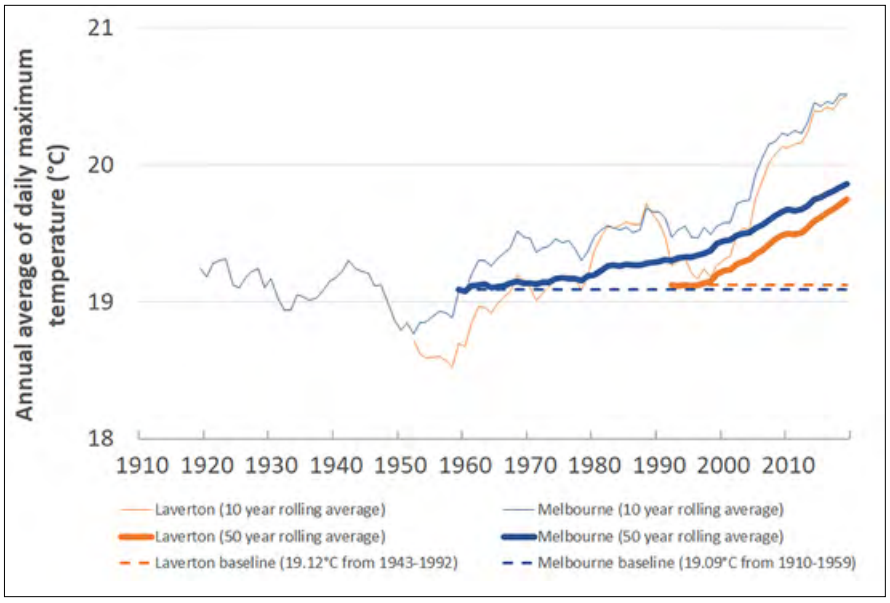


Figure 72: Annual average of daily maximum temperature (°C) from Bureau of Meteorology ACORN-SAT data for Melbourne and Laverton, 1910 to 2019.[1263]

1262. Bureau of Meteorology (BoM) 2021, 'Long-term temperature record' http://www.bom.gov.au/climate/data/acorn-sat/ Accessed 25 January 2021.
1263. Data used to generate the graph extracted from Bureau of Meteorology (BoM), ACORN-SAT Australia v2 (snapshot v.2.1.0.1), Australian Climate Observations Reference Network - surface air temperature (1910-May 2019).

The observed temperature increase along the Port Phillip Bay coastline of approximately 1°C during the first two decades of this century has significant ramifications when considered in the context of the 2015 Paris Agreement. Australia is a signatory to the Paris Agreement, which has a central aim of strengthening the global response to the threat of climate change by keeping a global temperature rise this century well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5°C.[1264]

Reliable temperature records are not available for Melbourne and Laverton prior to 1910, however indicative temperature measurements were recorded at the Bureau of Meteorology's Melbourne Regional Office from 1855. Analysis of this data for the Melbourne Regional Office weather station indicates that the average of annual mean maximum temperature during the 'pre-industrial' period to 1900 was within 0.1°C of the average during 1910-1959 (the first 50-year period of ACORN-SAT data). Because of this, we assume the first 50-years of ACORN-SAT temperature data for Melbourne is reasonably representative of the 'pre-industrial' temperature levels. Therefore, a temperature of 19.09°C (the average of the ACORN-SAT temperature for Melbourne from 1910-1959) has been used as an indicative reference value for Melbourne's pre-industrial temperature, which enables an indicative assessment of how temperature levels in Melbourne are tracking against the 1.5°C and 2°C targets in the Paris Agreement.

The average annual mean maximum temperature for Melbourne during the 2010s was 20.51°C, which means that current temperatures are approaching a 1.5°C degree increase from the indicative pre-industrial era temperature. Indeed, some years are now more than 1.5°C warmer than the indicative pre-industrial era baseline, with eight of the most recent 15 years being more than 1.5°C warmer than the indicative pre-industrial era temperature.

If the recent rate of temperature increase continues at the current trajectory of nearly 0.5°C per decade, temperatures along the Port Phillip Bay coastline will have increased by approximately 2.5°C from pre-industrial levels by 2040.

The observed warming measured along the Port Phillip Bay coastline since the middle of the 20th century is expected to continue. The amount of increase in the second half of the current century depends on the world's greenhouse gas emissions over the coming decades. Under the high emissions scenario, maximum temperatures in Greater Melbourne are expected to show a median increase of 1.2°C by 2020–2039, compared to 1986–2005. By mid-century, the increase is likely to be greater, with a median of 1.9°C. Under medium emissions, the mid-century maximum temperatures increase by a median of 1.6°C.[1265] Note that these projected temperature increases are relative to a baseline period of 1986-2005. As discussed previously, the Paris Agreement has a stated aim to keep global temperature rise this century below 2°C above pre-industrial levels, with the pre-industrial period defined as 1850-1900. Given the Paris agreement targets, viewed in a Victorian context, are already close to being breached and there is very high confidence that Victoria's climate will continue to warm this century,[1266] effective and swift action is required, globally, to keep the targets of the Paris agreement viable. However, it is important to note that the Paris agreement targets are based on global average temperatures, which encompass an average of temperatures over land and water. Temperatures over land are expected to warm more than those over water,[1267] which means that surface air temperatures over land are generally likely to be greater than 1.5°C if there is a global temperature increase of 1.5°C.

An analysis of temperatures recorded at Bureau of Meteorology weather stations along the Port Phillip Bay coastline highlights that summer temperatures are increasing at a faster rate than increases in annual temperatures (Table 29 and Table 30).

1264. United Nations 2015, 'Paris agreement'.
1265. Clarke JM, Grose M, Thatcher M, Round V and Heady C 2019, 'Greater Melbourne climate projections 2019', CSIRO, Melbourne Australia.
1266. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019'.
1267. Hoegh-Guldberg O, Jacob D, Taylor M, Bindi M, Brown S, Camilloni I, Diedhiou A, Djalante R, Ebi KL, Engelbrecht F, Guiot J, Hijioka Y, Mehrotra S, Payne A, Seneviratne SI, Thomas A, Warren R and Zhou G 2018, 'Impacts of 1.5°C global warming on natural and human systems', in 'Global warming of 1.5°C', an IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.

Table 29: Observed temperature measurements (rolling ten-year average of annual mean maximum temperatures) at the Bureau of Meteorology weather stations located along the Port Phillip Bay coastline.[1268]

* Note that this value is based on a ten-year average from 2005 to 2014 due to the Melbourne Regional Office weather station closing in 2015.

Weather Station	Average daily maximum temperature (°C) in the 1990s	Average daily maximum temperature (°C) in the 2010s	Temperature change (average daily maximum temperature in °C) per decade from the 1980s to the 2010s
Laverton RAAF	19.38	20.51	0.57 increase
Melbourne Regional Office	20.21	21.14*	0.62 increase*
Moorabbin Airport	19.34	20.46	0.56 increase

Table 30: Observed temperature measurements (rolling ten-year average of summer mean maximum temperatures) at the Bureau of Meteorology weather stations located along the Port Phillip Bay coastline.[1269]

* Note that this value is based on a ten-year average from 2005 to 2014 due to the Melbourne Regional Office weather station closing in 2015.

Weather Station	Average daily maximum temperature (°C) in the 1990s	Average daily maximum temperature (°C) in the 2010s	Temperature change (average daily maximum temperature in °C) per decade from the 1980s to the 2010s
Laverton RAAF	24.54	26.02	0.74 increase
Melbourne Regional Office	25.64	26.67*	0.69 increase*
Moorabbin Airport	24.70	26.17	0.74 increase

The rapidly increasing summer temperature rate is noteworthy when coupled with research that has found heatwaves cause more deaths than any other natural disaster in Victoria.[1270] One study has estimated there will be an extra 400 deaths per year in Victoria by 2050 due to heatwaves if no adaptation measures are taken.[1271] Many of these estimated deaths are likely to occur along the Port Phillip Bay coastline where Victoria's population is densely populated with a more elderly demographic that is more susceptible to the effects of extreme heat. A warmer climate has coincided with an increase in the number of extreme heat events in Victoria, with a significant increase in the number of days per year when Victorian temperatures are unusually warm.[1272]

One way to look at extreme temperatures is to look at the number of temperature exceedances per year (Table 31). For example, on average between 1981 and 2010, Melbourne experienced 8.3 days per year when the temperature exceeded 35°C, while there were 6.4 days per year meeting that criteria in Geelong. By the 2050s under high emissions, this is expected to increase to between 13 and 21 days on average for Melbourne, and between 9 and 16 days for Geelong.

1268. Prepared using Bureau of Meteorology (BoM), 'Climate data online' http://www.bom.gov.au/climate/data
1269. Ibid.
1270. Steffen W, Hughes L and Perkins S 2014, 'Heatwaves: hotter, longer, more often', Climate Council of Australia Limited, Potts Point, New South Wales.
1271. Keating A and Handmer J 2013, 'Future potential losses from extremes under climate change: the case of Victoria, Australia', Victorian Centre for Climate Change Adaptation Research (VCCAR), Melbourne, Victoria.
1272. Bureau of Meteorology (BoM) and CSIRO 2016, 'State of the Climate 2016'.

The increase is slightly less under medium emissions, reaching 10 to 16 days in Melbourne and 8 to 13 days in Geelong. Importantly for many people, minimum (usually overnight) temperatures are also expected to increase. For example, Melbourne's daily minimum temperature exceeded 20°C on average 5.8 days per year between 1981 and 2010. Under high emissions, by the 2050s, these hot nights are expected to occur 13.3 to 18.4 days per year on average.[1273,1274]

Table 31: Historic and projected days (median, 10th and 90th percentile) per year with maximum temperature greater than 35°C for two locations in 2040–2059.[1275,1276]

Town	Days/year above 35°C	
	1981–2010	2040–2059
Melbourne	8.3	RCP4.5 10.9 (7.7 to 12.6) RCP8.5 12.6 (9.1 to 15.6)
Geelong	6.4	RCP4.5 14.0 (10.2 to 15.8) RCP8.5 (13.1 to 20.4)

PPB 43: Water Temperature

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The east-west orientation of Victoria's coastline means there is limited variation in water temperature. Therefore, the water temperature indicator has been included as a statewide assessment.		

PPB 44: Ocean acidification

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The east-west orientation of Victoria's coastline means there is limited variation in ocean acidification. Therefore, the ocean acidification indicator has been included as a statewide assessment.		

1273. Clarke JM, Grose M, Thatcher M, Round V and Heady C 2019, 'Greater Melbourne climate projections 2019', CSIRO, Melbourne Australia.
1274. Clarke JM, Grose M, Thatcher M, Round V and Heady C 2019, 'Barwon climate projections 2019', CSIRO, Melbourne Australia.
1275. Clarke JM, Grose M, Thatcher M, Round V and Heady C 2019, 'Greater Melbourne climate projections 2019', CSIRO, Melbourne Australia.
1276. Clarke JM, Grose M, Thatcher M, Round V and Heady C 2019, 'Barwon climate projections 2019', CSIRO, Melbourne Australia.

PPB 45: Areas of coastal vulnerability

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	●	?	●
Justification for assessment ratings:	There is currently not enough published information to provide status and trend assessments for this indicator.		

Like all coasts, Port Phillip Bay is vulnerable to coastal hazards. As sea levels rises, areas along the coast are likely to experience increased erosion, inundation, and groundwater change, which threaten the security of communities, assets and ecosystems. With climate change increasing the frequency and severity of hazards and hazard events, it is important that we understand what this means in the bay area, so that we can plan for adverse impacts on coastal communities.[1277]

DELWP and CSIRO are working together to complete a coastal hazard assessment for Port Phillip Bay.[1278] This assessment will look at the likely extent of inundation (flooding), groundwater change, and erosion for the bay. The Coastal Hazard Assessment will identify likely coastal hazard impacts around Port Phillip Bay through data analysis and modelling of a range of anticipated climate change scenarios. The data generated through the assessment will be shared with land managers and the community, to help them consider climate change in their future planning. The findings of the hazard assessment have not yet been released and will be used to inform future State of the Marine and Coastal Environment reports.

Specific biophysical vulnerabilities are captured in the standalone indicators, such as sea level and coastal inundation, and coastal erosion. DELWP released a Draft Marine and Coastal Strategy in July 2021.[1279] Activity 4.4 in that Strategy is to deliver state-wide hazard maps that enable fit for purpose coastal hazard risk assessments, with a timeframe of 2022-2024 to deliver those maps. The combination of the Port Phillip Bay Coastal Hazard Assessment and the proposed state-wide hazard maps are expected to enable rigorous and robust reporting of this indicator in future State of the Marine and Coastal Environment reports.

PPB 46: Sea-level and coastal inundation

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	●	↙	●
Justification for assessment ratings:	The status and trend assessments of fair and deteriorating respectively reflect the increasing pressure being exerted on human coastal settlements and infrastructure.		

Sea level data from a tide gauge has been collected by the Bureau of Meteorology at three currently monitored locations in Port Phillip Bay since the 1960s. These locations are Williamstown, Geelong and Point Lonsdale. Local coastal processes, the effects of vertical land motion, and changes in site and/or reference levels affect local estimates of sea level change.

1277. Department of Environment, Land, Water and Planning (DELWP), 'Port Phillip Bay coastal hazard assessment' https://www.marineandcoasts.vic.gov.au/coastal-programs/port-phillip-bay-coastal-hazard-assessment Accessed 7 July 2020.
1278. Ibid.
1279. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Draft marine and coastal strategy', East Melbourne, Victoria.

The rolling thirty-year average of annual mean sea level rose by 4.3 cms from 1966-1995 to 1990-2019 at Williamstown, which equates to a rise of 1.8 cms per decade. A similar increasing sea level trend was observed at Geelong during its span of observations, while the sea level rise observed at Point Lonsdale has remained stable when assessed as a thirty-year rolling average. However, it is notable that Point Lonsdale's annual mean sea level during the most recent decade (2010-2019) was 9.5 cms higher than the previous decade (2000-2009), which indicates that sea levels at Port Phillip Heads have just experienced the most dramatic decadal increase in sea levels since measurement began. The indicator assessment for this region should be read in conjunction with the statewide assessment that highlights the consistent trend and projections for increasing sea level.

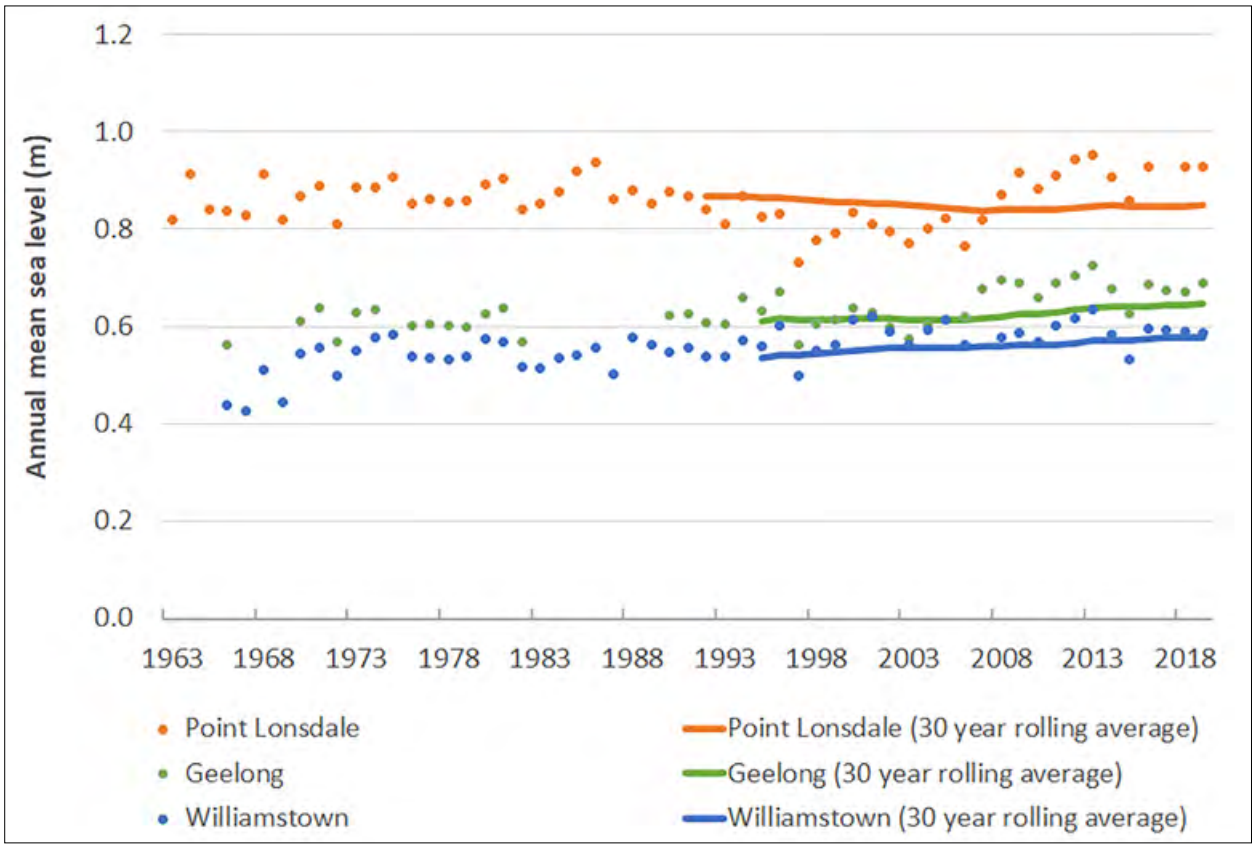


Figure 73: Observed sea level measurements at the Bureau of Meteorology's tide gauge in Port Phillip Bay, 1963-2019.[1280]

The highest sea level recorded at Williamstown between 1966 and 2019 occurred on 24 June 2014, when the gauge recorded values of up to 62 cms above Highest Astronomical Tide (the highest sea level that can be reached by astronomical tides).[1281] This event occurred in conjunction with a severe storm and caused inundation of many bayside foreshore reserves
and coastal infrastructure such as shared-use paths, beach access points and some roads.

1280. Prepared using Bureau of Meteorology (BoM), 'Tide gauge metadata and observed monthly sea levels and statistics' http://www.bom.gov.au/oceanography/projects/ntc/monthly/ Accessed 22 May 2021.
1281. Bureau of Meteorology (BoM), 'Tide gauge metadata and observed monthly sea levels and statistics', http://www.bom.gov.au/oceanography/projects/ntc/monthly/ Accessed 22 May 2021.

Figure 74: Sand deposited over the bicycle path at Middle Brighton on 24 June 2014.[1282]

1282. Photo: Andrew Watkins

Annual maximum sea levels at Williamstown have increased, on average, at a rate of 3.1 cms per decade between 1966 and 2019 when assessed as a thirty-year rolling average. This is a faster rate of increase for annual maximum sea level than annual mean sea level at Williamstown. A similar phenomenon has been observed at Geelong, with annual maximum sea levels there increasing at a rate of 1.9 cms per decade between 1966 and 2019 when assessed as a 30-year rolling average.

The frequency of very high sea levels has also increased, with statistically significant increases in the frequency at which the Highest Astronomical Tide is being exceeded at Williamstown and Geelong.

Sea level changes in association with the dredging works to deepen the shipping channels of Port Phillip Bay that occurred during 2008 and 2009 were assessed by the National Tidal Centre of the Bureau of Meteorology. An increase in tidal range of about 2 cms was found to have occurred due to the channel deepening. High tides were found to be about 1 cm higher and low tides were about 1 cm lower following the channel deepening. These changes were consistent with predicted changes reported in the Supplementary Environment Effects Statement for the Channel Deepening Project.[1283,1284]

Recent coastal inundation has mainly occurred when storm surges have coincided with high astronomical tides (for example, king tides or spring tides), which are higher than in the past due to sea level rise.

To visualise the possible impacts of coastal inundation, Figure 75 shows the extensive flooding (shaded in blue) that would occur in Point Lonsdale and Queenscliff, alongside Port Phillip Heads, in 2100 in a high tide under a high emissions scenario, which assumes a median sea level rise of 0.84 metres relative to the sea level of 1986–2005. This visualisation shows the considerable risk sea level rise and coastal inundation poses to property in Point Lonsdale and Queenscliff. The image was developed assuming average weather conditions (for example, no storm surges), which means that more extensive inundation is likely when sea levels are elevated above the normal high tide mark (for example, during a storm surge). In Queenscliff, the Highest Astronomical Tide was exceeded in all but two of the 24 months in 2018-2019. The image also does not account for any erosion that might happen between now and 2100, which would also lead to more extensive inundation.

Figure 75: Estimated coastal inundation at Point Lonsdale and Queenscliff, in high tide and assuming a 0.84 metre sea level rise relative to the sea level of 1986–2005.[1285]

1283. Symonds G and McInnes K 2013, 'Review of OEM assessment of potential causes of beach erosion at Portsea', CSIRO, Australia.
1284. Bureau of Meteorology (BoM) 2011, 'Tide height assessment in Port Phillip Bay report 9: quarter ending 31 December 2011'.
1285. Cooperative Research Centre for Spatial Information and NGIS, 'Coastal risk Australia' http://www.coastalrisk.com.au/ Accessed 26 September 2021.

PPB 47: Wave climate

Region	2021 status	2021 trend	2021 data
Port Phillip Bay		?	
Justification for assessment ratings:	A recent study on Port Phillip Bay's wave climate deepened the understanding of its characteristics and impacts. Extreme sea levels are often not associated with large extreme wave events in Port Phillip Bay, while meteorological and oceanographic forcing (that is, the combined wind, wave and climate conditions) is a key driver of impacts on marine and coastal infrastructure – this combination of various wave climate parameters produce approximately 70% of loads on structures. Because the research used for this indicator assessment is more of a characterisation of current wave climate rather than an analysis of the impacts of a changing wave climate due to climate change, the status has been rated as unknown, and the trend is unclear.		

The wave climate of Port Phillip Bay can be divided into two different regions: the northern, inner and southern portion including Port Phillip Heads.

In the inner part of the bay, wave climate is strongly linked with the wind patterns. During summer, in association with the mainland becoming a low-pressure region, the wind often blows towards the land (Figure 76). Therefore, waves propagate from south to north and the wave heights in the northern region of Port Phillip Bay are larger than in the south. The opposite wind pattern is true in winter. Wind generally blows from north to south in winter generating larger waves in the south than in the north. Waves in the southern region and entrance of the bay are more complex than in the inner region, especially in the vicinity of Port Phillip Heads, due to the presence of ocean swells from the Southern Ocean and strong tidal currents, the complexity of bathymetry and irregular shorelines.

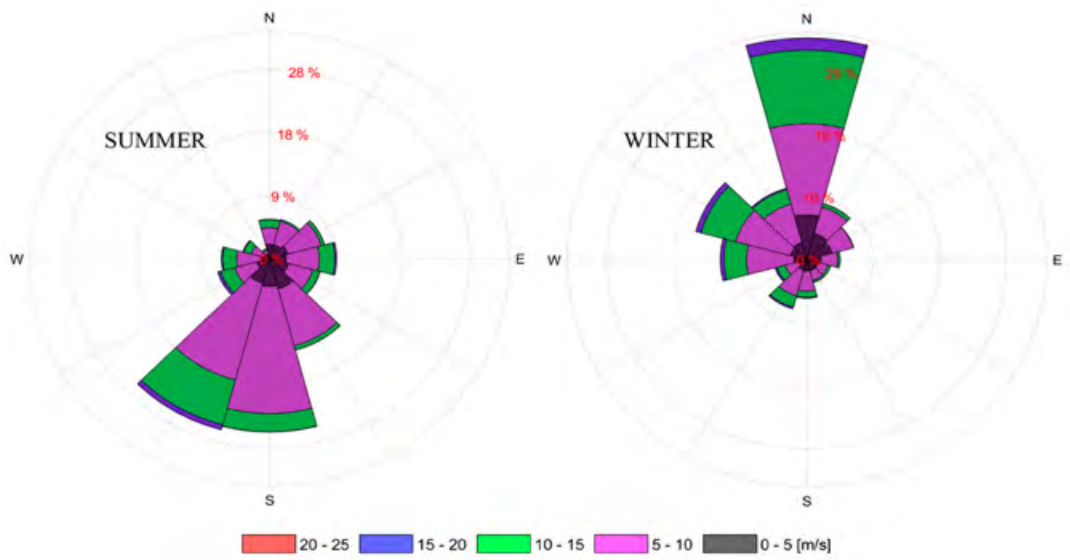


Figure 76: Wind roses at South Channel Island based on 15-year measurements (1998-2013).[1286]

Preliminary information from a recent study on Port Phillip Bay's wave climate provided to the Commissioner for Environmental Sustainability showed that large extreme sea levels are often not associated with large extreme wave events.[1287]

1286. Alex Babanin, the University of Melbourne, personal communication, 8 February 2021
1287. Ibid.

The study highlighted that meteorological and oceanographic forcing (that is, the combined wind, wave and climate conditions) is a key driver of impacts on marine and coastal infrastructure – this combination of various wave climate parameters produce approximately 70% of loads on structures and drives the sediment suspension and currents that propel sediment transport. This research covers 27 years of wave climate and will be a useful input to planning, as well as providing a benchmark for evaluating future trends.

PPB 48: Coastal erosion

Region	2021 status	2021 trend	2021 data
Port Phillip Bay		?	
Justification for assessment ratings:	The results of a 2017 erosion vulnerability assessment have been used to guide the status assessment for this indicator. 31% of Port Phillip Bay's coastline has been assessed as having very high or high vulnerability to coastal erosion, which is reflected in a status assessment of fair for this indicator. Because this mapping is a 'point-in-time' assessment, the trend is unclear.		

As part of the Port Phillip Bay Coastal Hazard Assessment, a Decision Support System is being built to provide a practical application to the increasing data and projections for coastal erosion. The Decision Support System is a platform that will enable planners to evaluate and understand the impacts of coastal hazards on land under different sea level rise scenarios. Coastal erosion is being mapped as part of the assessment and a sample visualisation of coastal erosion outputs within the Decision Support System prototype is shown in Figure 77. The erosion levels under different sea level rise scenarios will be shown in the form of zones based on probability.

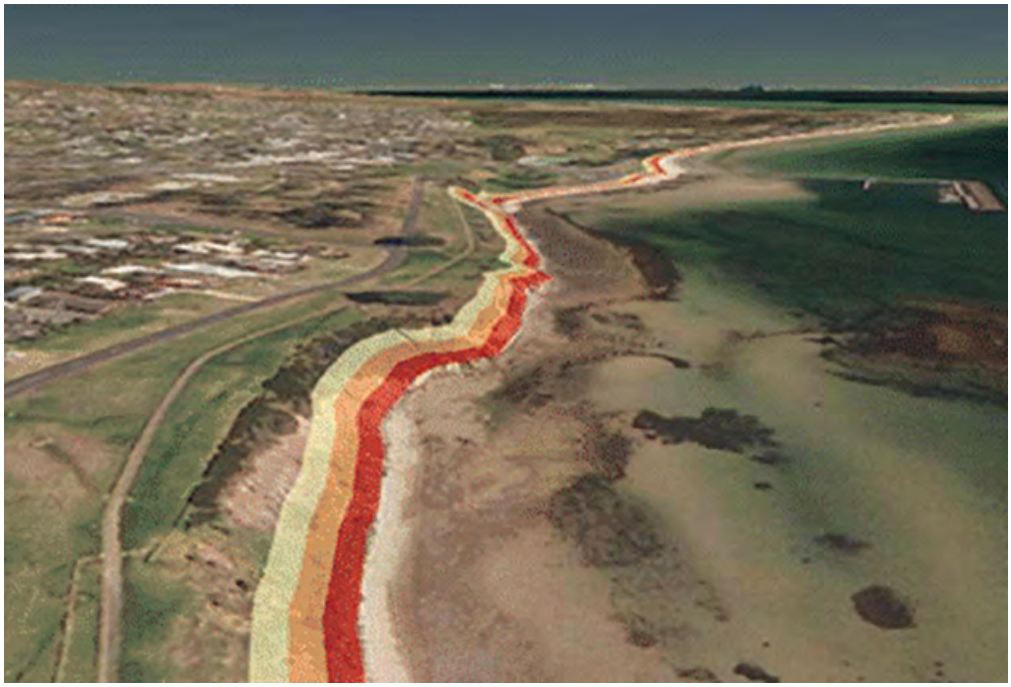


Figure 77: Visualisation of coastal erosion hazard within the Port Phillip Bay Coastal Hazard Assessment Decision Support System prototype.[1288]

1288. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Port Phillip Bay coastal hazard assessment – decision support system', East Melbourne, Victoria.

The results of a 2017 erosion vulnerability assessment commissioned by the Victorian Government show that 3.4% (15.2 km) of the Port Phillip Bay coastline is rated as having a very high vulnerability to coastal erosion (Table 32). Almost all this vulnerability is located along the eastern side of Port Phillip Bay.

Table 32: Coastline sediment compartment breakup showing total length and high and very high coastal erosion vulnerability ratings, Port Phillip Bay.[1289]

Location		Vulnerability rating				
		Very low	Low	Moderate	High	Very high
Port Phillip Bay West	Length (km)	0.0	15.0	154.2	67.0	1.6
	Proportion	0.00%	6.41%	64.76%	28.16%	0.67%
Port Phillip Bay East	Length (km)	0.0	13.0	123.7	56.7	13.6
	Proportion	0.00%	6.21%	59.82%	27.42%	6.55%
Port Phillip Bay Total	Length (km)	0.0	28.0	277.9	124.0	15.2
	Proportion	0.00%	6.32%	62.46%	27.81%	3.41%

PPB 49: Seawater intrusion into coastal aquifers

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. There is no published analysis of regional seawater intrusion into coastal aquifers in Victoria. More detail is available in the statewide assessment for this indicator.		

PPB 50: Frequency and impact of fire on marine and coastal ecosystems

Region	2021 status	2021 trend	2021 data
Port Phillip Bay	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The impact of fire on Port Phillip Bay's marine and coastal ecosystems is largely due to smoke plumes from major bushfires. This is covered in more detail within the coastal air quality indicator therefore no indicator assessment has been provided for this indicator for Port Phillip Bay.		

1289. Spatial Vision 2017, 'Victorian coastal hazard assessment 2017 technical report 1'.

PPB 51: Climate change impact on marine and coastal infrastructure

Region	2021 status	2021 trend	2021 data
Port Phillip Bay		?	
Justification for assessment ratings:	DELWP and CSIRO are working together to complete a coastal hazard assessment for Port Phillip Bay. This assessment will enable impact assessments and projections for inundation (flooding), groundwater change, and erosion for the Bay.		

DELWP and CSIRO are working together to complete a coastal hazard assessment for Port Phillip Bay. This assessment will enable impact assessments and projections for inundation (flooding), groundwater change, and erosion for the Bay. The Coastal Hazard Assessment will identify likely coastal hazard impacts around Port Phillip Bay through data analysis and modelling of a range of anticipated climate change scenarios. The data generated through the assessment will be shared with land managers and the community, to help them consider climate change in their future planning.[1290] The findings of the hazard assessment are scheduled to be published in 2022. While the assessment will not directly quantify the amount of infrastructure or buildings, it will provide up to date data which can be used to determine such impacts for Port Phillip Bay.

Western Port

WP 41: Rainfall

Region	2021 status	2021 trend	2021 data
Western Port		→	
Justification for assessment ratings:	The status and trend assessments of fair and stable respectively reflects the fluctuating pressure being exerted on the water resources and agricultural sectors by wetter and drier years. The confidence in the status and trend assessments is rated as moderate rather than high because even though the data quality on rainfall is good, knowledge on the impacts of rainfall on coastal settlements is constantly evolving.		

The Bureau of Meteorology has been measuring rainfall along the Western Port coastline since the 1880s. A weather station recorded rainfall observations at Cowes from 1882 until 1978, while current rainfall measurements are taken by the Bureau of Meteorology at Cerberus and Rhyll.

To account for the year-to-year variability associated with rainfall, a rolling ten-year average of annual rainfall has been assessed and shows there was not a significant long-term trend in annual rainfall at Western Port across the last 140 years (Figure 78). The start of the rainfall record in the 1880s was a wetter period, as were the 1950s, while the driest ten-year rolling average rainfall amounts were measured during the millennium drought early in the 21st century.

1290. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Port Phillip Bay coastal hazard assessment project overview', East Melbourne, Victoria.

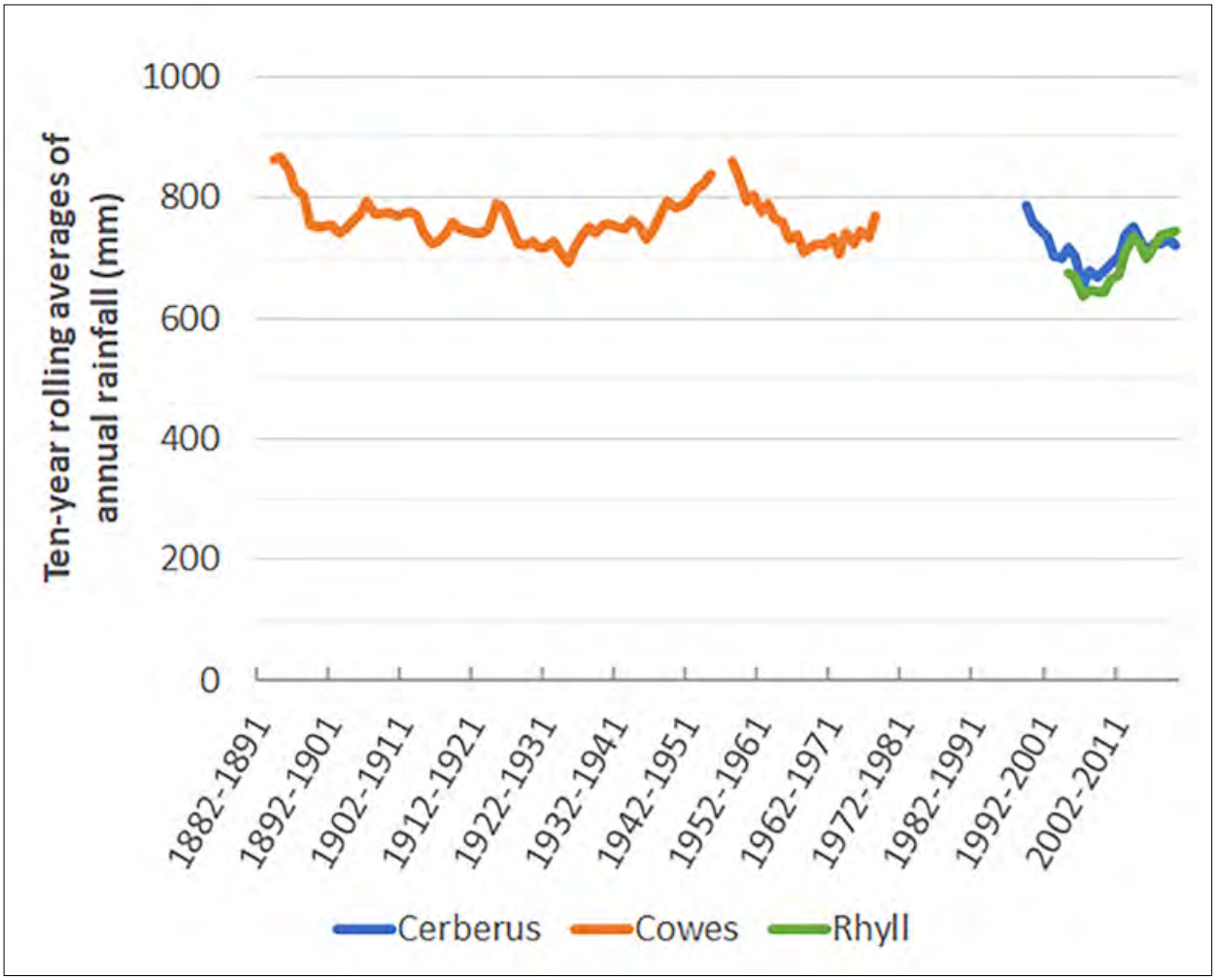


Figure 78: Observed rainfall measurements (presented as ten-year rolling averages) at the Bureau of Meteorology weather stations located along the Western Port coastline, 1882-1891 to 2010-2019.[1291]

The rainfall graph for cool-season rainfall (April to October) shows a similarly stable pattern of rainfall over a long-term trend period (Figure 79). Interestingly, the ten-year rolling average of cool season rainfall at Cerberus hasn't returned to pre-millennium drought levels even though the annual rainfall has increased during the past decade. Given there is high confidence that natural climate variability will remain the major driver of rainfall changes in the short term (until 2030), this recent decline in cool season rainfall in Cerberus is unlikely to become significantly more pronounced in the next decade. This window of opportunity for climate change adaptation action should be utilised by the agriculture and water resources sectors that are likely to be increasingly impacted by reduced water availability as the 21st century progresses.

1291. Prepared using Bureau of Meteorology (BoM), 'Climate data online' http://www.bom.gov.au/climate/data

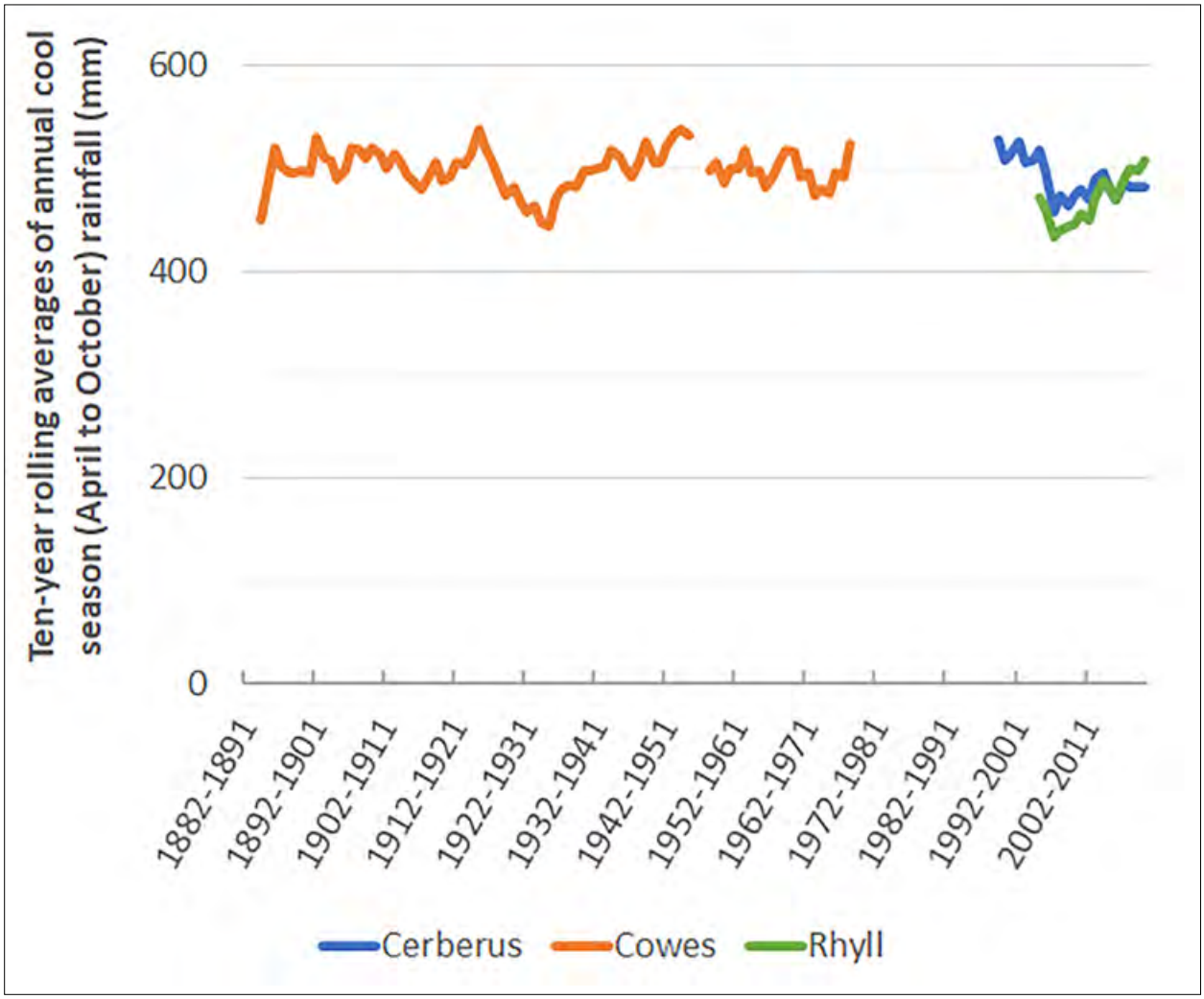


Figure 79: Observed rainfall measurements (presented as ten-year rolling averages) for the cool season (April to October) at Bureau of Meteorology weather stations located along the Western Port coastline, 1882-1891 to 2010-2019.[1292]

Rainfall will continue to be variable over time, but over the long term it is expected to continue to decline in winter and spring (medium to high confidence), and autumn (low to medium confidence). Extreme rainfall events are expected to become more intense on average through the rest of the 21st century (high confidence).[1293]

1292. Ibid.
1293. Clarke JM, Grose M, Thatcher M, Round V and Heady C 2019, 'Greater Melbourne climate projections 2019', CSIRO, Melbourne Australia.

WP 42: Air temperature

Region	2021 status	2021 trend	2021 data
Western Port			
Justification for assessment ratings:	The status and trend assessments of fair and deteriorating respectively reflect the increasing pressure being exerted on human health, biodiversity and coastal infrastructure. Temperature measurements made at coastal settlements along Western Port show that temperatures have increased by approximately 1°C from the 1990s to the 2010s, highlighting the rapid rate of recent warming. The confidence in the status and trend assessments is rated as moderate rather than high because even though the data quality on temperature is good, knowledge on the impacts of increasing temperatures is constantly evolving.		

Despite there being no ACORN-SAT temperature data constructed for the Western Port coastline, the Bureau of Meteorology has operated a range of weather stations along the Western Port coastline for over 100 years. The longest continuous records for currently open stations are at Cerberus and Rhyll, which both opened in late 1991. The rolling ten-year average of annual mean maximum temperatures has increased at Rhyll by 1.01°C and at Cerberus by 0.89°C per from 1992-2001 to 2010-2019, which equates to an increase of 0.53°C per decade at Rhyll and 0.47°C per decade at Cerberus. The temperature increase has been more distinct during the summer months at Rhyll, with the summer temperature increasing by 1.25°C from 1992-2001 to 2010-2019 (0.63°C per decade). The summer temperature trend at Cerberus is very similar to the annual trend.

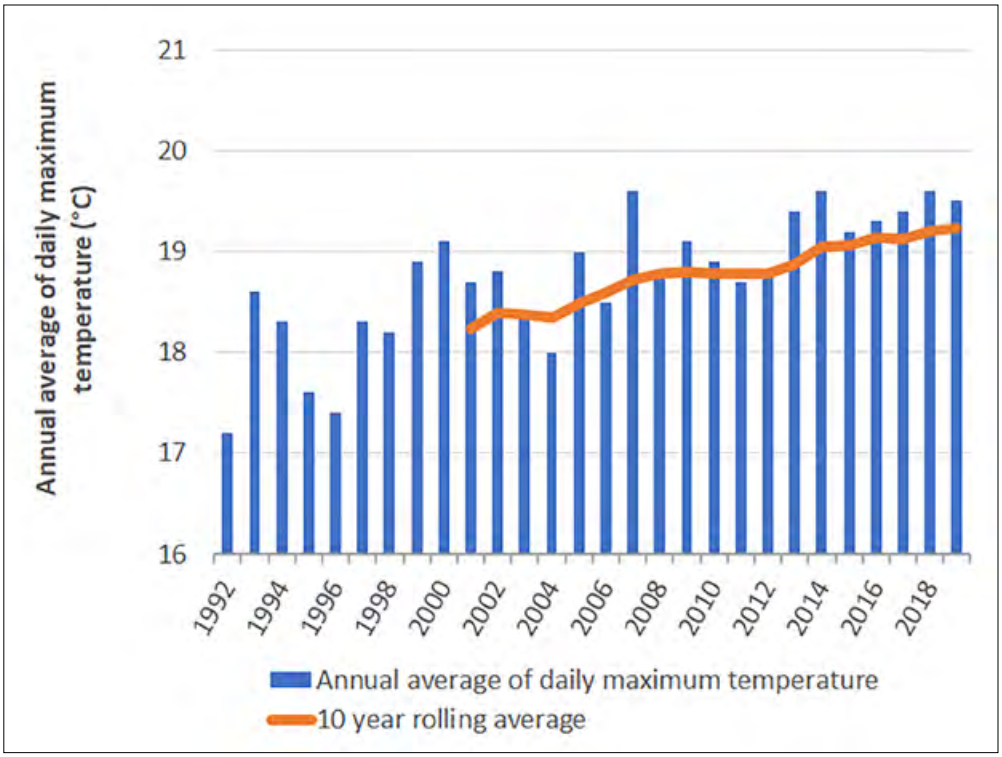


Figure 80: Observed temperature measurements at the Bureau of Meteorology's Rhyll station, 1992-2019.[1294]

1294. Prepared using Bureau of Meteorology (BoM), 'Climate data online' http://www.bom.gov.au/climate/data

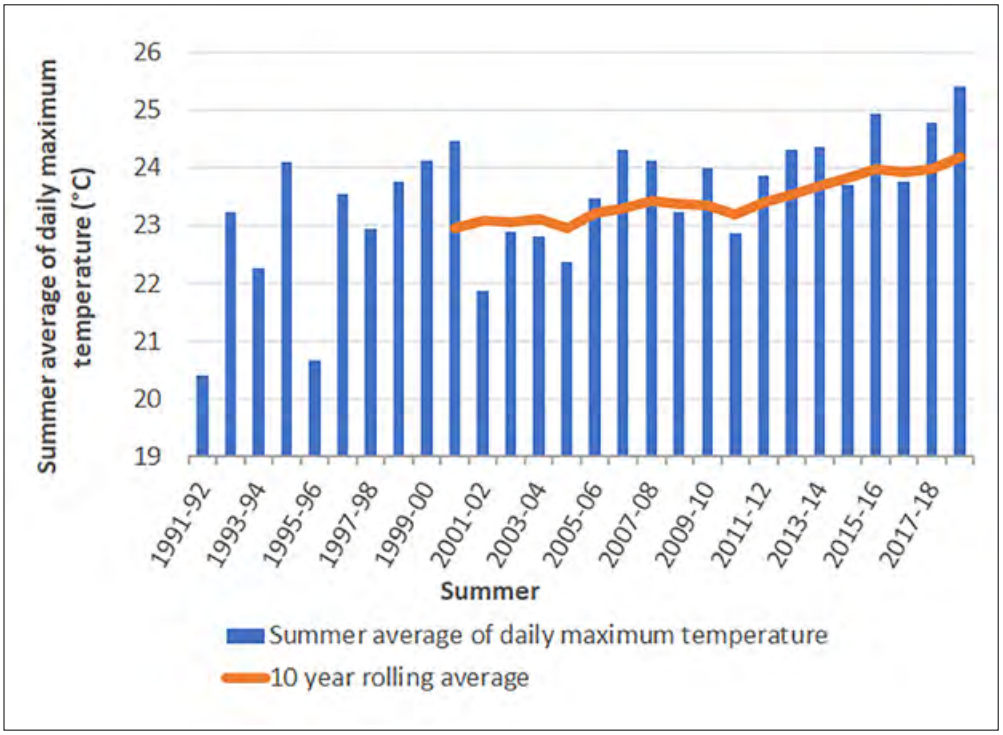


Figure 81: Observed summer temperature measurements at the Bureau of Meteorology's Rhyll station, 1991-92 to 2018-19.[1295]

WP 43: Water Temperature

Region	2021 status	2021 trend	2021 data
Western Port	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The east-west orientation of Victoria's coastline means there is limited variation in water temperature. Therefore, the water temperature indicator has been included as a statewide assessment.		

WP 44: Ocean acidification

Region	2021 status	2021 trend	2021 data
Western Port	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The east-west orientation of Victoria's coastline means there is limited variation in ocean acidification. Therefore, the ocean acidification indicator has been included as a statewide assessment.		

1295. Ibid.

WP 45: Areas of coastal vulnerability

Region	2021 status	2021 trend	2021 data
Western Port		?	
Justification for assessment ratings:	The most recent comprehensive assessment of coastal inundation and erosion hazards for Western Port occurred in 2014. A range of hazards were identified, however the spatial extent of the area of coastal vulnerability is unknown.		

Coastal inundation and erosion hazards vary significantly across Western Port and the most recent comprehensive assessment occurred in 2014.[1296] The 2014 assessment analysed erosion and inundation hazards, focusing on four locations: Balnarring to Somers, Tooradin and Coastal Villages, Lang Lang, and Rhyll Inlet and Silverleaves.

An overview of the key hazard components associated with inundation and erosion hazards for each of the representative locations is provided in Table 33.

Table 33: Overview of Coastal Hazards for the Representative Locations in Western Port.[1297]

Location	Shoreline types	Inundation hazards	Erosion hazards
Balnarring- Somers	Sandy spit Platform beach and bluff Estuarine	Estuarine (ICOLL) response Storm tide inundation	Backshore sand lobe migration Equilibrium profile recession Bluff reactivation
Tooradin and Coastal Villages	Coastal wetland fringed Estuarine	Storm tide inundation	Loss of coastal wetlands Backshore tidal inundation
Lang Lang	Low earth cliffed	Storm tide inundation	Cliff recession Backshore tidal inundation
Rhyll Inlet and Silverleaves	Sandy spit Coastal wetland fringed	Storm tide inundation	Backshore sand lobe migration Equilibrium profile recession Loss of coastal wetlands Bluff reactivation

1296. Water Technology 2014, 'Western Port local coastal hazard assessment report 1 (R01) – summary report', prepared for Melbourne Water.
1297. Ibid.

WP 46: Sea-level and coastal inundation

Region	2021 status	2021 trend	2021 data
Western Port			
Justification for assessment ratings:	The status and trend assessments of fair and deteriorating respectively reflect the increasing pressure being exerted on human coastal settlements and infrastructure.		

Tidal data has been collected in Western Port at Stony Point from 1981, although data was only intermittently collected until 1983. The rolling ten-year average of annual mean sea level rose by 9.8 cms from 1983-1992 to 2011-2020 at Stony Point, which equates to a rise of 3.5 cms per decade.

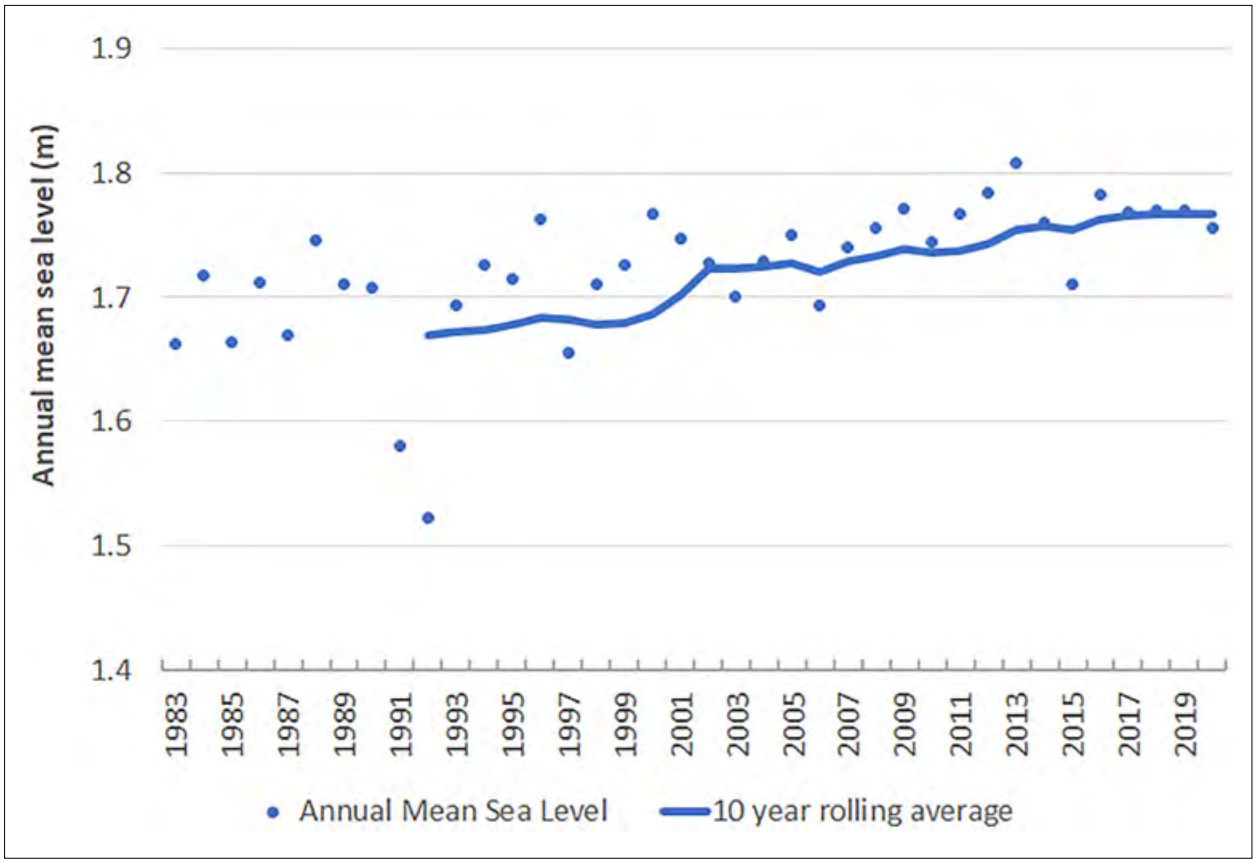


Figure 82: Observed sea level measurements at the Bureau of Meteorology's Stony Point tide gauge.[1298]

The highest sea level recorded in Stony Point occurred on 6 June 1988. This event occurred in conjunction with heavy rainfall. Annual maximum sea levels at Stony Point have increased by 10 cms from the 1990s to the 2010s, which is an average increase of 5 cms per decade.

1298. Prepared using Bureau of Meteorology (BoM) 'Tide gauge metadata and observed monthly sea levels and statistics' http://www.bom.gov.au/oceanography/projects/ntc/monthly/ Accessed 22 May 2021.

To visualise the possible impacts of coastal inundation, Figure 83 shows an area (shaded in blue) that would be flooded to the eastern side of Cowes on Phillip Island in 2100 at high tide under a high emissions scenario, which assumes a median sea level rise of 0.84 metres relative to the sea level of 1986–2005. This visualisation shows the considerable risk sea level rise and coastal inundation poses to property in Phillip Island. The image was developed assuming average weather conditions (for example, no storm surges), which means that more extensive inundation is likely when sea levels are elevated above the normal high tide mark (for example, during a storm surge).

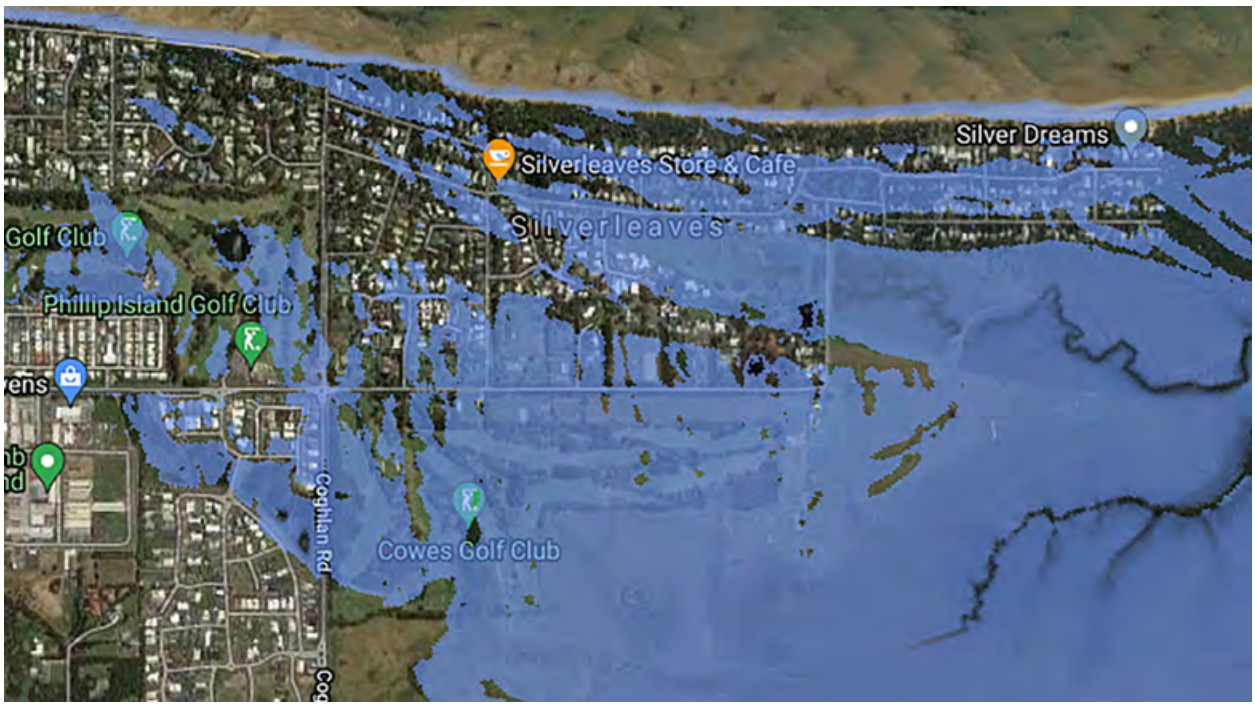


Figure 83: Estimated coastal inundation at Cowes, Phillip Island, in high tide and assuming a 0.84 metres sea level rise relative to the sea level of 1986–2005.[1299]

Areas of Western Port at risk to coastal inundation are included in Table 33 in Indicator WP 45: Areas of coastal vulnerability.

1299. Cooperative Research Centre for Spatial Information and NGIS, 'Coastal risk Australia' http://www.coastalrisk.com.au/ Accessed 26 September 2021.

WP 47: Wave climate

Region	2021 status	2021 trend	2021 data
Western Port	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. No specific wave climate studies for Western Port were available for use in this report. Therefore, this indicator is not assessed for this region. More detail is available in the statewide assessment for this indicator.		

WP 48: Coastal erosion

Region	2021 status	2021 trend	2021 data
Western Port	●	↙	●
Justification for assessment ratings:	Two studies in recent years have measured the Lang Lang coastline at the head of Western Port to be eroding, on average, by approximately 30 cms per year, while coastal bank erosion has also been estimated to be responsible for a third of the sediment delivered to Western Port annually. The results of a 2017 erosion vulnerability assessment have also been used to guide the status assessment for this indicator - 27% of Western Port's coastline has been assessed as having very high or high vulnerability to coastal erosion. This information is reflected in a status assessment of fair for this indicator, with a deteriorating trend.		

As part of the Victorian Coastal Monitoring Program, a series of projects are currently being undertaken by academics and government scientists to improve coastal erosion assessments for Victorian embayments and living shorelines, such as Western Port.[1300]

Relative sea level fall is common for coastal features worldwide and is usually associated with a drop in the base level of rivers connected to the coast. The resulting increase in discharge often leads to the deposition of sediments at the head of embayments. However, this is not the case in Western Port. During the Holocene, sea levels in Western Port reached 1.5 – 2 metres higher than present levels. The subsequent sea-level fall led to the stranding of extensive Koo Wee Rup coastal swamp deposits along the Lang Lang coastline at the head of Western Port. Two studies in recent years have measured the coastline in this region to be eroding on average by approximately 30 cms per year.[1301,1302]

This section of coastline is a significant contributor of sediment to Western Port, with coastal bank erosion estimated to be responsible for a third of the sediment delivered to Western Port annually.[1303,1304] Further analysis of sediments in Western Port is provided in Indicator WP 9: Total sediment loads.

The Lang Lang coastline lies at the end of the largest fetch available for the development of windwaves in Western Port. Evaporation has been correlated with erosion along this coastline. Additionally, the orientation of the coastline relative to the prevailing wave climate has also been identified as a potential driver.[1305]

1300. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Improving coastal erosion assessments for Victoria: embayments and living shorelines research project summaries - August 2019' https://www.marineandcoasts.vic.gov.au/coastal-programs/victorian-coastal-monitoring-program?a=436223 Accessed 7 July 2020.
1301. Wilkinson S, Anstee J, Joehnk K, Karim F, Lorenz Z, Glover M and Coleman R 2016, 'Western Port sediment supply, seagrass interactions and remote sensing', report to Melbourne Water Corporation, CSIRO, Melbourne, Australia.
1302. Tomkins K, McLachlan G, Coleman R 2014, 'Quantification of coastal bank erosion rates in Western Port', CSIRO Water for a Healthy Country Flagship, Australia.
1303. Ibid.
1304. Wallbrink PJ, Hancock GJ, Olley JM, Hughes A, Prosser IP, Hunt D, Rooney G, Coleman R, Stevenson J 2003, 'The Westernport Sediment Study', Consultancy Report, CSIRO Land and Water.
1305. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Improving coastal erosion assessments for Victoria: embayments and living shorelines research project summaries - August 2019' https://www.marineandcoasts.vic.gov.au/coastal-programs/victorian-coastal-monitoring-program?a=436223 Accessed 7 July 2020.

The results of a 2017 erosion vulnerability assessment commissioned by the Victorian Government show that only 200 metres of the Western Port coastline is rated as having a very high vulnerability to coastal erosion, however more than 100 km is rated as having a high vulnerability.

Table 34: Coastline sediment compartment breakup showing total length and high and very high coastal erosion vulnerability ratings, Western Port.[1306]

Location		Vulnerability rating				
		Very low	Low	Moderate	High	Very high
Western Port	Length (km)	0.0	45.0	243.4	105.0	0.2
	Proportion	0.0%	11.4%	61.9%	26.6%	0.1%

WP 49: Seawater intrusion into coastal aquifers

Region	2021 status	2021 trend	2021 data
Western Port	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. There is no published analysis of regional seawater intrusion into coastal aquifers in Victoria. More detail is available in the statewide assessment for this indicator.		

WP 50: Frequency and impact of fire on marine ecosystems

Region	2021 status	2021 trend	2021 data
Western Port	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. No specific studies on the frequency and impact of fire on marine and coastal ecosystems for Western Port were available for use in this report. Therefore, this indicator is not assessed for this region.		

1306. Spatial Vision 2017, 'Victorian coastal hazard assessment 2017 technical report 1'.

WP 51: Climate change impact on marine and coastal infrastructure

Region	2021 status	2021 trend	2021 data
Western Port			
Justification for assessment ratings:	A significant number of coastal infrastructure assets, valued in the billions of dollars, are at risk from climate change. For example, based on flood mapping information available in 2008, an estimated 18,000 properties with a total capital improved value of almost $2 billion are vulnerable to flood events.[1307] The effects of climate change are expected to dramatically increase the likelihood of this flood risk, with projections suggesting that a current 1-in-100-year storm surge could become a 1-in-1 to 1-in-4-year storm surge by 2070.		

A detailed 2008 report, jointly funded by the Commonwealth and Victorian State Government, investigated the impacts of climate change on settlements in the Western Port Region.[1308] Significant findings included in the report are presented below and categorised by sub-headings.

Impacts associated with coastal inundation

- Storm surge inundation simulations for the region, undertaken by CSIRO, suggest that a current 1-in-100-year storm surge could become a 1-in-1 to 1-in-4-year storm surge by 2070.
- Furthermore, the land area subject to inundation during a 1-in-100-year storm surge event may increase by 4-15% by 2030 and 16-63% by 2070.
- The fact that only a narrow strip of land is exposed to coastal processes such as storm surges means that the exposure of associated property, populations and infrastructure is inherently constrained. Nevertheless, such inundation would impinge upon over 2,000 individuals, over 1,000 dwellings, and approximately $780 million in improved property value.
- Community infrastructure is also at risk, including major thoroughfares such as the Nepean and South Gippsland Highways, and boating facilities. Beaches, foreshore reserves and coastal wetland areas throughout the region, as well as the amenities they provide, are likely to be affected as well.
- Areas most at risk include townships on Phillip Island in Bass Coast Shire, coastal townships in the City of Casey including Tooradin and Warneet, and the township of Hastings in the Mornington Peninsula Shire.

Impacts associated with intense rainfall and inland flooding

- At least 619 km^2 (18%) of the Western Port region lies in land areas subject to inundation or overland flow paths.
- While significant advancements in flood protection have been made over the past century, future climate change poses an additional challenge. Simulations of extreme rainfall in 2030 suggest increases of up to 25% in extreme rainfall from events of 1 to 24 hours in duration in at-risk areas of Western Port region. By 2070, extreme rainfall is projected to increase by up to 70%, depending on location. Such increases in extreme rainfall could drive increases in the frequency or magnitude of flood events or flood heights.
- Based on flood mapping information available in 2008, an estimated 18,000 properties with a total capital improved value of almost $2 billion are vulnerable to flood events. Approximately 13,000 of the properties were residential, with 40% of those containing dwellings vulnerable to above-floor flooding.

1307. Kinrade P and Preston B 2008, 'Impacts of climate change on settlements in the Western Port region: people, property and places', Australian Department of Climate Change and Victorian Department of Sustainability and Environment.
1308. Ibid.

- A range of Melbourne's and the State's major transport corridors also occur in at-risk areas including over 1,500 km of roads and 125 km of rail, and dozens of bridges. A range of businesses, industries, public services and utilities are also vulnerable to disruptions from flooding. Indirect economic costs associated with flooding of this infrastructure could be significant relative to direct damages.
- Areas most at risk include much of southern Cardinia Shire (the Koo Wee Rup swamp) and southeast and central Casey.

Impacts associated with changes to fire weather conditions

- As at 2008, an estimated 710 km^2 (21%) of the Western Port region was in bushfire prone areas. Given the distribution of property, people and infrastructure at that time, over 73,000 individuals and approximately 35,000 properties (including 28,000 dwellings), with a capital improved value of $7.6 billion, were located in at-risk areas.
- A range of major transport corridors also occur in at-risk areas including over 1,600 km of roads and 75 km of rail, including the Nepean, South Gippsland, and Bass Highways as well as heavily travelled rail lines. Electricity transmission lines from the Latrobe Valley that traverse the Western Port region and provide electricity to Melbourne and Gippsland are also exposed to bushfire in multiple locations.
- Overall, those areas most at risk include the Gurdies in Bass Coast Shire, much of northern Cardinia including the townships of Emerald, Cockatoo and Gembrook, central and southeast Frankston and bushland areas in Mornington Peninsula Shire, particularly around the townships of Dromana and Mornington as well as around HMAS Cerberus.

Coastal flooding at Lakes Entrance
© Rex Candy, East Gippsland Catchment Management Authority

Corner Inlet and Nooramunga

CIN 41: Rainfall

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga		↙	
Justification for assessment ratings:	The status and trend assessments of fair and deteriorating respectively reflect the fluctuating pressure being exerted on the water resources and agricultural sectors by wetter years interspersing a predominately drying climate. The enhanced rainfall reduction during the cool seasons is particularly important given the adverse impacts this can have on streamflows and the reduced reliability for water storage filling seasons. The confidence in the status and trend assessments is rated as moderate rather than high because even though the data quality on rainfall is good, knowledge on the impacts of rainfall on coastal settlements is constantly evolving.		

The Bureau of Meteorology has been operating a weather station and measuring rainfall at the Shallow Inlet in Yanakie since 1967, although this location is on the opposite side of Yanakie to Corner Inlet. A second weather station in Yanakie, situated on the Corner Inlet side, became operational in 2013. The annual rainfall amounts for both Yanakie weather stations average to within 17 mm of each other (or within 2%) for the seven years they have both been collecting data, indicating the rainfall data at Shallow Inlet dating back to 1967 is representative of the rainfall on the Corner Inlet side.

To account for the year-to-year variability associated with rainfall, a rolling ten-year average of annual rainfall has been assessed and shows there wasn't a strong long-term trend in annual rainfall at Yanakie.

The rainfall graph for cool-season rainfall (April to October) hasn't been included, but it has an almost identical shape. The most recent seven years of observations (2013-2019) for cool-season rainfall have recorded approximately 15% less rainfall, on average, than the years from 1967 to 2000. This highlights the pressures on agriculture, water resources and water quality in the region that are enhanced by reductions in winter and spring inflows after water storages are typically drawn-down during late autumn.

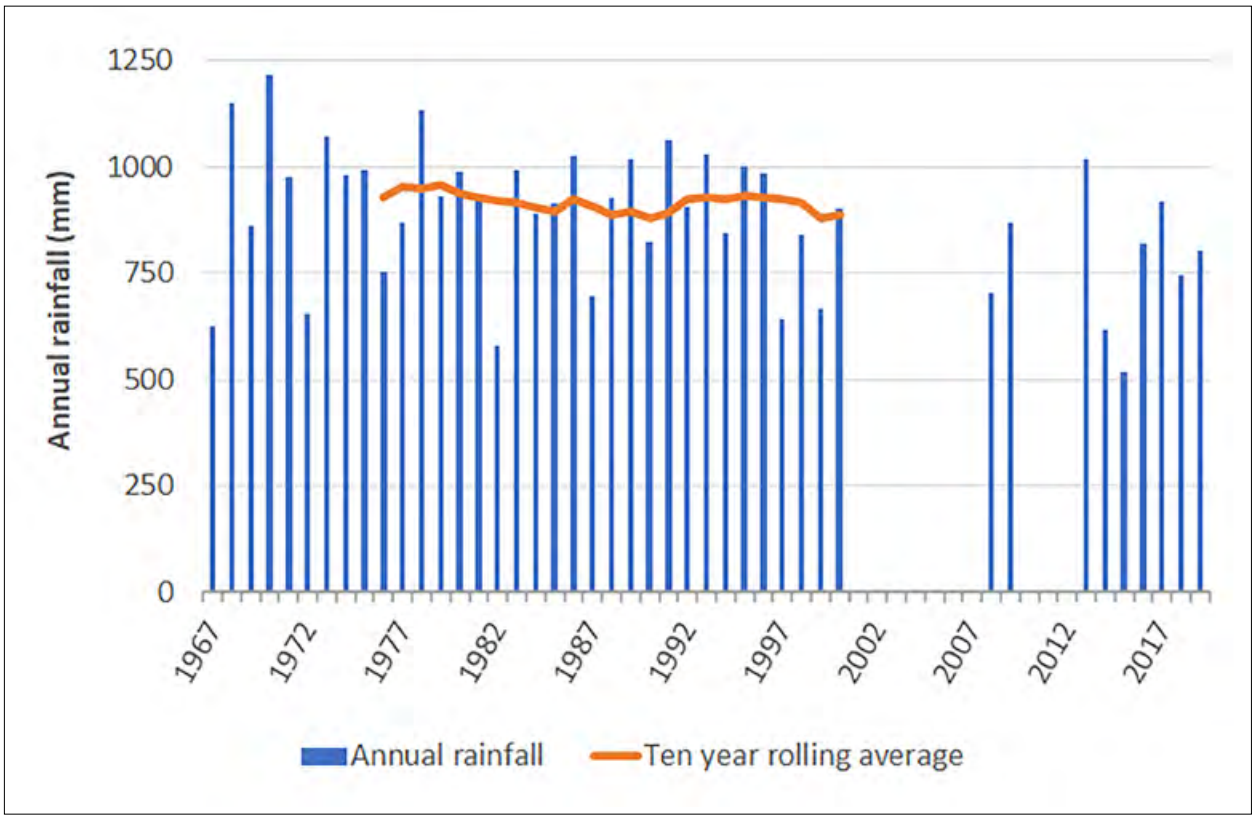


Figure 84: Observed rainfall measurements at the Bureau of Meteorology's Yanakie (Shallow Inlet) station, 1967-2019.[1309]

Rainfall will continue to be variable over time, but over the long term it is expected to continue to decline in winter and spring (medium to high confidence), and autumn (low to medium confidence). Extreme rainfall events are expected to become more intense on average through the rest of the 21st century (high confidence).[1310]

1309. Prepared using Bureau of Meteorology (BoM), 'Climate data online' http://www.bom.gov.au/climate/data
1310. Clarke JM, Grose M, Thatcher M, Round V and Heady C 2019, 'Greater Melbourne climate projections 2019', CSIRO, Melbourne Australia.

CIN 42: Air temperature

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga			
Justification for assessment ratings:	The status and trend assessments of fair and deteriorating respectively reflect the increasing pressure being exerted on human health, biodiversity and coastal infrastructure. Wilsons Promontory was 0.8°C warmer during the 2010s than the 1990s, highlighting the rapid rate of recent warming. The confidence in the status and trend assessments is rated as moderate rather than high because even though the data quality on temperature is good, knowledge on the impacts of increasing temperatures is constantly evolving.		

The Bureau of Meteorology has been operating a weather station and measuring temperature in Yanakie since 2013, however this dataset is too recent to determine trends. Yanakie is a small coastal town that sits on the coast of Corner Inlet. The closest Bureau of Meteorology weather station to Corner Inlet that has a long-term dataset of weather observations is at the southern tip of Wilsons Promontory, which is approximately 30 km from the southern edge of Corner Inlet. The seven years of data comparing Yanakie to Wilsons Promontory from 2013 to 2019 show annual mean maximum temperatures at Yanakie have been an average of 1.7°C warmer. The significant difference in temperature between the two nearby locations is most likely due to the weather station in Wilsons Promontory being located at the southern tip of Victoria and exposed to the weather patterns coming from Bass Strait.

Even though the absolute temperature values for Wilsons Promontory differ from those at Yanakie, they are still suitable for providing a relative guide for temperature trends in the broader region.

The Australian Climate Observations Reference Network – Surface Air Temperature (ACORN-SAT) is the dataset used by the Bureau of Meteorology to monitor long-term temperature trends in Australia. ACORN-SAT uses observations from 112 weather stations across Australia, selected for the quality and length of their available temperature data.[1311] The ACORN-SAT network provides temperature data for Wilsons Promontory since 1910.

The rolling fifty-year average of annual mean maximum temperatures for Wilsons Promontory remained stable within a temperature range of 16.23 to 16.29°C for the first 20 years of the fifty-year rolling average (from 1910-1959 to 1930-1979). This stability over a 20-year time period that encompasses a range of climatic phenomena (for example, El Nino, La Nina and the Sunspot cycle all occur over finer time resolutions) is indicative of the first 50-year rolling average of Wilsons Promontory temperature (1910-1959), 16.24°C, being representative of a pre-industrial era temperature profile.

1311. Bureau of Meteorology (BoM) 2021, 'Long-term temperature record' http://www.bom.gov.au/climate/data/acorn-sat/ Accessed 25 January 2021.

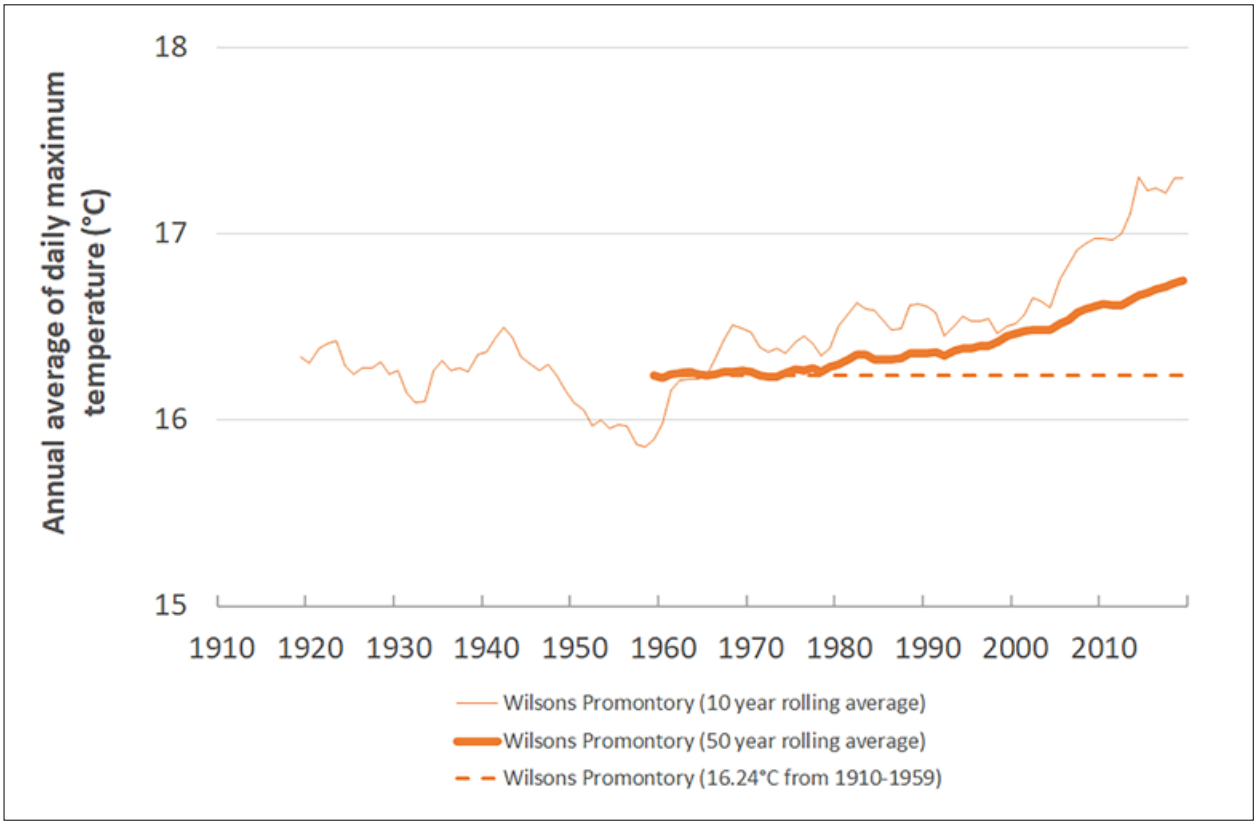


Figure 85: Annual average of daily maximum temperature (°C) from Bureau of Meteorology ACORN-SAT data for Wilsons Promontory, 1910 to 2019.[1312]

The rolling ten-year average has increased significantly, by 1.14°C, from the 1940s[1313] to the 2010s, with the rate of increase being most pronounced during the past 20 years, with the 2010s being 0.80°C warmer than the 1990s.

CIN 43: Water Temperature

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The east-west orientation of Victoria's coastline means there is limited variation in water temperature. Therefore, the water temperature indicator has been included as a statewide assessment.		

CIN 44: Ocean acidification

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The east-west orientation of Victoria's coastline means there is limited variation in ocean acidification. Therefore, the ocean acidification indicator has been included as a statewide assessment.		

1312. Data used to generate the graph is extracted from Bureau of Meteorology (BoM), ACORN-SAT Australia v2 (snapshot v.2.1.0.1), Australian Climate Observations Reference Network - surface air temperature (1910-May 2019).
1313. Note that the 1940s was used for this comparison rather than the 1950s because the data for the 1950s contained a few periods of missing data and is considered to be less reliable for a decadal analysis.

CIN 45: Areas of coastal vulnerability

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga			
Justification for assessment ratings:	Modelling predicts that Corner Inlet will be extensively impacted by climate change. With the impacts worsening over time. A range of hazards were identified, however the spatial extent of the area of coastal vulnerability is unknown so the confidence in the status and trend assessments is only rated as moderate.		

Corner Inlet will be extensively impacted by climate change according to modelling.

The potential impacts of coastal inundation have been assessed for the Victorian Coastal Monitoring Program using predicted sea level rise and storm surge data for three periods (2040, 2070 and 2100), the extent of 1-in-100-year coastal flood events, and the presence of coastal acid sulphate soils.[1314] The modelling uses a conservative sea level rise of 20 cms by 2040 and 82 cms by 2100 and, importantly, the effects of storm surges were incorporated into the modelling.[1315]

The modelling was used to inform the Victorian Environmental Assessment Council's (VEACs) Assessment of Victorian Coastal Reserves report that was published in 2020.[1316] Based on the modelled inundation and storm surge data, the Corner Inlet Boat Club Reserve and the Port Welshpool Bowling Club Reserve are expected to be completely inundated by 2040 due to sea level rise with the addition of a storm surge.[1317]

In addition to the reserves that are predicted to be totally inundated by sea level rise and during storm surges by 2040, Fisher Reserve (Foster Beach) and Lawson Beach, both at Port Franklin, are also predicted to be impacted over their entire areas by sea level rise combined with storm surge by 2100.[1318]

The West Gippsland Catchment Management Authority have advised that sea walls currently provide protection from flooding to large areas of private farming land in the terrestrial land adjacent to Corner Inlet and Nooramunga. Sea level rise is likely to result in these walls being overtopped by storm surges if they remain intact. These sea walls are not actively maintained, so sea level rise is likely to contribute to a deterioration in the condition of these walls, which would mean they are overtopped more regularly. This issue also impacts coastal habitats. As sea level continues to rise, the loss of intertidal coastal habitats can be expected to increase if the use of shoreline armouring also increases. Shoreline armouring refers to shore protection approaches that use built infrastructure (for example, seawalls, revetments and levees) for protecting coastlines and coastal assets against seaward risks such as storm surges and wave damage.[1319] Whilst being a familiar management approach, the use of hard infrastructure often comes at the cost of replacing natural habitats. Although armouring structures can provide temporary protection for coastal property, over the longer-term they cause changes in sediment, current and wave dynamics that accelerate erosion, often resulting in the loss of the very beaches and coastal habitats they were intended to protect.[1320]

1314. Spatial Vision 2017, 'Victorian coastal hazard assessment 2017 technical report 1'.
1315. Ibid.
1316. Victorian Environmental Assessment Council (VEAC) 2020, 'Assessment of Victoria's coastal reserves final report' Melbourne, Victoria.
1317. Ibid.
1318. Ibid.
1319. Leo KL, Gillies CL, Fitzsimons JA, Hale LZ, Beck MW 2019, 'Coastal habitat squeeze: a review of adaptation solutions for saltmarsh, mangrove and beach habitats', Ocean and Coastal Management, 175, pp. 180-190.
1320. Ibid.

CIN 46: Sea-level and coastal inundation

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga		?	
Justification for assessment ratings:	The status assessment of fair reflects the pressure being exerted on human coastal settlements and infrastructure. The confidence in the assessments is moderate rather than high to reflect that the time series of tidal gauge data covers less than two decades and contains many gaps.		

Tidal data has been collected at Port Welshpool, which is to the north east corner of Corner Inlet, since 2001. The data from 2001 to 2008 contain many gaps (for example, no data was collected during 2004, 2005, 2007 or 2008). No discernible trends are apparent from 2009 onwards.

To visualise the possible impacts of coastal inundation, Figure 86 shows an area (shaded in blue) that would be flooded at Port Franklin in 2100 in a high tide under a high emissions scenario, which assumes a median sea level rise of 0.84 metres relative to the sea level of 1986–2005. This visualisation shows the considerable risk sea level rise and coastal inundation poses to property in Port Franklin. The image was developed assuming average weather conditions (for example, no storm surges), which means that more extensive inundation is likely when sea levels are elevated above the normal high tide mark (for example, during a storm surge).

Figure 86: Estimated coastal inundation at Port Franklin in high tide and assuming a 0.84 metres sea level rise relative to the sea level of 1986–2005.[1321]

1321. Cooperative Research Centre for Spatial Information and NGIS, 'Coastal risk Australia' http://www.coastalrisk.com.au/ Accessed 26 September 2021.

CIN 47: Wave climate

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. No specific wave climate studies for Corner Inlet and Nooramunga were available for use in this report. Therefore, this indicator is not assessed for this region. More detail is available in the statewide assessment for this indicator.		

CIN 48: Coastal erosion

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	↙	●
Justification for assessment ratings:	The results of a 2017 erosion vulnerability assessment have been used to guide the status assessment for this indicator. 34% of Corner Inlet and Nooramunga's coastline has been assessed as having very high or high vulnerability to coastal erosion, which is reflected in a status assessment of fair for this indicator. Because this mapping is a 'point-in-time' assessment, the trend is unclear.		

The results of a 2017 erosion vulnerability assessment commissioned by the Victorian Government show that nearly 20 km of the Corner Inlet coastline is rated as having a very high vulnerability to coastal erosion (Table 35). Interestingly, 96% of Corner Inlet's entire coastline is rated as being moderately or highly vulnerable to erosion, which indicates the extent of vulnerability to erosion in the region.

Table 35: Coastline sediment compartment breakup showing total length and high and very high coastal erosion vulnerability ratings, Corner Inlet.[1322]

Location		Vulnerability rating				
		Very low	Low	Moderate	High	Very high
Corner Inlet	Length (km)	0.0	7.0	480.5	235.0	19.6
	Proportion	0.0%	0.9%	64.8%	31.2%	2.6%

CIN 49: Seawater intrusion into coastal aquifers

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. There is no published analysis of regional seawater intrusion into coastal aquifers in Victoria. More detail is available in the statewide assessment for this indicator.		

1322. Spatial Vision 2017, 'Victorian coastal hazard assessment 2017 technical report 1'.

Theme 6: Climate and Climate Change Impacts

CIN 50: Frequency and impact of fire on marine ecosystems

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. No specific studies on the frequency and impact of fire on marine and coastal ecosystems for Corner Inlet and Nooramunga were available for use in this report. Therefore, this indicator is not assessed for this region.		

CIN 51: Climate change impact on marine and coastal infrastructure

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. No specific studies on the climate change impact on marine and coastal infrastructure for Corner Inlet and Nooramunga were available for use in this report. Therefore, this indicator is not assessed for this region. More detail is available in the statewide assessment for this indicator.		

Gippsland Lakes

GL 41: Rainfall

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga	●	↙	●
Justification for assessment ratings:	The status and trend assessments of fair and deteriorating respectively reflect the fluctuating pressure being exerted on the water resources and agricultural sectors by wetter years interspersing a predominately drying climate. The enhanced rainfall reduction during the cool seasons is particularly important given the adverse impacts this can have on streamflows and the reduced reliability for water storage filling seasons. The confidence in the status and trend assessments is rated as moderate rather than high because even though the data quality on rainfall is good, knowledge on the impacts of rainfall on coastal settlements is constantly evolving.		

The Bureau of Meteorology has been operating a weather station and measuring rainfall in Bairnsdale since 1983. To account for the year-to-year variability associated with rainfall, a rolling ten-year average of annual rainfall has been assessed and shows that the ten-year rolling average of annual rainfall has decreased by approximately 111 mm from 1984-1993 to 2010-2019, equating to a decrease of 15%. The decrease in rainfall was most pronounced in the first decade of the 21st century, in association with the millennium drought, although it is worth noting that the past three years (2017-2019) have all been in the driest six years since 1984, indicating that the Gippsland Lakes region has experienced more severe rainfall deficiencies in the last three years than any three-year period in the millennium drought. More analysis of cool-season rainfall (April to October) and summer rainfall is required to determine the likely flow-on impacts for agriculture, water resources and water quality (linked to cool-season rainfall) and bushfire risk (linked to summer rainfall).

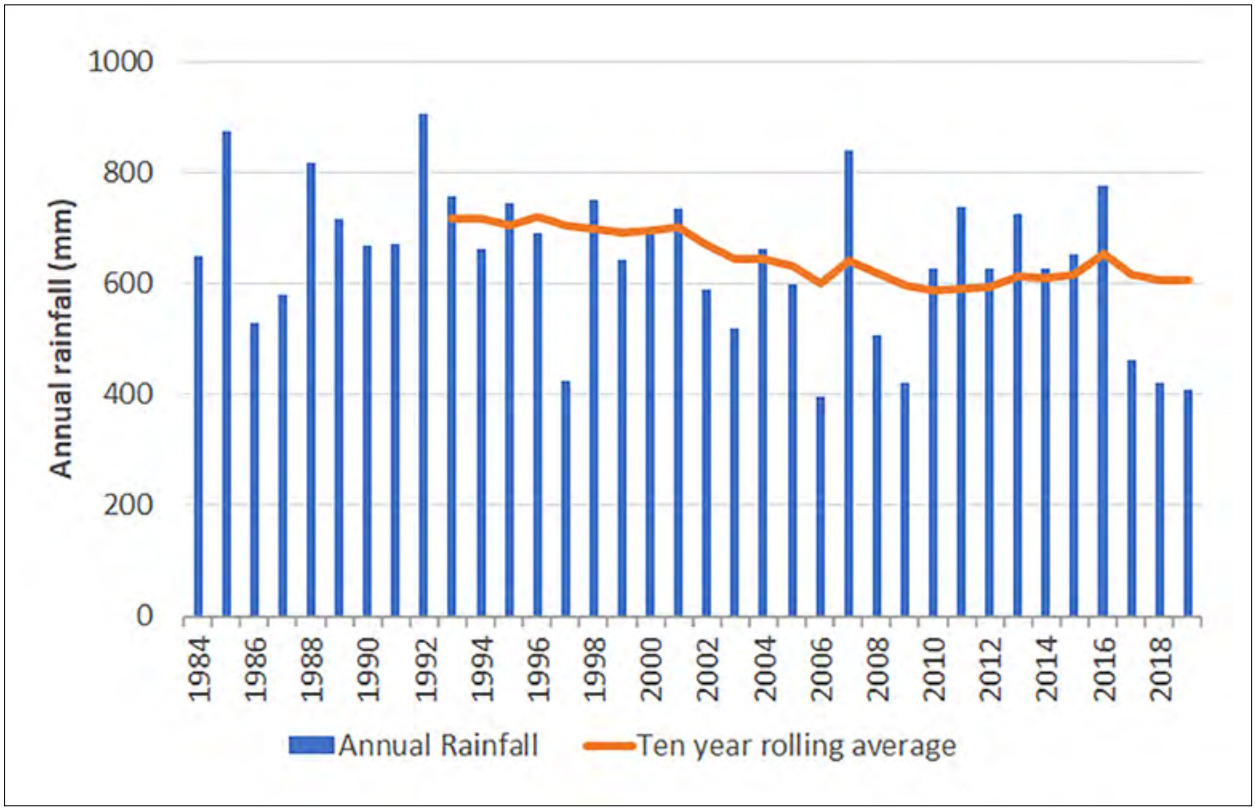


Figure 87: Observed rainfall measurements at the Bureau of Meteorology's Bairnsdale station, 1984-2019.[1323]

Rainfall will continue to be variable over time, but over the long term it is expected to continue to decline in winter and spring (medium to high confidence), and autumn (low to medium confidence). Annual rainfall for Bairnsdale is expected to decline by 9% by the 2050s under a high emissions scenario (RCP 8.5) compared to 1986–2005.[1324]

Extreme rainfall events are expected to become more intense on average through the rest of the 21st century (high confidence).[1325]

GL 42: Air temperature

Region	2021 status	2021 trend	2021 data
Corner Inlet-Nooramunga			
Justification for assessment ratings:	The status and trend assessments of fair and deteriorating respectively reflect the increasing pressure being exerted on human health, biodiversity and coastal infrastructure. The rolling ten-year average temperature has increased significantly at East Sale, by 1.14°C, from the 1950s to the 2010s, with the rate of increase being most pronounced during the past 20 years. The 2010s were 0.74°C warmer than the 1990s, highlighting the rapid rate of recent warming. The confidence in the status and trend assessments is rated as moderate rather than high because even though the data quality on temperature is good, knowledge on the impacts of increasing temperatures is constantly evolving.		

1323. Prepared using Bureau of Meteorology (BoM), 'Climate data online' http://www.bom.gov.au/climate/data
1324. Clarke JM, Grose M, Thatcher M, Round V and Heady C 2019, 'Greater Melbourne climate projections 2019', CSIRO, Melbourne Australia.
1325. Ibid.

The Australian Climate Observations Reference Network – Surface Air Temperature (ACORN-SAT) is the dataset used by the Bureau of Meteorology to monitor long-term temperature trends in Australia. ACORN-SAT uses observations from 112 weather stations across Australia, selected for the quality and length of their available temperature data.[1326] The ACORN-SAT network provides temperature data for East Sale, situated on the western side of Gippsland Lakes, since 1910.

The rolling fifty-year average of annual mean maximum temperatures for East Sale remained stable within a temperature range of 19.33 to 19.41°C for the first 20 years of the fifty-year rolling average (from 1910-1959 to 1930-1979). This stability over a 20-year time period that encompasses a range of climatic phenomena (for example, El Nino, La Nina and the Sunspot cycle all occur over finer time resolutions) is indicative of the first 50-year rolling average of East Sale temperature (1910-1959), 19.41°C, being representative of a pre-industrial era temperature profile.

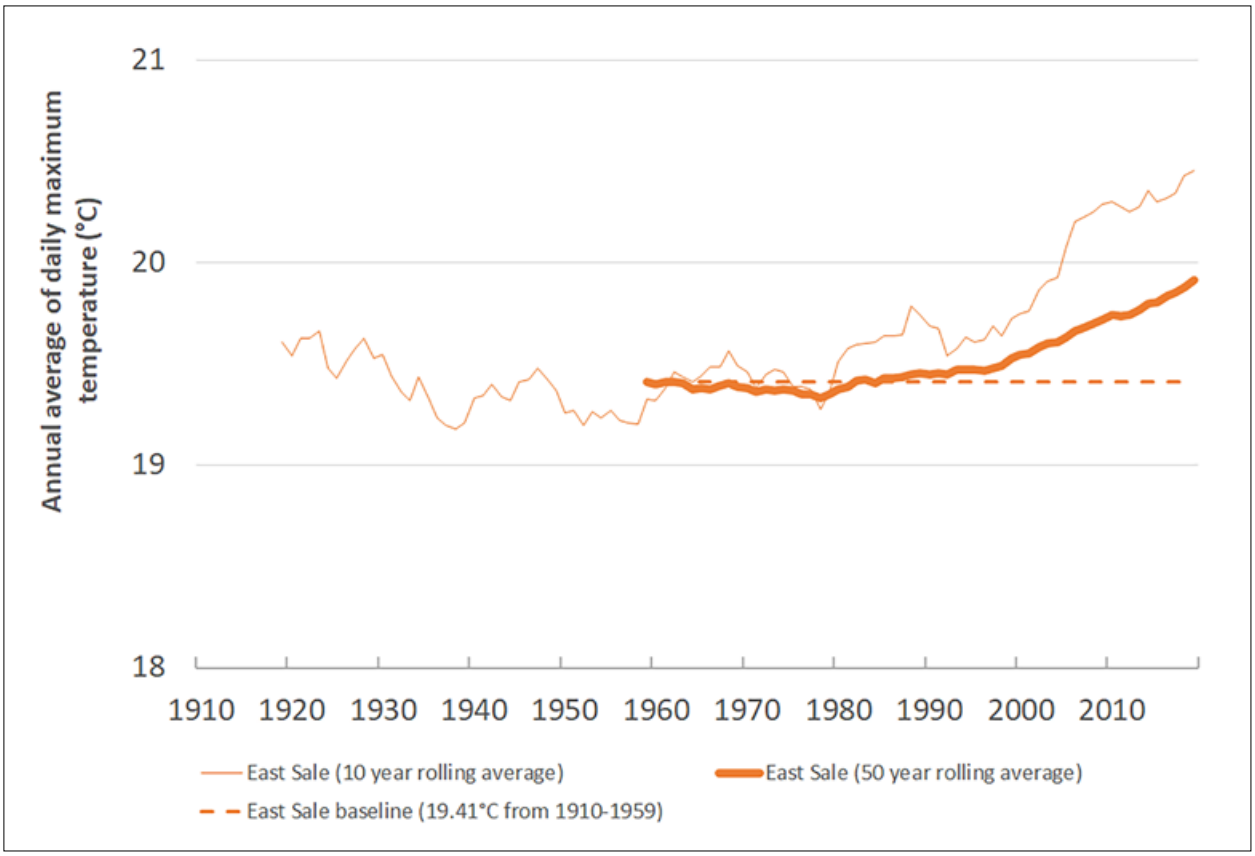


Figure 88: Annual average of daily maximum temperature (°C) from Bureau of Meteorology ACORN-SAT data for East Sale, 1910 to 2019.[1327]

The rolling ten-year average has increased significantly, by 1.14°C, from the 1950s to the 2010s, with the rate of increase being most pronounced during the past 20 years, with the 2010s being 0.74°C warmer than the 1990s.

The Bureau of Meteorology has been operating a weather station and measuring temperature in Bairnsdale, northwest from Lake King, since 1983. The rolling ten-year average of annual mean maximum temperatures has increased by 0.87°C from 1984-1993 to 2010-2019, which equates to an increase of 0.32°C per decade. The temperature increase has been more distinct during the summer months, with the summer temperature increasing by 1.45°C from 1984-1993 to 2010-2019 (0.54°C per decade).

1326. Bureau of Meteorology (BoM) 2021, 'Long-term temperature record' http://www.bom.gov.au/climate/data/acorn-sat/ Accessed 25 January 2021.
1327. Data used to generate the graph was extracted from Bureau of Meteorology (BoM), ACORN-SAT Australia v2 (snapshot v.2.1.0.1), Australian Climate Observations Reference Network - surface air temperature (1910-May 2019).

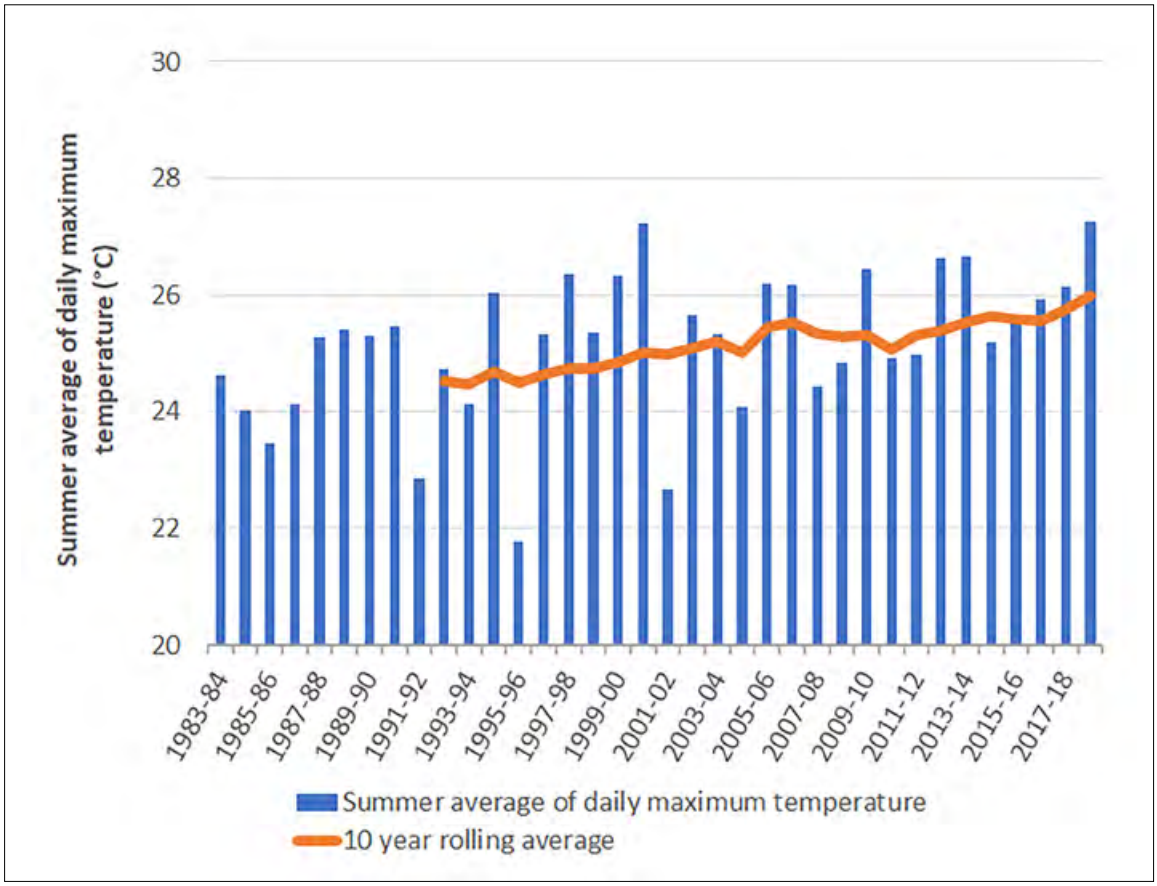


Figure 89: Observed temperature measurements during summer months at the Bureau of Meteorology's Bairnsdale station, 1983-84 to 2018-19.[1328]

One way to look at extreme temperatures is to look at the number of temperature exceedances per year (Table 36). For example, on average between 1981 and 2010, Bairnsdale experienced 6.2 days per year when the temperature exceeded 35°C. By the 2050s under high emissions, this is expected to increase to between six and 18 days on average. The increase is slightly less under medium emissions, reaching six to 12 days. Importantly for many people, minimum (usually overnight) temperatures are also expected to increase. For example, Bairnsdale's daily minimum temperature exceeded 20°C on average twice per year between 1981 and 2010. Under high emissions, by the 2050s, these hot nights are expected to occur 5.5 to 10.2 times per year on average.[1329]

Table 36: Historic and projected days (median, 10th and 90th percentile) per year with maximum temperature greater than 35°C for two locations in 2040–2059.[1330]

Town	Days/year above 35°C	
	1981–2010	2040–2059
Bairnsdale	6.2	RCP4.5 10.8 (5.9 to 12.5) RCP8.5 12.6 (6.6 to 17.2)

1328. Prepared using Bureau of Meteorology (BoM), 'Climate data online' http://www.bom.gov.au/climate/data
1329. Clarke JM, Grose M, Thatcher M, Round V and Heady C 2019, 'Greater Melbourne climate projections 2019', CSIRO, Melbourne, Australia.
1330. Ibid.

GL 43: Water Temperature

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The east-west orientation of Victoria's coastline means there is limited variation in water temperature. Therefore, the water temperature indicator has been included as a statewide assessment.		

GL 44: Ocean acidification

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. The east-west orientation of Victoria's coastline means there is limited variation in ocean acidification Therefore, the ocean acidification indicator has been included as a statewide assessment.		

GL 45: Areas of coastal vulnerability

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	↙	●
Justification for assessment ratings:	The most recent comprehensive assessment of coastal inundation and erosion hazards for the Gippsland Lakes occurred in 2014. A range of hazards were identified, however the spatial extent of the area of coastal vulnerability is unknown. The findings converged on increasing impacts, which is reflected in a deteriorating trend. The status has been rated as fair due to their currently being impacts associated with coastal risks such as inundation and erosion, however these are still relatively infrequent. For example, there is currently a 10% chance each year that Lakes Entrance will be subjected to inundation during a flood event.		

The most recent comprehensive assessment of coastal hazards in the Gippsland Lakes occurred in 2014.[1331] The overall objective of the assessment was to identify and assess the coastal erosion and inundation hazards within the study area under both present and future climate change conditions.

Sea level rise was found to have a greater impact at Lakes Entrance than Paynesville or Loch Sport. This is because there are larger areas of Lakes Entrance that are only slightly elevated above the current flood level compared to the other towns.

The findings of the 2014 local coastal hazard assessment are summarised below:

Lakes Entrance

- There is currently a 10% chance each year that Lakes Entrance will be subjected to inundation during a flood event. Inundation extents are predicted to increase with increasing mean sea level, with peak flood levels predicted to increase at a rate of approximately 0.9 times the amount of sea level rise.
- Recession of the Outer Barrier at Lakes Entrance is expected to accelerate with increasing mean sea level. A critical tipping point could occur between 0.4 and 0.8 metres sea level rise, when barrier overwash is likely to increase in frequency, leading to significantly larger hazard extents.

1331. Water Technology 2014, 'Report 1: summary report Gippsland Lakes/90 Mile Beach local coastal hazard assessment project', prepared for the Victorian Department of Environment and Primary Industries (DEPI).

Paynesville

- The key hazard at Paynesville is expected to be inundation. Peak flood levels are predicted to increase by approximately 0.65 times the rise in mean sea level.

Loch Sport

- Peak flood levels at Loch Sport were predicted to increase at approximately 0.65 times the rise in mean sea level. Increases in inundation extent were minimal when compared to Lakes Entrance and Paynesville due to the higher elevations of land surrounding Loch Sport.

Bunga Arm

- Recession of the Outer Barrier at Bunga Arm is expected to accelerate with increasing mean sea level. A critical tipping point could occur between 0.4 and 0.8 metres sea level rise, when barrier overwash is likely to increase in frequency, leading to significantly larger hazard extents.
- Peak flood levels are predicted to increase by approximately 0.65 times the rise in mean sea level.

Seaspray

- Recession of the Outer Barrier at Bunga Arm is expected to accelerate with increasing mean sea level. A critical tipping point could occur between 0.4 metres and 0.8 metres sea level rise, when barrier overwash is likely to increase in frequency, leading to significantly larger hazard extents.
- For 0.8 metre sea level rise, there is a 10% chance each year that inundation of low-lying areas around Seaspray from Lake Reeve will occur due to a flood event in the Gippsland Lakes.[1332]

1332. Ibid.

GL 46: Sea-level and coastal inundation

Region	2021 status	2021 trend	2021 data
Gippsland Lakes		?	
Justification for assessment ratings:	The status assessment of fair reflects the pressure being exerted on human coastal settlements and infrastructure. The confidence in the assessments is moderate rather than high to reflect that the time series of tidal gauge data only covers the most recent 12 years.		

Quality controlled tidal data has been collected in the Gippsland Lakes at Lakes Entrance since 2008 and no discernible trends are apparent. Historical tidal data are available back to 1974 and the Bureau of Meteorology is linking the historical and current data sets, which should be available for inclusion in future State of the Marine and Coastal Environment reports.

To visualise the possible impacts of coastal inundation, Figure 90 shows an area (shaded in blue) that would be flooded at Lakes Entrance in 2100 in a high tide under a high emissions scenario, which assumes a median sea level rise of 0.84 metres relative to the sea level of 1986–2005.

This visualisation shows the considerable risk sea level rise and coastal inundation poses to property in Lakes Entrance. The image was developed assuming average weather conditions (for example, no storm surges), which means that more extensive inundation is likely when sea levels are elevated above the normal high tide mark (for example, during a storm surge).

Theme 6: Climate and Climate Change Impacts

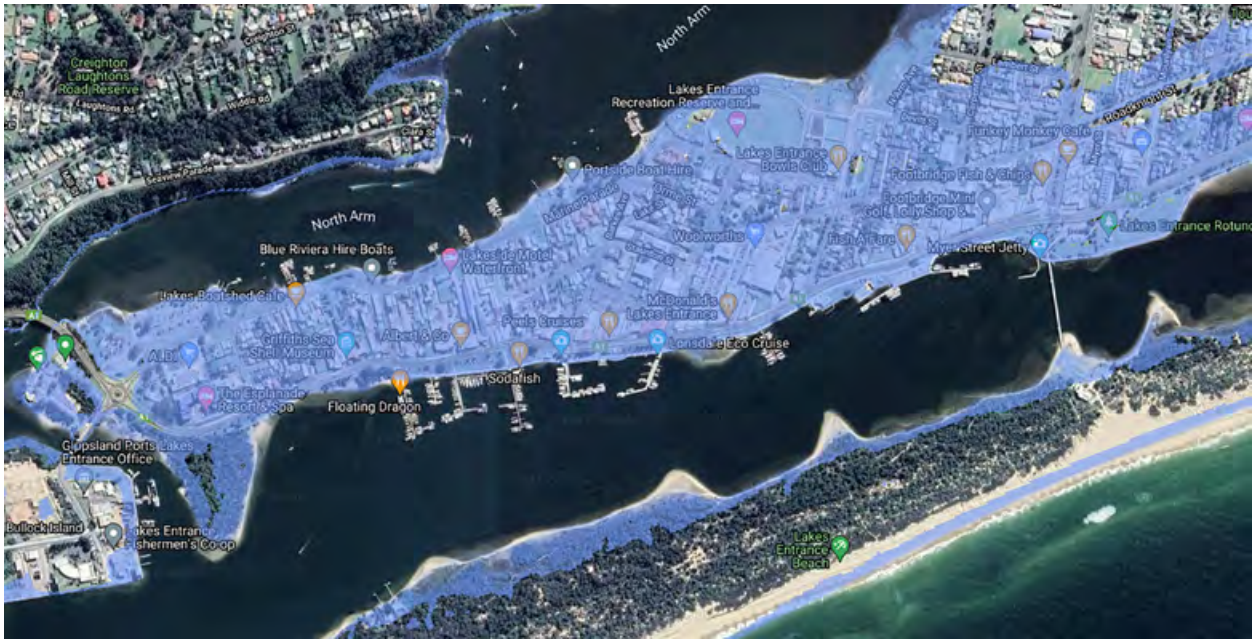


Figure 90: Estimated coastal inundation at Lakes Entrance in high tide and assuming a 0.84 metres sea level rise relative to the sea level of 1986–2005.[1333]

Areas of the Gippsland Lakes at risk to coastal inundation are discussed in Indicator 45: Areas of coastal vulnerability.

GL 47: Wave climate

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. No specific wave climate studies for the Gippsland Lakes were available for use in this report. Therefore, this indicator is not assessed for this region. More detail is available in the statewide assessment for this indicator.		

GL 48: Coastal erosion

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	↙	●
Justification for assessment ratings:	The results of a 2017 erosion vulnerability assessment have been used to guide the status assessment for this indicator. More than 100 km of the Gippsland coastline is rated as having a very high vulnerability to coastal erosion. This means that more than a quarter of the entire Victorian coastline most at risk to erosion is located along the Gippsland Lakes, which is reflected in a status assessment of poor. Because this mapping is a 'point-in-time' assessment, the trend is unclear.		

Shoreline erosion within the Gippsland Lakes is a function of a wide range of factors, including the physical form, environmental aspects such as waves and currents, and biological character which includes vegetation communities and land use.

1333. Cooperative Research Centre for Spatial Information and NGIS, 'Coastal risk Australia' http://www.coastalrisk.com.au/ Accessed 26 September 2021.

It can result in a loss of habitat (for example, intertidal sand flats for shorebirds), infrastructure (for example, threatening boat ramps, buildings and other shoreline assets), important geomorphic features such as the silt jetties, and lead to increased suspended sediments in the water column. In the case of the outer barrier (that is, the narrow strip of land separating the Gippsland Lakes from Bass Strait) coastal erosion processes that include sea level rise and an increased frequency and intensity of storms could lead to a temporary breaching of the barrier dunes, resulting in changes to the morphology and hydrology of the local area, over a variety of timeframes.

Information on shoreline stability and erosion is of the Gippsland Lakes is limited and it is unclear what proportion of shorelines are stable. There have been a small number of studies in recent years on the silt jetties, climate change influences and geomorphology, with the published information mostly qualitative and based on expert opinion.

It has been suggested that increasing salinity, resulting in a loss of shoreline vegetation has resulted in decreased shoreline stability and increased erosion. Climate change, especially sea level rise and an increased incidence and possibly severity of storm surges, could rapidly change the stability of the Gippsland Lakes shorelines.

The results of a 2017 erosion vulnerability assessment commissioned by the Victorian Government show that more than 100 km of the Gippsland Lakes coastline is rated as having a very high vulnerability to coastal erosion (Table 37). More than a quarter of the Victorian coastline most at risk to erosion is located along the Gippsland Lakes.

Table 37: Coastline sediment compartment breakup showing total length and high and very high coastal erosion vulnerability ratings, Gippsland Lakes.[1334]

Location		Vulnerability rating				
		Very low	Low	Moderate	High	Very high
Gippsland Lakes	Length (km)	0.0	186.0	383.8	72.1	107.4
	Proportion	0.0%	24.8%	51.3%	9.6%	14.3%

GL 49: Seawater intrusion into coastal aquifers

Region	2021 status	2021 trend	2021 data
Gippsland Lakes	●	N/A	N/A
Justification for assessment ratings:	Not assessed for this region. There is no published analysis of regional seawater intrusion into coastal aquifers in Victoria. More detail is available in the statewide assessment for this indicator.		

1334. Spatial Vision 2017, 'Victorian coastal hazard assessment 2017 technical report 1'.

GL 50: Frequency and impact of fire on marine and coastal ecosystems

Region	2021 status	2021 trend	2021 data
Gippsland Lakes		?	
Justification for assessment ratings:	The status assessment of fair is due to the Gippsland Lakes water quality being temporarily adversely affected by the large bushfires during the 2019-20 fire season. Previous fires during 2003 and 2006-07 were linked with algal blooms. No data on the frequency and impact of fires along the Gippsland Lakes coastline is available to ascertain a trend.		

Monitoring results showed that the large bushfires during the 2019-20 fire season temporarily impacted water quality at some East Gippsland sites, although the Gippsland Lakes catchment maintained very good water quality during 2019-20. For example, monitoring sites located in heavily bushfire-affected areas along the Nicholson River recorded very good water quality for the year.[1335]

The economic loss to local businesses due to the absence of recreational fishers is yet to be quantified but the overall impact on coastal tourism has been huge. Acknowledging the importance of recreational fishing to regional economies, which has been estimated at $600 million each year in north-eastern Victoria and Gippsland, the Victorian Government has released tagged fish into the state's waterways to lure recreational fishers back to fire affected areas, including Mallacoota, Cann River, Marlo, Lakes Entrance and Lake Tyers.[1336,1337]

Unprecedented algal blooms developed in the Gippsland Lakes after fires in 2003 and 2006–2007 that respectively burned 9% and 32% of the catchment. Intense rainfall and floods in June and July 2007 led to 'large increases in loads of suspended sediment, nitrogen and phosphorus from background levels', with the actual loads of phosphorus and nitrogen the 'highest of any year where measurements were available (over 30 years).[1338]

GL 51: Climate change impact on marine and coastal infrastructure

Region	2021 status	2021 trend	2021 data
Gippsland Lakes		↙	
Justification for assessment ratings:	A range of recent studies highlight significant likelihood of impact from climate change on coastal infrastructure including properties, the road network and utilities (for example, powerlines) along the Gippsland Lakes coastline. The studies don't provide quantitative estimates of the extent of the impact and the economic value of the vulnerable infrastructure, so the confidence in the status and trend assessments is low.		

Rising sea levels will exacerbate existing vulnerability of coastal towns and infrastructure in the Gippsland Lakes region.[1339]

The Gippsland Lakes, including Ninety Mile Beach and Corner Inlet, has previously been identified as one of the most vulnerable coastal areas in Australia.[1340]

1335. EPA Victoria 2020, 'Report card 2019–20', Carlton, Victoria.
1336. Victorian Fisheries Authority (VFA) 2020, 'Golden tags to lure fishers back to fire affected areas', 05 February 2020 https://vfa.vic.gov.au/about/news/golden-tags-to-lure-fishers-back-to-fire-affected-areas Accessed 18 November 2021.
1337. Australian Marine Conservation Society 2020, 'The impacts of bushfires on coastal and marine environments'.
1338. Cook P, Holland D and Longmore A 2008, 'Interactions between phytoplankton dynamics, nutrient loads and the biogeochemistry of the Gippsland Lakes', report prepared for the Gippsland Lakes Taskforce, Water Studies Centre, Monash University, Clayton.
1339. Commonwealth of Australia 2013, 'The critical decade: impacts for Gippsland, Victoria', Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education (DIICCSRTE), Canberra.
1340. Commonwealth of Australia 2009, 'Climate change risks to Australia's coast: a first pass national assessment', Department of Climate Change, Canberra.

By 2070, parts of the Gippsland Lakes coast are expected to be inundated to an extent requiring protection or relocation of assets, including dwellings and commercial buildings.[1341] Increased rainfall and higher sea levels will cause extensive flooding of low-lying towns such as Lakes Entrance.[1342] In the longer term, towns like Lakes Entrance are likely to be permanently flooded from sea level rise, along with important infrastructure such as the Princes Highway.[1343]

Additional risks include increased erosion of structures such as sea walls, roads and bridges, and flooding or erosion of commercial buildings, private residences, utilities (for example, powerlines) and stormwater drains.[1344]

A 2015 Climate Change Risk Assessment completed by VicRoads identified expected impacts on Victoria's road network associated with a range of climate change variables. The sea level rise and storm surge impacts for Victoria are predicted to be most pronounced in regional Gippsland, including Lakes Entrance, Tooradin and Tarwin Lower. Sea level rise and storm surges have the potential to cause widespread damage to road infrastructure, including pavements and structures, which is likely to result in flooding and road closures.[1345]

Statewide/broad-scale

SW 42: Air temperature

Region	2021 status	2021 trend	2021 data
Statewide	N	N	N
Justification for assessment ratings:	Not assessed for this region. Air temperature has been assessed in each of the other geographic regions in this chapter. To complement those assessments, a statewide air temperature narrative is provided here and includes a broader discussion on coastal air temperature across Victoria and temperature projections.		

At a global scale, the impact of pursuing a lower emission pathway is demonstrated by the degree of climate change expected by the mid-21st century. Higher ongoing emissions of greenhouse gases will lead to greater warming and associated impacts, while reducing emissions will lead to less warming and fewer impacts.[1346,1347]

By the 2050s, average temperatures in Victoria are projected to be 1.4 to 2.4°C warmer under a high emissions scenario (RCP 8.5) or 0.9 to 1.8°C warmer under a medium emissions scenario (RCP 4.5) compared to 1986–2005. By the 2090s, average temperatures in Victoria are projected to be 2.8 to 4.3°C warmer under a high emissions scenario (RCP 8.5) or 1.3 to 2.2°C warmer under a medium emissions scenario (RCP 4.5) compared to 1986–2005 (high confidence). However, if the world succeeds in matching aspirations under the Paris Agreement to limit global warming to 2°C, then Victoria is also expected to warm by around 2°C in line with the global average.[1348] The analysis provided within the specific regional assessments of air temperature highlights that Victoria's coastal regions are likely to have already warmed by more than 1°C, with areas of the Port Phillip Bay coastline now regularly experiencing years with temperatures approximately 1.5 degrees warmer than an indicative pre-industrial era baseline.

1341. Gippsland Coastal Board 2008, 'Climate Change, Sea level rise and coastal subsidence along the Gippsland Coast'.
1342. Commonwealth of Australia 2009, 'Climate change risks to Australia's coast: a first pass national assessment', Department of Climate Change, Canberra.
1343. Commonwealth of Australia 2013, 'The critical decade: impacts for Gippsland, Victoria' Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education (DIICCSRTE), Canberra.
1344. Ibid.
1345. VicRoads 2015, 'Climate change risk assessment' VicRoads, Kew, Victoria.
1346. Bureau of Meteorology (BoM) and CSIRO 2020, 'State of the Climate 2020'.
1347. Current scenarios are referred to as Representative Concentrations Pathways (RCPs). In this report, RCP8.5 is referred to as a 'high emissions scenario', RCP4.5 is referred to as an 'intermediate emissions scenario' and RCP2.6 is referred to as a 'low emissions scenario'. Note that RCP2.6 aligns most closely with the Paris Agreement target.
1348. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019'.

An increase in the average temperature leads to a corresponding increase in hot extreme daily maximum temperatures and a decrease in cold extreme daily minimum temperatures, assuming no change to variability or timing of events. The predicted hotter and more frequent hot days, fewer cold days, more intense heatwaves and fewer extreme cold nights was the most important and relevant message from the 2019 Victorian climate projections and was given with very high confidence.[1349]

The changes projected under high emissions for the long-term future are extreme compared to the current climate. Under a high emissions scenario by 2080–2099, the projections indicate that coastal locations within Victoria could experience days with maximum temperatures of approximately 55°C.[1350]

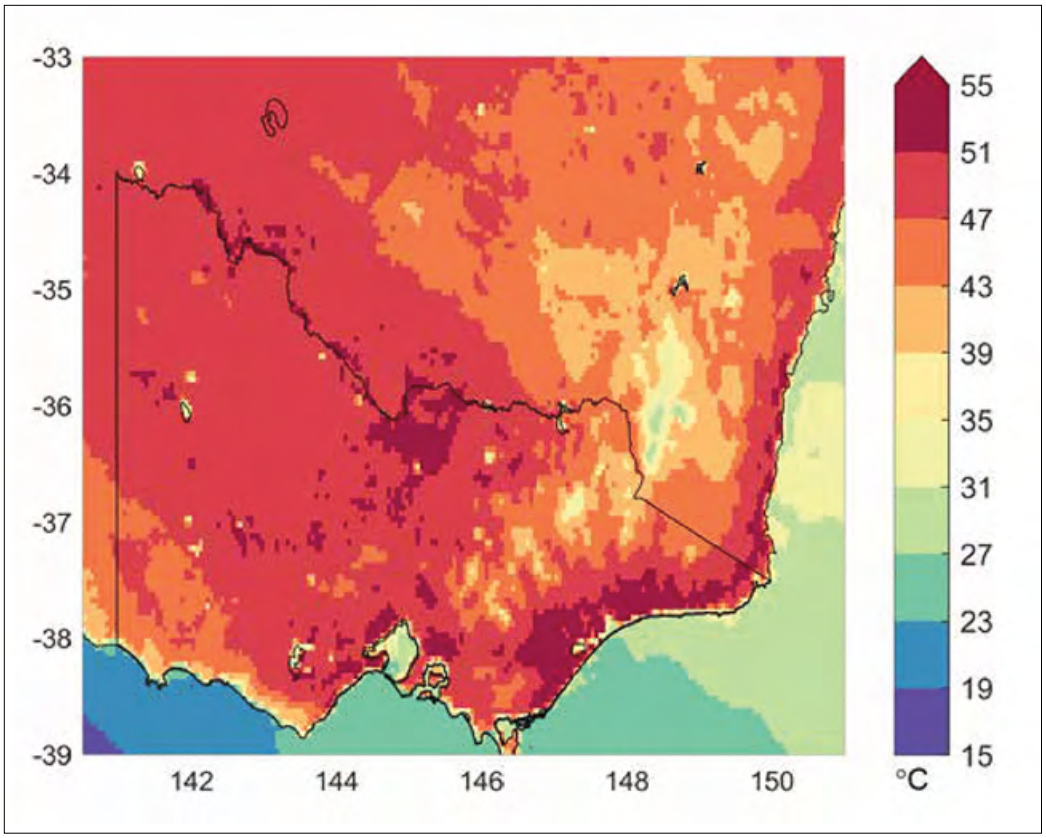


Figure 91: Daily maximum temperature for an example extreme heat summer day in the 2050s simulated under a high (RCP8.5) emission scenario.[1351,1352]

The increasing number of very hot days along the Victorian coastline, has significant implications for participants and spectators of recreational and professional summer sport near the coast. Many local sporting competitions have extreme heat policies and competitions take place during afternoons, when summer temperatures are at their warmest.

1349. Clarke JM, Grose M, Thatcher M, Hernaman V, Heady C, Round V, Rafter T, Trenham C and Wilson L 2019, 'Victorian climate projections 2019 Technical Report', CSIRO, Melbourne, Australia.
1350. Ibid.
1351. Ibid.
1352. Note the emission scenario is RCP8.5 and the image is produced for a summer day in the 2050s (HadGEM2-CC model downscaled by CCAM), where Melbourne reaches 50°C, and even higher temperatures inland. There is a warm bias in the simulation associated with the Gippsland region, so the temperature may be artificially elevated near the southeast coast. Note this is not the hottest day in simulations, it is just indicative of a very hot day in the future climate without a historical precedent

These sporting organisations will risk having their sporting fixtures being cancelled due to extreme heat unless they adapt:

- the times of day when their activities commence (for example, holding competitions during the mornings or evenings)
- the time of the season (for example, holding a competition during cooler seasons like autumn or winter rather than during summer).

The impacts associated with extreme heat and sport are notably observed during professional competitions that currently occur along Victoria's coastline during the summer months and hold significant public interest.

Many athletes and spectators at professional events have fallen seriously ill following exposure to extreme heat in recent years. For example, temperatures at the Australian Open Tennis in Melbourne have repeatedly exceeded 40°C with games suspended and players taken to hospital. In 2014, almost 1,000 spectators were treated for heat exhaustion.[1353] And, in December 2019, New Zealand cancelled the opening day of a match against Cricket Victoria because of an extreme heat forecast of 45°C for Melbourne. It is highly likely that in the near future this type of extreme heat will coincide with the annual Boxing Day test match held in Melbourne that is regularly attended by more than 200,000 spectators.[1354]

SW 43: Water temperature

Region	2021 status	2021 trend	2021 data
Statewide			
Justification for assessment ratings:	The increasing frequency of marine heatwaves around Australia in recent years has caused permanent impacts on marine ecosystem health, marine habitats and species. These impacts include depleting kelp forests and sea grasses, a poleward shift in some marine species, and increased occurrence of disease. This information is the basis of the status and trend assessments of poor and deteriorating, respectively.		

Average sea surface temperature in the Australian region has warmed by more than 1°C since 1900, with eight of the ten warmest years on record occurring since 2010.[1355]

The greatest ocean warming in the Australian region since 1970 has occurred around south-eastern Australia and Tasmania (Figure 92). The East Australian Current now extends further south, creating an area of more rapid warming in the Tasman Sea where the warming rate is now twice the global average.[1356]

1353. Climate Council of Australia Limited 2021, 'Game, set, match: calling time on climate inaction'.
1354. Ibid.
1355. Bureau of Meteorology (BoM) and CSIRO 2020, 'State of the Climate 2020'.
1356. Ibid.

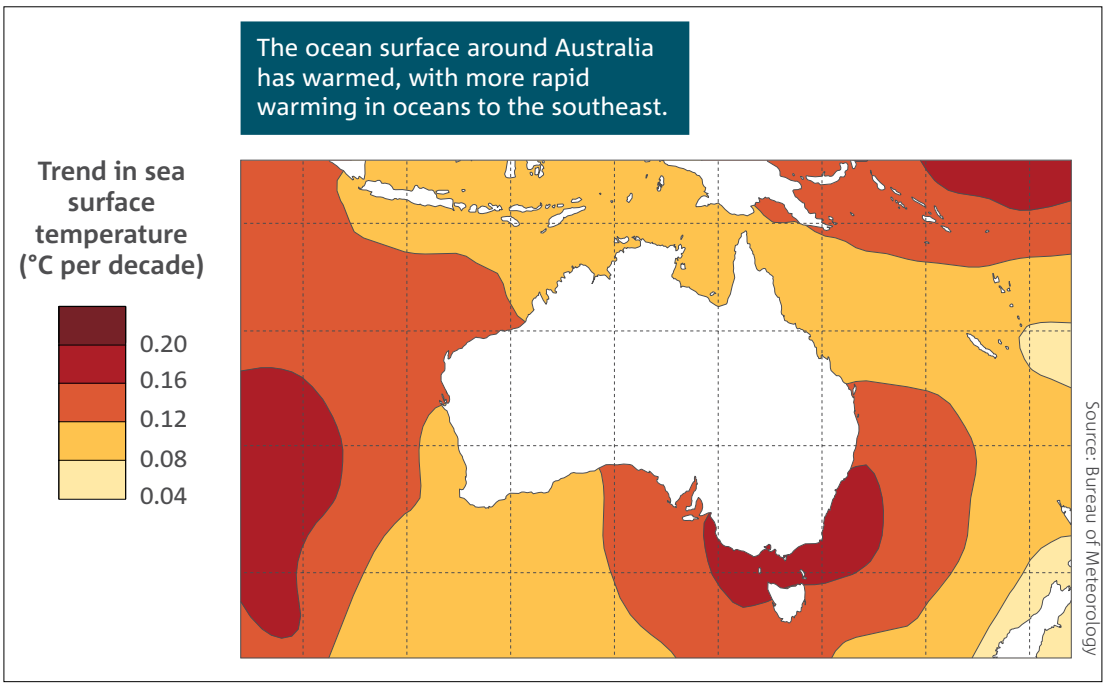


Figure 92: Trends in sea surface temperatures in the Australian region (4–46° S and 94–174° E) from 1950 to 2019.[1357]

Warming of the ocean has contributed to longer and more frequent marine heatwaves. Heatwaves in the ocean often persist much longer than heatwaves on land, sometimes spanning multiple months or even years. The increasing frequency of marine heatwaves around Australia in recent years has caused permanent impacts on marine ecosystem health, marine habitats and species. These impacts include depleting kelp forests and seagrasses, a poleward shift in some marine species, and increased occurrence of disease.[1358]

Temperate reefs from around the world are becoming tropicalised as warm-water species shift their distribution towards the poles in response to warming. This is already causing profound shifts in dominant foundation species and associated ecological communities as canopy seaweeds such as kelp are replaced by tropical species.[1359]

A 2019 international study involving Australian researchers found that marine heatwaves alter the fundamental structure of some marine ecosystems across the world, posing challenges for the industries that rely on them and threatening global biodiversity.[1360] The study also found that marine heatwaves will likely intensify further with ongoing climate change, threatening many species living near the upper end of their tolerable temperature range. The ocean off southeast Australia was identified as being particularly vulnerable to marine heatwaves.

This research was extended in 2020, analysing the links between enhanced predictions of marine heatwaves and marine conservation, fisheries and aquaculture management. It found that addressing the threats posed by marine heatwaves to the health and sustainability of marine ecosystems will require significant action, including:

- a coordinated global commitment to reduce greenhouse-gas emissions
- governance arrangements that support novel adaptation strategies, such as protecting refugia for foundation marine species of coral, kelp and seagrass that provide essential habitats to marine ecosystems.[1361]

1357. Ibid.
1358. Ibid.
1359. Vergés A, McCosker E, Mayer-Pinto M, Coleman MA, Wernberg T, Ainsworth T and Steinberg PD 2019, 'Tropicalisation of temperate reefs: implications for ecosystem functions and management actions', *Functional Ecology*, 33(6), pp. 1000–1013 https://doi.org/10.1111/1365-2435.13310 Accessed 6 July 2020.
1360. Smale DA, Wernberg T, Oliver ECJ, Thomsen M, Harvey BP, Straub SC, Burrows MT, Alexander LV, Benthuysen JA, Donat MG, Feng M, Hobday AJ, Holbrook NJ, Perkins-Kirkpatrick SE, Scannell HA, Gupta AS, Payne BL and Moore PJ. 2019, 'Marine heatwaves threaten global biodiversity and the provision of ecosystem services', *Nature Climate Change*, 9, pp. 306–312 https://doi.org/10.1038/s41558-019-0412-1 Accessed 2 February 2021.
1361. Holbrook NJ, Sen Gupta A, Oliver ECJ, Hobday AJ, Benthuysen JA, Scannell HA, Smale DA and Wernberg T 2020, 'Keeping pace with marine heatwaves', *Nature Reviews Earth and Environment*, 1, pp. 482–493 https://doi.org/10.1038/s43017-020-0068-4 Accessed 2 February 2021.

SW 44: Ocean acidification

Region	2021 status	2021 trend	2021 data
Statewide		↙	Low (status), High (trend)
Justification for assessment ratings:	Ocean surface waters around Australia have increased in acidity by more than 30% from 1880s to the 2010s. The increase in acidity has become mare rapid in recent decades. There are limited studies on the impacts of ocean acidification around Victoria, so the status is rated fair, but with low confidence. There is high confidence in the trend assessment.		

Between 1880–1889 and 2010–2019, the average pH of surface waters around Australia is estimated to have decreased by about 0.12. This corresponds to a more than 30% increase in acidity (and so the waters have become less alkaline). Due to latitudinal differences in ocean chemistry, the oceans to the south of Australia are acidifying faster than those to the north.[1362]

The rate of decrease in pH has accelerated to over 0.02 per decade, more than five times faster than from 1900 to 1960. This current rate of change is also 10 times faster than at any time in the past 300 million years.[1363]

Figure 93: Change in pH of surface waters around Australia between 1880–1889 and 2010–2019.[1364]

1362. Bureau of Meteorology (BoM) and CSIRO 2020, 'State of the Climate 2020'.
1363. Ibid.
1364. Ibid.

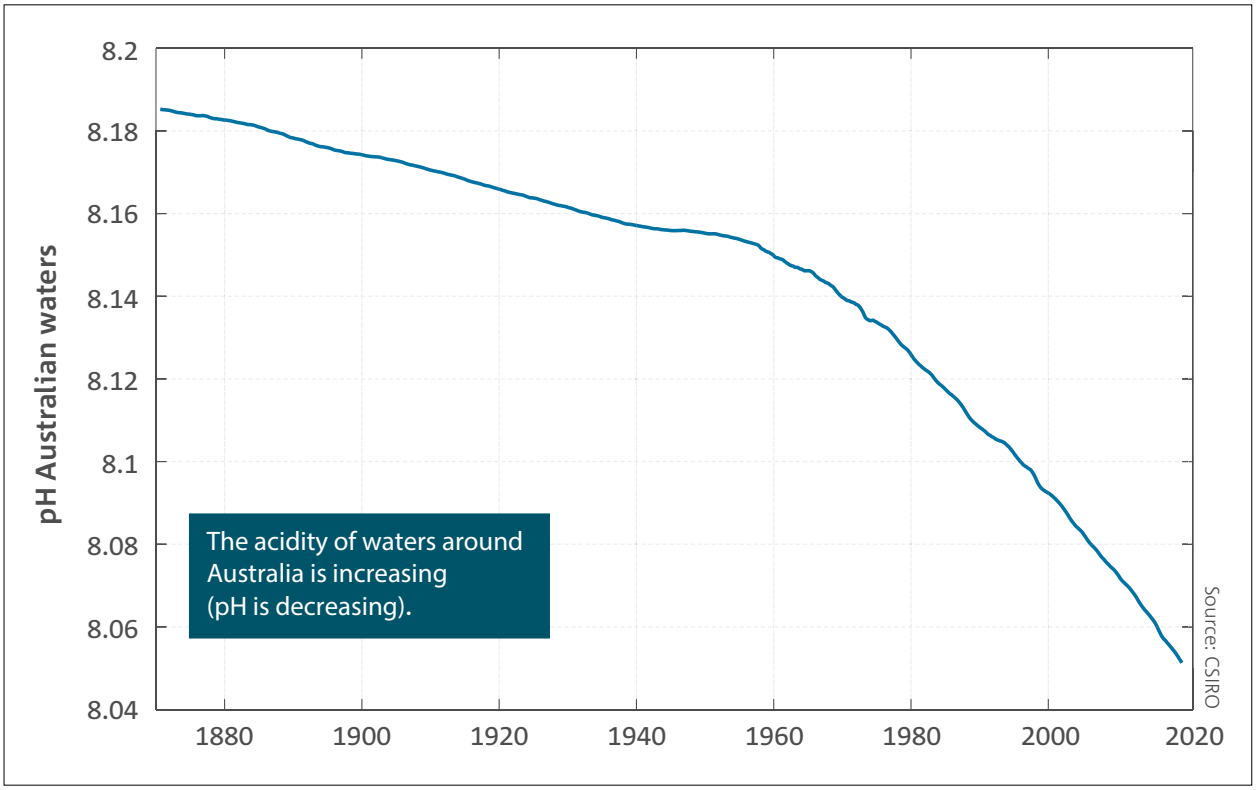


Figure 94: Average pH of water surrounding Australia.[1365]

Calculations are based on present-day data on the carbonate chemistry of surface seawater around Australia from the Integrated Marine Observing System and other programs, and extrapolation of atmospheric carbon dioxide concentration changes since the 1880s.

There is very high confidence that around Australia the ocean will become more acidic, with a net reduction in pH. There is also high confidence that the rate of ocean acidification will be proportional to the carbon dioxide emissions.[1366]

1365. Bureau of Meteorology (BoM) and CSIRO 2020, 'State of the Climate 2020'.
1366. CSIRO and Bureau of Meteorology (BoM) 2015, 'Climate change in Australia: information for Australia's natural resource management regions: technical report', Australia https://apo.org.au/sites/default/files/resource-files/2015-01/apo-nid52475.pdf Accessed 15 November 2021.

SW 45: Areas of coastal vulnerability

Region	2021 status	2021 trend	2021 data
Statewide	N	N	N
Justification for assessment ratings:	No indicator assessments were provided for this region, however an indicator narrative has been provided to highlight the nature of community vulnerability to the effects of climate change along the Victorian coastline.		

An important part of coastal vulnerability is the susceptibility of individuals and communities to effects of climate change.

Work undertaken by McKenzie and Canterford outlines the factors which may increase the vulnerability of individuals and communities.[1367] These factors were developed for use by the Geoscience Australia Risk Impact and Analysis Group and are based on literature review and stakeholder feedback. Population vulnerabilities have a geographical distribution. Some communities will have a greater measure of vulnerability than others and some locations may display multiple types. While the indicators may reflect an individual measure, the vulnerability level of a household will be determined by its weakest rather than its strongest member.

Table 38 presents a list of population vulnerability factors. The list is not exhaustive and there may be local factors that determine the pattern of vulnerability during and following an emergency. In some cases, there may be counterintuitive patterns of vulnerability. For example, in a study of drought in Lake Boga, it was found that relatively wealthy middle-class individuals were negatively affected by the drying of the lake because they had invested heavily in the lakeside amenity.[1368] This is relevant to many coastal situations where people have purchased more than simply a house – they have purchased natural amenity and a lifestyle which may be at risk from climate change impacts like coastal erosion, storm surge and inundation. Furthermore, some hazards, like drought, are slow and prolonged while others, like bushfire or flood, are sudden and require a rapid response. Research indicates that some people deal better with one or other of these types of events.[1369] The finding that length and intensity of such events may cause different experiences of hardship is important for understanding vulnerability to the immediate impact of an emergency compared to vulnerability during the longer period of recovery.

1367. McKenzie F and Canterford S 2018, 'Demographics for bushfire risk analysis', Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria.
1368. Waters E, McKenzie F, McCarthy C and Pendergast S 2010, 'The drying lake. Lake Boga's experience of change and uncertainty', Department of Planning and Community Development (DPCD), Melbourne, Victoria.
1369. Waters E, McKenzie F and Pendergast S 2012, 'Dealing with extremes. The Lake Boga follow-up study – report on findings', Department of Planning and Community Development (DPCD), Melbourne, Victoria.

Table 38: Vulnerability indicators of relevance to demographic risk analysis of natural hazards.[1370]

Indicator	Comments
Young at risk	The very young are at risk because they are dependent on others for care.
Elderly at risk	Elderly people tend to be more frail, have more health issues and may be dependent on others for care. While individual older people may be fit and active, aggregate data show that the number of people needing assistance increases with age.
Single parents	Single parents may face the demands of dependant children but with no additional support.
Volunteering	People who undertake volunteer activity within their community are more likely to have social networks which can be of assistance in times of emergency by providing information, support and resources.
Income	Low-income households may face more difficulty in recovering materially from a disaster. They may also be under insured or uninsured.
New to region	If a person has moved to an area in recent years, they may be unfamiliar with local environmental hazards and may be unaware of procedures for preparing for, or responding to, an emergency.
Public housing	Socio-economic disadvantage is a requirement for receiving public housing and those who are disadvantaged are likely to have a variety of social and economic problems that may require additional support in an emergency situation.
Education level	People with high levels of education are more likely to understand a range of information related to risk and preparation as well as warnings information.
Need assistance	People who identify that they have a need for assistance with self-care are likely to need help in an emergency, for instance with evacuation.
Car ownership	People without access to a car will be unable to evacuate themselves in an emergency.
Insufficient English	People with limited English may find it more difficult to access or understand various emergency messages and information.
Unoccupied dwellings	Absentee owners may not have high levels of engagement with the local community, nor may they have the time to attend meetings or undertake complete emergency preparations on their property (for example, during fire season).

When the vulnerability indicators are mapped for coastal areas in Victoria, some areas near Melbourne, such as Bass Coast, score highly on a number of indicators (Figure 95). Low income can be related to older age groups who are retired, while those new to the area may also reflect retirement migration. Those needing assistance also reflect the older age profile of areas like Bass Coast, Mornington Peninsula and Surf Coast. Overall, having an older aged population along the Victorian coast represents a significant risk for future climate change impacts and emergency preparedness.

1370. McKenzie F 2020, 'Coastal demographics in Victoria: background research paper prepared for the Victorian Marine and Coastal Council', Department of Environment, Land, Water and Planning (DELWP), East Melbourne Victoria, p. 26.

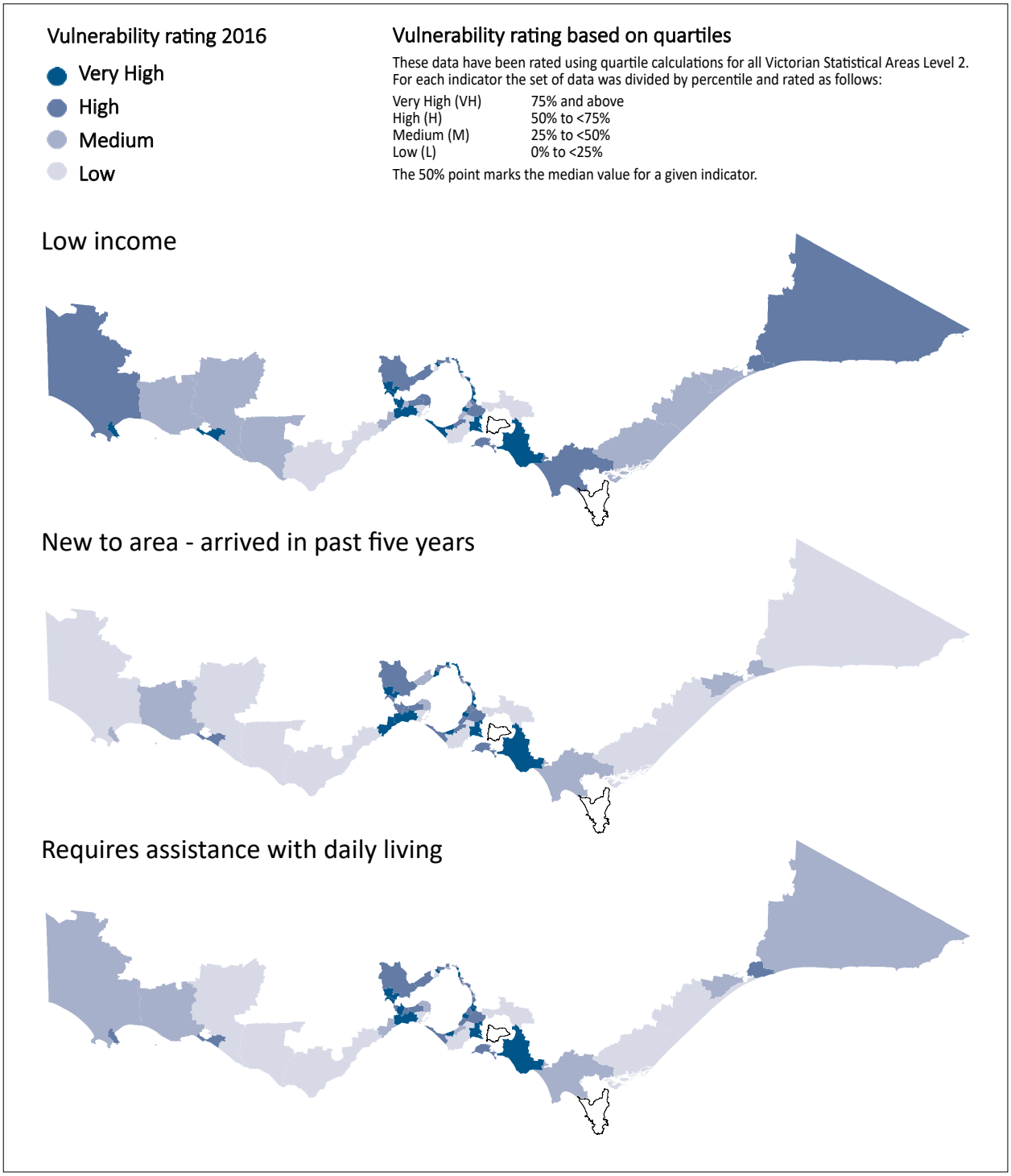


Figure 95: Selected indicators of population vulnerability, coastal Statistical Areas Level 2 (SA2s), 2016.[1371]

1371. Ibid. p. 27, based on data from Australian Bureau of Statistics (ABS) 'Census of population and housing 2016' Australian Government, Canberra.

SW 46: Sea-level and coastal inundation

Region	2021 status	2021 trend	2021 data
Statewide			
Justification for assessment ratings:	Future rises in sea level are projected with high confidence. Figure 96 shows sea levels are expected to rise by approximately 12 cm at various places along Victoria's coastline by 2030, with a rise of approximately 40 cm projected by 2070. The status and trend assessments of fair and deteriorating respectively reflects the increasing pressure being exerted on human coastal settlements and infrastructure.		

Future rises in sea level are projected with high confidence.[1372] Figure 96 shows sea levels are expected to rise by approximately 12 cms at various places along Victoria's coastline by 2030, with a rise of approximately 40 cms projected by 2070. These projected rises are based on a high emissions scenario (RCP8.5) and are relative to the levels observed for 1986-2005.

The various emissions scenarios all project a similar rise in sea level by 2030, with the global emissions pathway likely to have a greater impact by 2070 with sea level rise projections varying from approximately 40 cms by 2070 (RCP8.5) under a high emissions scenario to approximately 30 cms under a low emissions scenario (RCP2.6).[1373]

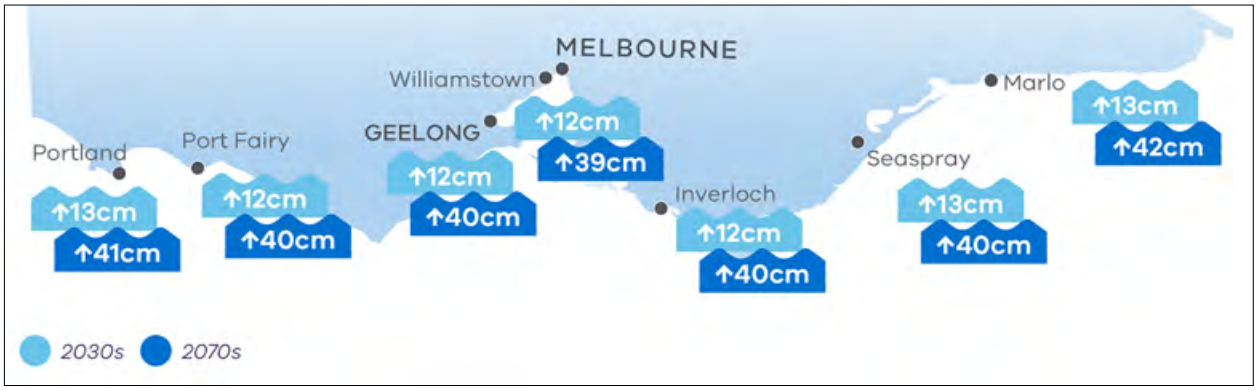


Figure 96: Sea level rise projections (cm) relative to the baseline (1986–2005) for key Victorian locations under high (RCP8.5) emissions scenarios for the 2030s and the 2070s.[1374]

Understanding the range of projections increases the robustness of climate change planning. Figure 96 shows the median results associated with the modelled projections, while Table 39 shows the range to provide detail about the less likely but still plausible scenarios. The ranges in Table 39 are based on the 5 to 95% range of model results for sea level rise. If the West Antarctic ice sheet begins to collapse, sea levels could be several tenths of a metre higher by late in the century than what is currently projected.[1375] In the much longer term, irreversible melting of ice sheets could lead to many metres of sea level rise.[1376,1377]

1372. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019'.
1373. CSIRO and Bureau of Meteorology (BoM) 2015, 'Climate change in Australia: information for Australia's natural resource management regions: technical report', Australia https://apo.org.au/sites/default/files/resource-files/2015-01/apo-nid52475.pdf Accessed 15 November 2021.
1374. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019'.
1375. CSIRO and Bureau of Meteorology (BoM) 2015, 'Climate change in Australia: information for Australia's natural resource management regions: technical report', Australia https://apo.org.au/sites/default/files/resource-files/2015-01/apo-nid52475.pdf Accessed 15 November 2021.
1376. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019'.
1377. Intergovernmental Panel on Climate Change (IPCC) 2019, 'Summary for policymakers', in IPCC 'Special report on the ocean and cryosphere in a changing climate' prepared by HO Pörtner, DCRV Masson-Delmotte, P Zhai, M Tignor, E Poloczanska, K Mintenbeck, M Nicolai, A Okem, J Petzold, B Rama and N Weyer (eds).

Table 39: Likely ranges for projections of regional sea level rise (m) relative to 1986–2005 under all emissions scenarios.[1378]

Locations	2030	2050	2070	2090
Geelong	0.06 – 0.17	0.12 – 0.33	0.18 – 0.54	0.22 – 0.82
Williamstown	0.06 – 0.17	0.12 – 0.32	0.17 – 0.54	0.22 – 0.81

Sea level rise not only results in changes in mean sea level but can also change the frequency and intensity of extreme sea level events, such as storm tides that occur when high tides combine with strong winds and low-pressure systems.[1379]

The sea level projections for Victoria are consistent with those at a national level. For example, projections published in 2015 show that, for 16 locations across Australia under a high emissions scenario, sea levels are projected to rise (based on median modelled values) by between 59 and 66 cms by 2090.[1380]

SW 47: Wave climate

Region	2021 status	2021 trend	2021 data
Statewide		?	
Justification for assessment ratings:	A recent study on Victoria's wave climate deepened the understanding of its characteristics. Despite this research, Victoria's relatively high wave-energy coastline is a major gap in Australia's knowledge of the open coast wave climate of Australia due to a lack of permanent wave buoys. There has been no statewide analysis of the impacts of Victoria's wave climate, with the published research focusing on the significant impacts that are estimated to occur at a global scale. Confidence in this indicator is rated as low because of the lack of local studies and data.		

The open coast of Victoria is one of the highest wave-energy coastlines globally and a proxy for other coastlines receiving Southern Ocean swells. An eastward decrease in wave height and period occurs from Portland to Wilson's Promontory. This trend then reverses on the east coast. Across the west and central coasts, wave direction is dominated by southwest swells as influenced by strong westerly winds and mid-latitude cyclone activity. On the east coast, wave direction becomes more variable with added southerly, southeast, and easterly components.[1381]

The west coast, between Discovery Bay and Cape Otway, sees the highest and longest period waves overall along Victoria's open coast.[1382] The sector of coast west of Cape Otway – known as the Shipwreck Coast due to the large number of shipwrecks from the 1700s to the 1900s – has been reported to receive the highest wave energy in Victoria.[1383]

Despite Victoria's relatively high wave-energy coastline, it is a major gap in Australia's knowledge of the open coast wave climate of Australia due to a lack of permanent wave buoys.[1384]

1378. CSIRO and Bureau of Meteorology (BoM) 2015, 'Climate change in Australia: information for Australia's natural resource management regions: technical report', Australia https://apo.org.au/sites/default/files/resource-files/2015-01/apo-nid52475.pdf Accessed 18 November 2021.
1379. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019'.
1380. CSIRO and Bureau of Meteorology (BoM) 2015, 'Climate change in Australia: information for Australia's natural resource management regions: technical report', Australia.
1381. McSweeney S 2020, 'Temporal and spatial variability of the open coast wave climate of Victoria, Australia', *Marine and Freshwater Research*, 71, pp. 394-413.
1382. Ibid.
1383. Sustainable Energy Authority 2004, 'Wave and tidal power assessment for the Victorian Coastline', Water Technology technical report.
1384. McSweeney S 2020, 'Temporal and spatial variability of the open coast wave climate of Victoria, Australia', *Marine and Freshwater Research*, 71, pp. 394-413.

Knowledge of historical wave conditions is necessary for many human endeavours, such as offshore structure design, coastal hazard assessment and renewable energy applications. Surface driven wind-waves and their climatological variability must be considered within any comprehensive assessment of potential climate change-driven impacts on the coastal zone. CSIRO and BOM researchers collaborated to develop a 31-year wave hindcast for 1979 to 2010 that encompassed the Australian region. This work was published in 2014 and the resolution outputs were available for each hour and generated down to 4 feet over the South Pacific and around the Australian coast, which is a far higher temporal and spatial resolution than has previously been achieved.[1385]

Research published during 2019 included a finding that changes in wave patterns are likely to stay inside natural climate variability if global warming is limited to below 2°C, in line with the Paris agreement target. However, in a business-as-usual climate, where warming continues in line with current trends, it is likely that significant changes in wave conditions will occur along 50% of the world's coasts.[1386] Projections for Australia's southern coastline show robust increases in annual mean wave periods, along with anticlockwise shifts in the south-westerly wave directions to become slightly more southerly. Associated changes in frequency and/or intensity of storm wave events can exacerbate coastal stress, either by contributing to episodic erosion events or altering coastal sediment budgets that can drive potential chronic erosion issues. For eastern Victoria, projections show a reduction in wave heights by the end of the 21st century under a high emissions scenario.[1387]

Features such as wave- height, length, frequency and direction can contribute to coastal stability. For example, some areas will see the height of waves remain the same, but their length or frequency change. This can result in more force exerted on the coast (or coastal infrastructure), perhaps seeing waves run further up a beach and increasing wave-driven flooding. Similarly, waves travelling from a slightly altered direction (suggested to occur over 20% of global coasts) can change how much sand they shunt along the coast.[1388]

Research completed as part of the Victorian Coastal Monitoring Program and published during 2021 demonstrated an approach through which impact-based thresholds for erosion could be developed for management applications and early warning systems. The researchers isolated the conditions that have occurred during known events at two temperate, high energy sandy beaches backed by foredunes in southeast Australia: Port Fairy and Inverloch. The data showed that at both sites, impacts mainly occur when there is higher than average still water levels and higher waves. This suggests that impactful events might be very sensitive to continued sea level rise into the future. By identifying the oceanic conditions that are conducive to impacts on the open coast, based on currently available data, the researchers have shown there is potential for the development of operational warning systems to be established from this kind of empirically based approach along the open coasts of Victoria, Australia, and potentially, further afield.[1389]

1385. The Centre for Australian Weather and Climate Research (CAWCR) 2014, 'A global wave hindcast focussed on the Central and South Pacific', CAWCR technical report no. 070.
1386. Morim J, Hemer M, Wang XL, Cartwright N, Trenham C, Semedo A, Young I, Bricheno L, Camus P, Casas-Prat M, Erikson L, Mentaschi L, Mori N, Shimura T, Timmermans B, Aarnes O, Breivik Ø, Behrens A, Dobrynin M, Menendez M, Staneva J, Wehner M, Wolf J, Kamranzad B, Webb A, Stopa J and Andutta F 2019, 'Robustness and uncertainties in global multivariate wind-wave climate projections', *Nature Climate Change*, 9, pp. 711-718 https://doi.org/10.1038/s41558-019-0542-5 Accessed 5 February 2021.
1387. Earth Systems and Climate Change Hub 2021, 'Wind-wave climate change along Australia's coast'.
1388. Morim J, Hemer M, Wang XL, Cartwright N, Trenham C, Semedo A, Young I, Bricheno L, Camus P, Casas-Prat M, Erikson L, Mentaschi L, Mori N, Shimura T, Timmermans B, Aarnes O, Breivik Ø, Behrens A, Dobrynin M, Menendez M, Staneva J, Wehner M, Wolf J, Kamranzad B, Webb A, Stopa J and Andutta F 2019, 'Robustness and uncertainties in global multivariate wind-wave climate projections', *Nature Climate Change*, 9, pp. 711-718 https://doi.org/10.1038/s41558-019-0542-5 Accessed 5 February 2021.
1389. Leach C, Hague B, Kennedy DM, Carvalho RC, Ierodiaconou D 2021, 'Identifying oceanographic conditions conducive to coastal impacts on temperate open coastal beaches and the importance of empirical impact data', *Natural Hazards* https://doi.org/10.1007/s11069-021-04845-z Accessed 7 July 2021.

SW 48: Coastal erosion

Region	2021 status	2021 trend	2021 data
Statewide		?	
Justification for assessment ratings:	Researchers have estimated that erosion hotspots extend (defined as that showed a landward shift in shoreline position between 1986 and 2017 at a rate greater than 0.5 m per year) over 76.6 km of the coastline, equivalent to approximately 6.2% of the Victorian coast. Because this mapping is a 'point-in-time' assessment, the trend is unclear.		

Research published in 2020 found significant change in shoreline position was experienced by 13% of the Victorian coast between 1986 – 2017.[1390] This includes coastal regions characterised by persistent landward shifts (erosion) or seaward advance (progradation) in shoreline position. Significant shoreline change was defined as shores at least 250 metres in length that showed a change in shoreline position at rates greater than 0.5 metres per year. The research was funded through the Victorian Coastal Monitoring Program, DELWP and the Earth Systems and Climate Change Hub of the Australian Government's National Environmental Science Program.[1391]

The researchers estimated that erosion hotspots extend over 76.6 km of the coastline, equivalent to approximately 6.2% of the Victorian coast. Progradation hotspots were estimated to extend over 72.7 km of coast, equivalent to approximately 5.9% of the coast.[1392]

The greatest rates of change were located near the entrances of tidal-inlets, indicating a strong landform and sediment supply component to hotspot development. However, hotspots were not strongly correlated to changes in wave height. This suggests that changes to wave height in isolation cannot predict shoreline change for the Victorian coastline.[1393]

Future studies into shoreline change were suggested to look beyond just projected changes to wave height and should include changes in wave direction and sediment transport.[1394]

1390. Konlechner TM, Kennedy DM, O'Grady JJ, Leach C, Ranasinghe R, Carvalho RC and Ierodiaconou D 2020, 'Mapping spatial variability in shoreline change hotspots from satellite data; a case study in southeast Australia', *Estuarine, Coastal and Shelf Science*, 246, 107018.
1391. The University of Melbourne, 'Mapping spatial variability in shoreline change hotspots from satellite data: a case study in southeast Australia' https://findanexpert.unimelb.edu.au/scholarlywork/1467937-mapping-spatial-variability-in-shoreline-change-hotspots-from-satellite-data%3B-a-case-study-in-southeast-australia Accessed 15 July 2021.
1392. Konlechner TM, Kennedy DM, O'Grady JJ, Leach C, Ranasinghe R, Carvalho RC and Ierodiaconou D 2020, 'Mapping spatial variability in shoreline change hotspots from satellite data; a case study in southeast Australia', *Estuarine, Coastal and Shelf Science*, 246, 107018.
1393. Ibid.
1394. Earth Systems and Climate Change Hub, 'Coastal erosion under a changing climate'.

SW 49: Seawater intrusion into coastal aquifers

Region	2021 status	2021 trend	2021 data
Statewide		?	
Justification for assessment ratings:	assessments for this indicator. The evidence to assess this indicator is minimal, therefore an indicator confidence assessment cannot be made.		

In 2012, Geoscience Australia and the National Centre for Groundwater Research and Training, in collaboration with state and territory water agencies, reported a literature review and national-scale assessment of the vulnerability of coastal aquifers to inundation and sea water intrusion. While there was insufficient data at both the national and local scales to complete a full assessment, the threats of seawater intrusion were assessed at many locations along the Australian coastline.[1395]

The study mapped areas in most Australian states and territories (Tasmania and the Australian Capital Territory were not included) at risk of inundation due to sea level rise and storm surges. Victoria had the smallest total area threatened by seawater intrusion, however no further analysis has been published to determine the fragility of the ecosystems most likely to be impacted by seawater intrusion.[1396]

The intrusion occurred within a bore adjacent to Port Phillip Bay. Seawater influx into the basalt aquifer was linked with high groundwater demand during a severe drought between 2002 and 2004.[1397] The 2012 study also found the Werribee River Delta was the only site in Victoria where seawater intrusion had been documented.[1398]

In addition to the documented case of seawater intrusion at Werribee, other areas in Victoria that are potentially at risk of seawater intrusion include Point Nepean, the Gippsland region (Orbost, Sale and Venus Bay) and the Koo Wee Rup, Nullawarre and Yangery areas.[1399]

Research from 2015 quantified the vulnerability of seawater intrusion into 28 coastal aquifers across Australia, although only one was in Victoria, which was in Werribee. Werribee was rated as a low to moderate location for seawater intrusion.[1400]

Additional analysis of freshwater lens systems found Point Nepean to be thicker and less vulnerable to seawater intrusion than two similar systems measured in Western Australia.[1401]

1395. Ivkovic KM, Marshall SK, Morgan LK, Werner AD, Carey H, Cook S, Sundaram B, Norman R, Wallace L, Caruana L, Dixon-Jain P and Simon D 2012, 'National-scale vulnerability assessment of seawater intrusion: summary report', National Water Commission, Canberra.
1396. Ibid.
1397. Sinclair Knight Mertz 2005, Werribee irrigation district groundwater investigations', Malvern, Victoria.
1398. Ivkovic KM, Marshall SK, Morgan LK, Werner AD, Carey H, Cook S, Sundaram B, Norman R, Wallace L, Caruana L, Dixon-Jain P and Simon D 2012, 'National-scale vulnerability assessment of seawater intrusion: summary report', National Water Commission, Canberra.
1399. Ibid.
1400. Morgan LK and Werner AD 2015, 'A national inventory of seawater intrusion vulnerability for Australia,' *Journal of Hydrology: Regional Studies*, 4, pp. 686-698 http://dx.doi.org/10.1016/j.ejrh.2015.10.005 Accessed 7 July 2020.
1401. Ibid.

Indicator 51: Climate change impact on marine and coastal infrastructure

Region	2021 status	2021 trend	2021 data
Statewide			

Justification for assessment ratings:

The status and trend assessments are based on:

- analysis of the Victorian Coastal Inundation digital dataset
- Microsoft's Australia Building Footprints dataset
- the research synthesis and commentary provided in Infrastructure Victoria's Draft 30-Year Infrastructure Strategy, which was released in December 2020.

There has been no statewide quantitative analysis of the risks to, and impacts on, Victoria's marine and coastal infrastructure from climate change so the confidence in this indicator's status and trend assessments is low. However, the examples provide in the indicator narrative all suggest a poor status and an unclear trend, although there is expected to be a deteriorating trend in the future as the impacts of climate change are projected to increase.

Nearly 14% of Victoria's population lives along the coast, with the state's coastal regions receiving around 70 million recreational visits each year.[1402,1403]

Coastal infrastructure supports residents and industries, including tourism and fishing, and caters for part-time populations, such as tourists and those who own holiday homes.[1404] For example, Lorne welcomes an extra 20,000 people during the annual Pier to Pub swim, which represents a 20-fold increase on its normal population.[1405]

As discussed in the other indicators within the climate and climate change impacts chapter of this report, rising sea levels and more intense storm surges are projected to increase coastal erosion and flooding, damaging many low-lying ecosystems, infrastructure, and homes. Valuable infrastructure is close to the coast, such as buildings, hospitals, roads, rail, electricity, telecommunications, stormwater, drainage and sewerage assets.[1406]

Rising sea levels have social and economic impacts beyond the infrastructure itself.[1407] For example, erosion is visibly threatening the Great Ocean Road's $1.1 billion visitor economy, while Phillip Island and Inverloch are also witnessing the loss of popular beaches.[1408,1409,1410]

The Victorian Coastal Inundation dataset has been used with Microsoft - Australia Building Footprints 2013-2018 data to quantify the number of buildings exposed to sea level rise.[1411] Under a high emissions scenario, Victoria is expected to experience a sea level rise of 82 cms by 2100. This projected sea level rise has been combined with expected inundation from a 1-in-100-year storm tide level and spatial layers of buildings to aggregate the potential number and percentage of buildings affected by LGA in Victoria due to sea level rise and storm surge by 2100.

1402. Department of Environment, Land, Water and Planning (DELWP), 'The coast and planning in Victoria', East Melbourne, Victoria www.planning.vic.gov.au/policy-and-strategy/coastal-planning-in-victoria#overview Accessed 9 March 2021.
1403. Infrastructure Victoria 2020, 'Victoria's draft infrastructure strategy volume 1'.
1404. Ibid.
1405. McKenzie F 2020, 'Coastal demographics in Victoria: background research paper prepared for the Victorian Marine and Coastal Council', Department of Environment, Land, Water and Planning (DELWP), East Melbourne Victoria.
1406. Infrastructure Victoria 2020, 'Victoria's draft infrastructure strategy volume 1'.
1407. Ibid.
1408. Australian Broadcasting Corporation (ABC) 2018, 'Great Ocean Road erosion prompts call for plant to preserve tourist destination's future' https://www.abc.net.au/news/2018-08-26/erosion-threatening-greatocean-road/10147918 Accessed 9 March 2021.
1409. Bass Coast Shire, 'Targeting erosion at Cowes' https://www.basscoast.vic.gov.au/about-council/news-listing/targeting-erosion-at-cowes Accessed 9 March 2021.
1410. Bass Coast Shire, 'Foreshore erosion response' https://www.basscoast.vic.gov.au/services/environment/foreshore-erosion-control Accessed 9 March 2021.
1411. Australian Urban Research Infrastructure Network (AURIN) 2021, 'State of the marine and coastal environment 2021 data gap 1 - preliminary investigation', unpublished report prepared by Lachlan Ng, University of Melbourne.

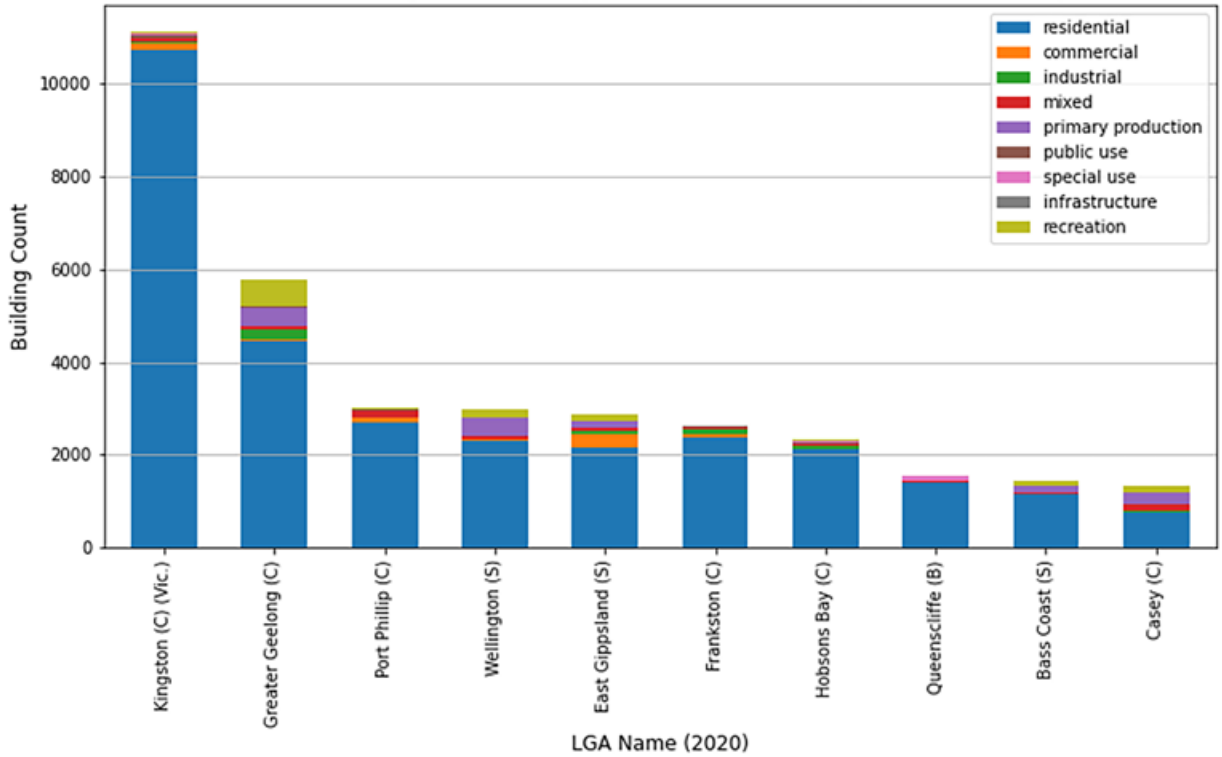


Figure 97: Number of buildings expected to be inundated by 2100 under a high emissions scenario with an expected sea level rise of 82 cms and 1-in-100 year storm tide, Victorian Local Government Areas.[1412]

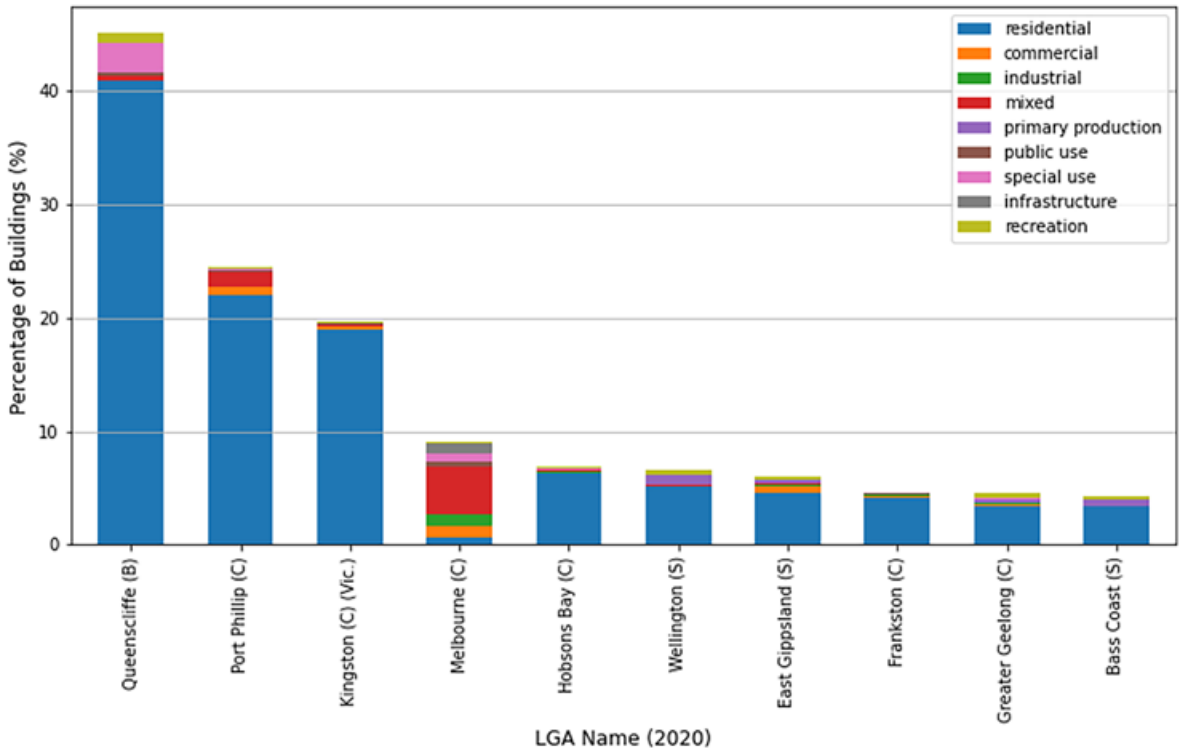


Figure 98: Proportion of buildings expected to be inundated by 2100 under a high emissions scenario with an expected sea level rise of 82 cms and 1-in-100 year storm tide, Victorian Local Government Areas.[1413]

1412. Ibid.
1413. Ibid.

From the results, the LGA with the most buildings at risk of inundation is Kingston, which is located on Port Phillip Bay's eastern coastline. Approximately 11,115 inundated buildings are projected for Kingston by 2100, with the majority of these likely to be located within the suburbs of Patterson Lakes and Chelsea Heights, which are primarily characterised by detached residential dwellings. These buildings may appear adjacent to the Edithvale-Seaford Wetlands and connecting parkland, which cuts north-south through the LGA and connects to the Mordialloc Creek and Patterson River. The percentages by LGA show that approximately 45% of building footprints in Queenscliffe are expected to be inundated by 2100. Queenscliffe is a relatively small LGA and the majority of buildings likely to be inundated are located in Point Lonsdale adjacent to Port Phillip Heads Marine National Park and Lonsdale Lakes Wildlife Reserve.

It should be noted that the analysis above is dealing with buildings only. Other types of infrastructure such as roads and utilities networks (water, waste, electricity, etc.) would also be affected with the inundation scenarios outlined above.

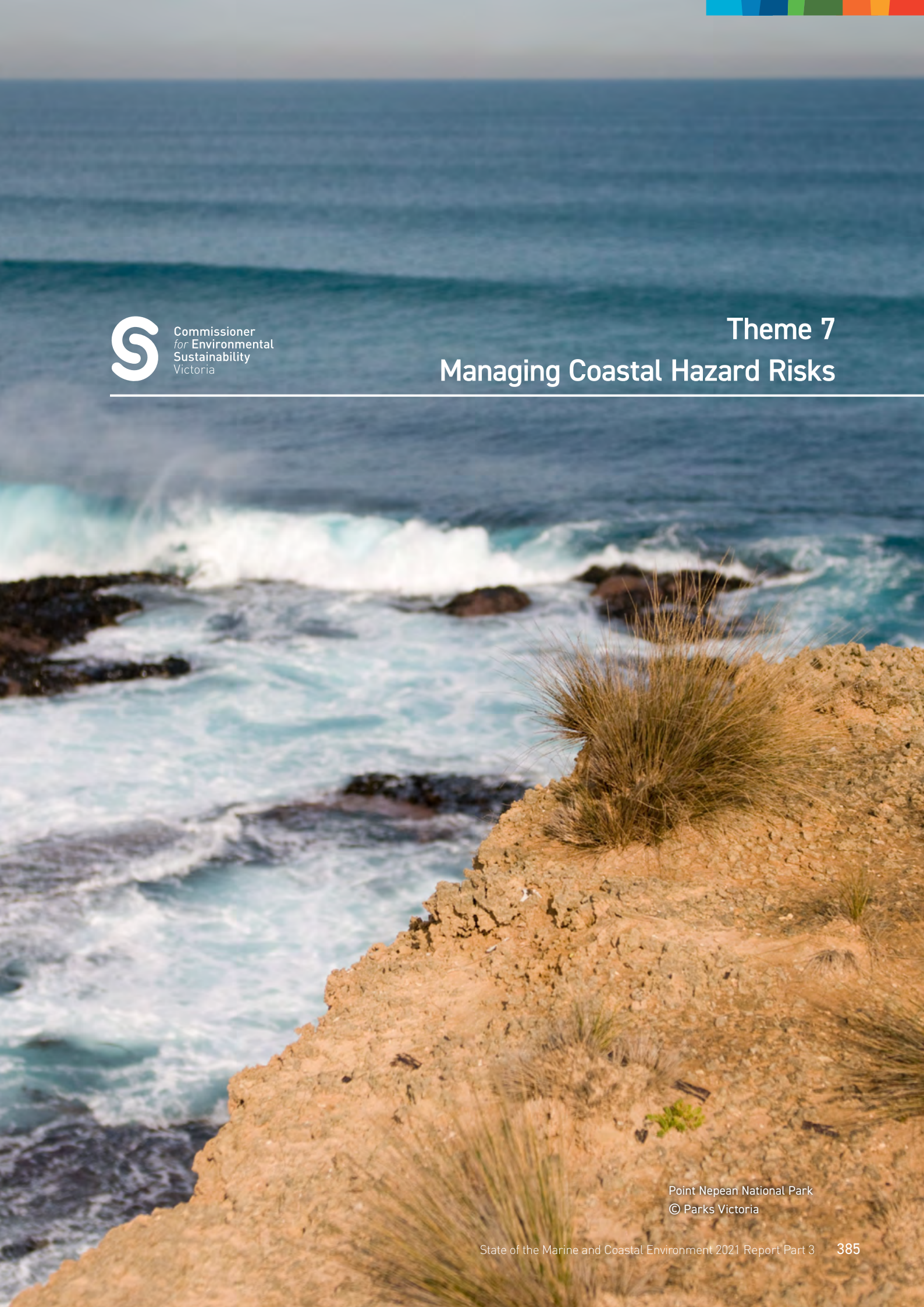
Infrastructure Victoria's Draft 30-Year Infrastructure Strategy, which was released in December 2020, contained analysis and recommendations on how Victoria can respond to a changing climate.[1414] A specific section looked at the coastal infrastructure risks associated with flooding and erosion.

Draft Recommendation 16 from Infrastructure Victoria's Draft 30-Year Infrastructure Strategy was for the Victorian Government to safeguard Victoria's coasts by committing at least an extra $30 million for coastal infrastructure maintenance and upgrades in the coming eight years, with a focus on the Barwon, Great South Coast and Gippsland regions.[1415]

1414. Infrastructure Victoria 2020, 'Victoria's draft infrastructure strategy volume 1'.
1415. Ibid.

Commissioner *for* Environmental Sustainability Victoria

Theme 7
Managing Coastal Hazard Risks



Point Nepean National Park
© Parks Victoria

Background

Analysis supplied by DELWP detailed the extent and quality that Victorian councils were considering climate change in land-use planning. There was a strong pattern when comparing inland and coastal councils, with coastal councils three times more likely to have an intermediate, high or advanced consideration of climate change in land-use planning than inland councils. However, 30% of coastal councils were assessed in 2018 as having no or basic integration of climate change into land-use planning.

Catchment Management Authorities (CMAs) are playing an important role in Victoria to help the state adapt to climate change. All ten CMAs across Victoria have developed and are implementing Climate Change Adaptation Plans or Strategies. These were developed using the latest climate change projections by the CSIRO and in conjunction with key research organisations across Australia.

Protecting and restoring coastal blue carbon ecosystems such as mangroves, tidal marshes and seagrasses offers opportunities for carbon sequestration and avoidance of greenhouse gas emissions. Improved management of blue carbon ecosystems can also improve fisheries and increase resilience of coasts to rising sea levels and storm surges. Research published in 2019 found that allowing coastal wetlands to naturally retreat with sea level rise in Victoria could sequester 1.6 million tonnes of carbon by 2050 with a value of $65 million.

Comparison with insights from State of the Bays 2016 Report and the State of the Environment 2018 Report

The only indicator in this chapter that has been previously reported by the Commissioner for Environmental Sustainability is the Considering climate change risks in land use planning indicator, which was included in the SoE 2018 Report. The SoE 2018 Report found there was consensus across local councils, particularly coastal councils, that land-use planning should be informed by up-to-date climate science. No additional quantitative analysis has been undertaken for the Considering climate change risks in land use planning indicator since the SoE 2018 Report. The only additional commentary for that indicator within this report encompasses updated planning guidance materials developed in recent years.

Climate change adaptation plans, nature-based adaptation and emergency planning and preparedness indicators are all new indicators for this report. The nature-based adaptation indicator is a particularly important addition, with its inclusion highlighting missed opportunities to capture carbon from saltmarshes, mangroves and seagrasses.

Theme 7: Managing Coastal Hazard Risks

Indicator 52: Considering climate change risks in land-use planning

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		?			?	

Data source:	DELWP
Measures:	Percentage of Victorian coastal councils assessed as having Advanced or Intermediate consideration of climate change in land-use planning

Why this indicator?

Current and future climate change impacts on communities can be mitigated through coordinated planning that considers climate risk. This includes land-use planning that considers the impacts of sea level rise, including increased frequencies of inundation and erosion.

This indicator is designed to report on management actions to reduce the impacts of climate change.

Current and future climate change impacts on communities can be mitigated through coordinated planning that considers climate risk. This includes land-use planning that considers the impacts of sea level rise, including increased frequencies of inundation and erosion.

The SoE 2018 Report found there was good agreement across local councils, particularly coastal councils, that land-use planning should be informed by up-to-date climate science.[1416]

1416. Commissioner for Environmental Sustainability (CES) 2018, 'Victorian State of the Environment 2018', Melbourne, Victoria.

Indicator 53: Climate change adaptation plans

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		↗			N/A	N/A

Data source:	Catchment Management Authorities
Measures:	Number of catchment management authorities that have developed and are implementing climate change adaptation plans or strategies

Why this indicator?

Climate change impacts are expected to vary across Victoria and may occur incrementally or rapidly. Adaptation will need to be responsive to local conditions, values, risk appetite, risk exposure, capability and capacity.

Climate change impacts are expected to vary across Victoria and may occur incrementally or rapidly. Adaptation will need to be responsive to local conditions, values, risk appetite, risk exposure, capability and capacity.[1417]

The *Climate Change Act 2017* requires Adaptation Action Plans are prepared from 2021 for key systems that are either vulnerable to the impacts of climate change or essential to ensure Victoria is resilient from 2021.[1418]

This indicator is designed to analyse the extent that government is working collaboratively with communities and industries to develop and implement adaptation measures that are appropriate and effective in local contexts.

Indicator 54: Nature-based adaptation

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		?			N/A	N/A

Data source:	DELWP
Measures:	Soil carbon stocks (tonnes of organic carbon per hectare) in saltmarsh, mangrove and seagrass ecosystems mapped across Victoria | Potential carbon sequestration gains from 2020 to 2100 by restoring coastal wetlands in areas inundated by levee breaching and sea-level rise | Economic benefit of carbon sequestration

Why this indicator?

The Marine and Coastal Policy 2020 details marine and coastal ecosystem goods and services, which includes the regulation of natural processes by ecosystems that benefit humans. Climate regulation is the contribution of a marine or coastal ecosystem to the maintenance of a favourable climate.

The Marine and Coastal Policy 2020 details marine and coastal ecosystem goods and services, which includes the regulation of natural processes by ecosystems that benefit humans. Climate regulation is the contribution of a marine or coastal ecosystem to the maintenance of a favourable climate.

Blue carbon ecosystems (saltmarsh, mangroves and seagrasses) capture and store carbon from the atmosphere and are an example of climate regulation.

1417. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Marine and coastal policy', East Melbourne, Victoria.
1418. Department of Environment, Land, Water and Planning (DELWP), 'Climate Change Act 2017', East Melbourne https://www.climatechange.vic.gov.au/legislation/climate-change-act-2017 Accessed 9 March 2021.

Theme 7: Managing Coastal Hazard Risks

Indicator 55: Emergency planning and preparedness

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide					N/A	N/A

Data source:	Emergency Management Victoria
Measures:	As per the Emergency Management Act 2013, the State Emergency Management Plan contains provisions for the mitigation of, response to and recovery from emergencies, and specifies the roles and responsibilities of agencies in managing emergencies.

Why this indicator?

Emergencies that impact on the marine and coastal environment are wide ranging, including coastal flooding, bushfires, marine wildlife stranding and entanglements, oil spills, water contamination and outbreaks of invasive species. Many coastal hazards, including flooding and erosion, will increase in severity due to climate change. The dynamic nature of these risks needs to be incorporated into emergency management planning.

'Emergency response and preparedness' is a chapter in the Marine and Coastal Policy 2020. The intended outcome is that emergencies that impact on the marine and coastal environment are effectively planned for to prevent or minimise immediate and long-term consequences on human health and safety, property, the natural environment and local values, and to enable recovery and reduce future risk.[1419]

Emergencies that impact on the marine and coastal environment are wide ranging, including coastal flooding, bushfires, marine wildlife stranding and entanglements, oil spills, water contamination and outbreaks of invasive species.[1420]

Many coastal hazards, including flooding and erosion, will increase in severity due to climate change. The dynamic nature of these risks needs to be incorporated into emergency management planning.[1421]

Emergencies can cause direct negative impact on local values, and emergency responses need to be carefully managed to minimise further impacts. Emergency prevention and preparedness are core components of reducing the likelihood of emergencies and minimising their consequences when they occur.[1422]

1419. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Marine and coastal policy', East Melbourne, Victoria.
1420. Ibid.
1421. Ibid.
1422. Ibid.

Statewide/broad-scale

SW 52: Considering climate change risks in land-use planning

Region	2021 status	2021 trend	2021 data
Statewide		?	

Justification for assessment ratings:	The status assessment of fair reflects data from 2018 that shows 70% of the 22 Victorian coastal councils were assessed as having advanced or intermediate consideration of climate change in land-use planning. Because this mapping is a 'point-in-time' assessment, the trend is unclear. As climate change risks regularly evolve, it is possible that coastal councils have advanced their consideration of climate change in land-use planning since 2018, so the confidence in the indicator assessment is only rated as moderate.

The SoE 2018 Report included an assessment of the extent that Victorian local governments are incorporating climate change into land-use planning decisions. The data used for the assessment were supplied by DEWLP and contained qualitative assessments of publicly available corporate governance documents. Figure 99 shows that 14% of all Victorian councils integrated climate change into land-use planning at a level considered high or advanced, while 65% of councils considered climate change at only a basic level, or not at all, during land-use planning.

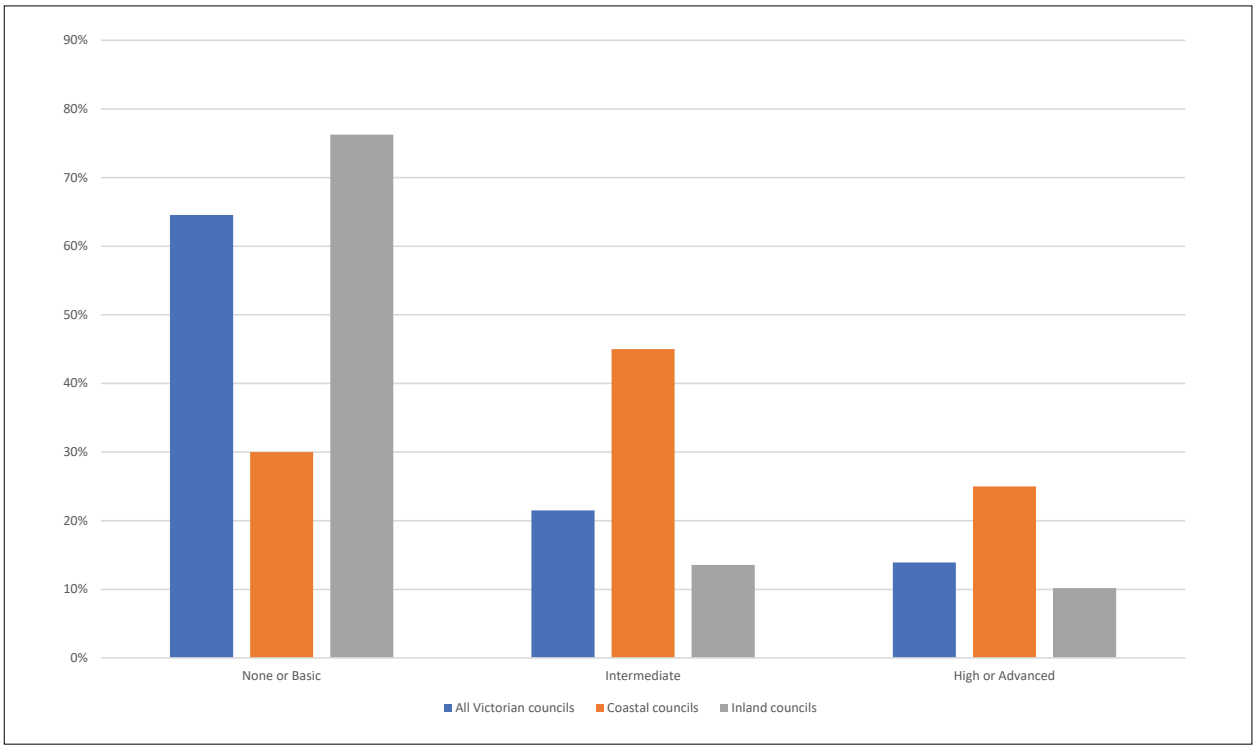


Figure 99: Percentage of Victorian councils that integrate climate change into land-use planning.[1423]

1423. Commissioner for Environmental Sustainability (CES) 2018, 'Victorian State of the Environment 2018, scientific assessments', p. 66.

Theme 7: Managing Coastal Hazard Risks

There was a strong pattern when comparing inland and coastal councils, with coastal councils three times more likely to have an intermediate, high or advanced consideration of climate change in land-use planning than inland councils. This highlights the increased awareness and response of coastal councils to the threats posed by climate change, however 30% of coastal councils still were assessed during 2018 as having no or basic integration of climate change into land-use planning.

Many government and non-government stakeholders manage coastal assets, pressures and issues. The planning system helps guide sustainable development within coastal settlements and manage development within non-urban areas.

The Victorian government supports the development of detailed coastal hazard mapping and risk assessments in preparation for storm surges and sea level rise. DELWP supports coastal adaptation planning by working with stakeholders to implement the best available coastal hazard information, including through planning schemes and related coastal management processes.

Recognising that population growth and the demand for coastal living are ongoing pressures, and that the potential impacts of climate change on existing coastal hazards are also likely to increase, Planning Practice Note 53 was developed to help with planning and guide responsible authorities on:

- managing coastal hazards
- the decision-making process for assessing coastal hazard risk
- planning for development in coastal areas.[1424]

In 2017, Melbourne Water released Planning for Sea Level Rise Guidelines that set out the specific requirements that apply to development proposals in areas that will be affected by tidal inundation (including storm surge and wave action) as a result of predicted sea level rise.[1425] The guidelines were developed to:

- help property owners, developers, designers and builders to understand the specific requirements that apply in areas at risk of tidal inundation
- detail the relevant considerations to be taken into account by Melbourne Water when assessing development proposals
- provide for consistency and transparency in decision-making.

1424. Department of Environment, Land, Water and Planning (DELWP) 2015, 'Managing coastal hazards and the coastal impacts of climate change – planning practice note 53', East Melbourne, Victoria.
1425. Melbourne Water 2017, 'Planning for sea level rise guidelines February 2017'.

SW 53: Climate change adaptation plans

Region	2021 status	2021 trend	2021 data
Statewide			
Justification for assessment ratings:	The status assessment of fair reflects that considerable work is being done to adapt to climate change based on the best scientific information. For example, all ten Catchment Management Authorities across Victoria have developed and are implementing Climate Change Adaptation Plans or Strategies that were developed using the latest climate change projections by the CSIRO and in conjunction with key research organisations across Australia. The trend is improving because more guidance material to enable organisations to develop climate change adaptation plans has been published during recent years. The low confidence rating reflects that only a minimal amount of evidence is available to assess the development and implementation of climate change adaptation plans preparation.		

Local governments are at the forefront of responding to climate change impacts, which is reflected in the Victorian Government's Climate Change Adaptation Plan 2017 – 2020 that includes a commitment to partner with local government on adaptation to help build local government capacity and collaborative action.[1426]

During 2020 the Victorian Government released a range of guidance material to support government, business and community in planning and delivering place-based adaptation to address the impacts of climate change. The guidance material supports organisations that are developing place-based climate change adaptation strategies, responses and actions.[1427]

Despite the focus on climate change adaptation activity since the release of the Victorian Government's Climate Change Adaptation Plan 2017–2020, little is currently known about the effectiveness of Climate Change Adaptation Plans. PhD research at RMIT University into the use of monitoring and evaluation in local government climate change action planning is beginning to provide insight into this poorly understood area. A conference paper published during 2018 concluded that:

- Local governments are forging ahead with climate change adaptation planning but monitoring and evaluating climate change adaptation plans and initiatives is at a less developed stage.
- There is a need to improve technical knowledge and skills for monitoring and evaluation of climate change adaptation, including developing monitoring and evaluation frameworks and indicators, and enhancing the knowledge of evaluation tools.
- Local government monitoring and evaluation efforts are currently communicating the amount of climate change adaptation activity that is taking place, but not yet contributing significantly to our understanding of whether we are adapting successfully.[1428]

Catchment Management Authorities (CMAs) are playing a key role in Victoria to help the state adapt to climate change. All ten CMAs across Victoria have developed and are implementing Climate Change Adaptation Plans or Strategies.[1429] These were developed using the latest climate change projections by the CSIRO and in conjunction with key research organisations across Australia. This work has included:

- developing spatial tools to assess climate change vulnerability across the State
- pioneering adaptation pathways planning in the State
- undertaking extensive engagement with the community and key stakeholders on climate change adaptation
- producing the most comprehensive natural resource management climate change adaptation planning to date in Victoria.[1430]

The coastal CMAs in Victoria are (from west to east): Glenelg Hopkins, Corangamite, Port Phillip and Westernport, West Gippsland, and East Gippsland.

1426. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Climate change risks to local government', East Melbourne, Victoria.
1427. Department of Environment, Land, Water and Planning (DELWP) 'Climate change adaptation resources', https://www.climatechange.vic.gov.au/climate-change-adaptation-resources Accessed 9 May 2021.
1428. Scott H 2018, 'Monitoring and evaluation of climate change adaptation by local government: the state of play in Australia', Proceedings of the 4th Practical Responses to Climate Change Conference: Climate Adaptation 2018: Learn, Collaborate, Act, 8–10 May 2018, Melbourne.
1429. Victorian Catchment Management Authorities (CMAs) and Department of Environment, Land, Water and Planning (DELWP) 'Regional natural resource management climate change adaption Victorian priorities'.
1430. Australian Government 'Climate ready natural resource management planning in Victoria' https://www.nrmclimate.vic.gov.au/ Accessed 27 July 2021.

SW 54: Nature-based adaptation

Region	2021 status	2021 trend	2021 data
Statewide		?	
Justification for assessment ratings:	The status assessment of poor reflects research published during 2019 that found saltmarshes, mangroves and seagrasses in Victoria are currently capturing approximately 2% of the carbon that would be possible to be captured by 2050 if coastal wetlands can naturally retreat. Because this research is a 'point-in-time' assessment, the trend is unclear.		

Saltmarshes, mangroves and seagrasses in Victoria and New South Wales currently capture 36,000 tonnes of carbon each year, equivalent to the annual emissions of 7,826 cars. In Victoria, it is estimated this could expand to 1.6 million tonnes of carbon by 2050 if coastal wetlands can naturally retreat.[1431]

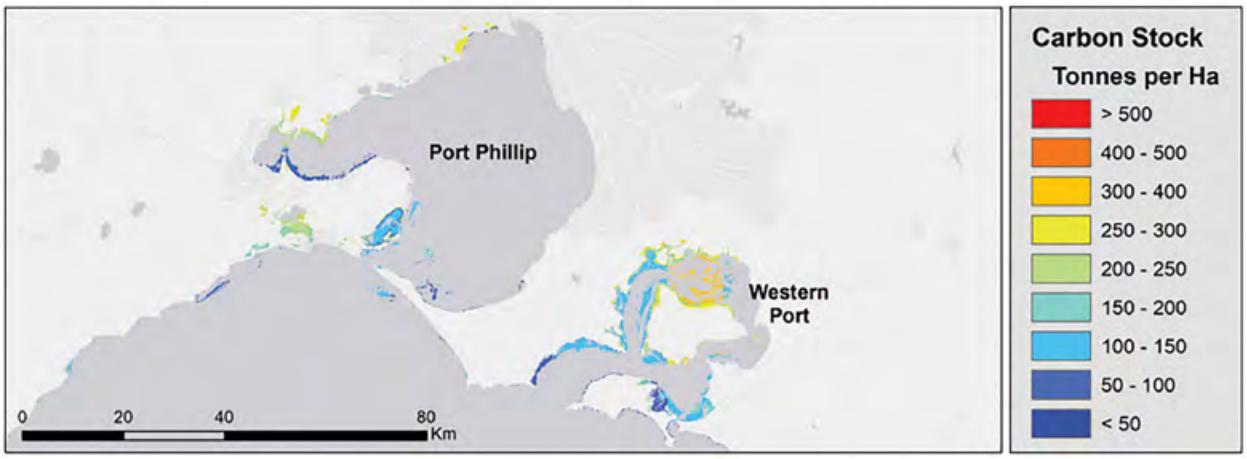


Figure 100: Examples of soil carbon stocks (tonnes of organic carbon per hectare) in saltmarsh, mangrove and seagrass ecosystems mapped across Victoria.[1432]

Coastal wetlands converted to alternative land uses emit 20% of their stored carbon, whilst restored wetlands can recapture between two and 11.5 tonnes of CO_2 per hectare per year, equivalent to the CO_2 emitted by 0.5–2.5 cars annually.[1433]

To harness the power of coastal wetlands to combat climate change, the Mapping Ocean Wealth team used possible future management actions or inactions, that would lead to expansion or contraction of coastal wetlands across the state of Victoria to determine how much carbon will be sequestered (or lost) with the change in wetland extent.

Three scenarios were assessed:

- reinstate tidal flow under current conditions by breaching levees that currently prevent natural tidal exchange
- a 'managed retreat' scenario which models the natural retreat of wetlands in a landward direction with future sea level rise
- a 'net wetland loss' scenario which modelled an overall decline in wetlands in areas with above-median risk of coastal erosion.[1434]

1431. Carnell PE, Reeves SE, Nicholson E, Macreadie P, Ierodiaconou D, Young M, Kelvin J, Janes H, Navarro A, Fitzsimons J and Gillies CL 2019, 'Mapping ocean wealth Australia: the value of coastal wetlands to people and nature', The Nature Conservancy, Melbourne.

1432. Ibid.
1433. Ibid.
1434. Ibid.

Removing levees now and allowing natural tidal exchange to occur would provide an additional 1.65 million tonnes of carbon sequestration (Figure 101), valued at $67 million using average carbon prices paid via the Australian Emission Reduction Fund (ERF) when the research was completed during 2019.[1435]

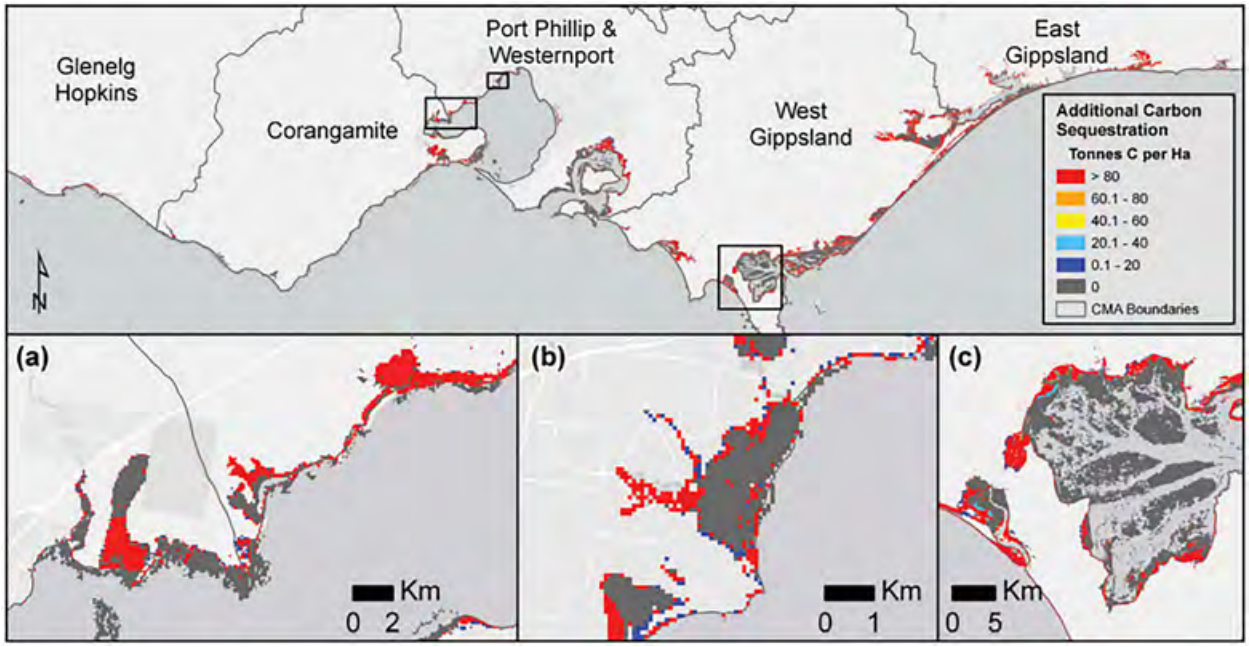


Figure 101: Carbon gained from 2020 to 2100 by restoring coastal wetlands in areas inundated by levee breaching and sea level rise at (a) Avalon Coastal Reserve to Point Wilson; (b) Point Cook; and (c) Corner Inlet and Shallow Inlet.[1436]

Sequestration was modelled using the InVEST Blue Carbon model. Additional sequestration was measured as tonnes of carbon gained when allowing newly inundated areas to transition to coastal wetlands compared to a scenario of allowing sequestration to continue only in areas with existing coastal wetlands. Grey patches indicate where coastal wetlands already exist, and carbon sequestration would not differ between the two management actions.[1437]

Allowing blue carbon ecosystems to naturally colonise into landward areas (that will be inundated by sea level rise in the future) would sequester 1.6 million tonnes of carbon by 2050, which would be valued at $65 million. This would increase to 5.7 million tonnes and be worth $159 million by 2100. This scenario is mapped across Victoria (Figure 102). While sea level rise will inundate a greater area than targeted levee removal, the levee removal strategy would allow for restoration to begin sooner in some locations, generating up to 14 thousand additional tonnes of sequestration and $2.9 million in ERF value by 2030.[1438]

In the coastal wetland loss scenario, if future erosion removes coastal wetlands and no action is taken to allow natural retreat, the carbon released from soils would exceed any sequestration gain from the remaining coastal wetland. By 2100, erosion of Victoria's blue carbon ecosystems would release a net 6.3 million tonnes of carbon into the atmosphere, after accounting for sequestration by remaining ecosystems. These emissions equate to $8.5 billion using the ERF price. While this study presents outcomes for the same management actions or inactions to the whole coast of Victoria, future coastal wetland distribution in any given region will likely be a mosaic of these management scenarios.[1439]

Protecting and restoring coastal blue carbon ecosystems such as mangroves, tidal marshes and seagrasses offers opportunities for carbon sequestration and avoidance of greenhouse gas emissions. The Australian Government is exploring opportunities for blue carbon activities to be included in the ERF, which is documented in a 2019 report detailing the path to an ERF for blue carbon.[1440]

1435. Ibid.
1436. Ibid.
1437. Ibid.
1438. Ibid.
1439. Ibid.
1440. Australian Government 2019, 'Towards an emissions reduction fund method for blue carbon', Canberra, Australia, Department of the Environment and Energy.

A 2019 Australian study analysed the impacts of land management practices on blue carbon stocks and greenhouse gas fluxes in coastal ecosystems.[1441] Improved management of blue carbon ecosystems can also improve fisheries and increase resilience of coasts to rising sea levels and storm surges; these topics are covered in more detail in other indicators within this report.

There are other instances of natural climate regulation opportunities, for example, kelps have an ability to absorb an estimated 20 times more carbon dioxide per acre than forests on land, supporting diverse marine plants and animals and helping to stabilise coasts through absorbing wave energy and dissipation through wrack (debris) on beaches.

SW 55: Emergency planning and preparedness

Region	2021 status	2021 trend	2021 data
Statewide	●	↗	●
Justification for assessment ratings:	The status assessment of good reflects the existence of the State Emergency Management Plan (SEMP) that provides arrangements for an integrated, coordinated and comprehensive approach to emergency management at the state level. The trend is assessed as improving due to anecdotal evidence of the maturation of the Victorian Government's improving capability and capacity to plan, prepare and respond to emergencies, with incident air monitoring cited as an example.		

The Victorian State Emergency Management Plan (SEMP) provides arrangements for an integrated, coordinated and comprehensive approach to emergency management at the state level. The *Emergency Management Act 2013* (EM Act 2013) requires the SEMP to contain provisions for the mitigation of, response to and recovery from emergencies, and to specify the roles and responsibilities of agencies in relation to emergency management.[1442,1443]

The SEMP Roles and Responsibilities are detailed for mitigation, response (including relief), and recovery. Agency roles are mapped for core capabilities and critical tasks under the Victorian Preparedness Framework (VPF) for the management of major emergencies. The VPF identifies 21 core capabilities, and subsequent critical tasks for each, that Victoria requires to effectively prepare for, respond to and recover from, major emergencies. To be effective, the core capabilities are interdependent, co-ordinated and overlap across mitigation, response and recovery.[1444]

Emergency risks covered in the SEMP that have been impacting, or have the potential to impact, the marine and coastal environment include bushfires, floods, storms, marine oil spills and blue-green algae.[1445]

Adequate documentation exists to detail the extent of emergency management planning and preparedness for a range of emergencies that have the potential to impact the marine and coastal environment. However, no robust metrics exist to measure the efficacy of such plans to improve emergency mitigation and response.

Incident air monitoring is an example of the maturation of the Victorian Government's improving capability and capacity to plan, prepare and respond to emergencies. Following the 2014 Hazelwood Mine Fire Inquiry, EPA Victoria has been steadily progressing its ability to measure and report smoke impacts associated with significant fires to meet the requirements of Recommendation 5 of the Inquiry.[1446] In a coastal context, this was demonstrated during the 2019-20 bushfire season when EPA Victoria, in partnership with Victoria's State Emergency Services, deployed air monitoring equipment to several coastal towns that were being impacted by smoke including Lakes Entrance, Bairnsdale, Sale, Orbost, Nicholson, Mallacoota and Marlo.

1441. O'Connor JJ, Fest BJ, Sievers M and Swearer, SE 2020, 'Impacts of land management practices on blue carbon stocks and greenhouse gas fluxes in coastal ecosystems - a meta-analysis', *Global Change Biology*, 26(3), pp. 1354-1366.
1442. Emergency Management Victoria (EMV) 2020, 'Victorian state emergency management plan', Melbourne, Victoria.
1443. Emergency Management Victoria (EMV) 'Roles and responsibilities', Melbourne, Victoria https://www.emv.vic.gov.au/responsibilities/semp/roles-and-responsibilities Accessed 9 May 2021.
1444. Ibid.
1445. Emergency Management Victoria (EMV), 'State emergency management plan sub-plans', Melbourne, Victoria https://www.emv.vic.gov.au/responsibilities/state-emergency-management-plan-sub-plans Accessed 9 May 2021.
1446. Hazelwood Mine Fire Inquiry 2014, 'Hazelwood mine fire inquiry report 2014'.

Theme 8
Communities

Commissioner *for* Environmental Sustainability Victoria

Junior Rangers at Ricketts Point Marine Sanctuary
© Parks Victoria

Theme 8: Communities

Background

Socioeconomic assessments

The *Marine and Coastal Act 2018* has introduced a socioeconomic objective into state of the environment reporting. While a healthy environment is fundamental to our socioeconomic needs, a healthy environment relies upon communities having social wellbeing and economic resources to contribute to good environmental outcomes.

With the formal inclusion of a socioeconomic objective for environmental reporting in the *Marine and Coastal Act 2018*, there is an opportunity to ensure that the social sciences and economics are incorporated into DELWP's Marine and Coastal Knowledge Framework and that measures and thresholds for future reporting on communities' indicators are developed in an integrated way with the biophysical science priorities.

The application of the SDGs as an operating framework for environmental reporting can address this need. In the Method described in Part 2, Phase 3 (Localisation of SDG reporting) and Phase 4 (Reporting on SDG targets) provide an approach to both identify priority issues of importance to coastal communities and, through the synthesis of socioeconomic and biophysical data, assess our progress against key targets, identifying the opportunities for co-benefits and recognising where trade-offs will need to be managed. This process has also identified knowledge gaps that the Marine and Coastal Knowledge Framework, expanding its scope to include the three science objectives of the *Marine and Coastal Act 2018*, could address in its future development.

Coastal communities

The Communities theme focusses on activities undertaken by, and the liveability of, coastal communities.

Coastal settlements development represents a significant change in land use, potentially reducing natural habitat and introducing impervious surfaces. It is often assumed that population in coastal areas is increasing faster than non-coastal areas. In Victoria this is not the case. Recent rates of coastal population growth (1.6%) have been lower than for non-coastal areas (2.2%) and in 2019, the coastal population of Victoria formed a slightly smaller proportion of the Victorian population than it had a decade earlier.[1447] Population growth in coastal suburbs of Melbourne has been rapid, with increasing density of development, while coastal locations near Melbourne and Geelong, particularly on the Bellarine Peninsula and around Torquay have also experienced rapid population growth. Work is currently underway to protect significant landscapes in several coastal areas that are subject to development pressure. On balance, planning controls are being enhanced to protect important landscapes, but we have no monitoring systems in place to determine whether the outcomes are being achieved in terms of protecting the qualities of significant landscapes.

Legislative protection is given to a range of cultural heritage for both Aboriginal and non-Aboriginal Victorians, on land and in marine environments. Data on the number of items of registered sites as having cultural significance are available, subject to certain restrictions in the case of Aboriginal cultural heritage. While cultural heritage can be assessed quantitatively - in March 2021, there were a total of 38,827 registered Aboriginal places on the Victorian Aboriginal Heritage Register and 1,143 cultural heritage management plans - it is important to monitor the qualitative status of sites and the degree to which investment is supporting their preservation and protection.

Tourism and recreation (especially boating and fishing) is supported through Victorian Government policy and is seen as a valuable source of jobs and revenue for Victorian coastal communities. A recent study estimated that recreational fishing and boating in Victoria in 2018–19 generated:

- $14.00 billion combined direct and indirect output, including $6.14 billion direct output
- $5.83 billion combined direct and indirect value added, including $2.12 billion direct value added
- 55,780 combined direct and indirect Full-Time Equivalent (FTE) jobs, including 25,058 direct jobs.[1448]

1447. Data based on coastal Statistical Areas Level 2 (SA2) average annual population growth between 2009 and 2019. Australian Bureau of Statistics (ABS), 'Regional population growth', cat. 3218.0.
1448. Better Boating Victoria (BBV) and Victorian Fisheries Authority (VFA) 2020, The economic value of recreational fishing and boating in Victoria, prepared by Ernst and Young, p. 7.

At present there appear to be limited links between tourism growth policies and visitor management or environmental management strategies. While data are available, they tend to be geographically broad and survey-based which makes detailed assessment of tourist impact very difficult. Environmental certification schemes do not yet enable comprehensive assessment of tourism operators' environmental credentials.

Recreational fishing provides a popular activity for people, contributing to their wellbeing. Increases in recreational fishing activity may lead to increased pressures on fisheries and the broader ecosystem. Management strategies and education are required to prevent such impacts. While some data are available on recreational fishing, there remain gaps in our understanding of its scale and impact. Increasingly, there are programs which aim to foster responsible fisher behaviour which enhances environmental outcomes.

While Victoria's commercial fisheries management systems are generally effective, there are still some threats evident such as: overfishing, illegal and unreported fishing, introduction of pests, bycatch and entanglements. State and Commonwealth commercial fisheries provided $101 million of gross production value to the Victorian economy and added value of $223 million.[1449] More than two thousand jobs (FTE) were provided in the industry, which translated into $129 million in household income. Aquaculture is an increasingly important source of seafood in Victoria, both for the domestic and export market. The main species farmed in Victorian coastal waters are Abalone and Blue Mussels. Regulations are in place to prevent the spread of invasive marine species in the aquaculture industry. However, disease outbreaks remain a threat to the industry – in 2021 an outbreak of abalone viral ganglioneuritis led to a local marine area closure near Portland. Coastal aquaculture contributed an estimated $35 million of added value and 427 full-time equivalent jobs to the Victorian economy in 2016-17.[1450]

Victoria uses both renewable and non-renewable resources from marine and coastal environments to generate electricity. Resources and energy generation are undergoing major change at present due to the decarbonisation of Victoria's energy sources. Development of wind and solar energy has been increasing in recent years and more projects are planned. There are nine operational wind farms located along the Victoria's coastline including Victoria's first wind farm built in 2001 at Codrington, east of Portland.[1451] This wind farm alone generates enough electricity each year to supply an equivalent of 10,000 Victorian homes, which avoids the emission of 49,000 tonnes of greenhouse gas emissions annually.[1452] Global initiatives towards decarbonisation are likely to place pressure on Victoria's fossil fuel use in the coming decade, requiring a more rapid transition to renewable energy sources.

Agriculture represents a major land use which provides economic benefits, and food for the wider community. Agricultural activities have the potential to be undertaken in a sustainable way where farmers can provide stewardship of the land through maintaining or improving soils, vegetation and other environmental features. However, there are some environmental risks related to agriculture which require management. Water runoff from farming land may have high nutrient loads from fertiliser or toxins from fertilisers.

Melbourne Water and CSIRO have undertaken studies to estimate fine sediment loads in runoff from the Western Port catchment. The catchment has been subject to increasing urbanisation, particularly in the urban growth areas of Casey and Cardinia Shires, although much of the catchment still comprises agricultural land use with some significant areas of remnant vegetation. Although the largest proportion of fine sediment load in catchment runoff is from grazing and cropping (21%), this reflects the fact that it comprises a high proportion of catchment land use (31%). By contrast roads, which only represent 3.4% of land use in the catchment, account for 24% of fine sediment load running into Western Port. Low density residential use also has a high impact (12% of runoff) despite being a small proportion of overall land use (2%).[1453]

Coastal infrastructure remains under threat from climate change due to sea level rise and increasing frequency of severe weather events. The condition of coastal assets and infrastructure is currently undergoing review. It is therefore difficult to fully assess their status.

1449. Abernethy K, Barclay K, McIlgorm A, Gilmour P, McClean N, Davey J 2020, 'Victoria's fisheries and aquaculture: economic and social contributions', FRDC 2017-092, University of Technology Sydney, Sydney..
1450. Ibid.
1451. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Wind energy projects as at 08/10/20' https://www.planning.vic.gov.au/permits-and-applications/specific-permit-topics/wind-energy-facilities/wind-energy-projects-planning?_ga=2.189197033.318809511.1602653626-245237306.1598233448 Accessed 14 October 2020.
1452. Pacific Hydro 2020, 'Codrington wind farm' https://www.pacifichydro.com.au/projects/operations/codrington-wind-farm/ Accessed 14 October 2020.
1453. Melbourne Water and CSIRO 2021, 'Westernport catchment planning tool' https://www.flowmatters.com.au/viz/#/mw-cpt?_page=0 Accessed 20 July 2021.

Theme 8: Communities

Indicator 56: Population (resident)

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide	N	N			N/A	N/A

Data source:	ABS, DELWP
Measures:	Resident coastal population growth rate by town suburb Statistical Areas Level 2 Projected coastal population growth rate by Statistical Areas Level 2

Why this indicator?

Population change is an important indicator against which community wellbeing and environmental health can be understood. Human populations may represent a threat or an opportunity for environmental management.

Justification for assessment ratings:

- Resident population growth remains high in specific locations along the Victorian coast.
- Land use planning policies have channelled most of this growth into designated locations.
- There are detailed and rigorous data available on population growth and government is able to make projections of future growth.
- While a vast amount of data are collected about resident populations, the nature and scale of their environmental impacts will depend on many other factors such as peoples' values and behaviour, the use of infrastructure and technology to minimise impact, and the planning regimes which influence where people can settle. For this reason, a formal assessment of this Indicator has not been undertaken. Instead, a narrative approach outlines the patterns of population change along the Victorian coast and the implications of this for environmental management.

Victoria's diverse coastal settlements include metropolitan suburbs, urban centres, coastal towns with large tourism sectors, rural towns and smaller coastal hamlets.[1454]

The scale and growth rate of coastal populations and settlements is of ongoing interest to coastal and environmental planners. Humans like living by, and visiting, the coast. In Australia, the beach has iconic cultural status and access to coastal foreshores and beaches is greatly sought after.

In the Marine and Coastal Policy, the intended outcomes for Coastal settlements are stated as:

- Coastal settlements are desirable places to live, work, visit and play.
- Non-urban breaks between coastal settlements are maintained to preserve the character of the coastline and coastal settlements.
- Growth of coastal settlements is ecologically, socially and economically sustainable.[1455]

Coastal settlements provide the opportunity for people to live in coastal locations. For residents, this brings associated mental health benefits of having access to natural marine and coastal environments.[1456] However, human settlements also bring pressures to the natural environment. The building of urban landscapes affects natural habitats and natural processes. Further discussion of this is provided for Indicator 59: Coastal settlements.

1454. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Marine and coastal policy', East Melbourne, Victoria.
1455. Ibid.
1456. Bell S, Phoenix C, Lovell R, and Wheeler B 2015, 'Seeking everyday wellbeing: the coast as a therapeutic landscape', *Social Science and Medicine*, 142(C), pp. 56-67.

Measuring the population of resident populations is relatively straightforward as data are collected by the ABS on a 5-yearly basis via the census to a small geographical scale, with annual estimates given for the intervening years. Population growth rates along the Victorian coast are quite variable and depend upon factors such as proximity to Melbourne and available land for development. Much of the Victorian coastline is in public ownership and coastal population growth is generally lower than that found in New South Wales, Queensland or Western Australia.

It is often assumed that population in coastal areas is increasing faster than non-coastal areas. In Victoria this is not the case. Recent rates of coastal population growth (1.6%) have been lower than for non-coastal areas (2.2%) and in 2019, the coastal population of Victoria formed a slightly smaller proportion of the Victorian population than it had a decade earlier.[1457] Figure 102 shows the average rate of population growth for Victorian coastal Statistical Areas level 2 (SA2s) of population growth. SA2s are a geographical unit defined by the Australian Bureau of Statistics (ABS) which is smaller than a Local Government Area. Those areas with growth rates above the Victorian average are shown in Table 40. Population growth in coastal suburbs of Melbourne has been rapid, with increasing density of development, while coastal locations near Melbourne and Geelong, particularly on the Bellarine Peninsula and around Torquay have also experienced rapid population growth. The very high growth rate of Point Cook is typical of new suburbs in their development when population rises from relatively low levels in a short space of time.

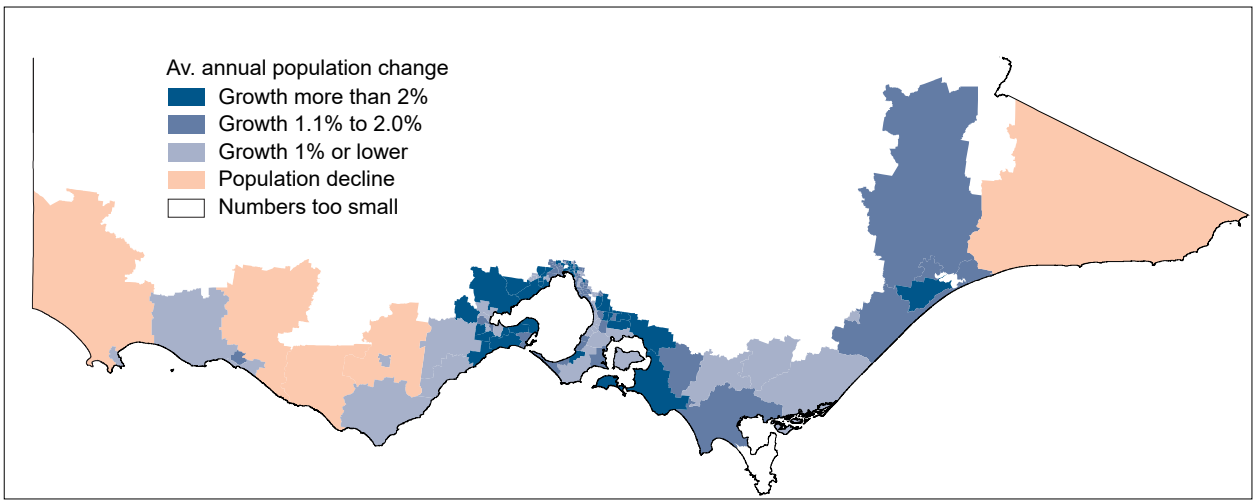


Figure 102: Average annual population change, Victorian coastal Statistical Areas Level 2 (SA2), 2010-2020.[1458]

1457. Data based on coastal Statistical Areas Level 2 (SA2) average annual population growth between 2009 and 2019, Australian Bureau of Statistics (ABS), 'Regional population growth', cat. 3218.0.
1458. McKenzie F 2020, 'Coastal demographics in Victoria: background research paper prepared for the Victorian Marine and Coastal Council', Department of Environment, Land, Water and Planning (DELWP), East Melbourne Victoria, p. 10.

Table 40: Victorian coastal areas with growth rates above the State average during the period 2009-19.[1459]

Statistical Local Area Level 2 (SA2)	Estimated Resident Population 2009	Estimated Resident Population 2019	Population Change 2009-19	Average annual population change 2009-19
Point Cook - East	5,721	17,886	12,165	12.1
Ocean Grove - Barwon Heads	17,946	28,053	10,107	4.6
Torquay	14,011	21,766	7,755	4.5
Leopold	9,485	13,836	4,351	3.8
Koo Wee Rup	6,223	8,566	2,343	3.2
Dromana	9,231	12,566	3,335	3.1
Lara	15,283	20,579	5,296	3.0
Werribee - South	10,604	14,162	3,558	2.9
Clifton Springs	11,558	15,399	3,841	2.9
Portarlington	6,186	8,158	1,972	2.8
St Kilda	23,451	30,447	6,996	2.6
Phillip Island	9,193	11,750	2,557	2.5
Wonthaggi - Inverloch	19,168	24,334	5,166	2.4
Paynesville	5,462	6,838	1,376	2.3
Albert Park	14,245	17,806	3,561	2.3

Future population growth can be estimated using population projections. The Victorian Government produces these on an annual or biennial basis. Such projections consider structural demographic factors such as age structure and the propensity of different age groups to move. They are not predictions but rather an assessment of future outcomes should current trends persist. Figure 103 shows projections undertaken in 2019, prior to the COVID-19 pandemic.

1459. Australian Bureau of Statistics (ABS) 'Regional population growth', cat. 3218.0.

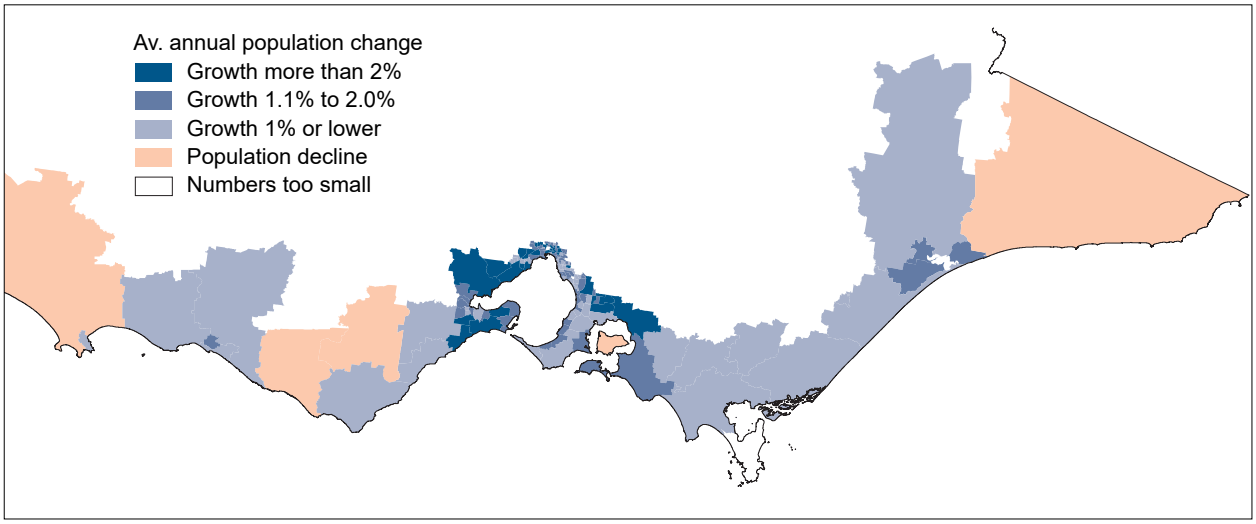


Figure 103: Projected population change, Victorian coastal Statistical Areas Level 2 (SA2), 2016 to 2036.[1460]

As Victorians are living through the COVID-19 pandemic, there are anecdotal reports of population changes occurring, for example, people moving to the coast in response to a desire to leave Melbourne. However, one needs to be cautious before reaching conclusions because we are not yet certain that these are long term trends. For example, people may relocate to a second home on a temporary, rather than permanent, basis. The relative scale of movements also needs to be considered as the scale of movement away from a large city like Melbourne may be smaller than the amount of growth which is generated by other demographic factors like natural increase. We do know that the COVID-19 pandemic has had a strong impact on movement from overseas to Victoria. Overseas arrivals would have predominantly favoured Melbourne and its growth has been dampened during 2020 and is likely to take several years to return to pre-COVID levels.

Internal migration is more difficult to measure. The 5-yearly census provides the best data on the movement of people. Intercensal estimates rely on analysis of other data sources such as Medicare records (for change of address) and overseas arrivals and departures data (for net overseas migration)

Migration patterns are strongly related to age. For example, there is a net gain to Melbourne of young adults from regional Victoria because of the wide range of educational and employment opportunities available. Regional areas have a net gain of older age groups because of their attraction for retirees and sea/tree changers. The degree to which COVID may have hastened this latter trend or inhibited the trend of young adults moving to Melbourne is not yet fully clear.

The transformation of various settlements on the Bellarine Peninsula and Surf Coast from small coastal hamlets to large urban settlements is notable. One reason for this is their proximity to Geelong and Melbourne. This location is attractive, not only to retirees or those seeking a 'seachange', but also commuters who can enjoy a coastal lifestyle while maintaining access to large employment markets and urban services. Figure 104 shows the difference in growth rates between Torquay-Jan Juc and Lakes Entrance. While both had similar population levels in 1981 (around 3,000), they have since diverged greatly. Improvement of commuting times through improved infrastructure (such as the Geelong bypass or Bass Highway duplication) enables a broader area to be included within a practical commuting range of the metropolitan area.

1460. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria in future 2019: population projections 2016 to 2056', East Melbourne, Victoria.

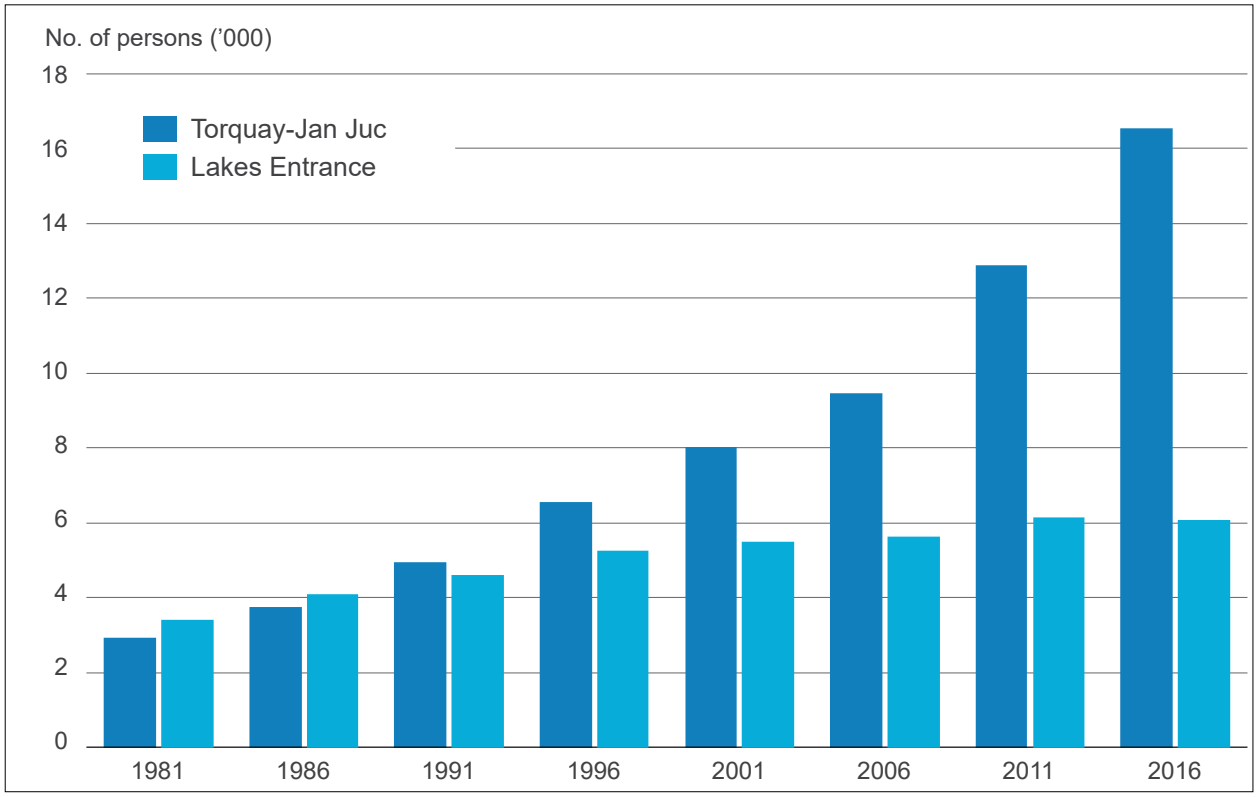


Figure 104: Population, Torquay-Jan Juc and Lakes Entrance, 1981 to 2016.[1461]

The Community Attitudes and Behaviour Study[1462] found that 13% of those living further than five km from the coast (n=1,052) were considering moving to the Victorian coast within the next 5 years. Melburnians were more likely to be considering a move to the coast than regional Victorians (14% vs 9%). Locations along the West Coast of Victoria, such as Torquay, Ocean Grove and Anglesea, received the most mentions when those who are considering a move were asked where they would be likely to move. The Port Phillip Bay and Mornington Peninsula also received numerous mentions. While these proportions might suggest very high numbers moving to the coast in the future, it is important to note that consideration of moving may not result in an actual move. Barriers to such migration can include the desire to remain near existing friends and family and the availability and affordability of coastal properties.

1461. Department of Environment, Land, Water and Planning (DELWP) 2018, 'Towns in time', based on ABS census data, East Melbourne, Victoria.
1462. Ipsos 2018, 'Wave 5 marine and coastal community attitudes and behaviour report', prepared for the Victorian Marine and Coastal Council (VMaCC), Parks Victoria and Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria, p. 32.

Indicator 57: Population (visitors)

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide	N	N			N/A	N/A

Data source:	DELWP Planning, Business Victoria, Phillip Island Nature Parks
Measures:	Estimates of peak population | Tourist visitor numbers Visitor numbers and coastal visitor management strategies – Phillip Island

Why this indicator?

Visitor populations can be as significant as resident populations in placing pressure upon marine and coastal environments. This indicator explores the nature of visitor populations and assesses potential management and education needs to produce positive and sustainable environmental outcomes.

Justification for assessment ratings:

- Issues such as over-crowding and congestion are often related to visitor rather than resident populations
- In many areas, data on visitor populations is poorer than for resident populations.
- Land use planning is less effective for visitor populations which create issues of people management rather than settlement planning
- The impact of population on the environment is not linear – it is dependent on behaviour, technology and the regulatory environment.
- The coronavirus pandemic has severely disrupted international travel which will have short to medium term impacts on international visitor numbers to major coastal attractions such as Phillip Island and the Great Ocean Road. However, the majority of visitors to these destinations are domestic.
- Domestic travel restrictions have also affected regional visitation rates in the short term.
- Data on visitor populations is not as robust as that collected for resident populations. The mobility of visitors makes such measurement inherently difficult. Even where data are available, the nature and scale of environmental impacts will depend on many other factors such as peoples' values and behaviour and the management regimes and infrastructure which are in place to minimise impact. For this reason, an assessment of this Indicator has not been undertaken. Instead, a narrative approach outlines the nature and scale of visitor populations along the Victorian coast and the implications of this for environmental management.

Most measures of population are based on numbers of people who are resident in a location. Mobile populations are very difficult to measure, precisely because of that mobility. While a variety of estimation techniques are available, there is no single measure which will cover all aspects of a dynamic population flow. Some existing methods include peak population estimates, counts of non-resident ratepayers and the use of proxy indicators to determine population fluctuations.

The national census of population and housing provides a 5-yearly snapshot of people's location on a particular night. However, some areas experience a large difference between the size of their resident population and the size of the population at specific times of the day, week or year. Part-time populations may comprise different groups of people, for example, those who own holiday homes, those who visit and stay in commercial accommodation and those who are day visitors (Table 41). In coastal areas of Victoria, high visitation levels contribute to peak population levels occurring in summer and, to a lesser extent, during the Easter break in March-April.

Table 41: Types of part-time and mobile populations.[1463]

Type	Characteristics	Potential Impacts
Weekend populations	Weekend holiday makers utilising second homes or commercial accommodation	Weekend tourism creates demand for accommodation and retail services thereby creating local employment and wealth generation
Holidaymakers	Holiday populations may be many times higher than the resident population	Often creates congestion and can stretch capacity of local shops, services and infrastructure but also adds to the economy
Day trippers	Day trippers to coasts and other attractions	Can create road congestion and high demand on services
Event attendees	One-off events that attract thousands (for example, surfing carnivals, folk festivals, car/bike racing).	Local accommodation and infrastructure capacity may be stretched but events can have major local economic benefits
Seasonal workers	May number in thousands (fruit pickers, contractors, seasonal tourist workers)	Demand for tourist or temporary accommodation, hotels, caravan parks. Also demand for schools, retail, health and other services
Working populations	Monday to Friday working population may be several times the resident population	Creates demand for further employment in retailing and other services, but can create congestion

A key characteristic of most coastal settlements is the relatively high proportion of houses which are vacant for periods of time during the year. These are usually holiday homes, with non-residents visiting for various lengths of time. Because the ABS Census is conducted during winter on a weeknight, visitor numbers are likely to be low, therefore the data on unoccupied dwellings can be used as a general proxy for holiday homes on the coast. A total of 36,800 unoccupied dwellings were counted in Victorian coastal towns and cities (excluding Melbourne and Geelong) by the 2016 census. This represents an average winter vacancy rate of around 37%.

Peak population estimates estimate overnight capacity based on census counts of unoccupied houses and consideration of commercial accommodation (Table 42). This accommodation is effectively 'filled up' for the purpose of estimating a peak overnight capacity. It does not account for day visitors.

1463. McKenzie F 2020, 'Coastal demographics in Victoria: background research paper prepared for the Victorian Marine and Coastal Council', Department of Environment, Land, Water and Planning (DELWP), East Melbourne Victoria, p. 16.

Table 42: Peak population estimates for selected Gippsland Lakes coastal towns (overnight capacity in residential buildings and tourist accommodation), 2016.[1464]

Town Name	Population 2016	Peak Population*	Multiplier
Bairnsdale	12,950	15,514	1.2
Eagle Point	843	1,647	2.0
Lakes Entrance	6,071	13,565	2.2
Loch Sport	809	5,120	6.3
Metung	1,210	2,564	2.1
Newlands Arm	627	817	1.3
Paynesville	3,378	4,758	1.4
Raymond Island	552	1,134	2.1

*NOTE: Peak population estimates take into account potential population should unoccupied dwellings and tourist accommodation be utilised. A count of unoccupied dwellings is provided by the ABS Census and this number has been multiplied by the average household size for regional Victoria in 2016 (2.4 persons). Tourist accommodation data has been obtained from AAA Tourism and the number of persons in tourist accommodation determined on the basis of either 2 persons per bedroom, or a person capacity where this was stated.

The Community Attitudes and Behaviour Study[1465] found that 18% of survey respondents reported having access to a Victorian beach house owned by themselves, family or friends. A significantly greater proportion of Melburnians had access to a beach house than those in regional Victoria (21% compared to 12%). Regional Victorians living in the east of the state were significantly more likely to have access to a coastal holiday house than those living in the west of the state (18% compared to 8%).

While the count of unoccupied dwellings gives some idea of the level of second homes in these locations, it does not provide information about day visitors or those who stay in commercial accommodation. Furthermore, the rise of share platforms such as Airbnb have blurred the line between private and commercial accommodation. Once restricted to Australia's major cities, peer-to-peer accommodation has since boomed in regional coastal Victoria. The impacts of this relatively recent phenomenon is unclear, however recent research has shown that it can facilitate 'invasive tourism', whereby local communities are transformed and gentrified, with low income residents sometimes displaced.[1466]

Home-sharing platforms can challenge conventional planning frameworks which often aim to segregate tourism and residential development. Victoria has developed new provisions to manage short-term rental units[1467] but stopped short of further controls applying to single residential homes.

While no single source of information provides definitive data on all types of visitors, tourism data shows a pattern of increasing numbers of tourists (day visitors and overnight stayers) for Victorian coastal regions up until the year ending 31 March 2020. The impact of COVID restrictions had a major impact in the following year, with international visitors not arriving. The total number of visitors for these regions fell from 29.2 million in the year to March 2020 to only 16.9 million in the following year - a drop of 42% (Figure 105).

1464. Australian Bureau of Statistics (ABS) 'Census of population and housing 2016', AAA Tourist accommodation data 2012.
1465. Ipsos 2018, 'Wave 5 marine and coastal community attitudes and behaviour report', prepared for the Victorian Marine and Coastal Council (VMaCC), Parks Victoria and Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria.
1466. Gurrna N, Zhang Y and Shrestha P 2020, ''Pop-up' tourism or 'invasion'? Airbnb in coastal Australia', *Annals of Tourism Research*, 81, 102845.
1467. Victorian Parliament 2018, 'Owners Corporations Amendment (Short-stay Accommodation) Act 2018'.

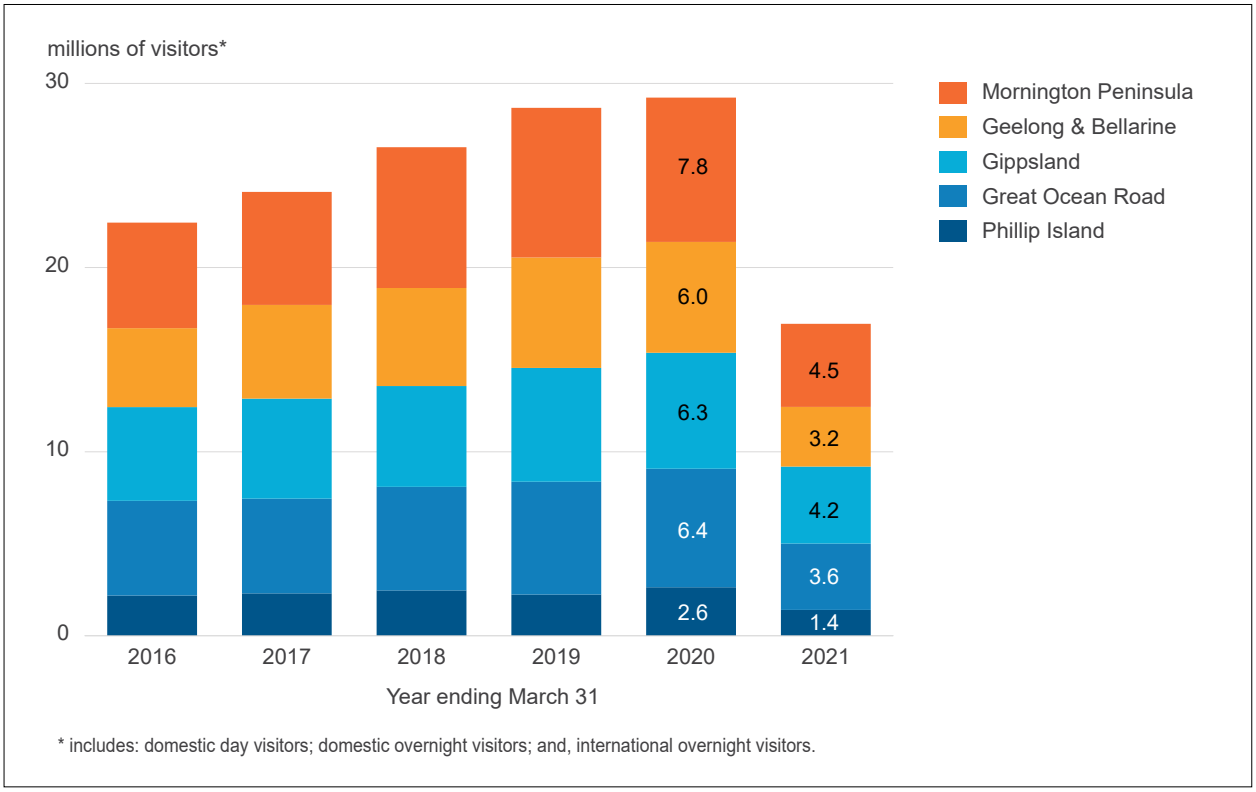


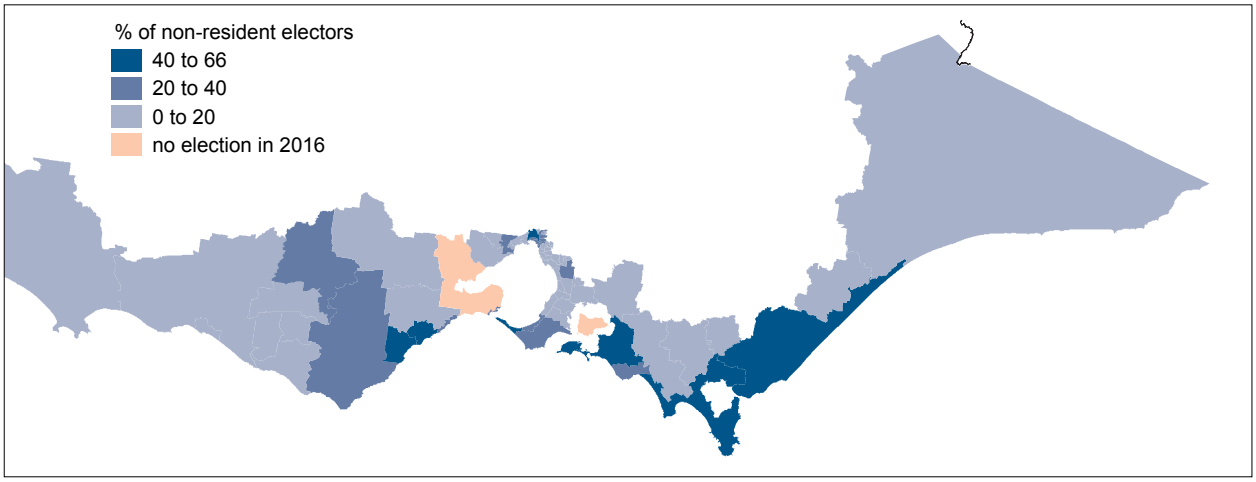
Figure 105: Visitor numbers to selected Victorian coastal tourism regions for years ending 31 March 2016 to 2021.[1468]

One factor influencing growth in the number of visitors is government policy. The improvement of road infrastructure can enable a larger catchment of people to gain access to the coast. The development of the Geelong bypass in 2009 reduced travel times for Melbournians wishing to travel to the coast. Similarly, improvements in the Bass Highway have improved access to the coast east of Melbourne. Almost all of Melbourne's 5 million population are now less than 1.5 hours travel time from Victoria's ocean coastline - not only because of regional road improvements but also metropolitan initiatives over recent decades such as the western ring road, EastLink and CityLink. Thus, many more people are now able to make daytrips to the coast. Through the Victorian Fisheries Authority, the Victorian Government is supporting recreational fishers through its plan to grow participation to one million anglers by 2020. This is likely to increase visitation to some locations where fishing is popular.

The Victorian Visitor Economy Strategy 2016[1469] sets the overall framework and direction to grow Victoria's 'visitor economy' from 2016 to 2026. There is no explicit consideration of visitor impacts in the document. Stage One of the Shipwreck Coast Master Plan has seen the Victorian Government invest $9.8 million to improve bridges, lookouts and information technology along this highly visited stretch of the Great Ocean Road. Over time, the newly formed Great Ocean Road Coast and Parks Authority will assume responsibility for management of all public land along the length of the Great Ocean Road. Managing increasing visitor numbers and impacts will be a key responsibility of the Authority.

The importance of properties that are use part time for holiday homes or simply as 'bushblocks' are also apparent from local government ratepayer data. In some municipalities, non-resident ratepayers can comprise 50% of the ratepayer base (Figure 106).

1468. Business Victoria 2021, 'Regional visitation. regional market summaries' https://business.vic.gov.au/business-information/tourism-industry-resources/tourism-industry-research/regional-visitation Accessed 9 August 2021.
1469. Department of Economic Development, Jobs, Transport and Resources (DEDJTR) 2016, 'Victorian visitor economy strategy', Melbourne, Victoria.



What this map shows: In local government elections, residents on the electoral roll are required to vote. Some other categories of people may vote, including up to two non-resident owners of any rateable residential property within the municipality. Following elections, the Victorian Electoral Commission (VEC) compiles a report on the conduct of the elections which includes a list of voter numbers, with non-resident voter numbers identified. This data source has been used to determine the proportion of electors whose primary residence is outside the local municipality.

Figure 106: Proportion of non-resident ratepayer electors in coastal Council Wards 2016.[1470]

Some work has also been done using proxy indicators, such as water usage, to estimate visitor numbers (Figure 107). The purpose of such indicators is to highlight the pattern of population fluctuation over time. The example of Phillip Island shows a very distinct pattern of peak water use in summertime when many holiday makers are at their beach house, staying in commercial accommodation or simply visiting for the day. Indicators like water use do not give us a direct number of people in an area, although some assumptions can be used to generate population estimates.

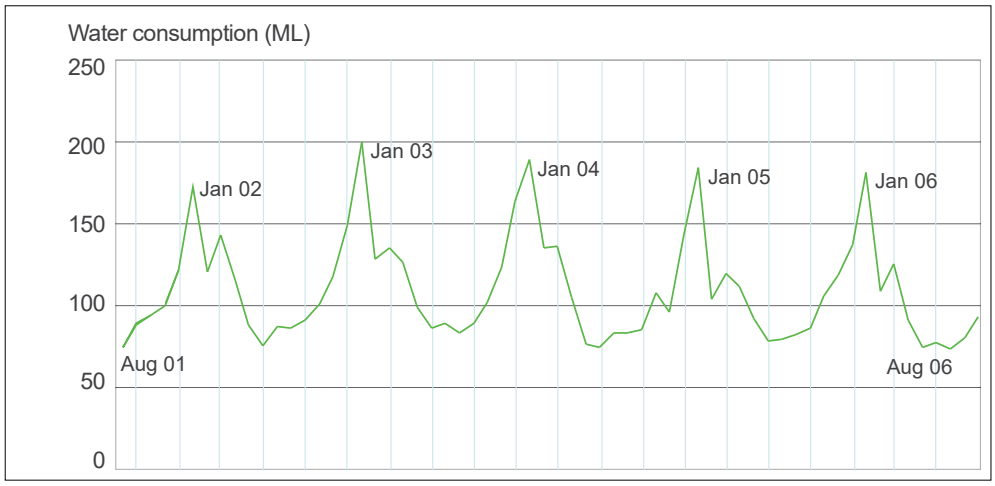


Figure 107: Monthly water consumption Phillip Island, 2001 to 2006.[1471]

1470. Victorian Electoral Commission (VEC) 2017, '2016 Local government elections report'.
1471. SGS Economics and Planning 2007, 'Impacts of coastal population fluctuations', report prepared for Department of Sustainability and Environment (DSE), Melbourne, Victoria.

There are emerging sources of data, although all tend to have specific limitations. Traffic counts and anonymised mobile phone location data are potential sources of visitor estimates, while estimates for attendance at major events may be provided by event organisers. The key message from all such estimates is that some locations, including popular coastal regions, can experience very large fluctuations in their population levels. By way of example, the town of Lorne had a resident population of 1,027 at the time of the 2016 census. Taking unoccupied houses and commercial accommodation into account, the overnight capacity of the town is likely to be around 10,000. Yet on the day of the Pier to Pub swim event in January each year, estimated crowds are around 21,000.[1472] This represents a 20-fold increase from the resident population. Port Fairy and Phillip Island experience similarly high population peaks for their respective folk festival and Moto Grand Prix events.

Managing the impacts of human populations

Increased numbers or concentrations of people (either resident or visitor) may result in environmental impacts such as:

- damage of habitats
- soil compaction and erosion
- wildlife roadkill
- plant damage from trampling
- introduction of weeds
- habitat fragmentation from development of housing and infrastructure
- removal of vegetation during the construction of infrastructure
- increased fire-ignition risk (accidental or deliberate)
- impacts on aquatic systems through changes to oxygen content, turbidity, run-off, pollution and water harvesting
- changes in nutrients from activities in the water (for example, swimming, boating) and in areas around rivers and estuaries (for example, camping, walking).[1473]

These impacts are likely to be heightened during peak periods. Coastal areas generally experience peak populations during summertime although there may be other peaks on public holidays or for specific events as mentioned previously. Peak populations may increase environmental impacts due to the volume of people using the coast and adjacent marine areas for swimming, boating, camping and walking.

A challenge in monitoring the impacts of humans is that there is rarely a simple linear relationship between the number of people and their environmental impact. A small number of people have the potential for large impacts but, depending on their behaviour, their use of technology and the regulatory environment, such impacts can be mitigated. For example: informed behaviours by residents can limit impacts of littering or damage to the natural habitat; introduction of engineering solutions and technology can enable issues of waste disposal to be addressed or enable sustainable resource use; and the regulatory environment can ensure protection of sensitive areas and a compliance regime.

This variable impact of humans on the natural environment challenges a concept such as carrying capacity. At one level, it is logical to think of population growth reaching a point where the environment suffers. But settlements along the Victorian coast show that large numbers and high densities can exist in coastal areas – for example coastal suburbs of metropolitan Melbourne. While this is a highly modified environment (and thus difficult to directly compare to more pristine or vulnerable environments) the findings of the State of the Bays 2016 Report[1474] suggest that certain environmental impacts are relatively low despite this large and dense population. The explanation for this involves the three factors listed above – behaviour, technology and regulatory regime.

1472. McKenzie F 2020, 'Coastal demographics in Victoria: background research paper prepared for the Victorian Marine and Coastal Council', Department of Environment, Land, Water and Planning (DELWP), East Melbourne Victoria, p. 16.
1473. Spenceley A, Kohl J, McArthur S, Myles P, Notarianni M, Paleczny D, Pickering C and Worboys GL 2015, 'Visitor management', in GL Worboys, M Lockwood, A Kothari, S Feary and I Pulsford (eds), 'Protected area governance and management', pp. 715–750, ANU Press, Canberra, p. 739.
1474. Commissioner for Environmental Sustainability (CES) 2016, 'State of the Bays 2016', Melbourne, Victoria.

While land-use planning has been used to direct and influence settlement planning, it is less suited to addressing issues of mobile or visiting populations. In fact, dealing with crowding and congestion is better understood as a people management task rather than a land-use planning issue. There are precedents for dealing with visitor populations in response to concerns about overcrowding and avoidance of negative impacts on environmental or cultural assets.

Controlling access, limiting numbers and applying fees are potential tools, however the more difficult question is how impacts can be assessed and measured in order to refine prevention measures. In this regard, the concept of 'carrying capacity' is often used with the aim of understanding the limits which an area may have in relation to visitor numbers. Tourism carrying capacity has been defined as 'the level of human activity an area can accommodate without the area deteriorating, the resident community being adversely affected or the quality of visitor experience declining'.[1475] While this definition reflects a widely held aspiration, it is a concept which is difficult to define in practice, largely because coasts are highly dynamic. Visitors can have very different impacts depending on their concentration or individual behaviours. Areas can also have variable 'limits' depending on a range of environmental factors (weather, seasons, extreme events). In other words, people have unequal impacts on environments depending on their behaviour, age, and density. Environments themselves are dynamic and may be more, or less, vulnerable at different times. For these reasons the determination of a single 'population capacity' is impossible. Rather, a variety of policy responses (education, access restrictions to certain places at certain times) may be required.

Due to these conceptual limitations, alternative approaches have been developed. There are examples from around the world where features – environmental or cultural – have required protection from being 'loved to death'. There are examples of visitor population management approaches in response to overcrowding including controlling access, limiting numbers and applying fees. The more difficult question is how impacts can be assessed and measured in order to refine prevention measures. A number of frameworks have been developed for impact management such as Limits of Acceptable Change (LAC) and visitor impact management.[1476] Rather than focussing on numbers, such approaches rely on identification of concerns and issues; development of resource management objectives; management options; implementation actions and monitoring of conditions. The process of identifying issues and monitoring responses provides an important dynamic process of evaluation and adjustment rather than simply aiming for a specific number of visitors to a sensitive location. Many of these approaches are used in sustainable tourism and ecotourism practices.

For example, Marion (2016) proposes a visitor use management framework which provides an adaptive process for managing characteristics of visitor use,[1477] The visitor use management framework involves a visitor impact management toolbox which contains five management strategies, many of which have been used in the United States where national parks are often subject to very high visitor pressures. The strategies include:

- managing levels of use, especially in areas where environments have low levels of resilience (for example, areas subject to erosion, soil compaction or fragile plant species)
- modifying the location of use towards more resilient locations within a park or reserve
- increasing resource resistance by designing tracks or camping sites in suitable locations or areas with suitable features (for example, avoiding having walking paths on steep slopes or camping sites in areas flora susceptible to trampling)
- modifying visitor behaviour through appropriate signage and educational opportunities (for example, the US 'Leave no Trace' program)
- close and rehabilitate the resource in areas which have sustained damage.[1478]

1475. Chamberlain K 1997, 'Carrying capacity', UNEP Industry and environment no. 8, UNEP, Paris.
1476. Spenceley A, Kohl J, McArthur S, Myles P, Notarianni M, Paleczny D, Pickering C and Worboys GL 2015, 'Visitor management', in GL Worboys, M Lockwood, A Kothari, S Feary and I Pulsford (eds), 'Protected area governance and management', pp. 715–750, ANU Press, Canberra, pp. 743-44.
1477. Marion J 2016, 'A review and synthesis of recreation ecology research supporting carrying capacity and visitor use management decision-making', *Journal of Forestry*, 114(3), pp. 339-351.
1478. Ibid., p. 342.

Northcote (2020) has proposed a Sustainable Visitation Index (SVI) to support managers.[1479] The SVI framework does not define visitor limits, but instead takes the view presented in the LAC approach:

The shift in focus to visitor impacts over visitation levels means that visitor numbers per se are not the sole concern given that visitor behaviour, frequency of use, landscape characteristics, period of use and management approaches are also relevant factors.[1480]

Phillip Island provides an example of how conservation objectives and visitor management can be achieved in parallel. Figure 108 shows the increase in visitor numbers to the Phillip Island Nature Parks over the past decade.

These parks and reserves encompass more than 1,805 hectares of Crown land which is used for the conservation of areas of scientific, historic, archaeological or natural interest. Natural attractions include the world-famous penguin parade, koala conservation reserve, boat tours to the Seal Rocks colony and Churchill Island which contains a heritage-listed farm. Although visitor numbers have continued to rise, conservation programs focused on research, rehabilitation, removal of pest animals and protection of wildlife have been highly successful. Evidence of this can be seen in the recovery and increase of little penguin numbers on the island (Figure 109). Revenue raised from visitors has assisted in funding many of the programs on the island.

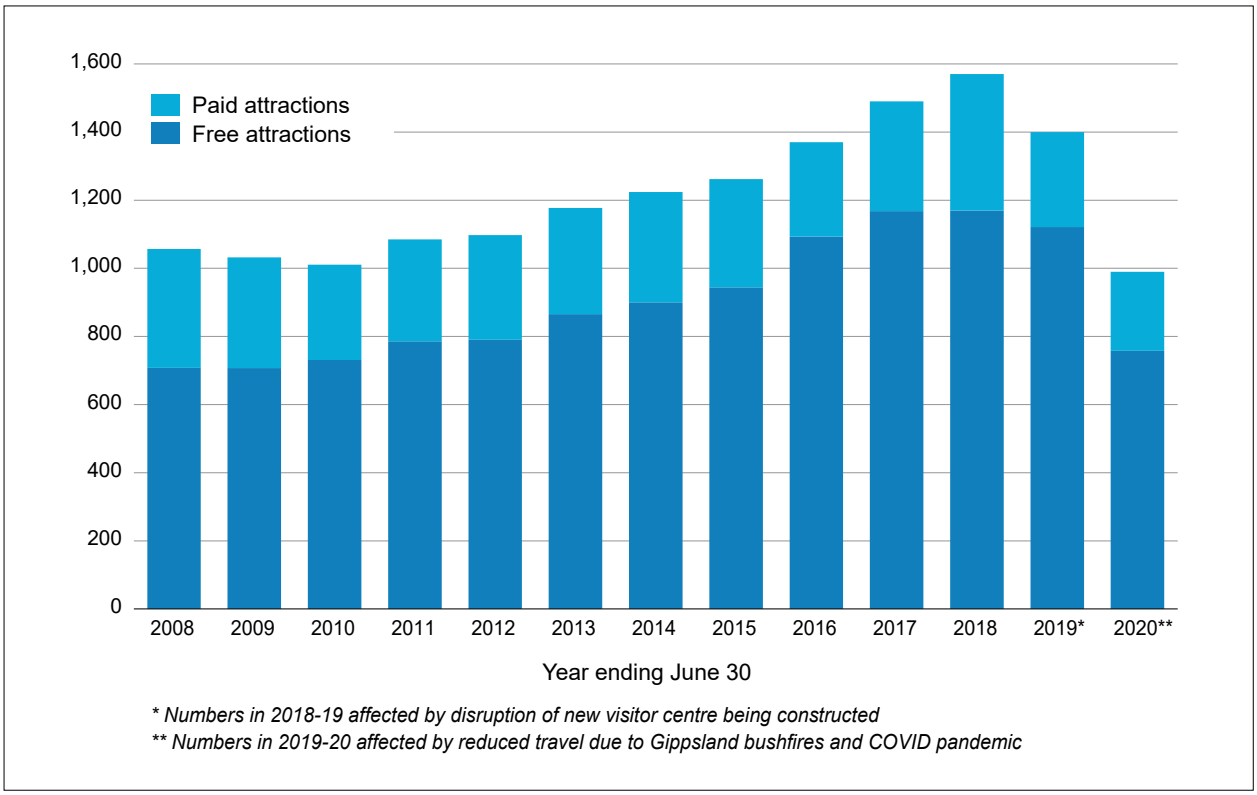


Figure 108: Number of visitors to Phillip Island Nature Parks, 2007-08 to 2019-20.[1481]

1479. Northcote J 2020, 'Sustainable visitation index: a new visitor management framework for assessing destination sustainability', *Journal of Ecotourism*, DOI: 10.1080/14724049.2020.1715417.
1480. Ibid.
1481. Phillip Island Nature Parks, 'Annual report', various years https://www.penguins.org.au/about/corporate-affairs/publications/annual-reports/ Accessed 14 May 2021.

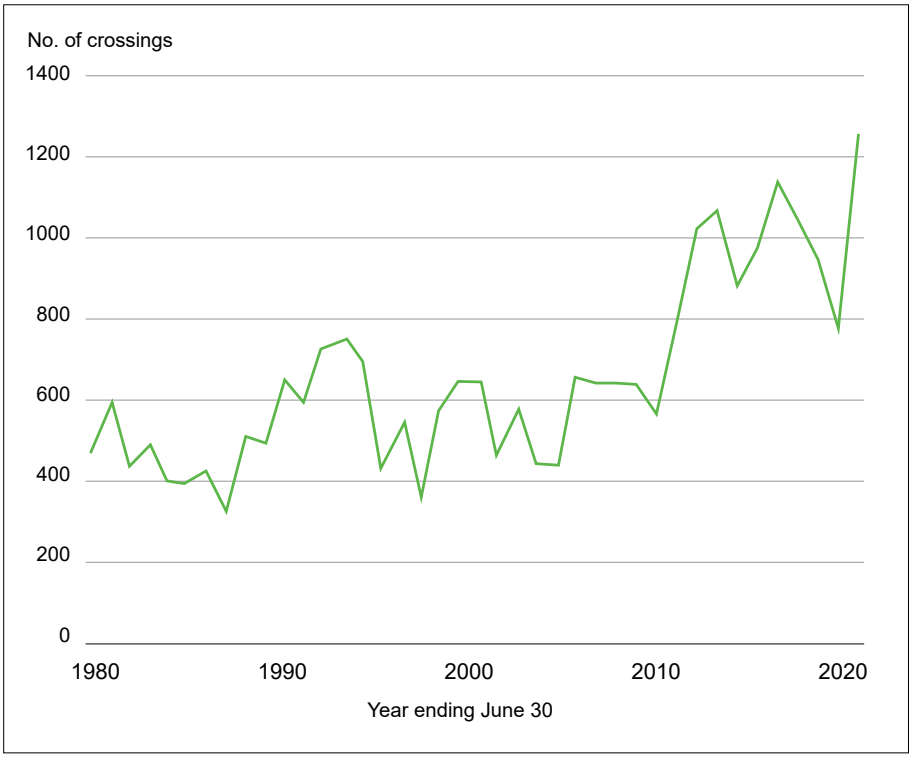


Figure 109: Average number of nightly crossings of little penguins at Phillip Island penguin parade, 1977-78 to 2019-20.[1482]

The *Great Ocean Road and Environs Protection Act 2020* (s.17) provides for a Great Ocean Road strategic framework plan to be developed. The purposes of this strategic framework plan will be:

- to provide the strategic direction for the future use of land in the Great Ocean Road region and for sustainable economic development across that region
- to identify areas for protection within the Great Ocean Road region
- to guide sustainable visitation within the Great Ocean Road region by providing for a regional policy for visitor management
- to guide planning and investment relating to visitor facilities and infrastructure in the Great Ocean Road region.

This plan is currently being developed.

1482. Ibid.

Indicator 58: Significant landscapes

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide					N/A	N/A

Data source:	DELWP Planning
Measures:	Number of permits for dwellings or other buildings in areas covered by a Special Landscape Overlay Number of planning Declarations of Distinctive Areas and Landscapes Number of approvals for statements of planning policy for Distinctive Areas and Landscapes

Why this indicator?

This indicator will measure the number of new developments in areas of landscape significance and the types of planning controls which have been developed to protect landscape values.

Justification for assessment ratings:

- Victorian Land Use Planning legislation is providing enhanced protection through declarations of distinctive areas and landscapes.
- Planning Permit data are able to provide quantitative assessments of how many planning permits are being issued for residential development in areas subject to a Special Landscape Overlay. However, they cannot show the degree to which qualitative aspects of building design are enhancing or impacting negatively on landscape quality.
- The trend assessment reflects that, on balance, planning controls are being enhanced to protect important landscapes, but we have no monitoring systems in place to determine whether the outcomes are being achieved in terms of protecting the qualities of significant landscapes.

During the mid-2000s, significant Victorian coastal landscapes were identified to ensure sustainable use and development.[1483] Landscape assessment was based on assessing landform features, views, and areas which were predominantly natural or undeveloped. Local, regional, state and national levels of significance were assigned to coastal areas (excluding Melbourne). Following this assessment, those designated as having regional or state significance were protected through a Significant Landscape Overlay (SLO) which forms part of the Victorian Planning Provisions under the Victorian *Planning and Environment Act 1987* (Figure 110).

1483. Department of Sustainability and Environment (DSE) 2006, 'Coastal spaces landscape assessment study', Melbourne, Victoria.

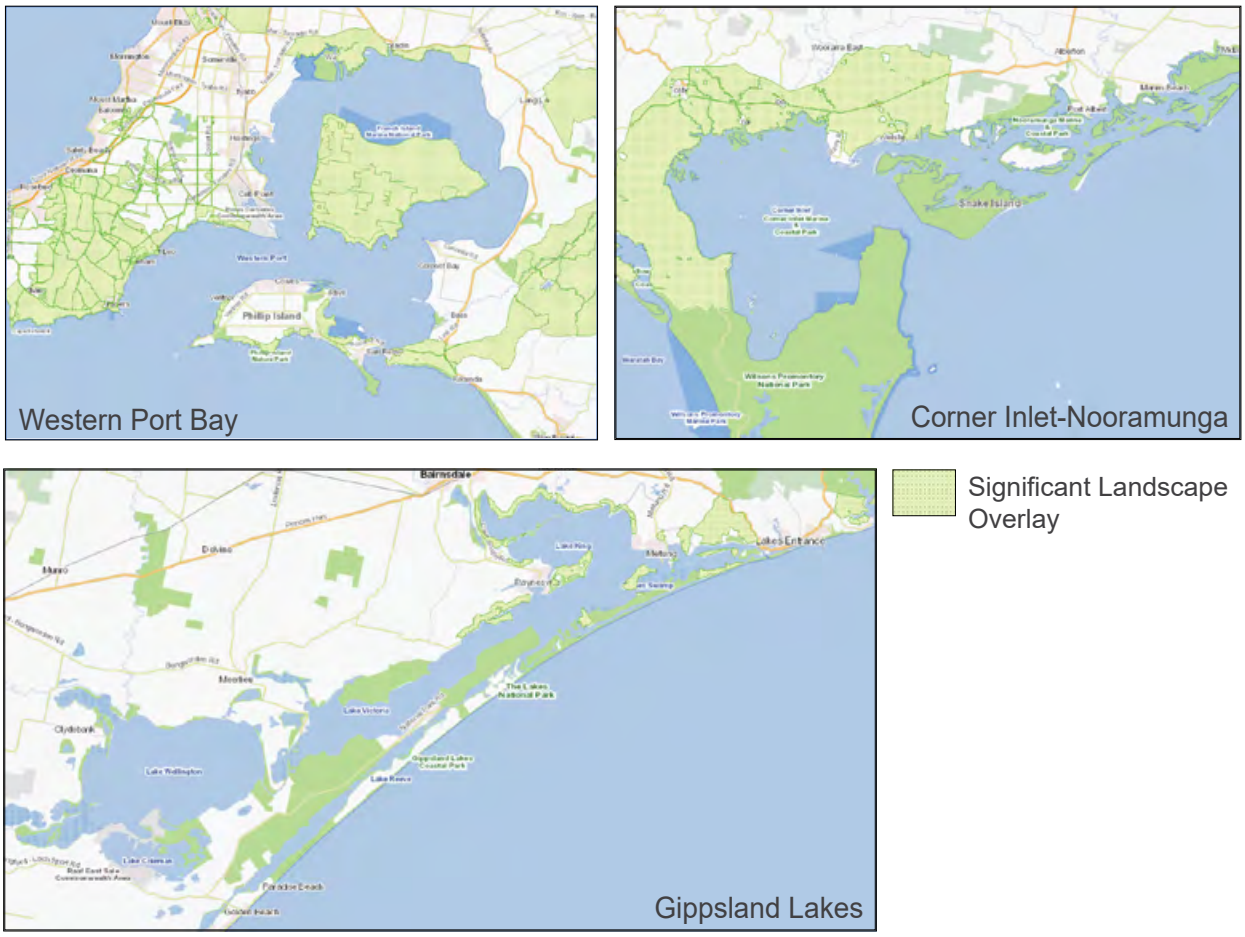


Figure 110: Victorian Planning Provisions Significant Landscape Overlay (SLO), selected coastal regions.[1484]

Table 43 shows the number of dwellings for which planning permits have been approved over the period 2016 to 2020. While these data provide an indication of the amount of building activity being undertaken in these areas, there are some limitations to a purely quantitative measure. For example, if buildings are well designed, they may have minimal impact on the landscape while others may be more visually intrusive. In other words, you could have five well designed buildings nestled into the landscape with appropriate building materials, green roofs, setbacks and vegetation that do not detract from the surroundings or one poorly designed building that does.

1484. Department of Environment, Land, Water and Planning (DELWP) 2021, 'CoastKit' https://www.marineandcoasts.vic.gov.au/coastal-programs/coastkit Accessed 26 August 2021.

Table 43: Number of permits for dwellings or other buildings in Victorian coastal areas, within 5km of coastline, covered by the Significant Landscape Overlay (SLO), 2016 to 2020.[1485]

Year	No. of permits issued	No. of dwellings
2016	1,466	3,524
2017	1,442	2,935
2018	1,452	3,588
2019	1,308	2,872
2020	971	2,618

The Significant Landscape Overlay applies to private land only. Crown Land is less likely to be subject to development, however consent may be obtained for particular activities or structures. All use, development or works on marine and coastal Crown land (including that undertaken by committees of management and local government) requires consent under the *Marine and Coastal Act 2018*. In 2019-20 a total of 268 consents were granted for the three DELWP regions that cover the marine and coastal environment. These include Gippsland (40 consents granted), Port Phillip (172), and Barwon South West (56).[1486]

The *Planning and Environment Amendment (Distinctive Areas and Landscapes) Act 2018* provides a further level of protection to guard against inappropriate development in sensitive areas across Victoria. The legislation enables better management of the peri-urban areas around metropolitan Melbourne and Victoria's regional cities, strengthening the process for protecting social, environmental and economic values in these key areas.[1487] A summary of areas declared as a Distinctive Area and Landscapes (DAL) since the 2018 legislation was passed are shown in Table 44. New significant landscape assessments are being undertaken for the DALs projects as well as the Great Ocean Road region.

Table 44: Status of areas declared as a Distinctive Area and Landscape as at 12 May 2021.[1488]

Distinctive Area and Landscape	Declared	Consultation on draft Statement of Planning Policy	Statement of Planning Policy Approval
Macedon Ranges	August 2018	Early 2019	December 2019
Bass Coast	October 2019	Mid 2021	Late 2021
Bellarine Peninsula	October 2019	Mid 2021	Late 2021
Surf Coast	September 2019	Late 2020/Early 2021	Late 2021

1485. Department of Environment, Land, Water and Planning (DELWP) 2021, Planning permit activity reporting system (PPARS) special data request.
1486. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Annual report', East Melbourne, Victoria, p. 27.
1487. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Planning and Environment Amendment (Distinctive Areas and Landscapes) Act 2018 fact sheet'.
1488. Information provided by places and precincts team, Planning Implementation and Heritage Branch, Planning Group, Department of Environment, Land, Water and Planning (DELWP), 12 May 2021.

Localised Planning Statements (LPS) had already been prepared for several peri-urban areas around Melbourne, including the Bellarine and Mornington Peninsulas. The Bellarine Peninsula LPS will be updated and transitioned to a Statement of Planning Policy under the *Planning and Environment Act 1987* once the area is declared as a distinctive area and landscape.

Coastal areas which have been recognised as a Distinctive Area and Landscape include:

Bass Coast

The Bass Coast region on Western Port Bay contains distinctive landscapes, productive agricultural land, and sensitive environments with significant biodiversity value. The area attracts retirees and lifestyle residents, as well as large numbers of tourists. Phillip Island is a key destination for local visitors and international tourists. A Statement of Planning Policy is currently being developed for the area.[1489]

Bellarine Peninsula

With proximity to both Geelong and Melbourne, parts of the Bellarine Peninsula are under significant urban development pressure. The region also attracts large numbers of visitor populations to enjoy its historic towns and renowned beaches. As a result of its declaration as a distinctive area and landscape, a Statement of Planning Policy will be developed to protect the region's environment, landscape and lifestyle.

Surf Coast

The Surf Coast is well known for its beaches, coastal biodiversity, and tourism opportunities. It is the gateway to the Great Ocean Road, a national heritage site. Like the Bellarine Peninsula, parts of the Surf Coast, notably Torquay-Jan Juc, have experienced significant urban development pressure. As a result of its declaration as a distinctive area and landscape, a Statement of Planning Policy will be developed and will include a review of Torquay's settlement boundary.

In addition to the policy developments above, the Great Ocean Road Action Plan provided specific policy actions for this significant part of the Victorian coast. On 1 December 2020 the Great Ocean Road Coast Committee and the Otway Coast Committee transitioned to the Great Ocean Road Coast and Parks Authority.[1490] The Authority will assume responsibility for the management of public land along the Great Ocean Road and is expected to play a lead role in managing visitor populations and government investment in the region.[1491]

Landscapes of significance must be protected to adhere to the international principles of ecologically sustainable development. It is not just about diversity, it is also about determining what areas are significant, why they are significant and how protection delivers the core mandate of promoting intergenerational equity and adhering to the precautionary principle. This is likely to require a measure of community-based landscape values derived through survey methods for each region. Sustainability involves the design and implementation of property and property rights that have a minimal impact, both long and short term, upon the environment and – in particular, upon landscapes of significance. This indicator measures the number and area of new developments in each area of landscape significance over time.

1489. Department of Environment, Land, Water and Planning (DELWP), 'Distinctive areas and landscapes' https://www.planning.vic.gov.au/policy-and-strategy/distinctive-areas-and-landscapes Accessed 20 August 2020.
1490. Great Ocean Road Coast and Parks Authority (GORCC) https://www.gorcc.com.au/gorcapa/ Accessed 10 May 2021.
1491. Department of Environment, Land, Water and Planning (DELWP) 2019 'Great Ocean Road coast and parks authority fact sheet', East Melbourne, Victoria.

Theme 8: Communities

Indicator 59: Coastal settlements

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide	N	N			N/A	N/A

Data source:	ABS, Agriculture Victoria, DELWP Planning
Measures:	Building approvals | Land-use change Vegetation removal | Development outside urban boundaries

Why this indicator?

Coastal settlements across some regions of Victoria have seen high growth since the early 2000s. This indicator will assess whether coastal towns are being planned and developed in a sustainable manner.

Justification for assessment ratings:

- Settlements generally represent an urbanisation of land use through the building of structures (houses and commercial) and associated infrastructure such as roads and pathways.
- This process represents a significant change in land use, potentially reducing natural habitat and introducing impervious surfaces. There may also be a significant change in landscape amenity as built form replaces or is incorporated into natural environments.
- The rezoning of land from rural to urban uses could be tracked using amendments data, however, the dataset is difficult to use for monitoring as it was established to streamline amendment processes rather than as an analytical tool. Further work would be needed to enable the dataset to be used to track changes in urban and rural land use.
- Although data are available which provide information on the growth of settlements in Victoria, it is not possible to make an overall assessment of status and trend for this indicator. While some people will view urbanisation as fundamentally damaging to the environment, the provision of housing is a basic element of human wellbeing and the availability of affordable housing a matter of social and environmental justice. Future assessment of this type of indicator might therefore focus on the degree to which built form is meeting environmental standards.

Due to the intensity of urban land use, it constitutes a relatively small proportion (5%) of all land in Victoria (Figure 111). Another way of measuring the amount of land used for rural purposes is through planning zones. Land use zones related to rural activities include: Farming, Rural Activity, Rural Conservation, Rural Living, Green Wedge and Green Wedge A Zones. These account for 14,323,611 hectares or 63% of the total zoned land area in Victoria.[1492] Agriculture is the predominant activity undertaken in these areas.

1492. Victorian Farmers Federation 12 July 2021.

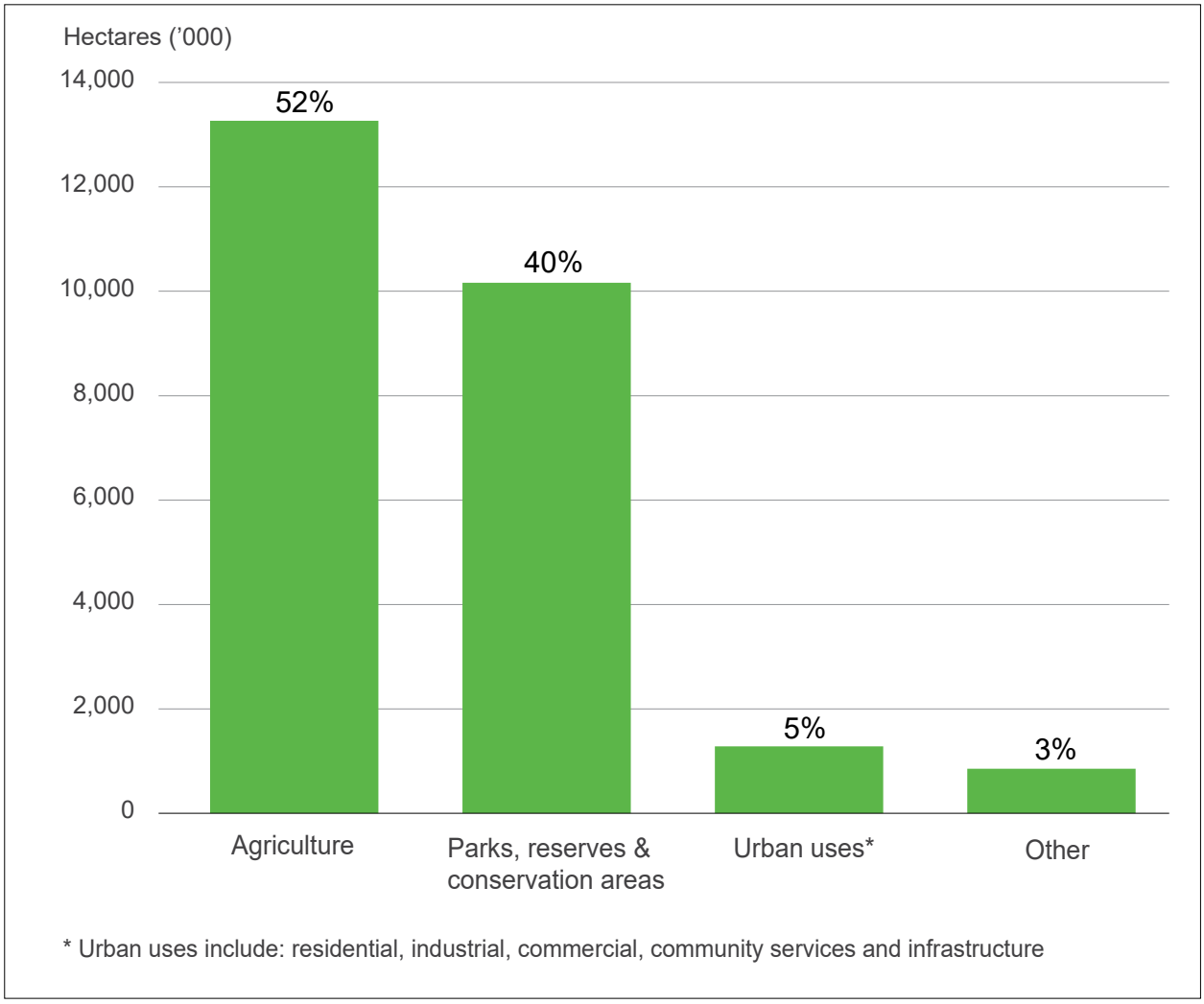


Figure 111: Land Use in Victoria, 2016-17.[1493]

In general, urban development represents a permanent land use change. For this reason, its impact on habitat and environmental processes is notable. New development can also have impacts on coastal character and amenity especially where there is a change from a vegetated coastal settlement to a more suburban form. The impact of urban growth can be particularly intense in certain locations. Areas like the Bellarine Peninsula, Surf Coast and Bass Coast have experienced strong population growth over several decades and this has led to increased building activity and urbanisation (Figure 112). These areas are also popular holiday locations which creates demand for holiday homes and commercial accommodation for visitors. Associated commercial activities related to the visitor economy further add to the development of such coastal settlements.

1493. Agriculture Victoria 2020, 'Strategic agricultural land and development in Victoria final report', prepared by Price Waterhouse Coopers (PwC) for the Department of Jobs, Precincts and Regions (DJPR), Melbourne, Victoria, p. 14.

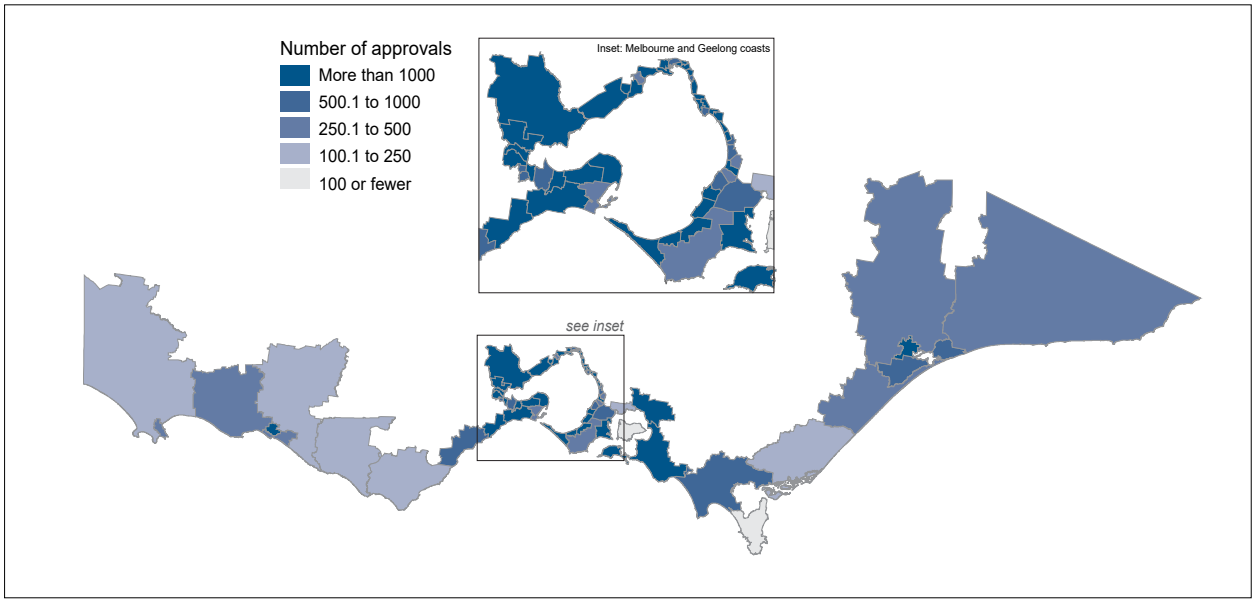


Figure 112: Residential dwelling approvals, Coastal Statistical Areas Level 2 (SA2), Q3 2009 to Q2, 2019.[1494]

Coastal settlements near Melbourne and Geelong have seen high growth since the 1990s. The attraction of coastal locations in these areas is driven by both amenity and good access to urban services and labour markets. Areas like the Bellarine Peninsula have attracted a mix of commuters, those seeking a 'seachange' lifestyle, second-home owners and retirees.

The Marine and Coastal Policy states the following in relation to coastal settlements:

In all scenarios, robust and sound strategic planning of settlements is needed to ensure that economic growth and prosperity can be sustained without adversely affecting the local marine and coastal environment (which in many cases is the attraction) and liveability for the community.[1495]

Land Use Change

A significant land use change occurs when non-urban land uses (such as farming) are rezoned to an urban land use. Urban land zoning enables an intensification of uses in terms of higher population densities and more infrastructure including housing. Urbanisation is accompanied by significant changes to the land surface through paving, roads and roof surfaces, and this has a significant impact on environmental processes related to water flow and catchment hydrology. Volume and velocity of water runoff increases during rainfall events while lack of infiltration creates reduced soils moisture during dry periods. Rapid runoff to waterways during rainfall can create scouring of aquatic habitats, and inflows of urban pollutants such as oils, nutrients, toxins and litter. Changing flow patterns and water quality ultimately affect instream and riparian flora and fauna.[1496] Associated pollution from stormwater runoff may be high unless well managed (refer Indicator 07: Stormwater).

1494. Australian Bureau of Statistics (ABS), 'Building approvals', cat. 8731.0.
1495. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Marine and coastal policy', East Melbourne, Victoria.
1496. Melbourne Water 2018, 'Healthy waterways strategy 2018', Melbourne, Victoria, p. 36.

This type of contaminated runoff may be concentrated to particular areas of a catchment. For example, the Werribee catchment, which extends from Port Phillip Bay to Ballan, has an overall condition rating of good yet, within the urbanised sections of that catchment, stormwater condition can be much poorer, as seen in the very low subcatchment ratings for Kororoit Creek Lower, Cherry Creek and Laverton Creek.[1497] This region of the Werribee catchment contains the largest state significant industrial precinct which comprises 6,156 hectares.[1498]

The need to develop a more integrated approach to urban development has been recognised with the establishment of Integrated Water Management (IWM) Forums. These Forums bring together all organisations with an interest in water management within the catchment. Five such Forums cover the Port Phillip and Western Port catchments.[1499] While some water management interventions can be done retrospectively (for example, water harvesting from rooftops), the most effective way to undertake IWM for urban areas is to incorporate these considerations prior to development occurring. IWM Guidelines for urban developers have been published, recognising that 'The land development process offers a one-time only opportunity for developers and authorities to plan the services and infrastructure that will determine the ongoing liveability and function of a development's future community'.[1500] Selected objectives include:

- provide alternative water sources to minimise use of potable water (eg recycled rainwater, storm water etc)
- recover valued resources from the sewerage system (eg recycled water)
- manage stormwater to maintain existing hydrology, minimising downstream impacts [1501]

Vegetation removal

The area of coastal vegetation removed through development is a measure which can provide an understanding of the changing coastal landscape and any loss of terrestrial habitat. As highlighted previously, such loss can have far reaching implications including the loss of biodiversity, habitat and ecosystem services, potential increases in coastal erosion, and sediment and pollutant inputs.

The construction of new residential (and other) buildings is likely to have an impact on local habitat, especially where this development happens on greenfield sites. The process of strategic land-use planning aims to minimise this impact in a number of ways:

- identifying areas of environmental importance in which development should not be allowed
- facilitating higher density residential development to minimise the amount of greenfield land being absorbed by urban development
- regulating the protection of native vegetation and/or requiring offsets for any vegetation removed (i.e. any loss to be offset by replanting elsewhere).

Removal of vegetation is regulated through the Victorian Planning Provisions (Sec. 52-17) enabled by the *Planning and Environment Act 1987*. The purpose of this section is: 'to ensure that there is no net loss to biodiversity as a result of the removal, destruction or lopping of native vegetation.' This objective is achieved through a 3-step process outlined in the guidelines for the removal, destruction or lopping of native vegetation:[1502]

- avoid the removal, destruction or lopping of native vegetation
- minimise impacts from the removal, destruction or lopping of native vegetation that cannot be avoided
- provide an offset to compensate for the biodiversity impact if a permit is granted to remove, destroy or lop native vegetation.

Information on vegetation removal is collected through the Planning Permit Activity Reporting System (PPARS) process. Table 45 shows the number of permits granted for vegetation removal along the Victorian coast over the past 5 years.

1497. Victorian Government 2020, 'Healthy waterways strategy 2018-2028, Port Phillip and Westernport, Victoria, Stormwater condition baseline and targets' https://healthywaterways.com.au/waterway-conditions/stormwater Accessed 22 July 2021.
1498. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Urban development program metropolitan Melbourne – industrial', East Melbourne, Victoria, p. 28.
1499. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Integrated water management forums' https://www.water.vic.gov.au/liveable/integrated-water-management-program/forums Accessed 22 July 2021.
1500. Western Water 2018, 'Integrated water management developer guidance', p. 2.
1501. Ibid. p. 6.
1502. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Guidelines for the removal, destruction or lopping of native vegetation' East Melbourne, Victoria.

Table 45: Number of permits for vegetation removal issued for coastal areas within 5 km of the Victorian coastline, 2016 to 2020.[1503]

Year	No. permits
2016	372
2017	425
2018	396
2019	366
2020	325

Development outside of urban boundaries

Monitoring of planning outcomes enables the assessment of effectiveness of planning controls to limit negative outcomes such as coastal sprawl. Amendments data can indicate whether new urban development is being contained within urban boundaries and permits data can determine the extent or nature of development outside those boundaries. The rezoning of land from rural to urban uses could be tracked using amendments data, however, the dataset is difficult to use for monitoring as it was established to streamline amendment processes rather than as an analytical tool. Further work would be needed to enable the dataset to be used to track changes in urban and rural land use.

The DELWP Planning Permit Activity Reporting System (PPARS) enables an assessment of the number of planning permits granted for dwellings outside of coastal settlements and within 5 km of the Victorian coastline. Assessment suggests that, in recent years, coastal settlement policy and planning regulations have resulted in more than 97% of new residential development being concentrated in existing coastal settlements (Table 46). Between 2016 and 2020, an average of 504 dwellings per year were approved in coastal areas outside of existing settlements. This represents a small proportion (an average of 2%) of total dwellings approved along the coast. Numbers of new dwellings dropped sharply during 2020 due to the COVID pandemic.

Table 46: Number of dwellings approved in planning permits within 5 km of the coastline, within and outside of existing settlements, Victoria, 2016 to 2020.[1504]

Data Quality: A degree of caution is needed in interpreting this data. The boundaries to define existing settlements are based on an ABS definition of an urban centre. This uses statistical (SA1) boundaries that do not necessarily align with the planning settlement boundary. Refinement of boundaries is expected to occur in the future.

Year	No. of new dwellings approved in coastal areas	No. of new dwellings approved in coastal areas outside of settlement boundaries	Proportion (%) of new dwellings in coastal areas that are outside settlement boundaries
2016	37,559	537	1.4
2017	36,976	497	1.3
2018	21,156	607	2.9
2019	19,805	585	3.0
2020	13,723	296	2.2

1503. Department of Environment, Land, Water and Planning (DELWP) 2021 planning permit activity reporting system (PPARS) special data request.
1504. Ibid.

Land use planning

The change from rural to urban uses is planned many years in advance. Projections of population and housing drive most of the decisions about where and how population will be housed. Land use planners seek to avoid having urban uses in areas of environmental significance or natural hazard, however, there are inevitable environmental impacts from simply creating built urban form.

To limit the extent of environmental impacts, planners may seek to increase settlement densities rather than allowing low-density sprawl, however, they do not have complete control over housing market demand which reflects where people desire to live. The attraction of coastal locations is longstanding in Australia and demand remains high, especially in coastal locations near large cities like Melbourne.

The price of housing and the economic dynamics of the housing market may seem somewhat distant from environmental concerns. However, it is important for land use planners because they are tasked (among other things) with considering issues of housing affordability[1505]. While demand for housing may be market-led, government has a critical role in land supply. State Government can influence the location and timing of land release for development as well as regulating aspects of how that development should occur. Pressure is often placed upon government to supply more land in order to keep housing process affordable. The supply-demand-price relationship is complex, but at a simple level the effects can be seen in coastal towns like Lorne. Demand is high, yet land release is constrained for reasons related to fire risk and the highly significant landscapes and environments in the vicinity. The median house price in Lorne has been over $1 million since 2017[1506] creating issues of housing affordability for service workers in the town. Protection of the Great Ocean Road in the early 2000s occurred through nominating centres such as Torquay and Ocean Grove as growth centres. Such policies can be controversial as one area's protection may be perceived as coming at the expense of another's amenity.

These housing market dynamics highlight the affordability issues which may arise where restrictions to housing development apply. This needs to be considered against the potential damage to ecosystems or habitat loss which may occur if more development is enabled. It is worth noting that land-use planners have to balance these competing objectives rather than act solely in the interests of development or environmental protection. They are responsible for the sustainable development of communities which considers both environmental health and social wellbeing (in which housing affordability is a consideration). Furthermore, restricting residential development will not affect visitor populations hence an integrated approach to population and settlement is required.

This raises a question (and a challenge) as to whether coastal settlement can occur in a more environmentally benign way. For planners, this might be a way of addressing, or at least balancing, issues of environmental impact, housing affordability and equity of access to locations of high amenity.

1505. Victorian Planning Provisions 'Section 16.01-2S Housing Affordability', DELWP (Department of Environment, Land Water and Planning) East Melbourne, Victoria https://www.planning.vic.gov.au/schemes-and-amendments/browse-planning-scheme/planning-scheme?f.Scheme%7CplanningSchemeName=VPPS Accessed 6 May 2021.

1506. Valuer-General Victoria 2020, 'A guide to property values - annual analysis of property sales data from Valuer-General Victoria, January – December 2019', Department of Environment, Land, Water and Planning (DELWP), Melbourne, Victoria, p. 74.

Theme 8: Communities

Indicator 60: Cultural heritage

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide					N/A	N/A

Data source:	First Peoples – State Relations Group, Heritage Victoria
Measures:	Number of items included on Aboriginal Cultural Heritage Register Number of cultural heritage management plans Number of coastal heritage items/sites included on the Victorian Heritage Register Value of investment ($) through the Living Heritage program for coastal heritage Number of registered coastal heritage sites under threat from natural hazards

Why this indicator?

This indicator assesses the protection of cultural heritage (indigenous and non-indigenous). The protection of marine and coastal sites, objects and landscapes provides a source of learning and identity for both local communities and visitors.

Justification for assessment ratings:

- Legislative protection is given to a range of cultural heritage for both Aboriginal and non-Aboriginal Victorians, on land and in marine environments.
- Data on the number of items of registered as having cultural significance are available, subject to certain restrictions in the case of Aboriginal cultural heritage.
- While various data are available, there are constraints in undertaking non-standard analysis of Heritage Victoria data (for example, for GIS) which limits their potential use.
- While cultural heritage can be assessed quantitatively (number of sites, etc) it is important to monitor the qualitative status of sites and the degree to which investment is supporting their preservation and protection.

In Part 1 of this report, the theme of Cultural Landscape Health and Management was discussed. Within this section on Cultural Heritage, a narrower reporting focus is presented on those aspects of indigenous and non-indigenous cultural heritage which are recognised through legal registration. In this context, cultural heritage includes both tangible and intangible assets which contribute to community identity, sense of history and sense of place. It may include a site, object, building or tree and protection for such heritage may be sought through legislation such as the *Aboriginal Heritage Act 2006* (administered by Aboriginal Victoria in the Department of Premier and Cabinet) or the Victorian *Heritage Act 2017* (administered by Heritage Victoria and the Heritage Council of Victoria).

Aboriginal Cultural Heritage

Aboriginal Cultural Heritage in Victoria is protected under the *Aboriginal Heritage Act 2006* and Aboriginal Heritage Regulations 2018, and refers to the knowledge and lore, practices and people, objects and places that are valued, culturally meaningful and connected to identity and Country and has been passed on from Ancestors to future generations.[1507] The Act establishes a framework of mechanisms for the management and protection of Aboriginal Cultural Heritage, including Cultural Heritage management plans, Cultural Heritage permits, Protection Declarations and Aboriginal Cultural Heritage land management agreements.

1507. Victorian Aboriginal Heritage Council (VAHC) 2020, 'Aboriginal cultural heritage' https://www.aboriginalheritagecouncil.vic.gov.au/aboriginal-heritage Accessed 21 September 2020.

The Victorian Aboriginal Heritage Register is a central repository for Traditional Owners to store information about cultural heritage and includes:

- Aboriginal cultural heritage place registrations
- Aboriginal intangible heritage registrations and agreements
- approved cultural heritage management plans
- cultural heritage permits
- certified preliminary Aboriginal heritage tests
- archaeological reports.

Each part of Victoria has places where Aboriginal people have lived, traded, created, celebrated and engaged in a range of other activities. Since European settlement, there have been other sites of significance created by this contact. These range from sites of conflict and massacre, mission stations and, in more recent decades, places associated with the Aboriginal rights movement. Not all places of significance contain physical evidence. Information about places of spiritual significance, for example, may have been passed down through generations or have been recorded in European historical records.

Aboriginal places and objects can be found all over Victoria and are often near major food sources such as rivers, lakes, swamps and the coast. Riverine and coastal areas are important places for both tangible and intangible Aboriginal cultural heritage. Coastal shell middens are a recognised cultural heritage feature. These contain the remains of food eaten by Aboriginal people. As the name suggests, they are characterised by shellfish remains, but may also include evidence of other food eaten such as fish, seal or kangaroo. Other items such as stone and bone artefacts can also be found in these middens.[1508]

As at 23 March 2021, there were a total of 38,827 registered Aboriginal places on the Victorian Aboriginal Heritage Register. Figure 113 shows the proportion of different components of Aboriginal heritage that are recorded. The number of items added to the register between 1 January 2011 and 31 December 2020 was 8,554 – an average annual addition of 855 sites.[1509]

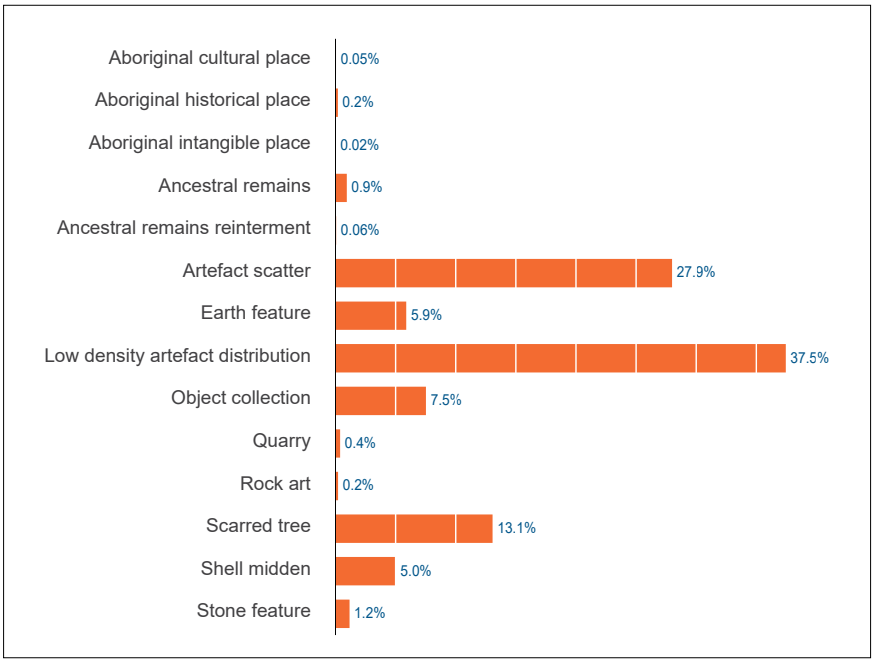


Figure 113: Types of registered Aboriginal places on the Victorian Aboriginal Heritage Register, as at 23 March 2021.[1510]

1508. Aboriginal Victoria 2019, 'Fact sheet: Aboriginal coastal shell middens' https://www.aboriginalvictoria.vic.gov.au/fact-sheet-aboriginal-coastal-shell-middens Accessed 21 September 2020.
1509. Aboriginal Victoria, special data request.
1510. Ibid.

The *Aboriginal Heritage Regulations 2018* define areas of cultural heritage sensitivity which include landforms and soil types where Aboriginal places are more likely to be found. These include land within 200 metres of named waterways and land within 50 metres of registered Aboriginal cultural heritage places. All of Victoria's coastline falls within the category of areas of cultural heritage sensitivity. Areas within Port Phillip Bay, nearly all of Western Port and all of Corner Inlet, Nooramunga and the Gippsland Lakes also fall within this category.[1511] Areas of cultural heritage sensitivity are defined for the purpose of specifying when a cultural heritage management plan must be prepared under the *Aboriginal Heritage Act 2006*. These plans address issues that may arise from some high impact land use and development activities which have the potential to harm Aboriginal cultural heritage when carried out in sensitive areas. Before such activities are carried out, a management plan needs to be prepared to address the potential risk to Aboriginal cultural heritage.[1512] As at 23 March 2021, the total number of Cultural Heritage Management Plans in Victoria was 1,143.[1513]

Non-Aboriginal Cultural Heritage

Under the *Victorian Heritage Act 2017*, the Heritage Council determines what places and objects are of significance to the State of Victoria and includes these in the Victorian Heritage Register. Places included in the Register cannot be demolished or developed without approvals. A wide range of heritage places are in the Register including buildings, structures, trees, gardens, archaeological sites, shipwrecks and cultural landscapes. The Great Ocean Road is included on the Victorian Heritage Register 'for its historical, archaeological aesthetic and social significance to the State of Victoria'.[1514] while The Great Ocean Road and Scenic Environs is included on the National Heritage List.[1515] At June 2021, there were more than 1,200 heritage sites and objects listed on the Victorian Heritage Register that were located within 5 km of the Victorian coastline.[1516]

Many heritage sites are linked to the central role of the sea in the economic, social and physical development of Victoria by Europeans. In the 19th Century, many ships sailing along the Victorian coast were shipwrecked due to storms and treacherous conditions. Around 600 shipwreck sites have been recorded in Victoria including sailing ships and steam vessels. Heritage Victoria manages shipwreck sites and shore-based maritime archaeological sites in coastal and inshore waters. Apart from shipwrecks, Victoria's diverse maritime heritage includes sunken aircraft, jetties, piers, navigation structures, artefacts, maritime defence infrastructure such as forts and gun stations, ship-building sites and maritime landscapes. Shipwrecks in enclosed waters such as bays, rivers and lakes are protected by the Victorian *Heritage Act 2017* and the *Heritage (Underwater Cultural Heritage) Regulations 2017*. Shipwrecks located outside these areas are protected by the Commonwealth *Underwater Cultural Heritage Act 2018*. All shipwrecks and related artefacts that are 75 years or older are automatically protected by these pieces of legislation and are recorded on the Victorian Heritage Register.[1517]

Most shipwreck sites are open to recreational fishing and diving, although some sites which are more fragile or dangerous may be off-limits to boat access through the provision of declared protected zones. These zones are shown in Figure 114. Divers can apply for a permit to access specific protected zones for recreational diving purposes.[1518]

1511. Aboriginal Victoria, 'Aboriginal cultural heritage register and information system (ACHRIS)' https://achris.vic.gov.au/#/onlinemap Accessed 23 March 2021.
1512. Aboriginal Victoria 2021, 'Cultural heritage sensitivity' https://www.aboriginalvictoria.vic.gov.au/cultural-heritage-sensitivity Accessed 23 March 2021.
1513. Aboriginal Victoria, special data request.
1514. Heritage Council of Victoria 2021, 'The Victorian heritage database - the Great Ocean Road', VHR no. H2261 https://vhd.heritagecouncil.vic.gov.au/search?kw=great+ocean+road&aut_off=1 Accessed 1 July 2021.
1515. Australian Heritage Database, 'Great Ocean Road and scenic environs listed place 105875', Department of Agriculture, Water and Environment, Canberra https://www.environment.gov.au/cgi-bin/ahdb/search.pl Accessed 1 July 2021.
1516. Department of Environment, Land, Water, and Planning (DELWP) 2021, 'Victorian heritage register', map layer ANZVI0803004621, 3 July 2021.
1517. Heritage Victoria 'Maritime heritage' https://www.heritage.vic.gov.au/heritage-listings/maritime-heritage Accessed 18 November 2021.
1518. Ibid.

Figure 114: Victorian Shipwreck Protected Zones.[1519]

Apart from maritime heritage, registered heritage places on the Victorian coast include 20th century heritage such as bathing boxes, reflecting the continued connection between Australians and the coast. Bells Beach near Torquay, an internationally famous centre of surfing culture, is included in the Register. Other places in the Heritage Register include colonial buildings, lighthouses, whaling stations, forts and gun stations, coastal landscapes, and numerous buildings and structures in pre-goldrush settlements such as Portland, Port Fairy, Warrnambool, Geelong and Port Albert.[1520]

Some of these sites may be affected by sea level rise due to climate change over coming decades, Nearly 50 sites on the Victorian Heritage Register are in such areas, for example: Brighton beach bathing boxes, lighthouses at Point Hicks, Cape Otway, Cape Nelson and Wilsons Promontory, foreshore areas at Bells Beach and Clifton Springs and the Great Ocean Road, to name just some.[1521]

Apart from simply protecting cultural heritage, investment in conservation is provided to many places and objects included in the Victorian Heritage Register through the Living Heritage Program. This maintains and enhances the value provided by such heritage. Over 20 projects have been funded since 2016-17 to the value of $30.72 million.

Additional protections are provided through state planning policy which provides for the conservation and enhancement of places which are of aesthetic, archaeological, architectural, cultural, scientific or social significance. One instrument used for such protection are Heritage Overlays which are part of local government planning schemes and which apply additional requirements for development proposals. Overlays may apply to individual sites or to precincts.

1519. Ibid.
1520. Heritage Victoria 2020, 'Victorian heritage database' https://vhd.heritagecouncil.vic.gov.au/ Accessed 23 September 2020.
1521. Department of Environment, Land Water and Planning (DELWP) 2021, Victorian heritage register map layer overlaid with 5 km coastal area.

Theme 8: Communities

Indicator 61: Use of marine and coastal areas

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		?			N/A	N/A

Data source:	DELWP (Ipsos), Parks Victoria
Measures:	Activities undertaken while visiting the Victorian coast | Value of the coast

Why this indicator?

Marine and coastal areas are used for many different purposes. This indicator will examine this range of uses, the community benefits which marine and coastal areas provide and potential environmental impacts that need to be addressed.

Justification for assessment ratings:

- The assessment of this indicator is based on the social and economic benefits derived from the use of marine and coastal areas, rather than environmental impact (which is explored in other sections)
- Victorian coastal areas are used by a range of people for a variety of purposes. Many of these activities have positive health benefits and support economic activity in coastal communities.
- Appropriate management of people and their activities can minimise potential environmental impacts. This is of particular importance as population (resident or visitor) grows.
- Survey-based data does not always lend itself to time-series analysis. Hence assessment of trend has not been undertaken for this indicator.

'Recreation and tourism' is a chapter in the Marine and Coastal Policy. The intended outcomes are stated as: 'the marine and coastal environment hosts a diverse range of recreation and tourism experiences that are strategically planned and located to be safe and sustainable now and in the future'.[1522]

Recreation and tourism are key economic drivers for Victoria, contributing billions of dollars to the state economy each year. By connecting people with the marine and coastal environment, recreation and tourism also foster a sense of stewardship among users and provide communitywide health benefits from active and outdoor lifestyles.

The coast plays an extremely important role in Australian culture. Even though the Victorian coast is subject to cold periods in winter, its coastal areas receive visitors throughout the year. The coast is the location of many festivals, sporting activities and cultural events. The coast is a public good which is accessible to all. Ninety-six percent of the Victorian coast is in public ownership,[1523] unlike coastal areas in most other Australian States.

In line with this public ownership, the community plays a key role in caring for it through volunteer activities. Importantly, the coast provides space for passive recreational activities.

According to the Marine and Coastal Community Attitudes and Behaviour Report 2018, more than three-quarters of the 2,500 Victorians surveyed had made at least one trip to the coast in the previous 12 months.[1524] Walking/hiking was the most common activity, followed by swimming/surfing, eating/drinking and relaxing on the beach (Figure 115).

1522. Department of Environment, Land Water and Planning (DELWP) 2020, 'Marine and coastal policy', East Melbourne, Victoria.
1523. Department of Environment, Land, Water and Planning (DELWP) 2018, 'Victoria's marine and coastal reforms final transition plan', East Melbourne, Victoria, p. 4.
1524. Ipsos 2018, 'Wave 5 marine and coastal community attitudes and behaviour report', prepared for the Victorian Marine and Coastal Council (VMaCC), Parks Victoria and Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria.

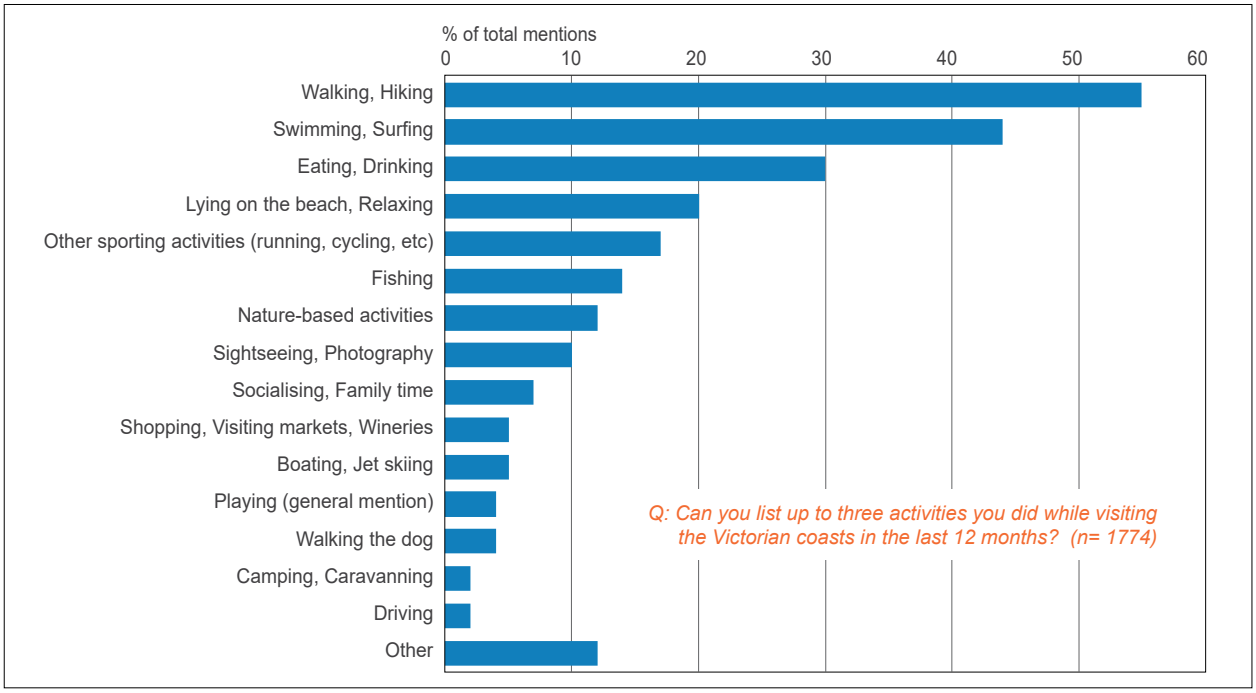


Figure 115: Activities undertaken while visiting the Victorian coast, 2018.[1525]

Most visitors to the beach in warmer months will engage in swimming activities. There are also many organised swimming events and competitions which occur throughout the year, mainly in summer. Around 40 events are held annually along the Victorian coast and in Port Phillip Bay.[1526] Many of these events are organised as fund raising activities by local surf lifesaving clubs, but with the increasing popularity of the competitions they are becoming more professional and receive broad media coverage. Just as swimming is a significant part of Australian culture, surf lifesaving holds an iconic place in Australian coastal life. While the activity clearly has a community safety role in supervising and aiding those swimming and recreating along the coast, surf lifesaving clubs are also key community assets. They often provide important facilities such as entertainment venues and function rooms and offer a range of sports training opportunities for locals. Currently Victoria has 57 operating Clubs from Portland in the west to Mallacoota in the east.[1527]

As well as land-based coastal activities, the marine environment supports many recreational activities such as boating, fishing, diving and wildlife observation. Opportunities to observe whales, dolphins, seals and penguins provide economic benefits to tour businesses but also personal enhancement of wellbeing through connection with nature. Research undertaken by Parks Victoria showed the activities undertaken by visitors to marine parks and sanctuaries (Figure 116). Recreational activities such as walking and sightseeing are the most common activities undertaken by park visitors. Overall, it was estimated that between 34% and 43% of Victorians aged 18 years and over had visited the marine park system in the 12-month period prior to the survey.[1528] This period was affected by various COVID travel restrictions and almost half of survey participants indicated that they would visit parks more often during a usual year.[1529]

1525. Ibid.
1526. Casey Seals Masters Swimming Club '2020/21 Open water swim calendar' updated 23 August 2020.
1527. Life Saving Victoria 2020, 'Join a life saving club' https://lsv.com.au/clubs-members/support/join-a-life-saving-club/#:~:text=Life%20Saving%20Victoria%20has%2057,all%20the%20way%20to%20Mallacoota Accessed 4 September 2020.
1528. Parks Victoria 2021, 'Victorian community usage, awareness and perceptions of marine parks and sanctuaries', written by Jacky Heath, Lonergan, Sydney, p. 26.
1529. Ibid. p. 40.

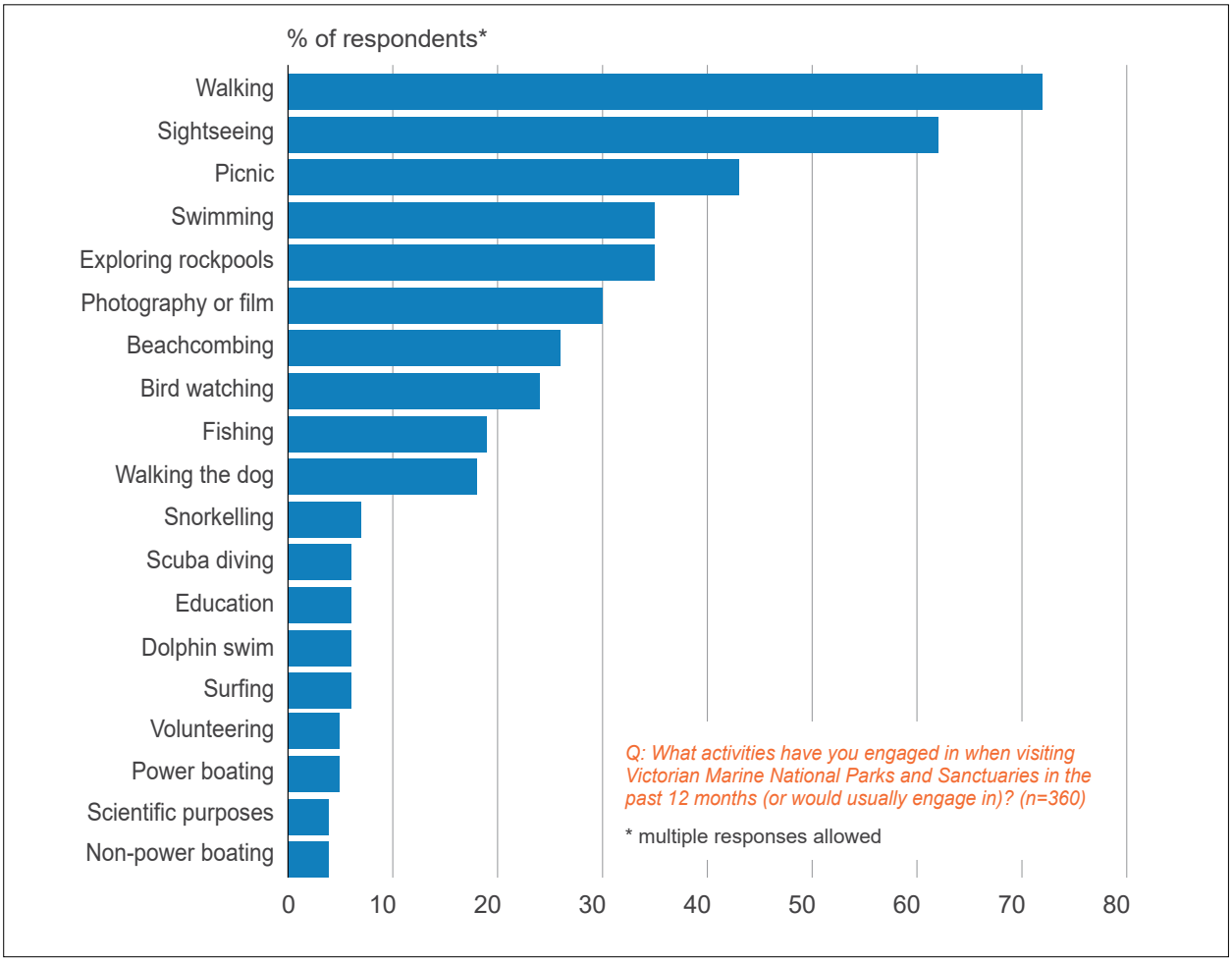


Figure 116: Activities undertaken while visiting Victorian Marine National Parks and Sanctuaries in the 12 months to January 2021 (n=360).[1530]

Survey-based data does not always lend itself to time-series analysis. For example, although the Ipsos survey has been undertaken 5 times, it can be difficult to analyse time-series trends due to changes in sample size, methods (online or in person) and times of the year in which the survey was undertaken.[1531] It is also difficult to compare different surveys. Tourism surveys (discussed in Indicator 62: Tourism) have shown increasing numbers of visitors to coastal regions up until 2019 yet Wave 5 of the Ipsos attitudes survey undertaken in 2018 suggests declining use of coastal areas since the previous Wave 4 survey was undertaken 5 years prior. Again, different methods, timing and types of questions makes it difficult to determine exact trends in the use of coastal areas. Hence assessment of trend has not been undertaken for this indicator.

1530. Ibid. p. 64.
1531. Ipsos 2018, 'Wave 5 marine and coastal community attitudes and behaviour report', prepared for the Victorian Marine and Coastal Council (VMaCC), Parks Victoria and Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria, pp. 13-14.

Indicator 62: Tourism

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide					N/A	N/A

Data source:	Business Victoria 2020, Parks Victoria, Tourism Victoria
Measures:	Visitor numbers and total spend for selected Victorian tourism regions | Number of visitors to coastal and marine parks | Annual number of tourists visiting significant coastal tourist attractions

Why this indicator?

The natural environment attracts tourists. While providing an economic benefit for many coastal communities, the number and behaviours of tourists can potentially have negative impacts on these environments.

Justification for assessment ratings:

- Tourism is supported through government policy and it is seen as a valuable source of jobs and revenue for Victorian coastal communities.
- At present there appear to be limited links between tourism growth policies and visitor management or environmental management strategies. This has the potential to lead to management conflict and lack of policy coherence.
- While data are available, they tend to be geographically broad and survey-based which makes detailed assessment of tourist impact very difficult.
- Environmental certification schemes do not yet enable comprehensive assessment of tourism operators' environmental credentials
- The coronavirus pandemic has severely disrupted international travel which will have short to medium term impacts on international visitor numbers to major coastal attractions such as Phillip Island and the Great Ocean Road. However, the majority of visitors to these destinations are domestic.
- Domestic travel restrictions have also affected regional visitation rates in the short term.

Victoria's tourism industry contributed an estimated $29.4 billion to gross state product during the 2018-19 financial year, representing 6.5% of the Victorian economy. Tourism performance in terms of gross state product has increased consistently in recent years and rose by 9.1% between 2017-18 and 2018-19. Tourism jobs numbered 263,300 in 2018-19 having risen by 6.2% from the previous financial year.[1532]

Tourism data are available at a regional and local government scale however they are difficult to disaggregate to smaller scales or to custom regions such as the coastline. Figure 117 shows the Victorian tourism regions used for data reporting that abut the coast.

1532. Business Victoria 2020, 'Victoria's visitor economy 2018-19 state tourism satellite account results'.

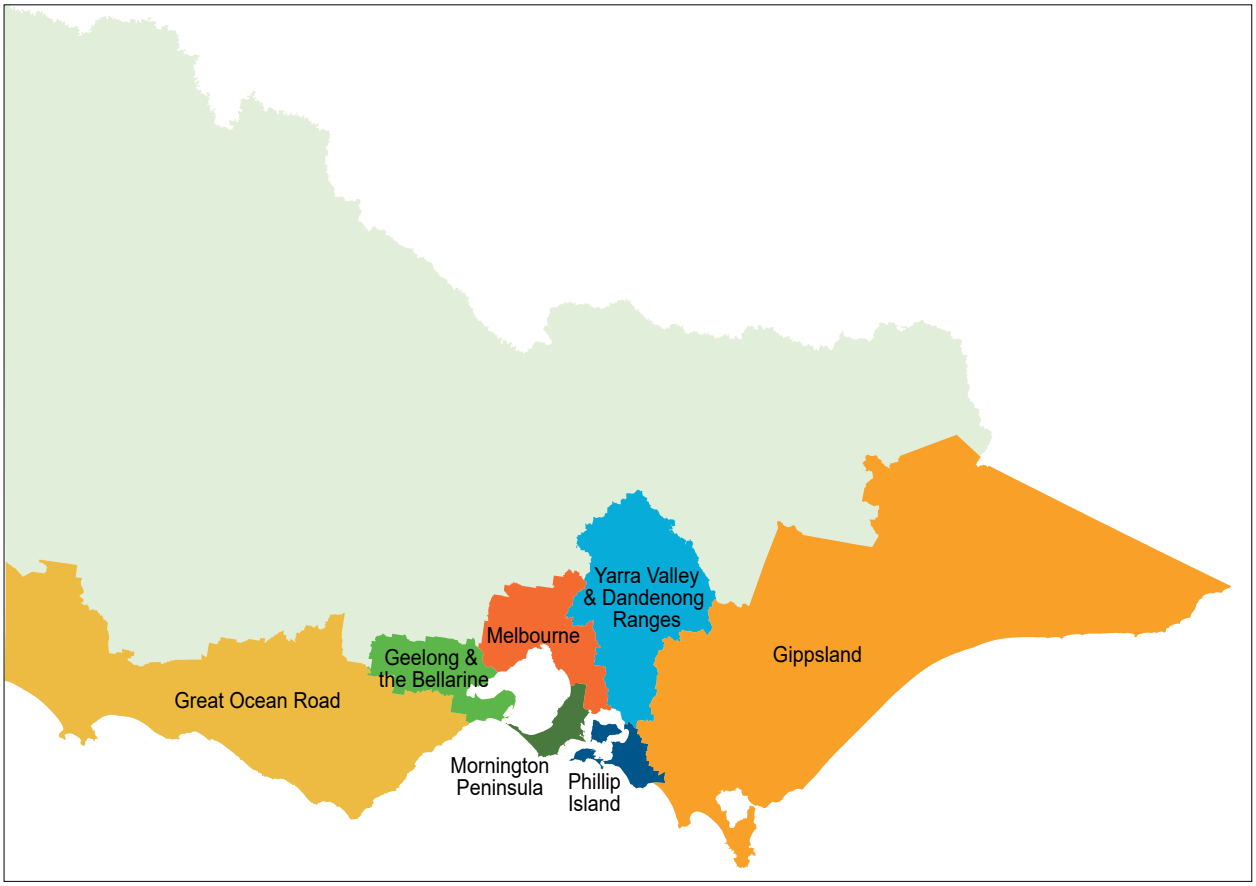


Figure 117: Victoria's coastal tourism regions.[1533]

Table 47 provides a summary of key tourism data for the tourism regions which abut the Victorian coast.

Table 47: Visitor numbers for selected Victorian tourism regions, year ending March 2020.*[1534]

NOTE: Yarra Valley and Dandenong Ranges are not included in this analysis as only a very small proportion of the tourism region abuts the coast.

	Domestic overnight		Domestic day trip		International overnight	
	No. visitors ('000)	Total spend ($ million)	No. visitors ('000)	Total spend ($ million)	No. visitors ('000)	Total spend ($ million)
Geelong & Bellarine	16,000	630	4,400	369	57	71
Gippsland	2,300	711	4,000	408	69	31
Great Ocean Road	2,700	1,200	3,600	333	212	90
Mornington Peninsula	1,900	740	5,900	460	65	77
Phillip Island	1,000	369	1,600	135	49	24

1533. Business Victoria 2020, 'Victoria's tourism regions'.
1534. Business Victoria 2020, 'Regional visitation, regional market summaries' https://www.business.vic.gov.au/tourism-industry-resources/research/regional-visitation Accessed 25 September 2020.

These data are also used for specific estimation of visitor numbers such as that undertaken by Deloitte Access Economics for the Great Ocean Road[1535]. Figure 118 shows estimated visitor numbers, by type, for the region.

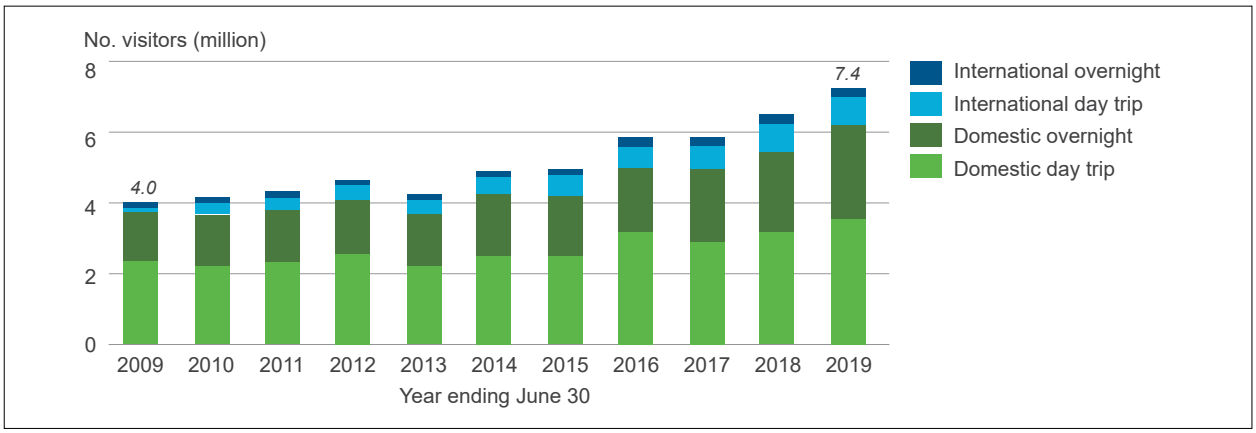


Figure 118: Visitor numbers to the Great Ocean Road region, 2009-2019.[1536]

Another source of data is provided by Parks Victoria who undertake biennial surveys of visitor numbers and visitor satisfaction. In the year to June 2019, a total of 131 million visitors were estimated to have visited parks managed by Parks Victoria. 52 million of these were to piers and jetties while the remainder visited National, State, urban and other terrestrial parks.[1537]

Data are available on aggregate tourism numbers and related metrics such as expenditure and overnight stays. These are generally reported at the scale of tourism region or Local Government Area. The data are not provided in a form that would enable specific coastal reporting.

Certification schemes are often used to promote ecotourism. However, because these schemes are related to promotion and marketing, there is little related assessment or monitoring of environmental benefit. As a sector with numerous small business operators, data are fragmented which makes it impossible to confidently assess the sustainability of tourism activities. The scope of certification schemes could be expanded to include assessment and monitoring of the environmental benefits provided by tourism activities. A carefully constructed database of certification schemes that incorporates environmental benefits would enable aggregated data to be analysed and meaningful insights on the sustainability of tourism activities to be realised.

Apart from certification and accreditation schemes, there are also international and national standards related to sustainability. An example is standards relating to sustainable events management.[1538,1539] As with certification schemes, there seems to be little analysis that relates the use of such initiatives to the improvement (or otherwise) of environmental outcomes.

1535. Deloitte Access Economics 2020, 'Visitor demand and accommodation forecast – final report. Great Ocean Road'.
1536. Ibid.
1537. Parks Victoria 2019, 'Annual report 2018–19', p.16.
1538. International Standard: ISO 20121, 'International standard on sustainable event management'.
1539. Australian Standard: AS ISO 20121-2013, 'Event sustainability management systems – requirements with guidance for use'.

Indicator 63: Recreational boating and fishing contribution to the Victorian economy

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		↙			N/A	N/A

Data source:	Better Boating Victoria, Victorian Fisheries Authority
Measures:	Recreational boating and fishing contribution to the Victorian economy Revenue from licence fees

Why this indicator?

Recreational boating and fishing provide substantial economic benefits to the Victorian community through supporting industries (equipment, tourism) and the jobs generated. This indicator will measure the benefits contributed by these recreational activities.

Justification for assessment ratings:

- The assessment of this indicator is based on the economic and social benefits derived from these marine and coastal activities, rather than environmental impact (which is explored in other sections).
- Recreational boating and fishing are supported through government policy and are seen as a valuable source of jobs and revenue for the Victorian economy.
- Recreational boating and fishing are also recognised as having human health benefits through providing a relaxing activity that enhances mental and social health.
- The impact of COVID restrictions has led to a decline in the number of licences and subsequent revenue from recreational fishing and boating. While this has led to a deteriorating trend assessment, it is likely to improve once travel restrictions are more permanently eased.

Recreational boating and fishing have been estimated to contribute billions of dollars to the Victorian economy. A recent study estimated that recreational fishing and boating in Victoria in 2018/19 generated:

- $14.00 billion combined direct and indirect output, including $6.14 billion direct output
- $5.83 billion combined direct and indirect value added, including $2.12 billion direct value added
- 55,780 combined direct and indirect full-time equivalent (FTE) jobs, including 25,058 direct jobs.[1540]

The projected impact of recreational fishing and boating between 2018–19 and 2038–39 was also estimated using Victorian Government population projections.

Between 2018–19 and 2038–39, recreational fishing and boating in Victoria was estimated to generate the following:

- output contribution (direct and indirect) from $14.00 billion (in 2018–19) to $19.07 billion (in 2038–39), with an NPV over the 20-year model period of $181.12 billion
- value added contribution (direct and indirect) from $5.83 billion (in 2018–19) to $8.00 billion (in 2038–39) with an NPV over the 20-year model period of $75.48 billion
- employment contribution (direct and indirect) from 55,780 (in 2018–19) to 76,088 (in 2038–39) with an average annual employment of 66,094 FTE jobs.[1541]

1540. Better Boating Victoria (BBV) and Victorian Fisheries Authority (VFA) 2020, 'The economic value of recreational fishing and boating in Victoria', prepared by Ernst and Young, p. 7.
1541. Ibid. p. 7.

Direct revenue is collected from those involved in recreational fishing and boating through the collection of licence fees. Fishing licences may be bought for different lengths of time ranging from 48 hours to an annual licence. Figure 119 shows the breakdown of these licence types for 2019–20.

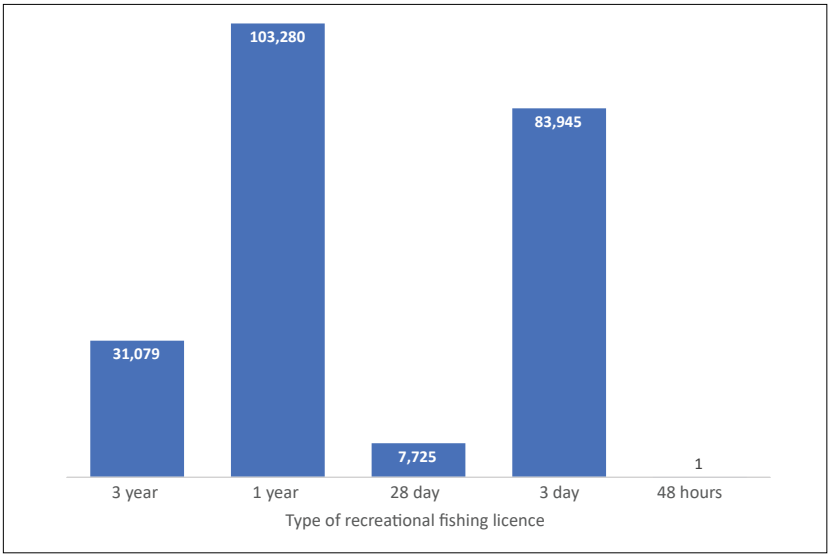


Figure 119: Number of recreational fishing licences issued in 2019–20, by type.[1542]

The total revenue from recreational fishing licences can be seen in Table 48. It has been in the range of 7.5 to 8.5 million per year since 2016–17. Revenue from recreational boating registration and marine licence renewal amounted to more than $31 million in 2018-19.[1543] Note that the final quarter of the 2019–20 season was affected by COVID lockdowns and the continuing impact of travel restrictions since then is also likely to have had a negative impact on licence numbers and revenue. As a result, the increase in recreational fishing envisaged by the Target One Million is not being met.

Table 48: Revenue from recreational fishing licences in Victoria 2016–17 to 2019–20.[1544]

	2016–17	2017–18	2018–19	2019–20
Receipts	$8,556,139.78	$7,831,804.19	$8,712,710.18	$7,501,237.68
No licences	271,395	258,531	264,814	226,030

1542. Victorian Fisheries Authority (VFA) 2020, 'Recreational fishing licence trust account. a report to each house of parliament on the disbursement of recreational fishing licence revenue', Melbourne, Victoria.
1543. VicRoads 2019, 'Annual report 2018-19', Melbourne, Victoria, p. 120.
1544. Victorian Fisheries Authority (VFA), various years, 'Recreational fishing licence trust account. a report to each house of parliament on the disbursement of recreational fishing licence revenue'.

Indicator 64: Recreational boating

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide					N/A	N/A

Data source:	Victorian Fisheries Authority, Better Boating Victoria, academic researchers
Measures:	Participation in recreational boating | Number of boat licence holders

Why this indicator?

Recreational boating is a popular pastime which requires appropriate management and education to control environmental risks such as pollution, or disturbance (for example, erosion from boat wakes). This indicator will assess the degree to which such initiatives are occurring and supporting sustainable practices.

Justification for assessment ratings:

- Licencing arrangements enable generally good data on the scale and nature of boating, although impact of boating on specific habitats and geographical areas is more elusive.
- Despite COVID restrictions having affected activities such as recreational fishing and boating, this is not reflected in the number of registered vessels and numbers of people with current boating licences. In fact, both have increased over the past year. This suggests that activity will recover quickly once travel restrictions are eased.

To operate a boat In Victoria, the vessel must be registered and the operator must have a marine licence to operate it. Personal Water Crafts (PWC) like jet-skis require an additional endorsement to the marine licence. Children between the ages of 12 and 15 can obtain a restricted marine licence.

As of 31 March 2021, the total number of Victorian recreational boating licence holders was 432,000 and the total number of registered vessels was 200,000.[1545] Figure 120 shows the demographic breakdown of recreational boating licence holders.

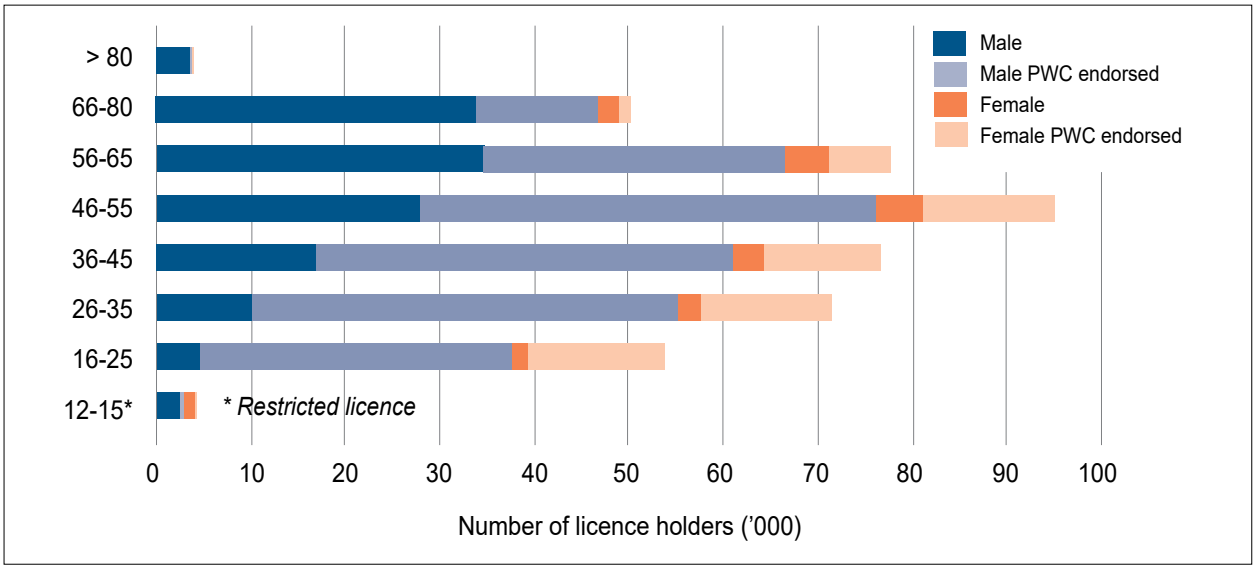


Figure 120: Victorian boating licence type by age and gender.[1546]

1545. Maritime Safety Victoria 2021, 'On deck. Maritime Safety Victoria stakeholder update, Data extract April 2021', p. 2.
1546. Ibid. p. 2.

Recreational vessel registrations grew at 2.5% per annum up until June 2019. In 2018–19, there were approximately 696,000 people who participated in recreational boating across Victoria, with 48% of these also taking part in recreational fishing (Figure 121).[1547]

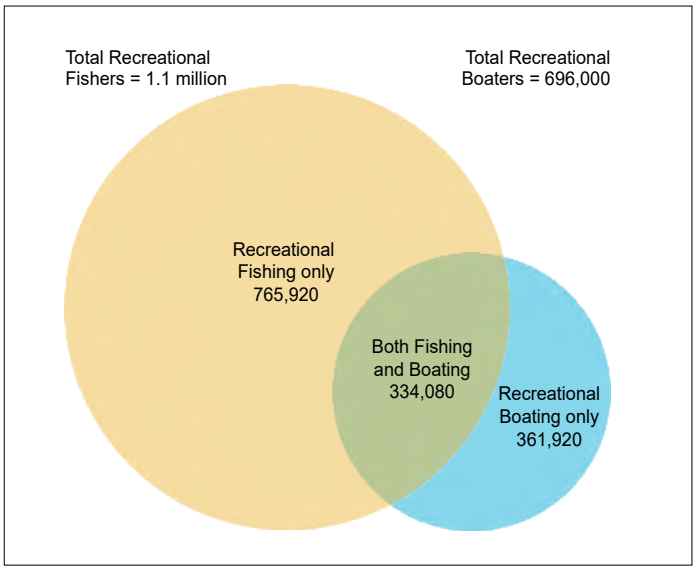


Figure 121: Numbers involved in recreational fishing and boating in Victoria 2019-19.[1548]

While COVID restrictions have affected the level of fishing and boating activities, they have not resulted in a falling number of vessel registrations or boating licences. In fact, both have continued to increase, even during the past year (Figure 122). This suggests that fishing and boating activity will recover quickly once travel restrictions are eased.

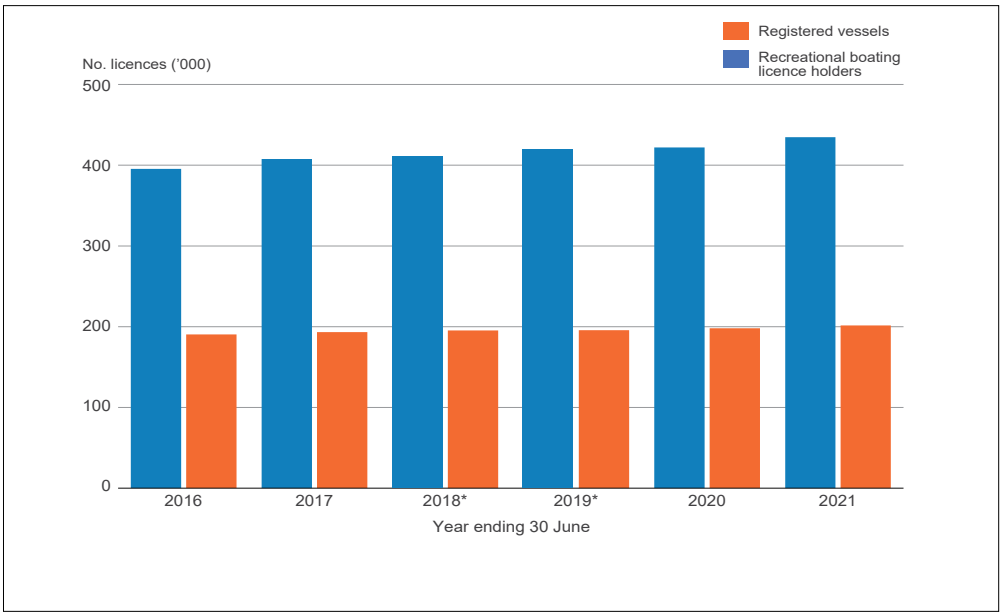


Figure 122: Number of recreational boating licence holders and registered vessels 2020-21.[1549]

1547. Better Boating Victoria (BBV) and Victorian Fisheries Authority (VFA) 2020, 'The economic value of recreational fishing and boating in Victoria', prepared by Ernst and Young, p. 5.
1548. Ibid.
1549. Maritime Safety Victoria, various years, 'On deck stakeholder update', data extracts and annual reports https://transportsafety.vic.gov.au/maritime-safety/recreational-vessel-operators/report-a-rec-boating-incident/maritime-incident-statistics#_ga=2.71464272.27516040.1601950094-575231943.1601950094 Accessed 10 August 2021.

Theme 8: Communities

Better Boating Victoria (BBV), a Division within the Victorian Fisheries Authority, was established in early 2019 to implement the Victorian Government's commitment to facilitate recreational boating[1550] – its focus is on improving boating facilities and safety. Over the next four years, BBV will continue to remove boat launching and parking fees at public boat ramps, upgrade boat ramps at six priority locations; review management arrangements of boating infrastructure at Port Phillip and Western Port; and establish the Better Boating Fund for improving boating facilities and safety. This is likely to increase visitation to specific areas, the most popular being Port Phillip Bay, Western Port and the Gippsland Lakes (refer Indicator 57 for further discussion of visitor populations).

A survey undertaken by Transport Safety Victoria in 2015 found that boating was not only undertaken as a recreational activity for the direct purpose of fishing, touring or racing, but also for emotional reasons such as spending time with family, fostering life skills in children and taking friends out on their boat. Relaxation was also a motivation, with survey respondents commenting on the peace and serenity they found by being out on the water.[1551]

A higher proportion of respondents indicated that they undertook boating on coastal waters, bays or inlets (57%) compared to those who used inland waters (42%).[1552]

Indicator 65: Recreational fishing

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		?			N/A	N/A

Data source:	Victorian Fisheries Authority, academic researchers
Measures:	Number of recreational fishers | Hours spent in recreational fishing Quantity of fish caught through recreational fishing | Environmental impacts of recreational fishing Preferred species | Fish restocking programs (quantity)

Why this indicator?

Recreational fishing provides a popular activity for people, contributing to their wellbeing. Increases in recreational fishing activity may lead to increased pressures on fisheries and the broader ecosystem. Management strategies and education are required to prevent such impacts. This indicator will explore the community benefits of fishing while assessing whether sustainable practices are being achieved.

Justification for assessment ratings:

- Increasingly, there are programs which aim to foster responsible fisher behaviour which enhances environmental outcomes. These range from legislative, regulatory and compliance measures through to citizen science programs which involve anglers in environmental research.
- While some data are available on recreational fishing, there remain gaps in our understanding of its scale and impact. This is partly due to the dispersed nature of the activity and a reliance on survey-based data.
- Lack of recreational fishing data means that it is not possible to connect our understanding of its overall impact on fish stocks and ecological wellbeing.

Recreational fishing involves fishing for pleasure rather than for financial gain. Research shows that recreational fishers gave more importance to non-catch related motives such as: to be outdoors, relaxation, the desire to get away from the normal routine, for sport, and to be with family.[1553,1554]

1550. Better Boating Victoria (BBV) https://betterboating.vic.gov.au/ Accessed 5 October 2020.
1551. Transport Safety Victoria, 'Boating behaviour report 2015', p. 24.
1552. Ibid. p. 26.
1553. Frijlink S and Lyle J 2010, 'An evaluation of motivations, attitudes and awareness of Tasmanian recreational fishers', Tasmanian Aquaculture and Fisheries Institute, University of Tasmania, Hobart.
1554. Griffiths S, Bryant J, Raymond H and Newcombe P 2017, 'Quantifying subjective human dimensions of recreational fishing: does good health come to those who bait?' *Fish and Fisheries*, 18, pp. 171-184.

Recreational fishing has been recognised as contributing to peoples' health and wellbeing.[1555] A Western Australian study completed in 2011 found that 80% of surveyed recreational fishers reported that recreational fishing was important or very important to their health and wellbeing.[1556] In 2018–19, an estimated 1.1 million adult Victorian residents participated in recreational fishing across the State. These fishers made 7.6 million recreational fishing trips across Victoria.[1557]

In 2018, the Victorian Fisheries Authority undertook a survey of fishing licence holders living in Victoria.[1558] A total of 14,121 respondents completed the survey. Eighty-two percent of respondents indicated that they had fished in a marine/estuarine location in the previous 12 months compared to 74% of respondents who had fished in an inland location. The preferred marine/estuarine fishing location was Port Philip Bay (52%) followed by Western Port (28%) and Gippsland Lakes (12%).

A formal assessment of the Western Port recreational fishery was undertaken in 2015. The assessment workshop was attended by:

- representatives from recreational and commercial fishing sectors
- Fisheries Victoria managers, scientists and compliance officers
- catchment management, university and conservation representatives.

The assessment used a weight-of-evidence approach based on recreational fishery survey data from boat ramp interviews collected over a 15-year period from 1998 to 2013. The stock assessment data presented at the workshop did not indicate need for a review of fishery management arrangements and participants supported maintaining the current management regime. Table 49 shows the assessments made in relation to key species targeted by recreational fishers.

Table 49: Recreational fishing in Western Port Bay – stock assessments.[1559]

Species	Recreational catch rates	Stock assessment	Factors
Elephant Fish	Trending downward	Contraction in distribution	Long-term variation may be linked to environmental change (for example, seagrass cover).
King George whiting	Trending upwards	Improving	
Snapper	Stable	Stable	
Flathead	Stable after long-term decline	Stable	Long-term decline though to have been caused by environmental factors
Gummy Shark	Trending upwards	Good	

1555. Ibid.
1556. McManus A, Hunt W, McManus J, and Creegan R., 2011, 'Investigating the health and well-being benefits of recreational fishing in Western Australia'. Centre of Excellence for Science Seafood and Health (CESSH), Curtin Health Innovation Research Institute, Perth, Western Australia.
1557. Better Boating Victoria (BBV) and Victorian Fisheries Authority (VFA) 2020, 'The economic value of recreational fishing and boating in Victoria', prepared by Ernst and Young.
1558. Victorian Fisheries Authority (VFA) 2018, 'Recreational fishing in Victoria. report of survey findings', Melbourne, Victoria.
1559. Melbourne Water 2018, 'Understanding the Western Port environment 2018. A summary of research findings from the Western Port environment research program 2011-2017 and priorities for future research', p. 75.

The Victorian government has encouraged recreational fishing activity through its Target One Million program which aims to get 'more Victorians fishing, more often'.[1560] The program covers both inland as well as coastal angling activities and includes initiatives such as:

- phasing out commercial fishing in the Gippsland Lakes
- investing in science and habitat restoration in the Gippsland Lakes
- stocking Lake Tyers with eastern king prawns
- improving recreational fishing infrastructure at locations in Geelong, Ocean Grove
- installing and upgrading fish cleaning tables
- investing in reef development in Port Phillip Bay to enhance fish habitat
- abolishing boat ramp parking and launching fees
- improving boat ramps, boating safety, infrastructure and facilities
- reviewing management of boating infrastructure in Port Phillip and Western Port.

Increasing numbers of recreational fishers requires additional management in terms of education. A recent increase of recreational fishing in New South Wales has been accompanied by injuries to wildlife caused by hooks, sinkers and lines which have been ingested by, or become entangled with, birds. Many birds affected by discarded tackle are unable to be caught by rescuers and even those treated do not always survive.[1561]

Other potential impacts of recreational fishing include pressure on particular target species. Restocking of fish is one measure through which recreational fishing can be supported. In 2019-20 over 6 million fish were released into Victorian coastal and inland waters, 84% of which were native species (Table 50). Coastal regions which received fish stocks included Barwon Southwest, Gippsland and Port Phillip (Table 51).

Table 50: Fish restocking levels in Victoria, 2017-18 to 2019-20.[1562]

	2017-18	2018-19	2019-20
Natives Total	4,883,336	5,974,816	5,131,235
Salmonids Total	1,203,019	1,022,400	1,000,793
Total	6,086,355	6,997,216	6,132,028

Table 51: Regional fish restocking levels in Victoria, 2019-20.[1563]

	Natives Total	Salmonids Total	Total
Barwon SW	633,095	301,650	934,745
Gippsland	477,300	44,500	521,800
Grampians	423,500	187,204	610,704
Hume	1,878,570	254,066	2,132,636
Loddon Mallee	1,528,211	168,382	1,696,593
Port Phillip	190,559	44,991	235,550
Grand Total	5,131,235	1,000,793	6,132,028

1560. Victorian Fisheries Authority (VFA) 2020, 'Target one million – phase 2', Melbourne, Victoria https://vfa.vic.gov.au/recreational-fishing/targetonemillion2/target-one-million Accessed 6 October 2020.
1561. Australian Broadcasting Corporation (ABC) 2021, 'Australian seabird rescue says wildlife is paying the price for fishing boom', written by Hannah Ross and Bruce Mackenzie, posted 15 July https://www.abc.net.au/news/2021-07-15/anglers-create-a-nightmare-for-seabirds/100294268 Accessed 19 July 2021.
1562. Victorian Fisheries Authority (VFA), various years, 'Recreational fishing licence trust account. a report to each house of parliament on the disbursement of recreational fishing licence revenue'.
1563. Ibid.

Recreational fisheries have management issues which differ from those of commercial fisheries. Fishing effort and catch are more difficult to monitor and enforcement is more difficult due to the large number of people involved, at different locations and different times. Key controls for recreational fisheries in Victoria include bag limits and size limits. Fishing licences are also required for all recreational fishers. Licence fees are allocated to projects that improve recreational fishing in Victoria.

According to the VFA survey of Recreational Fishing in Victoria:

- 39% of respondents indicated that enforcing fishing rules and improving fishing habitat would be an effective way to improve fishing in Victoria.
- Open ended commentary indicated that stopping or limiting commercial fishing, netting and trawling (especially in certain locations) would improve recreational fishing in Victoria as would improving pest control (carp and cormorants).
- More than a third of respondents (37%) answered that Victorian Fisheries Authority and Victorian natural resource management agencies should work together a great deal to create better fisheries and habitat in Victoria.
- When asked about particular agencies VFA should collaborate with, the three agencies most selected were Parks Victoria (67%), Department of Land, Water and Planning (58%), and Catchment Management Authorities (50%).
- 62% of respondents indicated that halting commercial netting in Port Phillip and Corio Bays had improved recreational fishing in Victoria since 2014.[1564]

According to findings from the VFA Licence survey report 2018, the top four fish species caught by recreational fishers in Victorian marine/estuarine areas were: snapper (45%), King George whiting (39%), flathead (other than dusky) (38%) and squid (24%). According to SAFS classification of fish stocks discussed in this report (Indicator 23: Commercially and recreationally important invertebrates and Indicator 24: Commercially and recreationally important fish), stocks of snapper, King George whiting and squid have been assessed as sustainable while sand flathead at Port Phillip Bay are assessed as recovering.[1565]

Stock assessments are the primary tools used to manage Victoria coastal and marine recreational and commercial fisheries. Stock assessments aim to measure the distribution, abundance, age structure and recruitment of target species to determine whether regulations are appropriate to ensure the stock is sustained and not over-fished. This is achieved by using multiple data sources and taking a weight of evidence approach. This includes data from commercial fishery catch and effort reporting, recreational fishery monitoring programs and scientific surveys.

Specific regulations may be adjusted on an annual basis to ensure management is responsive to variation in stock characteristics. These characteristics are often described in specific stock performance indicators which are prescribed in fishery managed plans. Catch Per Unit Effort (CPUE) is the most used proxy for biomass trends in stock assessments. CPUE reference levels represent the estimated biomass above which a stock is sustainably fished, or below which represents unsustainable fishing. These performance indicators are a critical component of the decision framework for the management of individual fisheries.

Recreational fishing activity has peaks of activity at specific times such as public holidays and fish seasons. During such times, congestion can occur around facilities such as boat ramps and enforcement officers may have difficulty operating. Peak fishing times can also result in conflict between different users of the marine environment.

The ecological impacts of fishing can be broken down into three categories:

- direct impact on fish stocks
- direct impacts on nontarget species (for example, discards, birds and mammals)
- general ecosystem effects.[1566]

1564. Victorian Fisheries Authority (VFA) 2018, 'Recreational fishing in Victoria, report of survey findings', Melbourne, Victoria. p. 2.
1565. Fisheries Research and Development Corporation (FRDC) 2018, 'Status of Australian fish stocks' https://www.fish.gov.au/reportstock?kw=sand+flathead&page=1&sort=LatestFirst Accessed 29 March 2021.
1566. Ford J and Gilmour P 2013, 'The state of recreational fishing in Victoria: a review of ecological sustainability and management options, a report to the Victorian National Parks Association, Melbourne'.

In general, our understanding of the direct impacts is far greater than that of ecosystem effects. A 2013 report on the State of Recreational Fishing in Victoria prepared for the Victorian National Parks Association found that in many cases there is a lack of monitoring systems to detect ecological impacts, or simply insufficient understanding of the natural fluctuations of ecosystems to be certain of the impacts. The report stated that, despite the lack of monitoring, the magnitude and nature of recreational fishing pressure suggest that it can and does impact on marine ecosystems.[1567] Further information on the sustainability of fisheries is provided in the discussion for Indicator 23: Commercially and recreationally important invertebrates, and Indicator 24: Commercially and recreationally important fish.

Although most Australian states undertake state-wide recreational fishing surveys, Victoria relies on regional catch rate surveys. The most recent national recreational catch survey was undertaken in 2001.[1568] A national social and economic survey of recreational anglers was undertaken during 2019-20 and collected data are currently being analysed. This should provide a clearer picture of Victoria's recreational catch.

Improvements in technology have intensified the pressure from recreational fishing. For example, improved hooks and lures, boat-based technology, phone apps and social media platforms have enabled anglers to improve their catch.[1569] Data on recreational fishing catch can have limitations which mean they are generally not used to estimate stock size or species abundance. Catches can be affected by various contextual factors and can sometimes increase or appear stable even while fish numbers decline. This can occur when fishing expands into unexploited areas, targets different species or exploits fish spawning aggregations.[1570]

Seagrasses are a haven for fish targeted by recreational fishers. As a preferred location for recreational fishing, seagrass in Melbourne's two most popular coastal bays, Port Phillip and Western Port, provide a nonmarket recreational benefit estimated at $33.1 million per annum.[1571] Further information on seagrass habitat is provided in the discussion for Indicator 34: Seagrass.

1567. Ibid.
1568. Henry G and Lyle J (eds) 2003, 'The national recreational and Indigenous fishing survey', Fisheries Research and Development Corporation (FRDC) project no. 99/158, Commonwealth of Australia, Canberra.
1569. Cooke S, Venturelli P, Twardek W, Lennox R, Brownscombe J, Skov C, Hyder K, Suski C, Diggles B, Arlinghaus R and Danylchuk A 2021, 'Technological innovations in the recreational fishing sector: implications for fisheries management and policy', *Reviews in Fish Biology and Fisheries*, 31, pp. 253–288.
1570. Erisman B, Allen L, Claisse J, Pondella D, Miller E, Murray J and Walters C 2011, 'The illusion of plenty: Hyperstability masks collapses in two recreational fisheries that target fish spawning aggregations', Canadian *Journal of Fisheries and Aquatic Sciences*, 68(10), pp. 1705–1716 https://doi.org/10.1139/f2011-090
1571. Carnell PE, Reeves SE, Nicholson E, Macreadie P, Ierodiaconou D, Young M, Kelvin J, Janes H, Navarro A, Fitzsimons J, Gillies CL 2019, 'Mapping ocean wealth Australia: the value of coastal wetlands to people and nature', The Nature Conservancy, Melbourne, p. 19.

Indicator 66: Shipping and ports

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide					N/A	N/A

Data source:	Bureau of Infrastructure and Transport Research Economics; Department of Infrastructure, Transport, Regional Development and Communications; Port of Melbourne, Gippsland Ports, Department of Agriculture, Water and the Environment
Measures:	Volume of shipping | Value of shipping Stormwater and ballast discharge | Number of spills and pollution events Introduction of pest species through ballast and biofouling | Channel dredging

Why this indicator?

Shipping is an important economic indicator for global trade. It requires an effective regulatory framework to minimise negative environmental impacts such as pollution or the introduction of pest species into marine and coastal ecosystems.

Justification for assessment ratings:

- Shipping continues to be an important part of Victoria's transport system and the associated trade flows make a positive contribution to the Victorian economy.
- Some of the risks associated with shipping, for example oil spills, represent low probability – high consequence events. It is therefore difficult to use past data to determine the likelihood of future events. However, the potential for major impacts from such events requires effective regulatory regimes and emergency response systems. Victoria has both of these, but diligence is still required to maintain their readiness for unexpected events.
- The increase in environmental reporting and use of sustainable development goals as a framework among port authorities is a positive development although it is too early to have a long enough time series of data to determine trends regarding environmental impact.
- Introduction of pest species remains a significant threat which could undermine environmental quality.

The marine and coastal environment contains many different industries that are vital employers and sources of prosperity for Victorians. They include well-established industries such as shipping and ports, commercial fishing, aquaculture, and gas and petroleum extraction, as well as emerging industries such as renewable energy production and storage, and carbon sequestration. These industries rely on a healthy marine and coastal environment for their ongoing success.[1572] In addition to these industries are many small businesses that supply inputs and provide services for coastal and marine-based industries.

The Marine and Coastal Policy states that the use of the marine and coastal environment by industry should be ecologically, socially and economically sustainable.[1573]

Ports

Ports generate significant levels of economic activity. They are the foci of trade which enables wealth generating exports and imports. They provide employment and can offer tourism opportunities and support recreational activities such as boating and fishing. In 2021, Ports Victoria was established following the Victorian Government's Independent Review of the Victorian Ports System.[1574] The establishment of this agency aimed to overcome some of the confusion and duplication which had been identified through the inquiry, thus enhancing the governance arrangements of ports.[1575] Ports Victoria is leading the strategic management and operation of Victorian commercial ports and waterways.

1572. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Marine and coastal policy', East Melbourne, Victoria.
1573. Ibid.
1574. Victorian Ports 2021, 'VPCM and VRCA to combine as Ports Victoria', article date 3 March 2021 https://www.vicports.vic.gov.au/News/Pages/ports-victoria-establishment.aspx Accessed 1 July 2021.
1575. Department of Transport (DoT) 2021, 'Independent review of the Victorian ports system – initial government response', Melbourne, Victoria https://transport.vic.gov.au/ports-and-freight/commercial-ports Accessed 1 July 2021.

Victoria is serviced by four major ports (Melbourne, Geelong, Portland and Hastings) as well as a number of local ports which cater for the commercial fishing industry and other boating interests (Figure 123).

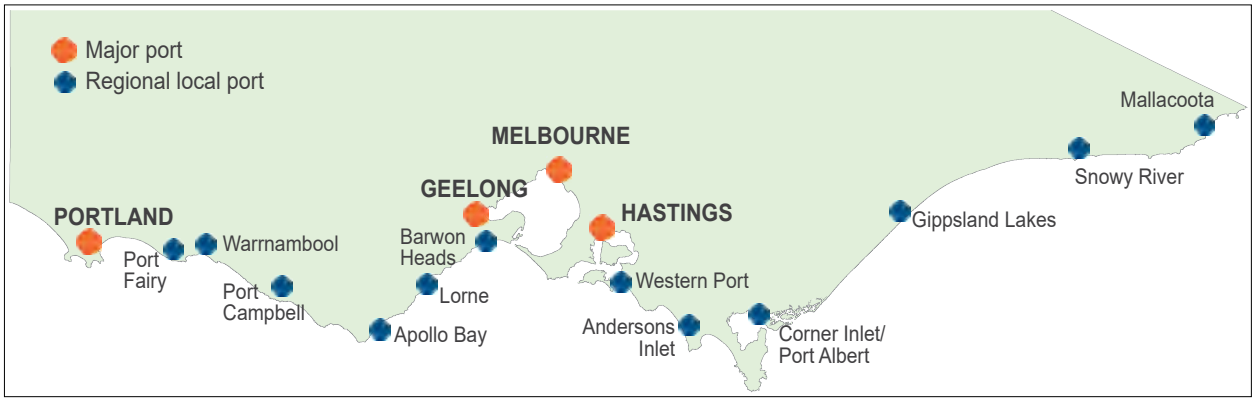


Figure 123: Victoria's coastal ports.[1576]

Victoria's major ports include:

Port of Melbourne:
The Port of Melbourne is Australia's largest maritime hub for containerised and general cargo. In 2018-19, over a third of the 3,000 commercial ships visiting the port were servicing the container trade.[1577]

Port of Geelong:
The Port of Geelong is Victoria's second biggest port, handling more than 10 million tonnes of product annually and dealing with around 600 vessel visits each year. Its main commodities include crude oil, woodchips, fertiliser and break-bulk cargo.

Port of Hastings:
The Port of Hastings, located on Western Port Bay, offers the deepest shipping channel in Victoria. It handles around 1.5 million tonnes of petroleum products, oil, gas, and steel across four jetty complexes: BlueScope Wharves, Long Island Point Jetty, Crib Point Jetty, and Stony Point.[1578] Stony Point also acts as access point for ferry services to French and Phillip Islands.

Port of Portland:
The Port of Portland is Victoria's only naturally deep-water port. It specialises in bulk commodities, particularly agricultural, forestry and mining products as well as aluminium and fertiliser. It receives 300 ships per annum and deals with 7.5 million tonnes of exports and imports annually. Portland is also a major fishing port.[1579]

The major functions of the local ports across Victoria are to provide safe havens and services to the commercial fishing industry, charter boats, and recreational fishing and boating interests. These local ports are managed by several different entities. The Gippsland Ports Committee of Management Inc is responsible for five local ports: Gippsland Lakes, Corner Inlet and Port Albert, Snowy River, Mallacoota and Anderson Inlet. A number of ports are managed by local councils including Portland Bay (Glenelg Shire Council), Port Fairy (Moyne Shire Council), Warrnambool (Warrnambool City Council) and Apollo Bay (Colac-Otway Shire Council). Parks Victoria manages local ports at Port Phillip, Western Port and Port Campbell while Lorne is managed by the Great Ocean Road Coast and Parks Authority and Barwon Heads by the Barwon Coast Committee of Management.

1576. Department of Transport (DoT) 2021, 'About Victoria's commercial ports' https://transport.vic.gov.au/ports-and-freight/commercial-ports Accessed 1 July 2021.
1577. Department of Transport (DoT) 2021, 'Commercial shipping' https://www.portofmelbourne.com/port-operations/commercial-shipping/ Accessed 1 July 2021.
1578. Port of Hastings Development Authority 2019, 'Annual report 2018/19'.
1579. Port of Portland https://www.portofportland.com.au/ Accessed 1 July 2021.

Global shipping volumes have increased rapidly in recent decades and, prior to the coronavirus pandemic, were forecast to increase by 240% to 1209% by 2050 (Figure 124).[1580] In Victoria, there has been an overall increase in the number of cargo ships making port calls in Victoria with an average annual growth rate of 1.2% (Victoria) and 1.5% (Melbourne) over the two decades since 1999-2000.

In 2018-19, 1,359 cargo ships made port calls in Victoria with just over half of these (791 = 58.2%) calling into the Port of Melbourne. The number of port calls was 4,290 for Victoria with 3,270 (76.2%) being to Melbourne. Declines in shipping volumes were seen in 2008-09 and 2009-10 (Global Financial Crisis) and 2019-20 (COVID pandemic) highlighting the relationship between shipping volumes and global economic conditions.

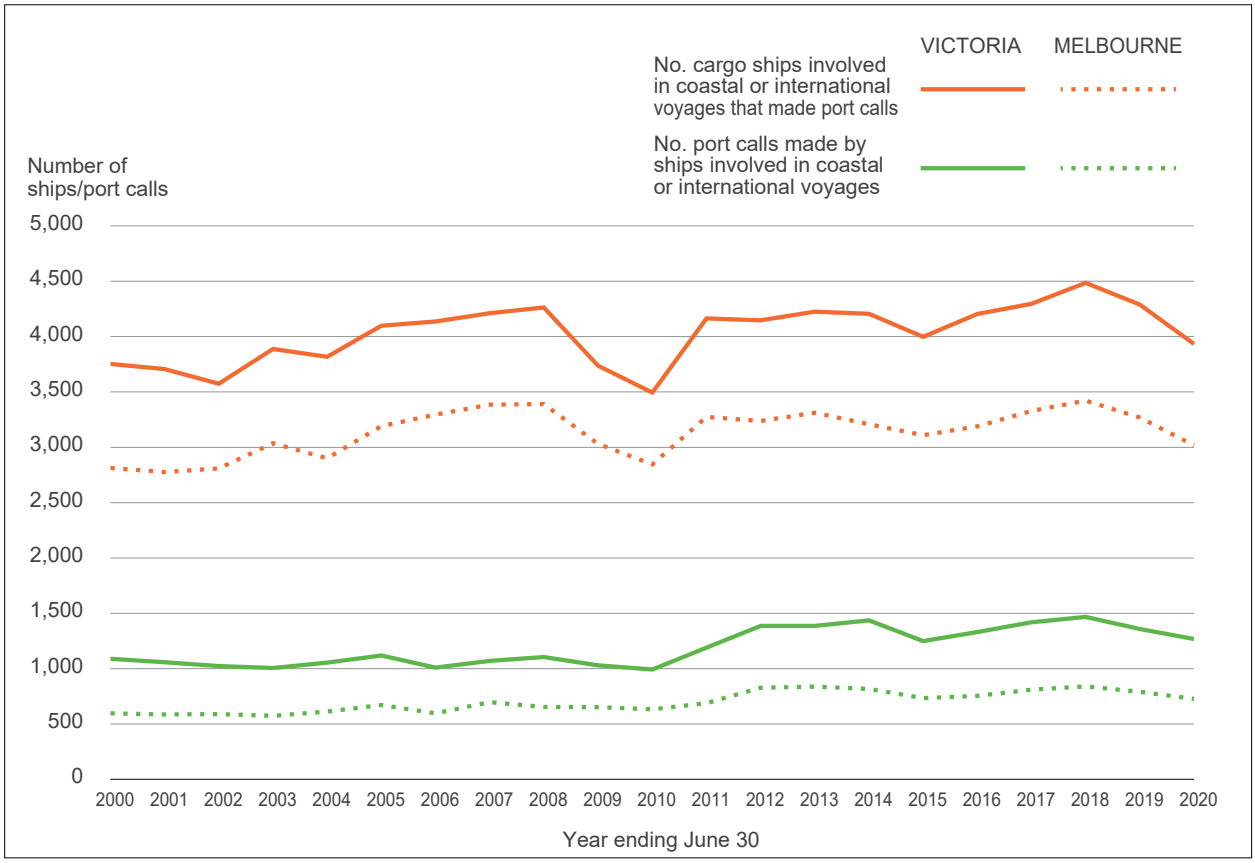


Figure 124: Volume of Shipping, Victoria and Melbourne 1999–00 to 2019–20.[1581]

The value of international shipping through Victoria's ports represents billions of dollar of trade value. In 2016-17, $60.1 billion worth of shipped imports had their final destination in Victoria while $20.1 billion of shipped goods were exported from Victoria (Figure 125). As with trade volumes, there has been impact from global events such as the GFC during which imports fell from $57.3 billion (2008-09) to $51.8 billion (2009-10), however, the overall trend between 2007-08 and 2016-17 was one of growth for imports to Victoria at an average of 0.6% per annum, and a decline for exports from Victoria of -0.5% per annum.

1580. Sardain A, Sardain E and Leung B 2019, 'Global forecasts of shipping traffic and biological invasions to 2050', *Nature Sustainability*, 2, pp. 274-282.
1581. Bureau of Infrastructure and Transport Research Economics (BITRE) 2020, 'Australian infrastructure statistics—yearbook 2020', Department of Infrastructure, Transport, Regional Development and Communications, Canberra. Data are BITRE estimates based on Lloyds List Intelligence data.

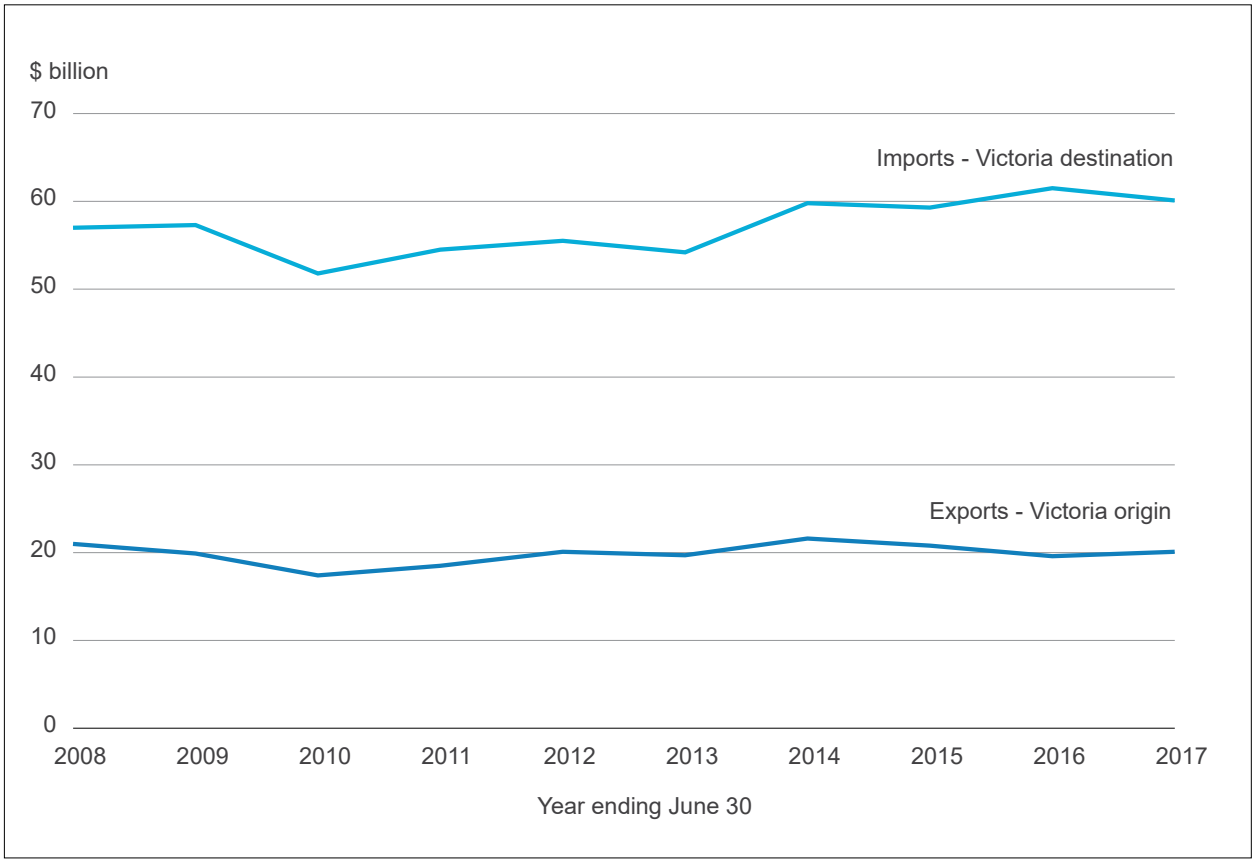


Figure 125: Value of international sea freight, Victoria imports and exports (2016–17 prices).[1582]

The amount and nature of activity generated by ports can also pose risks for the environment.[1583] These may include:

- impacts of channel dredging on marine habitats
- oil spills
- potential for toxic spills where fuels or chemicals are being stored or transported
- release of pollutants ranging from litter to pest species in ballast water
- introduction of pest species through biofouling of vessels
- noise impacts
- air pollution
- impact of shipping and boating wakes on foreshore environments.

Dredging

Dredging activities are generally undertaken to maintain or widen shipping channels into ports. This type of channel maintenance has responded to trends in global shipping design which continues to move to wider and longer vessels. While dredging has potential negative impacts, larger shipping volumes per vessel can have a lower environmental footprint (for example in fuel use) per trade volume.

1582. Bureau of Infrastructure and Transport Research Economics (BITRE) 2019, 'Australian sea freight 2016-17', Department of Infrastructure, Transport, Regional Development and Communications, Canberra. Figures are presented in real terms, adjusted for price changes using CPI. Includes ship stores and non-merchandise trade.
1583. Tull M 2006, 'The environmental impact of ports: an Australian case study', paper presented at the XIV International Economic History Congress (session no. 58), Helsinki, Finland, 21-25 August 2006.

Dredging activities were undertaken in 2019-20 in the Port of Melbourne and South Channel. This dredging was approved by DELWP and conducted in accordance with the Dredging Environmental Management Plan. It was undertaken to maintain safe access for commercial shipping into the Port. The dredging campaign was timed to follow the completion of the migration of juvenile Australian grayling from Hobsons and Port Phillip Bays to the Yarra River. The grayling is a native freshwater fish listed as vulnerable. By delaying the dredging, turbidity was reduced which facilitated successful fish migration.[1584] While dredging impact cannot be reduced to zero, this example shows that careful timing can minimise certain negative effects on the local ecosystem. It also highlights the importance of fully understanding lifecycles of fish and other marine species so that appropriate management decisions can be taken in relation to human activities. While mitigation efforts can lessen the impact of dredging, there are some effects that still occur. Prior to the dredging for the Port of Melbourne, it was recognised that the project would result in projected changes in tidal heights around the Bay, ranging from a reduction of two millimetres to an increase of eight millimetres.[1585]

DELWP (and some local councils) are increasingly using dredging as part of beach renourishments across Port Phillip Bay. These involve smaller quantities of material than those for channel deepening with recent beach renourishment at Dromana involved 43,000 cubic metres of sand dredged onto the beach.[1586]

Lakes Entrance is home to the largest commercial fishing fleet in Victoria and is also used by recreational vessels. A permanent entrance connecting the Lakes to Bass Strait was constructed in 1889. Sand from the Ninety Mile Beach naturally accumulates around the entrance and dredging of this sand is an ongoing activity required to maintain safe navigation for vessels. Gippsland Ports undertakes the dredging to maintain ocean access. The ongoing maintenance program involves relocating an estimated 200,000 to 300,000 cubic metres of oceanic sand annually, mostly from the Lakes Entrance Bar.[1587] Smaller-scale dredging for maintenance of inner channels is undertaken when required. Dredging volumes have decreased since the early 2000s (Figure 126).

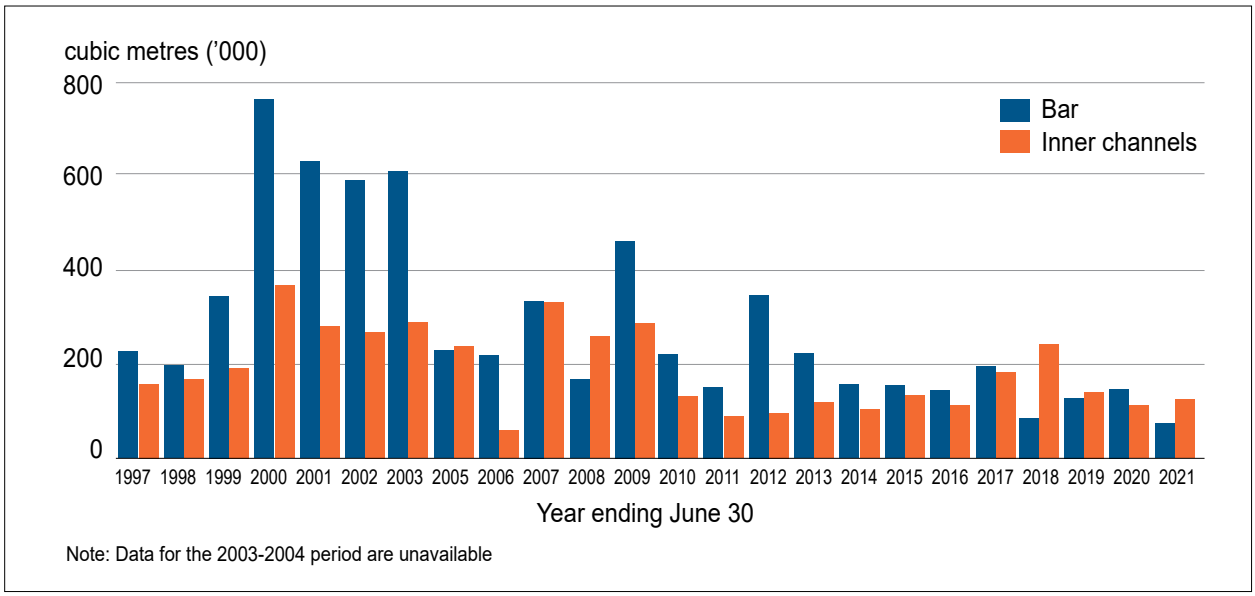


Figure 126: Historic dredging volumes at Lakes Entrance, 1996-97 to 2020-21.[1588]

1584. Port of Melbourne 2020, 'Sustainability report based on financial year 2020', p. 38.
1585. Sampson J, Easton A and Singh M 2005, 'Modelling the effect of proposed channel deepening on the tides in Port Phillip Bay', *Australia and New Zealand Industrial and Applied Mathematics Journal*, 46, pp. C888-C901.
1586. Senior coastal programs officer, DELWP, personal communication, 12 July 2021.
1587. Gippsland Ports 2021, 'Sand management' https://www.gippslandports.vic.gov.au/ports-and-waterways/sand-management/ Accessed 16 July 2021.
1588. Gippsland Ports 2021, 'History of dredging the entrance to Gippsland Lakes, fact sheet', p. 4.

While maintenance of channels is important for life safety and the facilitation of economically valuable activities, the process of dredging is often the subject of concern in relation to environmental impacts. Turbidity is a key concern due to its potential negative effects on marine life. Gippsland Ports has developed an Environmental Management Plan (EMP) which outlines when, where and how dredging is to occur and how obligations under Victorian and Commonwealth laws are to be met. The EMP employs risk minimisation approaches such as setting threshold levels of turbidity that must not be exceeded during the grayling migration period from September to January. This period also encompasses some of the summer period of higher recreational use by people, hence the limits on operations also avoid potential negative impacts of turbidity for recreational users. Dredging is required to occur in specific zones and operations are monitored via GPS tracking to ensure compliance.[1589] The environmental auditing regime has shown an improvement in compliance since 2011 (Table 52).

Table 52: Environmental audit results for dredging in Gippsland Ports.[1590]

Year	Proportion (%) of total audit criteria					
	Fully compliant	Compliant but needs improvement	Minor non-compliance	Major non-compliance	Critical non-compliance	Undeterminined
2011	4,883,336	5,974,816	5,131,235	4,883,336	5,974,816	5,131,235
2012	1,203,019	1,022,400	1,000,793	1,203,019	1,022,400	1,000,793
2013	4,883,336	5,974,816	5,131,235	4,883,336	5,974,816	5,131,235
2014	1,203,019	1,022,400	1,000,793	1,203,019	1,022,400	1,000,793
2015	4,883,336	5,974,816	5,131,235	4,883,336	5,974,816	5,131,235
2016	1,203,019	1,022,400	1,000,793	1,203,019	1,022,400	1,000,793
2018	4,883,336	5,974,816	5,131,235	4,883,336	5,974,816	5,131,235

Oil spills

Some events, such as major oil spills, are rare but have the potential to be catastrophic in terms of environmental impact. Assessing emergency response procedures and preventative policies is necessary to minimise the likelihood of any such risk.

The Australian Maritime Safety Authority has responsibility for vessel condition monitoring and responding to oil spills in Commonwealth Waters. The Victorian Department of Transport assists with the mitigation of, and response to, maritime oil spills. It is the control agency for larger marine pollution oil spills in Victorian coastal waters while local spill incidents are the responsibility of port managers and facility operators.[1591]

In terms of recorded major oil spills in Victoria, the Australian Maritime Safety Authority list only four. Three of these occurred during the 1980s and 1990s but there have been none this century (Table 53). Although these events are rare, there are organised response plans in place to minimise or mitigate any damage. Planning and training exercises are carried out at national and state level in Australia.

1589. Gippsland Ports 2015, 'Gippsland Lakes ocean access environmental management plan', p. 22.
1590. EthosNRM 2019, 'Gippsland Lakes ocean access maintenance dredging 2018: independent audit of environmental management plan. Final audit report Gippsland Ports', p. 13.
1591. Emergency Management Victoria (EMV) 2020, 'State emergency management plan, roles and responsibilities' https://www.emv.vic.gov.au/responsibilities/semp/roles-and-responsibilities/role-statements/dot Accessed 10 March 2021.

Table 53: Major historical oil spill incidents in Victorian waters.[1592]

Date	Vessel	Location	Amount of oil
28 November 1903	Petriana	Port Phillip Bay, Victoria	1,300 tonnes
28 July 1988	Al Qurain	Portland, Victoria	184 tonnes
21 May 1990	Arthur Phillip	Cape Otway, Victoria	unknown
18 December 1999	Sylvan Arrow	Wilson's Promontory, Victoria	less than 2 tonnes

Aside from shipping as a source of oil spills in marine areas, pollution events may also arise from offshore oil and gas platforms. Prevention and management of such risks in Commonwealth waters is the responsibility of the National Offshore Petroleum Safety and Environmental Management Authority. They may also be given responsibilities within state waters, as is the case in Victoria which conferred responsibilities to the national agency in 2013.[1593]

In 2019-20, two minor pollution incidents in the Port of Melbourne were reported to the regulators. Clean up responses were initiated, and no significant water quality issues were reported.[1594]

Introduced species

Shipping is recognised as a pathway through which exotic species may be transported between ecosystems. This can occur via ballast water contamination or through biofouling of ships' hulls. These pathways together are estimated to account for 60-90% of marine bioinvasions.[1595]

Ballast water is carried in empty hulls of ships to ensure stability at sea. Ballast water which is loaded overseas and brought to Australia can contain unwanted microorganisms or marine species which in some cases cause serious environmental problems. Other species can accumulate on the hulls of ships causing biofouling. Exotic fish, worms, molluscs, seaweed and toxic algae have been introduced to Australia in ballast water or on the hulls of ships. There are now more than 250 exotic species known to be present in the Australian marine environment. About one in six introduced marine species become pests.[1596] The risks associated with ballast water can be addressed through water treatment prior to release while biofouling can be limited through hull cleaning and the use of anti-fouling paints.[1597] Further information on pest species is provided in the assessment for Indicators 56: Invasive Marine Species.

Management responses

A variety of standards, guidelines and strategies have been developed to mitigate risks associated with shipping and ports. The International Convention for the Control and Management of Ships' Ballast Water and Sediment places obligations on vessels to manage ballast water to reduce the translocation of invasive marine species.[1598] Australian commercial shipping standards assist in maintaining vessel safety, thus minimising the risk of potential accidents, such as oil spills.[1599] The Australian Government's *Biosecurity Act 2015* deals with ballast water and marine pests.[1600] The Australian Ballast Water Management Requirements set out the obligations on vessel operators with regards to the management of ballast water and ballast tank sediment when operating within Australian seas.[1601]

1592. Australian Maritime Safety Authority (AMSA) 2021, 'Major historical incidents - a summary list of major historical oil spill incidents' https://www.amsa.gov.au/marine-environment/incidents-and-exercises/major-historical-incidents Accessed 10 March 2021.
1593. Emergency Management Victoria (EMV) 2020, 'Role statement - National Offshore Petroleum Safety and Environmental Management Authority' https://www.emv.vic.gov.au/responsibilities/semp/roles-and-responsibilities/role-statements/nopsema Accessed 10 March 2021.
1594. Port of Melbourne 2020, 'Sustainability report based on financial year 2020', p. 40.
1595. Sardain A, Sardain E and Leung B 2019, 'Global forecasts of shipping traffic and biological invasions to 2050', *Nature Sustainability*, 2, pp. 274-282.
1596. Department of Agriculture, Water and the Environment (DAWE) 2021, 'The introduction of marine pests to the Australian environment via shipping', Australian Government, Canberra https://www.environment.gov.au/biodiversity/threatened/nominations/ineligible-ktp/introduction-marine-pests-via-shipping Accessed 23 February 2021.
1597. Hewitt C, Gollasch S and Minchin D 2009, 'The vessel as a vector – biofouling, ballast water and sediments', pp. 117-131 in G Rilov and J Crooks (eds), 'Biological invasions in marine ecosystems, ecological, management, and geographic perspectives', Ecological Studies 204, p 127.
1598. International Maritime Organisation 2004, 'The international convention for the control and management of ships' ballast water and sediments', adopted: 13 February 2004, entry into force 8 September 2017 https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Control-and-Management-of-Ships%27-Ballast-Water-and-Sediments-(BWM).aspx Accessed 6 July 2021.
1599. Australian Maritime Safety Authority (AMSA) 2021, 'National standard for commercial vessels (NSCV)', Australian Government, Canberra https://www.amsa.gov.au/about/regulations-and-standards/national-standard-commercial-vessels-nscv Accessed 1 July 2021.
1600. Australian Government, 'Biosecurity Act 2015', no. 61, compilation no. 8 incorporating amendments up to 25 March 2020 https://www.legislation.gov.au/Details/C2020C00127 Accessed 6 July 2021.
1601. Department of Agriculture, Water and the Environment (DAWE) 2020, 'Australian ballast water management requirements version 8', Australian Government, Canberra.

To minimise the risks associated with marine pests, the Australian government, in conjunction with state and territory governments, industry, research organisations and non-government organisations, has released MarinePestPlan 2018-2023.[1602] The five objectives of the plan are to:

- minimise the risk of marine pest introductions, establishment and spread
- strengthen the national marine pest surveillance system
- enhance Australia's preparedness and response capability for marine pest introductions
- support marine pest biosecurity research and development
- engage stakeholders to better manage marine pest biosecurity.

National guidelines exist to address issues such as biofouling,[1603] while State Government has strategies covering emergency preparedness.[1604] Cooperation and coordination between agencies can enhance emergency preparedness, including the development and regular review of agreed emergency response arrangements, and ensuring adequate training and capacity.

Response to invasive pest species is addressed through the State Emergency Management Plan (SERP) Biosecurity Sub-plan. This plan describes the integrated approach and shared responsibility between state and commonwealth governments, agencies, business and the community in responding to biosecurity emergencies which may include: new invasive plant and animal incursions, and rapid increases in established pest populations.[1605]

At a more local level, ports have become more proactive in environmental monitoring and reporting. The Port of Melbourne, for example, has released a sustainability report which uses the UN SDG framework in its approach.[1606] The Strategy identifies ways in which it can help protect the environment, for example: supporting marine pollution cleanup activities, using Environment Management Plans to identify risks to ecosystems from construction; supporting surveys to detect invasive marine species in and around port waters, and undertaking protective environmental management of ecologically sensitive areas within port zones.

Other initiatives to address environmental concerns include:

- monitoring of noise and vibration levels to identify the specific sources of noise emissions that are of concern to some people in the surrounding residential community
- air quality assessments to maintain compliance with EPA Victoria and AMSA requirements and dust monitoring of major construction activities and dry bulk cargo that may have negative impacts on air quality
- regular monitoring of groundwater wells across the Port to provide information on potential high environmental risk sites
- provision and maintenance of rock revetments to protect water quality from increased sedimentation from riverbank scour and erosion
- ensuring that any waste waters in vessels' bilge tanks are only discharged in accordance with the Ports Victoria and EPA requirements
- maintenance of gross pollutant traps, shut-off valves and interceptor pits to help mitigate potential harmful materials such as pollutants or litter entering the water from stormwater.[1607]

1602. Department of Agriculture and Water Resources (DAWR) 2018, 'MarinePestPlan 2018-2023: the national strategic plan for marine pest biosecurity', Canberra, Australia.
1603. Department of Agriculture, Water and the Environment (DAWE) 2015, 'Anti-fouling and in-water cleaning guidelines', Australian Government, Canberra.
1604. Emergency Management Victoria (EMV) 2016, 'State maritime emergencies (non-search and rescue) plan, a subplan within the State Emergency Management Plan (SEMP) 2020', Melbourne, Victoria https://www.emv.vic.gov.au/responsibilities/semp-sub-plans/state-maritime-emergencies-non-search-and-rescue-plan Accessed 1 July 2021.
1605. Emergency Management Victoria (EMV) 2018, 'State emergency response plan. biosecurity sub-plan, edition 1.1', p. 11. Note that the State Emergency Response Plan (SERP) has been superseded by the State Emergency Management Plan (SEMP) which incorporates existing Subplans from the SERP.
1606. Port of Melbourne 2018, 'Sustainability report'.
1607. Port of Melbourne 2020, 'Sustainability report based on financial year 2020', p. 39.

Geelong Port has an environmental strategy which it released in 2019.[1608] The strategy includes long-term environmental objectives which address: water use, stormwater discharge, renewable energy, carbon emissions, noise levels, dust, waste generation, environmental spills, land protection and environmental leadership. In 2021, Geelong Port was formally certified to ECO SLC Port Environmental Review System, the second port in Australia (after Newcastle) to become certified.[1609]

Gippsland Ports has a Safety and Environmental Management Plan as required by the *Port Management Act 1995 (Victoria)*. This plan addresses the following environmental issues: dredging and sand management, refuelling, marine pests, sewage and waste disposal, marine pollution, and damage from boating wake.[1610]

Indicator 67: Commercial fishing

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		→			N/A	N/A

Data source:	ABS, Fisheries Research and Development Corporation, Victorian Fisheries Authority, academic researchers
Regions:	Statewide (SW)
Measures:	Value of commercial fishing production | Quantity of commercial fishing production Employment in fishing-related industries | Cetacean entanglements

Why this indicator?

Most commercial fishing is reliant on healthy marine and coastal environments. It also provides valuable economic activity and employment. This indicator provides measures to assess whether the industry is ecologically, socially and economically sustainable.

Justification for assessment ratings:

- Commercial fishing continues to be an important part of the Victorian economy (domestic and export).
- Commercial fishing relies on healthy marine and coastal environments. Regulatory and management regimes aim to balance resource demand and environmental health.
- While Victoria's fisheries management systems are more effective than in many other parts of the world, there are still some threats evident such as: overfishing, illegal and unreported fishing, introduction of pests, bycatch and entanglements.

The economic value of commercial fisheries in Victoria is smaller than many other sectors when measured in terms of output or monetary value. It is also relatively small when compared to other states of Australia (Figure 127). However, the availability of healthy, local seafood provision is valued highly by many in the community who wish to consume, but not catch, their own fish. Furthermore, for some coastal communities there are significant flow-on effects that support local communities such as processing plants, transportation of the produce, bait, boat and dive accessories and repairs. These services can be important sources of employment for local communities. Seafood production adds to the diversity of economic opportunities, which is critical for economic resilience in regional towns, especially in places where there are few alternative industries and where it can alleviate dependence on large sectors and companies.

1608. GeelongPort 2019, 'GeelongPort environmental strategy', p. 7.
1609. GeelongPort 2021, 'GeelongPort environment policy' https://geelongport.com.au/hseq/environment/#:~:text=GeelongPort%20is%20committed%20to%20ensuring,Nurturing%20our%20port%20land Accessed 2 July 2021.
1610. Gippsland Ports 2020, 'Environment' https://www.gippslandports.vic.gov.au/ports-and-waterways/environment/ Accessed 24 August 2020.

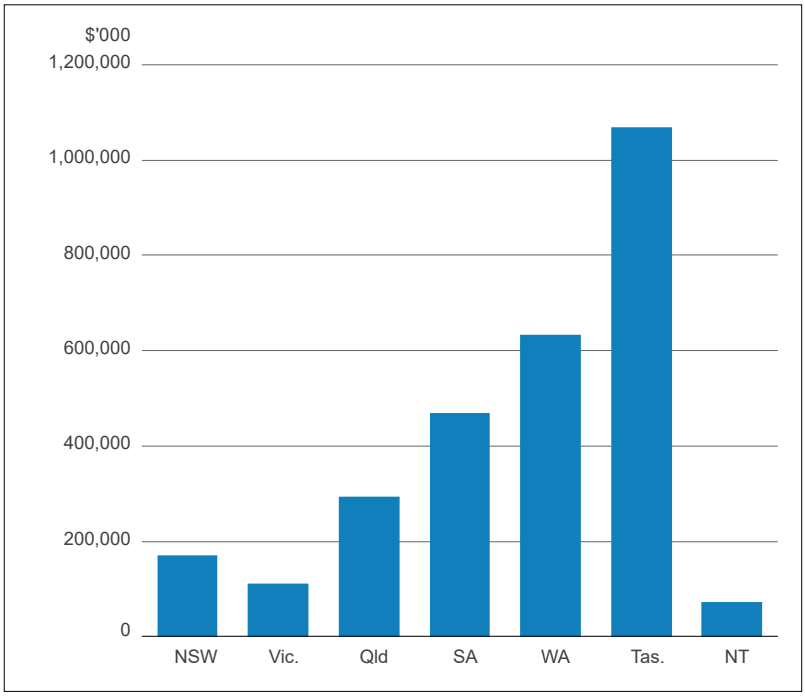


Figure 127: Value of fisheries industry, Australian States and Territories, 2017-18.[1611]

Australian fisheries statistics provide a timeseries overview of commercial fishing production. Since the late 1990s, the quantity of fish caught commercially in Victoria has declined from a total of 5,301 tonnes in 1998-99 to 3,961 in 2017-18 (Figure 128). Fluctuations in the annual catch are evident with total catch ranging from 6,404 (2007-08) to 3,802 (2014-15). Part of the reason for falling catch rates relates to policy decisions which have allocated a larger portion of fisheries resources to recreational fishing in Victorian bays and inlets. In 2000, Anderson Inlet, Shallow Inlet and Tamboon Inlet were closed to professional fishing. This was followed by closure of Lake Tyers and Mallacoota Inlet (2003), Western Port Bay (2007), and Gippsland Lakes (2020). Commercial netting was banned from Corio Bay in 2018 and will be phased out in the rest of Port Phillip Bay in 2022.

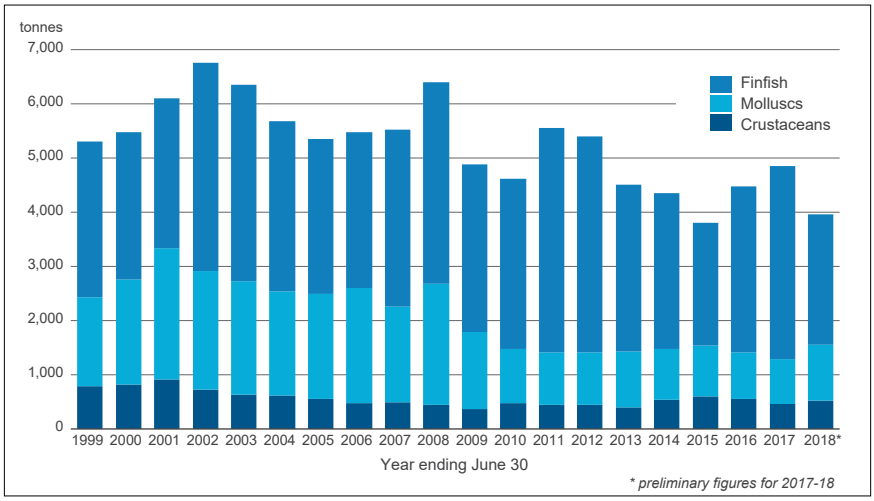


Figure 128: Quantity caught by Victorian commercial fisheries 1999-20 to 2017-18.[1612]

1611. Steven A, Mobsby D and Curtotti R 2020, 'Australian fisheries and aquaculture statistics 2018', Fisheries Research and Development Corporation (FRDC) project 2019-093, ABARES, Canberra.
1612. Ibid.

Just as there has been variation in the quantity of fish caught, there has also been variability in the value of Victoria's wild catch (Figure 129). While quantity can be affected by natural variation in species availability and the management regimes controlling the amount able to be caught, the value of fisheries is also affected by market forces and changing consumer preferences. Hence the graph shows a somewhat different pattern to that showing quantity.

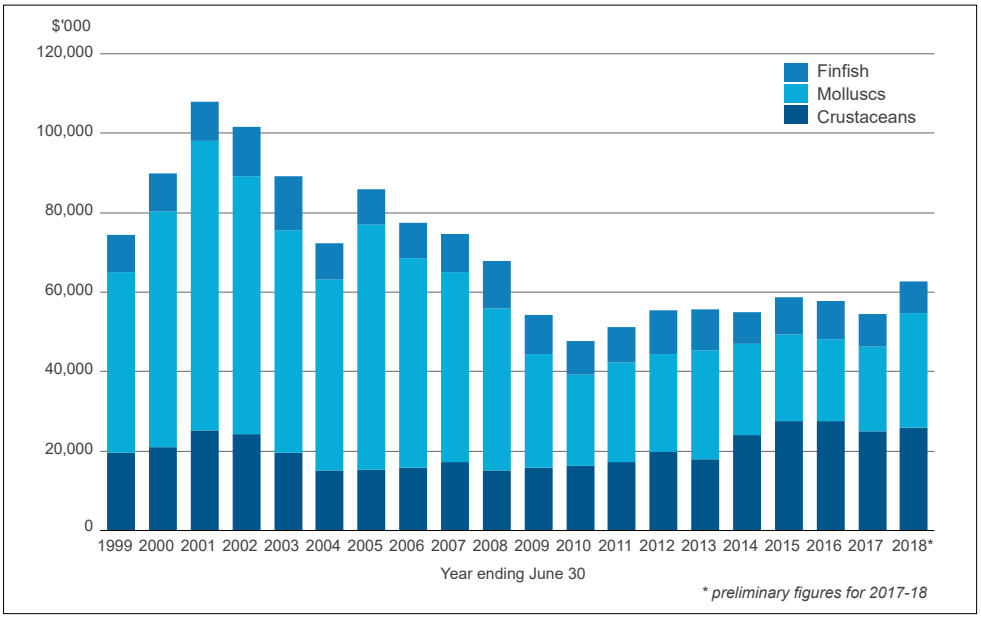


Figure 129: Value of Victorian commercial fisheries 1999-20 to 2017-18.[1613]

Finfish made up the majority of Victoria's wild catch. In 2017-18 these represented 61% of Victoria's catch with Australian sardines and salmons being the main species fished. Molluscs accounted for 26% of the catch, mainly Abalone, while Crustaceans accounted for 13% of Victoria's catch, notably southern rock lobster and prawns.

The economic contribution of commercial fishing to the Victorian economy is shown in Table 54. State and Commonwealth fisheries provided $101 million of gross production value and added value of $223 million. More than two thousand jobs (FTE) were provided in the industry, which translated into $129 million in household income.

Table 54: Economic contribution of professional fishing (state and Commonwealth fisheries operating in Victoria) to Victoria for the financial year 2016-17.[1614]

Sector	Gross production value ($mill)	Added value ($mill)	Household income ($mill)	Full-time equivalent jobs
State professional fisheries	54	112	55	909
Commonwealth professional fisheries	48	111	74	1,205
TOTAL	102	223	129	2,114

1613. Ibid.
1614. Abernethy K, Barclay K, McIlgorm A, Gilmour P, McClean N, Davey J 2020, 'Victoria's fisheries and aquaculture: economic and social contributions', Fisheries Research and Development Corporation (FRDC) 2017-092, University of Technology Sydney, Sydney.

The processing sector (using Victorian seafood production) is estimated to contribute $37 million of added value and 645 full-time equivalent jobs.[1615]

Based on regional modelling, Table 55 shows the importance of professional fishing to specific coastal regions of Victoria. East Gippsland, which includes the major commercial fishing centre of Lakes Entrance, shows the highest level of jobs and added value from commercial fishing activities. It accounted for 42% of total full-time equivalent jobs and 39% of total added value.

Table 55: Economic contribution of professional fishing to Victorian regions for the financial year 2016-17.[1616]

Region	Added value ($mill)	Full-time equivalent jobs
Far East Coast (East Gippsland)	76	810
Near East Coast (Gippsland and Mornington Peninsula)	26	298
Melbourne area (Melbourne and Geelong)	28	276
Near West Coast (Bellarine Peninsula and Great Ocean Road)	22	198
Far West Coast (west of Warrnambool)	42	352

Commercial fisheries may also contribute to defining coastal communities and the tourist experience. Being able to watch a fishing vessel offload its catch from the pier and then consume some of that produce at a local restaurant can add to the tourism experience. In some coastal communities, like San Remo or Lakes Entrance, the fishery industry can distinguish the town from other coastal towns and can be a source of pride for the community. Although fishing has become more technologically advanced and sophisticated, the act and skill of fishing may have been handed down from generation to generation in some families and for many is an important part of their identity as well as that of the community.

The economic benefits of fishing (both commercial and recreational) have flow-on benefits beyond the actual task of catching fish. Information from the ABS census provides detailed data by industry sector and, from this, employment in several related industries can be compared (Figure 130 and Figure 131). Interestingly, the spatial pattern of this data shows that more remote parts of Victoria benefit from the primary task of fishing, while areas in and near Melbourne play an important role in ancillary services such as boat building and repair. This pattern of primary sectors in remote areas and services concentrated in Melbourne is seen in many employment sectors across the economy.

1615. Ibid.
1616. Ibid.

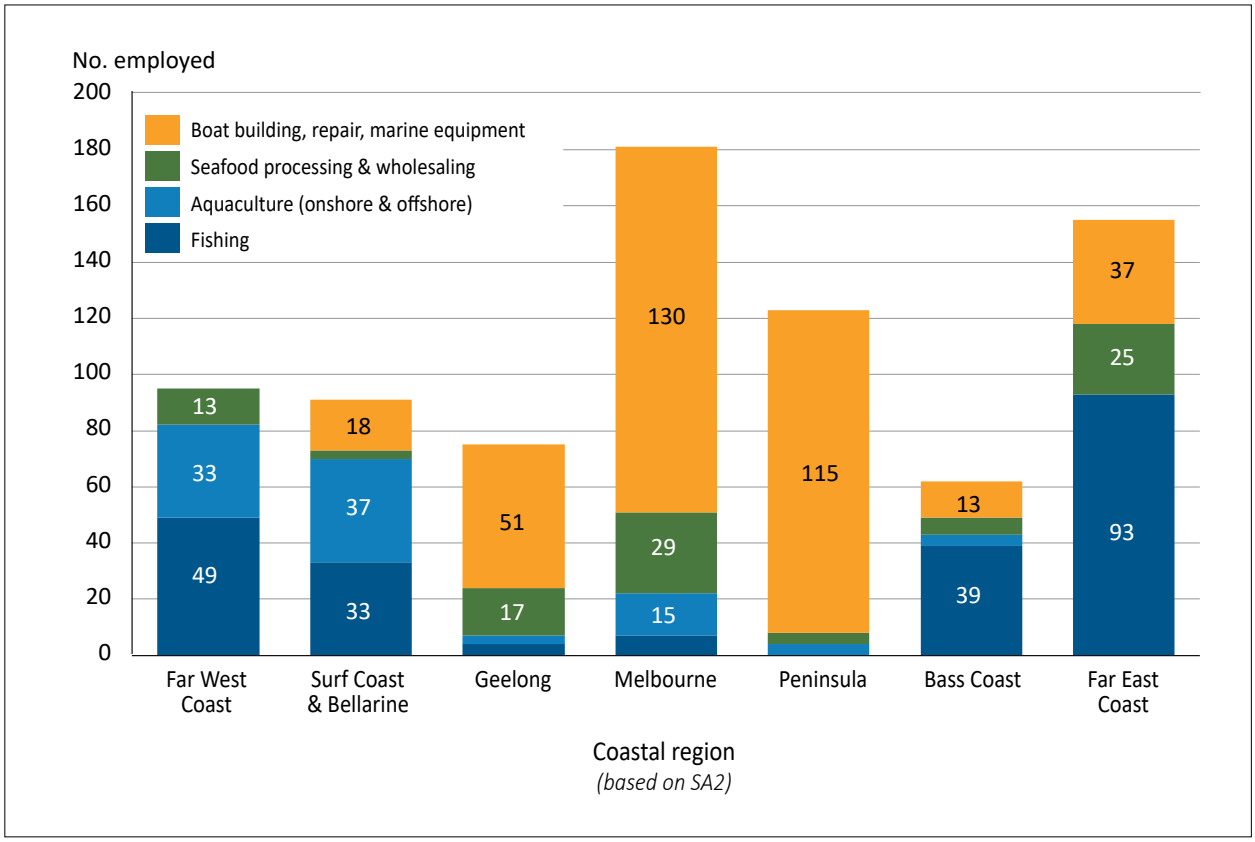


Figure 130: Number of persons employed in fishing-related industries, coastal Statistical Areas Level 2 (SA2s), 2016.[1617]

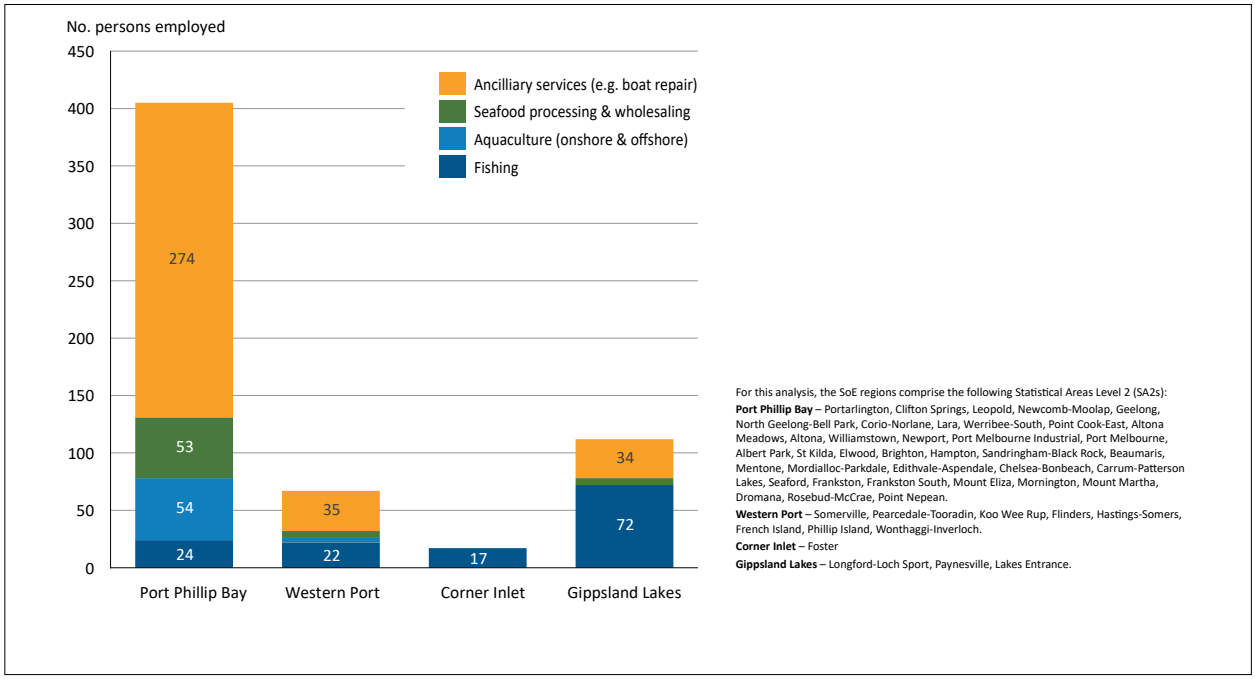


Figure 131: Number of persons employed in fishing-related industries, SoE Regions Statistical Areas Level 2 (SA2s), 2016.[1618]

1617. Australian Bureau of Statistics (ABS) 'Census of population and housing 2016', TableBuilder using 4-digit ANZSIC Codes, place of work.
1618. Ibid.

Management of commercial fisheries aims to ensure sustainability of fish stocks through regulation (controlling the amount caught in different locations and for different species) and monitoring. Discussion of the sustainability of fish stocks is provided by Indicator 23: Commercially and recreationally important invertebrates and Indicator 24: Commercially and recreationally important fish. In some cases, commercial aquaculture may supplement wild catch (discussed in the following section of this report).

Management instruments for commercial fisheries may include licensing requirements, size limits and quotas. These have been progressively introduced for most coastal and marine target species in Victoria. These are defined in the *Fisheries Regulations 2019* and described in management plans for individual fisheries. A Total Allowable Commercial Catch (TACC) is often defined on an annual rolling basis. Further information on the sustainability of fisheries is provided in the discussion for Indicator 23: Commercially and recreationally important invertebrates, and Indicator 24: Commercially and recreationally important fish.

These approaches can mitigate some of the potential threats which face commercial fisheries. However, the threats are varied and include:

- overfishing
- illegal and unreported fishing
- climate change
- introduction of pests
- new technologies
- pressure on the quality of aquatic environments.

Each of these threats may require different management responses or monitoring approaches. For example, the prevention of marine pests being introduced is managed through various shipping-related legislation and regulatory instruments in recognition that shipping is a key pathway for such species to be introduced (see discussion under Indicator 66: Shipping and ports).

Management of marine habitats is also needed to secure reliable fishing stocks. This is not just the environment in which the fish are caught but also the habitats that are important for important for different fish life stages. The management of a seagrass habitat in Western Port Bay may affect the viability of a fishery many miles distant. Maintaining coordinated monitoring and management systems is therefore important in fisheries management.

Interactions between certain marine species and commercial fishing can cause problems. Entanglement of cetaceans (whales and dolphins) in fishing gear has been identified as a leading cause of death of these animals around the world.[1619] Other marine mammals such as seals are also at risk of entanglement in plastic pollution and fishing gear. Entanglements are declared emergencies in Victoria and, where detected, they are recorded in a cetacean emergency database.

While data on entanglements is imperfect, a recent national study has reviewed known records and provided estimates of cetacean entanglements for Australia. Nationwide, shark nets were found to have been responsible for most cetacean entanglements overall, accounting for one quarter (n=478) of all entanglements, followed by trawl nets with 315 entanglements. Different fishing gear was found to have impacts on different species. For example, deep diving species were likely to be affected by trawl gear whereas inshore species were more likely to be affected by shark nets, fishing line and aquaculture gear, whilst offshore dolphin and whale species made up the majority of purse seine entanglements.[1620] Victoria shows a lower level of entanglements than other states although records are from the early 2000s only.

There were 71 records for cetacean entanglements in Victorian waters with 8 different species identified. Figure 132 shows the annual number of reported entanglements between 2001 and 2015, while Figure 133 shows maritime locations in which such entanglements occurred. While there is an annual average of 5 entanglements reported over the period, numbers range from 14 in 2004 to none reported in 2008.

1619. Tulloch V, Pirotta V, Grech A, Crocetti S, Double M, How J, Kemper C, Meager J, Peddemors V, Waples K, Watson M and Harcourt R 2020, 'Long-term trends and a risk analysis of cetacean entanglements and bycatch in fisheries gear in Australian waters', Biodiversity and Conservation, 29, pp. 251–282 https://doi.org/10.1007/s10531-019-01881-x

1620. Tulloch V, Pirotta V, Jonsen I, Grech A and Harcourt R 2017, 'National assessment of cetacean entanglements in fishery gear in Australia, final report', Macquarie University, Faculty of Science and Engineering, p. 27.

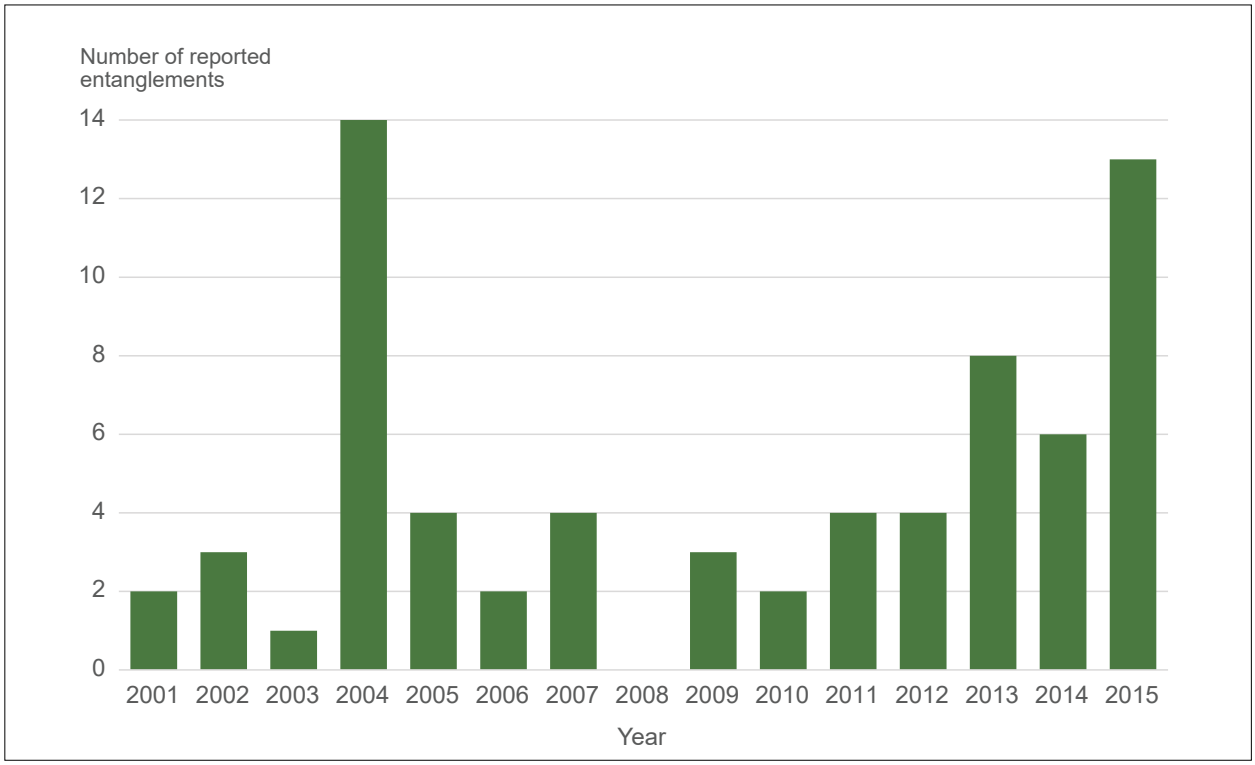


Figure 132: Number of cetacean entanglements reported in Victorian waters between 2001 and 2015.[1621]

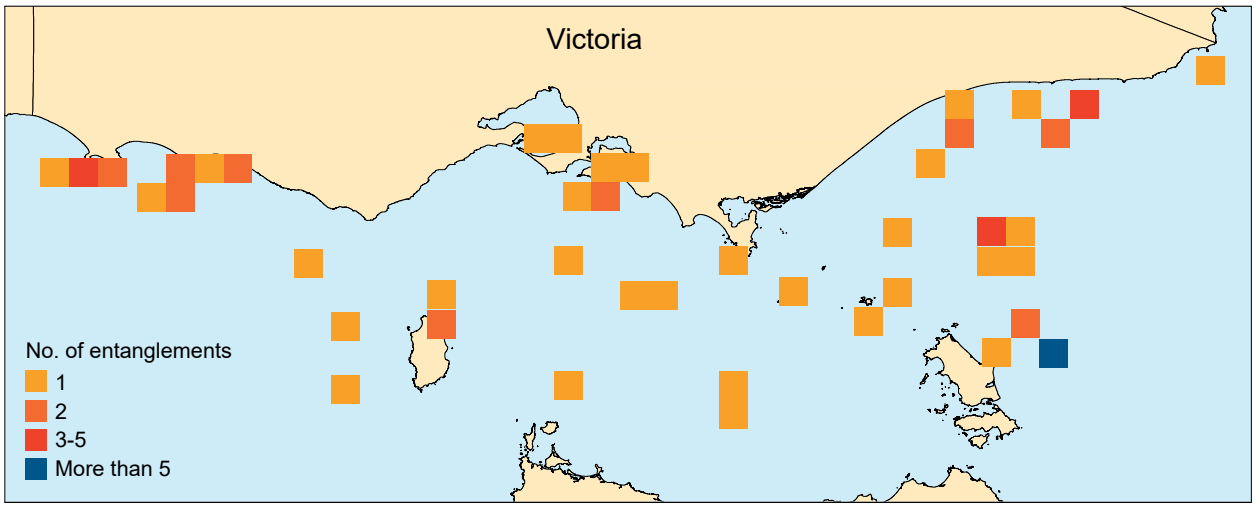


Figure 133: Hotspots of entanglements in Victorian and northern Tasmanian waters.[1622]

Over half the records from Victorian waters involved unidentified dolphin species (n=42). There were 16 records of baleen whale entanglements, most of which occurred between 2005 and 2010. These included one record of the endangered blue whale, and 5 records of the endangered southern right whale. The remaining 12 records involved dolphin species.[1623]

1621. Ibid. p. 46.
1622. Ibid. p. 44.
1623. Ibid. p. 46.

Most dolphin entanglements in Victoria have been in trawl gear (n=22) or gillnets (n=24). In contrast, baleen whale entanglements have occurred across a range of gear including lobster traps (n=6), rope (n=3), and other fishing nets or lines. A small number of inshore Indo-Pacific bottlenose dolphins have been entangled in shark control nets as well. Almost all interactions proved fatal (n=50) or resulted in the animal remaining entangled in fishery gear (n=4) which is likely to have led to death. Only 11 records indicate the animal was successfully disentangled, either through the animal releasing itself or by human intervention. Outcomes in the remaining cases were not recorded.[1624]

Monitoring of Australian fur seals at Seal Rocks near Phillip Island has revealed that around 1% (302 individuals) of the site population are entangled in marine plastic and fishing materials: the most common entangling materials are trawl net fragments and recreational fishing line.[1625,1626] Drone surveillance has detected a prevalence of 0.1-0.3% at five sites across the state of Victoria (Deen Maar Island, Marengo Reef, Rag Island, Seal Rocks and The Skerries). It has been estimated that at least 700 Australian fur seals are killed as bycatch every year on South East Trawl Fishing vessels.[1627]

While commercial fishing gear has a proven potential to impact on marine mammals, increased monitoring regimes are leading to exploration and evaluation of mitigation responses. For example, 'pingers' which emit acoustic signals to deter marine mammals in the vicinity of fishing gear; remote release mechanisms to enable animals to be released; and greater use of biodegradable gear which, if lost, will not create a permanent marine hazard. Electronic devices can also be used on some gear so that they can be found and retrieved if lost at sea.

Dolphins in Port Phillip Bay
© Parks Victoria

1624. Ibid. p. 47.
1625. McIntosh RR, Kirkwood R, Sutherland DR and Dann P 2015, 'Drivers and annual estimates of marine wildlife entanglement rates: A long-term case study with Australian fur seals', *Marine Pollution Bulletin*, 101(2), pp. 716-725 DOI: 10.1016/j.marpolbul.2015.10.007
1626. McIntosh unpublished data.
1627. Knuckey IA, Eayrs S and Bosschietter B 2002, 'Options for reducing 659 incidental catch of seals on wet-boats in the SETF: a preliminary assessment', Final Report to the Australian Fisheries Management Authority, ARF Project R01/0887, Marine and Freshwater Resources Institute, p. 59.

Indicator 68: Aquaculture

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		↗			N/A	N/A

Data source:	Fisheries Research and Development Corporation, Agriculture Victoria
Measures:	Value of aquaculture production | Quantity of aquaculture production

Why this indicator?

Aquaculture has the potential to provide sustainable economic development through the farming of marine species. This indicator will assess growth of the industry and highlight the degree to which potential hazards and risks are being addressed.

Justification for assessment ratings:

- Aquaculture is an increasingly important source of seafood in Victoria, both for the domestic and export market.
- Abalone and blue mussels are the main species farmed in Victorian coastal waters. Guidelines and protocols are in place for these and other aquaculture species along with regulation and licensing systems to help prevent the spread of invasive marine species in the aquaculture industry. Monitoring of aquaculture farms is also undertaken by the EPA.
- Disease is a potential threat to the industry and in 2021 a period of formal closure of a marine area near Portland was instigated to prevent the spread of abalone viral ganglioneuritis. The process of closure and restriction suggests that management regimes are responsive to such threats, however costs to the aquaculture industry and to others affected by the closure (commercial and recreational fishers, divers) can be high.
- As some farms grow much larger, there may be an increasing risk in relation to biosecurity and pollution. Countering this, however, is the concurrent improvement in biosecurity technology and management regimes.

Aquaculture in Victoria is undertaken in offshore, coastal and inland environments and involves the cultivation of many species including: trout, abalone, blue mussel, Murray cod, barramundi and yabby.[1628] Coastal aquaculture contributed an estimated $35 million of added value and 427 full-time equivalent jobs to the Victorian economy in 2016-17.[1629] There is significant growth in the mussel and abalone sector and growing interest in seaweed aquaculture.

Farmed aquaculture species are generally also native marine species. In terms of the major aquaculture species grown in Victoria, abalone and blue mussels are the only species that are relevant to this report. Blue mussels are predominantly farmed in open systems in Port Phillip Bay and anecdotally do not suffer from any diseases through this process. There are no structured surveillance activities undertaken for this species.

Abalone in Victoria are farmed at 4 sites in 'pump ashore' farms. Marine water is taken onto the farm at a rate of up to 1000 litres/second. This water moves through the farm and is released into the ocean again after transiting settlement ponds. This activity is licensed by the Victorian Fisheries Authority and monitored by the EPA.

In 2017-18, Victoria produced 3,362 tonnes of fish from aquaculture, representing 46% of Victoria's total fisheries production (Table 56). The value of this production was $48.3 million representing 43.5% of the total value of Victorian fisheries (Table 57).

1628. Victorian Fisheries Authority (VFA) 2021, 'Aquaculture' https://vfa.vic.gov.au/aquaculture Accessed 22 July 2021.
1629. Abernethy K, Barclay K, McIlgorm A, Gilmour P, McClean N, Davey J 2020, 'Victoria's fisheries and aquaculture: economic and social contributions', Fisheries Research and Development Corporation (FRDC) 2017-092, University of Technology Sydney, Sydney.

Table 56: Quantity of aquaculture production in Victoria, 2017-18.[1630]

Quantity (tonnes)	2017-18p
Abalone	525
Blue Mussel	1,346
Yabbies	4
Salmonids	1,179
Warmwater Finfish	294
Freshwater Eels	14
Total aquaculture	3,362
Total fisheries quantity	7,323
Aquaculture as % of total quantity	45.9%

Table 57: Value of aquaculture production in Victoria, 2017-18.[1631]

VALUE $'000	2017-18p
Abalone	25,216
Blue Mussel	5,189
Yabbies	24
Salmonids c	13,740
Warmwater Finfish d	3,976
Freshwater Eels	124
Total aquaculture	48,269
Total fisheries value	111,039
Aquaculture as % of total value	43.5%

The importance of aquaculture in Victorian fisheries has increased over the past two decades in terms of both quantity and value. In production terms. it has increased its share from 30% in 1998-99 to 46% in 2017-18. In terms of share of total value, aquaculture has increased to a greater degree, from 17% to 43.5% over the same period (Figure 134).

Although aquaculture can complement wild fisheries, it is unlikely to reduce pressure on wild stocks, as the demand for wild fish is high. Species farmed through aquaculture tend to be higher priced species grown for luxury markets, rather than the high-volume fish species (such as blue grenadier or whiting) which are caught by commercial fishing fleets.

1630. Steven A, Mobsby D and Curtotti R 2020, 'Australian fisheries and aquaculture statistics 2018', Fisheries Research and Development Corporation (FRDC) project 2019-093, ABARES, Canberra.
1631. Ibid.

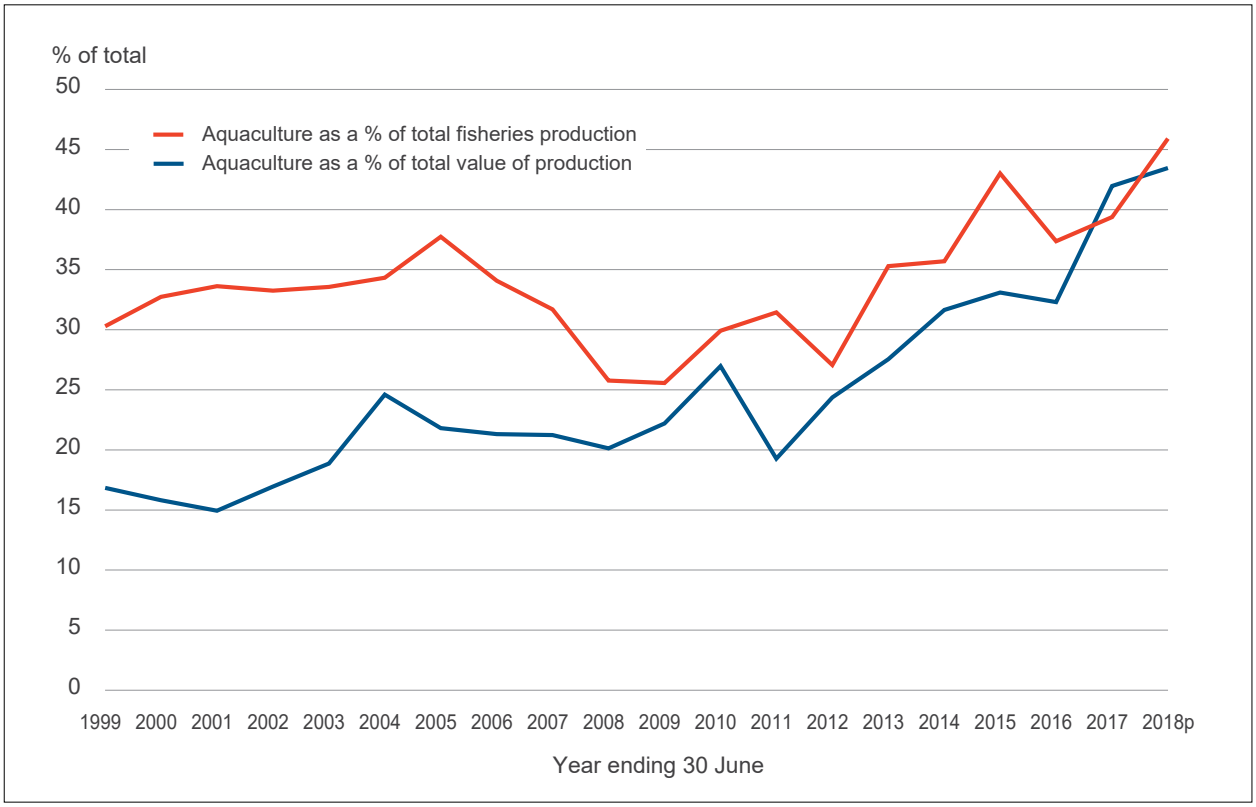


Figure 134: Aquaculture production as a proportion of total fisheries production, Victoria, 1998-99 to 2017-18.[1632]

The major legislation to which aquaculture activities are bound is the *Fisheries Act 1995*, which provides for the management, development and promotion of an ecologically sustainable and viable aquaculture industry. However, the industry is also affected by other legislative requirements reflecting the complexity of management issues involved. The industry may be perceived as providing a sustainable way of producing seafood, however, the industry itself can have impacts which need to be managed. These are varied and include human health concerns (food safety), biosecurity, land use considerations, and potential impacts on natural environments.[1633] Some aquaculture facilities in Victoria have been certified by the Marine Stewardship Council, which reflects sustainable production. As some farms grow much larger, there may be an increasing risk in relation to biosecurity and pollution. Countering this, however, is the concurrent improvement in biosecurity technology.

Invasive marine species can have economic impacts including management costs for fishing and aquaculture businesses. In shellfish aquaculture the key impact is the direct fouling of stock causing physical damage, mechanical interference, biological competition and environmental modification, while infrastructure is also impacted. In contrast, the key impact in finfish aquaculture is the fouling of infrastructure, which restricts water exchange, increases disease risk and causes deformation of cages and structures.

1632. Ibid.
1633. Victorian Fisheries Authority (VFA) 2021, 'Aquaculture management' https://vfa.vic.gov.au/aquaculture/aquaculture-management Accessed 22 July 2021.

The Victorian Fisheries Authority (VFA) has produced translocation guidelines and protocols for several aquaculture species (including abalone and blue mussels) along with other policy documents and regulation and licensing systems to help prevent the spread of invasive marine species in the aquaculture industry. The guidelines provide a risk assessment and administrative framework for the assessment of translocation proposals associated with closed, semi-closed or open system stocking proposals. In addition to the processes in place to manage the risks of pest and disease spread via aquaculture, the VFA also manages similar risk associated with the stocking of commercial and public waters.

The major disease of concern in the abalone industry (farmed and wild) is abalone viral ganglioneuritis caused by a herpes virus. Most farms are part of a nationally agreed to accreditation program with biosecurity elements and specific surveillance to certify freedom from this disease. An outbreak was reported near Portland in May 2021 which led to a control area being established to prevent spread of the disease.[1634] The disease can be spread via fishing equipment such as ropes, anchors and wetsuits, hence recreational and commercial fishing activities as well as snorkelling and diving are banned when such control areas are in place.[1635] It is likely that the virus is endemic in wild stock at low levels. The impacts of climate change will affect industries such as aquaculture that are reliant on harvesting biological resources as environmental conditions and species distribution and abundance change.[1636]

Blue mussels (*Mytilus edulis galloprovincialis*)
© Victorian Fisheries Authority

1634. Agriculture Victoria 2021, 'Abalone disease' https://agriculture.vic.gov.au/biosecurity/animal-diseases/abalone-disease Accessed 22 July 2021.
1635. The Age, May 5, 2021, 'Divers heartbroken as virus returns, and not just for shellfish reasons', by Benjamin Preiss https://www.theage.com.au/national/victoria/divers-heartbroken-as-virus-returns-and-not-just-for-shellfish-reasons-20210505-p57p0d.html Accessed 22 July 2021.
1636. Abernethy K, Barclay K, McIlgorm A, Gilmour P, McClean N, Davey J 2020, 'Victoria's fisheries and aquaculture: economic and social contributions', Fisheries Research and Development Corporation (FRDC) 2017-092, University of Technology Sydney, Sydney.

Indicator 69: Resources and energy generation

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		↗			N/A	N/A

Data source:	Department of the Environment and Energy; DELWP; Department of Jobs, Precincts and Regions; academic researchers.
Measures:	Offshore oil production in Victoria | Gas production in Victoria Electricity (MW) generated from renewable marine sources (wave, tidal, offshore wind)

Why this indicator?

With a move towards a low carbon economy, marine and coastal areas are providing new opportunities for energy generation. This indicator tracks the development of such development as well as addressing the degree to which environmental objectives are being achieved.

Justification for assessment ratings:

- Development of wind and solar energy has been increasing in recent years and more projects are planned as Victoria makes the transition to low carbon sources of energy.
- Oil, gas and coal production still contribute to Victoria's energy sector and export markets.
- Victoria does not currently have any operating offshore wind generation although three proposals are currently being considered.
- Some sources of energy such as wave, tidal and geothermal energy have been the subject of trials and research projects but none of these have yet emerged as major contenders in Victoria's energy production market.
- While hydrogen power is not yet contributing to Victoria's energy generation, there is a pilot project underway (HESC) which aims to produce and transport liquid hydrogen from the Latrobe Valley, through the Port of Hastings, to Japan.
- Global initiatives towards decarbonisation are likely to place pressure on Victoria's fossil fuel use in the coming decade, requiring a more rapid transition to renewable energy sources.

Victoria uses both renewable and non-renewable resources from marine and coastal environments to generate electricity.

There are two major offshore oilfields in Victoria – the Gippsland Basin and the Otway Basin. The Gippsland Basin has been a major producer of Australia's oil and gas since the 1960s. Currently, there are 23 offshore platforms and installations in Bass Strait (Figure 135). The Gippsland Basin has both onshore and offshore components.

Overall, the basin covers an area of 46,000 km^2, with two thirds located offshore. Onshore, the Gippsland Basin stretches from Western Port Bay to Orbost. The Kingfish offshore oil field, discovered in 1967, remains Australia's largest petroleum discovery. Commercial petroleum discoveries made in the Gippsland Basin have all been found offshore. It is estimated to contain reserves of 2.7 trillion cubic feet of natural gas and ethane, as well as 220 million barrels of oil and condensate.[1637]

1637. Department of Jobs, Precincts and Regions (DJPR) 2020, 'Oil and gas in Victoria' https://earthresources.vic.gov.au/geology-exploration/oil-gas/oil-and-gas-in-victoria Accessed 6 October 2020.

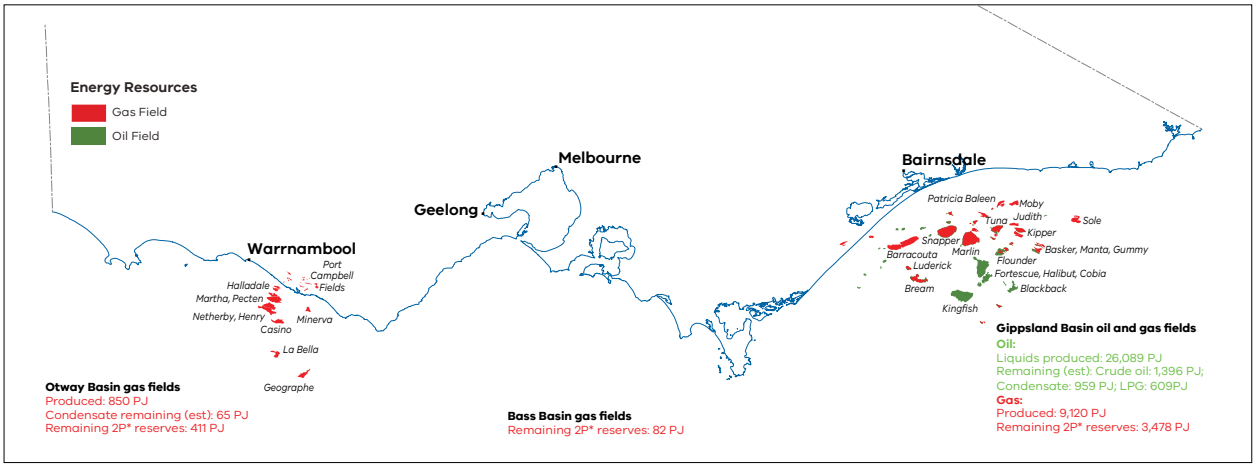


Figure 135: Location of oil and gas production in Victoria.[1638]

Victoria's oil production peaked in the 1970s and 1980s (Figure 136). In 1984-85, Victoria produced 26,457 Megalitres of oil and natural gas liquids. By 2004-05, production had fallen below 5000 ML and in 2015-16 it was only 2418 ML.

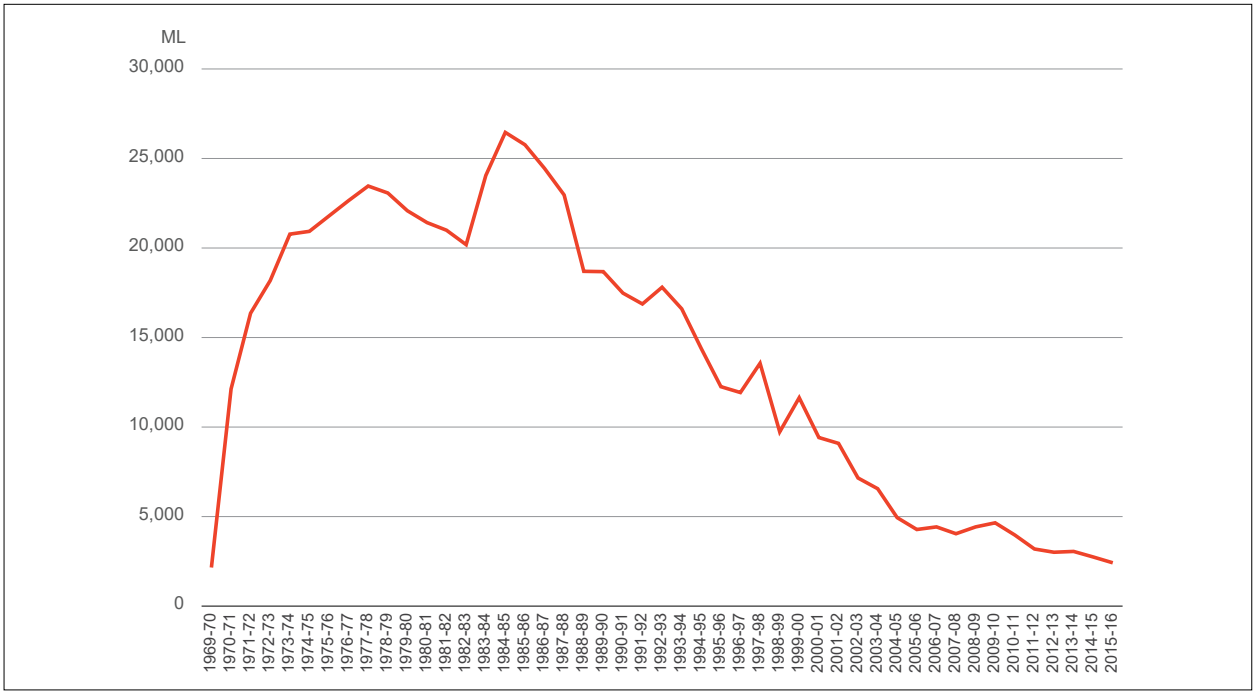


Figure 136: Production of crude oil and natural gas liquids in Victoria, 1969-70 to 2015-16.[1639]

1638. Department of Jobs, Precincts and Regions (DJPR) 2020, 'Earth resources – Victoria', Melbourne, Victoria.
1639. Department of the Environment and Energy 2017, 'Australian energy statistics', table I3, Australian Government, Canberra.

The Gippsland region contains many processing facilities and gas pipelines associated with the offshore oil and gas industry. There are also other facilities and services related to the industry such as flight services for offshore workers. Gas produced from the Basin services Melbourne, Victorian regional centres and the east-coast gas market.

Like the Gippsland basin, the Otway Basin has onshore and offshore components. It is around 155,000 km^2 in size, with the onshore component stretching from Geelong in Victoria to Lucindale in South Australia. Within the Victorian part of the Basin, commercially viable gas discoveries have been found both onshore and offshore in the Peterborough-Port Campbell region. Depleted onshore gas fields near Port Campbell are used for underground gas storage. As with the Gippsland Basin, the Otway Basin provides gas for Melbourne, Victorian regional centres and the east-coast gas market.[1640]

Marine energy is an emerging industry which includes any form of renewable energy that is generated using the marine environment. Once captured, energy can be converted into electricity. Potential marine energy resources in Victoria include wave, tidal and offshore wind generation.

While Victoria's electricity generation is still dominated by non-renewable energy sources (88%),[1641] there has been rapid development of wind and solar power which is expected to become more dominant in the future as the world decarbonises.

Wind energy

Wind energy is a rapidly growing industry in Victoria with 29 operational wind farms located throughout the State.[1642] Around nine of these are located along the southern coast including Victoria's first wind farm built in 2001 at Codrington, east of Portland. This wind farm alone generates enough electricity each year to supply an equivalent of 10,000 Victorian homes, which avoids the emission of 49,000 tonnes of greenhouse gas emissions annually.[1643] Other coastal locations with wind farms include areas near Port Fairy and Peterborough in the west and Inverloch and Toora in the east.

Wind energy may also be developed in offshore locations. Currently, Victoria does not have any offshore wind generation facilities in operation, however, there are three proposals in the pipeline (Figure 137). The Star of the South project and the Gippsland Project would transmit electricity to the coast which would then connect to existing Latrobe Valley electricity infrastructure for distribution.[1644]

1640. Department of Jobs, Precincts and Regions (DJPR) 2020, 'Oil and gas in Victoria' https://earthresources.vic.gov.au/geology-exploration/oil-gas/oil-and-gas-in-victoria Accessed 6 October 2020.
1641. Department of the Environment and Energy 2017, 'Australian energy statistics', table O3, Australian Government, Canberra.
1642. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Wind energy projects, as at 08/10/20' https://www.planning.vic.gov.au/permits-and-applications/specific-permit-topics/wind-energy-facilities/wind-energy-projects-planning?_ga=2.189197033.318809511.1602653626-245237306.1598233448 Accessed 14 October 2020.
1643. Pacific Hydro 2020, 'Codrington wind farm' https://www.pacifichydro.com.au/projects/operations/codrington-wind-farm/ Accessed 14 October 2020.
1644. Star of the South Wind Farm 2020, 'Star of the south – the project' https://www.staroftheseouth.com.au/the-project Accessed 14 October 2020.

VICTORIA OFFSHORE WINDFARM PROJECT

Size	495 MW
Operational	n/a
Technology	n/a
Owner	Australis Energy
Comments	Sited between Portland and SA border, proposes up to 62 turbines

STAR OF THE SOUTH

Size	2000 MW
Operational	n/a
Technology	n/a
Owner	Copenhagen Infrastructure Partners
Comments	$10 billion project proposes underground transmission line to Latrobe Valley

PROJECT GIPPSLAND

Size	1500 MW
Operational	n/a
Technology	Floating wind
Owner	Floatation Energy
Comments	Proposing to build floating wind project off 90-mile beach connecting into Latrobe Valley

Figure 137: Offshore windfarm proposals in Victoria as at June 2021.[1645]

Wave energy

The oceans hold massive amounts of energy in the form of wave movement. Wave energy can be captured by turbines that are either fixed to the shore or floating on the water's surface. A wave's capacity to generate electricity is dependent on its height and speed. The higher and faster the wave, the more energy it contains.

Victoria has potential for wave energy and there have been some pilot projects undertaken in the past. In December 2015, the Port Fairy Wave Energy Project was established as a pilot project, however it was decommissioned in 2019 due to technical difficulties and uncertainty around the project's viability. The location, 850 metres offshore, has high-powered waves. While this creates the potential for high levels of energy generation, it also caused problems of maintenance and damage to the underwater power cable which connected the bioWAVE generation unit to onshore electrical infrastructure.[1646] Other wave energy projects have been trialled at Lorne and Portland.[1647]

Tidal energy

Tidal energy is generated from naturally occurring tidal currents. Power generation opportunities in Victoria are limited because of the small tidal ranges in Bass Strait. Nevertheless, test facilities have been installed in Western Port and Port Phillip Bays. Atlantis Resources Corporation have run a test facility for tidal turbine technology at San Remo since 2006 and other companies such as HydroGen, EnGen Institute and Infratidal have also undertaken test projects at the same location. Another EnGen test site has been established at Stony Point and Cetus and Atlantis resources have established tidal generators at Melbourne and Corio Bay respectively.[1648] As with wave energy, there is still a high level of research and development being undertaken with a variety of turbine designs being developed and tested.

1645. Renew Economy 2021, 'Offshore wind farm map of Australia' https://reneweconomy.com.au/offshore-wind-farm-map-of-australia/ Accessed 30 June 2021.
1646. McNeil M 2019, 'Port Fairy wave energy project decommissioned after technical challenges in 'harsh marine environment'', *The Standard*, Warrnambool, April 5 https://www.standard.net.au/story/5989332/challenging-victorian-wave-energy-project-pilot-goes-under/#:~:text=A%20%2424%20million%20pilot%20wave,any%20electricity%2C%20has%20been%20decommissioned.&text=Ongoing%20technical%20problems%20and%20uncertainties,was%20deployed%20in%20December%202015 Accessed 8 October 2020.
1647. Manasseh R, McInnes K and Hemer M 2017, 'Pioneering developments of marine renewable energy in Australia', *The International Journal of Ocean and Climate Systems*, 8(1), pp. 50-67. DOI: 10.1177/1759313116684525.
1648. Ibid.

Geothermal energy

Geothermal energy comes from naturally occurring hot rocks and hot water reservoirs deep beneath the earth's surface. Hot water brought to the surface via drilling can be used to generate electricity. The water is then returned to the original aquifer, albeit slightly cooler, in a closed-loop system. Victoria has three geothermal basins, two of which are in coastal regions: the Otway and Gippsland basins.

In addition to high temperature resources, lower temperature resources are commonly found in Victoria. These are often used in spas and in the heating of buildings, swimming pools, greenhouses, and fish farms. Other uses include the washing of wool, pasteurising milk, dehydrating fruit, production of paper and various industrial processes.

Toora Wind Farm
© Film Victoria

Hydrogen energy

While hydrogen power is not yet contributing to Victoria's energy generation, there are developments emerging such as the pilot Hydrogen Energy Supply Chain (HESC) Project which aims to produce and transport liquid hydrogen from the Latrobe Valley, through the Port of Hastings, to Kobe, Japan. The production of hydrogen gas in the Latrobe Valley commenced in 2021. The gas is produced through the gasification of coal, after which it is transported by high pressure tube trailers to the Port of Hastings where liquefaction, storage and loading will occur at a newly constructed facility. The liquefied hydrogen will then be transported by sea to Japan using a specifically designed hydrogen carrier.[1649,1650]

In 2016, the International Maritime Organisation (IMO) approved these arrangements for the safe transport of bulk liquefied hydrogen over waters. In the demonstration phase of this project, the specialised marine carrier is expected to have little impact on the surrounding area because of the small size and limited nature of the activities to be undertaken. The first shipment is planned in 2021.[1651] If the pilot is found to be commercially viable, larger scale commercial operations may commence in the 2020s or 2030s.[1652]

1649. HESC 2021, 'Supply chain - Latrobe Valley' https://hydrogenenergysupplychain.com/latrobe-valley/ Accessed 2 July 2021.
1650. HESC 2021, 'Supply chain - Port of Hastings' https://hydrogenenergysupplychain.com/port-of-hastings/ Accessed 2 July 2021.
1651. Ibid.
1652. HESC 2018, 'Hydrogen energy supply chain factsheet'.

Indicator 70: Agriculture

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide					N/A	N/A

Data source:	Agriculture Victoria, DELWP Planning, Melbourne Water
Measures:	Agricultural runoff – contaminants reaching marine and coastal ecosystems (nutrients/toxins) | Change in land use from agricultural to residential and urban land uses | Loss of agricultural land

Why this indicator?

Agriculture represents a major land use which has the potential to be undertaken in a sustainable way where farmers can provide stewardship of the land, economic benefits, and food for the wider community while maintaining soils, vegetation and other environmental features. This indicator assesses the degree to which such sustainability outcomes are being achieved and environmental damage minimised or reversed.

Justification for assessment ratings:

- Agriculture represents a major land use which provides economic benefits, and food for the wider community. Agricultural activities have the potential to be undertaken in a sustainable way where farmers can provide stewardship of the land through maintaining or improving soils, vegetation and other environmental features.
- There are environmental risks involved in agriculture such as the impact of water runoff which may have high nutrient loads from fertiliser or toxins from fertilisers. Limiting contaminated runoff is the focus for a number of policy initiatives which focus on recycling high nutrient water and managing the application of chemicals.
- Although research in the Western Port catchment has shown the largest proportion of fine sediment load in catchment runoff is from grazing and cropping, this reflects the fact that it comprises a high proportion of catchment land use. In contrast, urban uses which comprise a smaller land area have higher impacts on runoff.
- Agricultural land use change is able to be measured using land use data. This is providing a basis for protection of high-quality agricultural land through land use planning in areas where agricultural land is under threat from urban and residential uses

Agriculture occupies around half of Victoria's land area and contributes nearly $10 billion to Victoria's gross state product.[1653] Agricultural activities have a range of environmental impacts, some of which are positive. Soil management, for example is of central importance to farmers maintaining the productivity of their land. Control of erosion, pest animals and introduced weeds are also activities undertaken by farmers to maintain the health of their land. Farming activities have the potential to also cause some detrimental impacts on the environment. Soil compaction by farmed animals or machinery can affect productivity and can increase runoff.

Although most coastal areas in Victoria are held as Crown land and not used for agricultural production, land use activities further into the catchment can have implications for coastal and marine environments. As noted above, agricultural activities can affect hydrological systems through contaminated runoff. Melbourne Water and CSIRO have undertaken studies to estimate fine sediment loads in runoff from the Western Port Bay catchment. The catchment has been subject to increasing urbanisation, particularly in the urban growth areas of Casey and Cardinia, although much of the catchment still comprises agricultural land use with some significant areas of remnant vegetation.

1653. Agriculture Victoria 2020, 'Strategic agricultural land and development in Victoria final report', prepared by Price Waterhouse Coopers (PwC) for the Department of Jobs, Precincts and Regions (DJPR), Melbourne, Victoria, p. 5.

Although the largest proportion of fine sediment load in catchment runoff is from grazing and cropping (21%), this reflects the fact that it comprises a high proportion of catchment land use (31%). By contrast roads, which only represent 3.4% of land use in the catchment, account for 24% of fine sediment load running into Western Port Bay. Low density residential use also has a high impact (12% of runoff) despite being a small proportion of overall land use (2%).[1654] Forests and grasslands account for the lowest fine sediment runoff. High levels of sediment in runoff can create issues for marine ecosystems (refer to discussion for Indicator 07: Stormwater, Indicator 08: Total nutrient loads, and Indicator 09: Total fine sediment loads). Furthermore, such runoff may contain contaminants from urban, industrial or agricultural land uses.

In the case of agriculture, the use of fertilisers and pesticides, if not managed carefully, can lead to contaminants entering river systems, estuaries and marine ecosystems. The Australian Pesticides and Veterinary Medicines Authority (APVMA) governs use of chemicals including application rates which limits unwanted runoff. They have developed guidelines to limit problems such as spray drift.[1655] New farming technology has also had an important impact on the targeted application of fertilisers and pesticides to maximise effectiveness and or contaminated runoff.

Knowledge of potential impacts can lead to effective management regimes. For example, Melbourne Water provides guidance to rural land holders within the wider catchment areas of its jurisdiction to minimise unwanted runoff of contaminants into the stormwater system.[1656] Agricultural activities such as dairy farming can implement systems to reuse effluent and wastewater, thus reducing the use of chemical fertilisers while reducing nutrient-rich runoff from their property.[1657]

While agriculture has environmental impacts within a catchment, changes to agricultural land use can create changes in that impact. This may include changes within agriculture, such as a move from cropping to grazing or from grazing to silviculture. Other changes may include the loss or fragmentation of agricultural land use to other uses such as urbanisation. The latter can have a very different profile in terms of environmental impact, and energy or water use within a catchment.

Fragmentation of land use can, in turn, affect the viability of agricultural enterprises. Thus, land use change within a coastal hinterland may have implications for coastal, estuarine and marine ecosystems, even where the narrow coastline zone is protected from development. Another way in which land use change can affect local environments is that, in the development process, broadacre land may be purchased and then 'land banked' for future development. This can take many years as developers accumulate large sites during which time levels of active land management may decline, leading to consequent problems of weeds and pest animals.[1658]

Fragmentation or loss of agricultural land has generally been greatest in areas close to urban areas where population growth and urbanisation comes into competition with agricultural land use. In the ten years to 2016-17, residential land use increased by around 210,000 hectares across Victoria. An area of pressure over this period was the Geelong, Bellarine Peninsula, Surf Coast and Golden Plains region where fragmentation of agricultural land occurred due to pressures of population growth and land subdivision. These areas were found to have had a reduction in agricultural land of about 33,000 hectares in the decade to 2016-17, mainly affecting mixed farming and grazing.[1659] It should be noted that there can be fluctuation in farming activities in response to seasonal conditions and commodity markets and, while there is an overall decline in agricultural land use for the region above, there was an increase between 2014-15 and 2016-17. Nevertheless, it is true that this region has experienced expanding areas of urban development to the south of Geelong, on the Bellarine Peninsula and Surf Coast and in Golden Plains which lies to the south of Ballarat (Figure 138).

1654. Melbourne Water and CSIRO 2021, 'Westernport catchment planning tool' https://www.flowmatters.com.au/viz/#/mw-cpt?_page=0 Accessed 20 July 2021.
1655. Australian Pesticides and Veterinary Medicines Authority (APVMA) 2020, 'Spray drift management', Australian Government, Canberra https://apvma.gov.au/node/10796 Accessed 20 July 2021.
1656. Melbourne Water 2012, 'Rural land program: a guide to reducing the impact of runoff to waterways'.
1657. Agriculture Victoria 2020, 'Applying dairy shed effluent to land', Melbourne, Victoria https://agriculture.vic.gov.au/livestock-and-animals/dairy/managing-effluent/applying-dairy-shed-effluent-to-land Accessed 19 July 2021.
1658. Agriculture Victoria 2020, 'Strategic agricultural land and development in Victoria final report', prepared by Price Waterhouse Coopers (PwC) for the Department of Jobs, Precincts and Regions (DJPR), Melbourne, Victoria, p. 29.
1659. Ibid. p. 29.

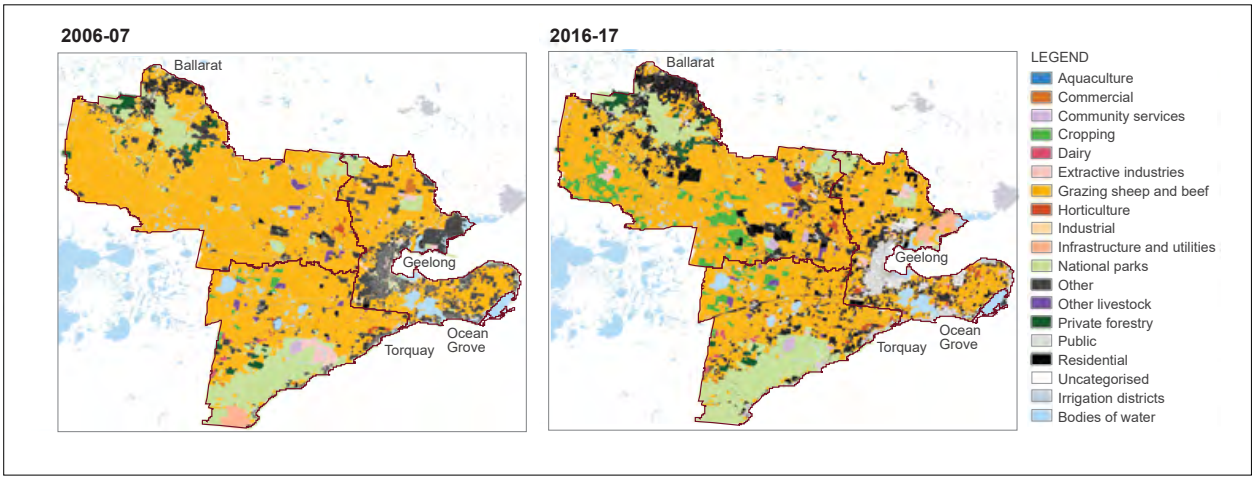


Figure 138: Land use change in Greater Geelong and neighbouring municipalities between 2006-07 and 2016-17.[1660]

Alongside the expansion of existing urban settlements there can be pressure put on agricultural land by rural residential or hobby farm type subdivision. This style of 'rural living' is popular but can have a large impact on fragmentation due to the area which they can potentially take out of traditional agricultural activities. In contract, urban development at higher density will have less impact on area of land loss, albeit greater impacts on local hydrology due to the creation of impervious surfaces. Thus, the impacts of subdivision and development affects both the viability of agriculture (through land loss and fragmentation) and the nature of runoff affecting catchment dynamics and processes. Ultimately, this runoff along with other hydrological changes can have downstream impacts on coastal and marine areas.

1660. Ibid. p. 30.

Hastings
© Mornington Peninsula Shire

Indicator 71: Built and public benefit infrastructure

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		→			N/A	N/A

Data source:	DELWP Coastal Programs, Victorian Auditor-General's Office
Measures:	Number of assets in coastal areas | Built assets at risk of climate change (sea-level rise) impacts

Why this indicator?

This indicator reports on the number and type of various infrastructure assets along the coast. The condition of these assets is important to limit negative environmental impacts. Potential threats such as climate change are also relevant for future construction and management.

Justification for assessment ratings:

- The condition of coastal assets and infrastructure is currently undergoing review. It is therefore difficult to fully assess their status.
- Siting and Design Guidelines have been developed for coastal infrastructure which is likely to strengthen the resilience of any new construction. However, given the legacy of built assets currently sited along the coast, it is evident that climate change presents a clear threat to coastal and marine infrastructure through rising seas levels and more extreme weather events.
- The trend assessment of stable recognises that although assets have been recently reviewed with a view to improving their condition, there is a clear threat to many of these assets due to climate change. Thus, levels of improvement are likely to be balanced by the loss or degradation of some coastal infrastructure in coming decades.

Buildings and structures in the marine and coastal environment support the functioning of communities and industries. They include:

- maritime assets— jetties, piers, docks, wharves and boat ramps
- access assets— stairs, boardwalks, paths, signage
- recreational assets - toilet blocks, picnic facilities, structures to maintain community safety
- coastal protection structures (for example, seawalls, revetments, groynes, breakwaters, hybrid structures).

Buildings and structures that are well located and designed, and properly maintained, support a diversity of uses in the marine and coastal environment. Given the numbers of people using coastal buildings and infrastructure there is a need to consider community benefits and safety in their construction, use and ongoing maintenance. This is particularly important where the infrastructure itself is part of protecting the environment from human activity – for example walkways in sensitive coastal environments. Degradation of these types of infrastructure is likely to have detrimental impacts on the environment that they are intended to protect.[1661] Public infrastructure also supports access to natural environments which can enhance human wellbeing and increase people's awareness of natural habitats. However, such access and associated infrastructure needs to be balanced with maintaining ecological values of an area. The total length of coastal protection structures in Victoria has been estimated to measure more than 166 km comprising over 1,572 assets (Table 58).

Managing these protective structures is an important way in which water and land-based natural coastal assets are themselves protected. This is particularly the case where population pressures (visitor or resident) place stress on local environments. Appropriate management is also important given the likely impacts of climate change in the future. Land managers of public land include DELWP, Parks Victoria, local government, local port managers and Committees of Management.

1661. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Marine and coastal policy', East Melbourne, Victoria.

Table 58: Coastal protection infrastructure in Victoria.[1662]

Type of Coastal Protection Structure	Number of assets
Seawall	655
Revetment	387
Groyne	383
Breakwater	59
Wharf	35
Retaining Wall	28
Other	25
TOTAL	1572

In their review of coastal assets in 2018, the Victorian Auditor General's Office (VAGO) concluded that responsible agencies were not managing their coastal assets as well as they needed to. This included management for current and future risks such as erosion, sea level rise, and population pressures. According to VAGO, fragmented management responsibility for coastal assets and the existence of agencies of various sizes and capabilities was preventing a strategic approach to the management of coastal assets.[1663]

Since the review was released, DELWP have addressed many of the recommended actions. A statewide database of all coastal protection structures has been established and climate change response options are considered during planning for new projects.[1664]

In May 2020, Siting and Design Guidelines for Structures on the Victorian Coast were released.[1665] These updated earlier guidelines from 1998 and aligned them with the Victorian Marine and Coastal Policy 2020, which outlines State Government directions for planning and management of Victoria's marine and coastal environment. Importantly, the guidelines take population growth and climate change into consideration. Population growth has implications for the level of use of coastal structures, while climate change can present a risk to the integrity of such structures. Another important feature of the guidelines is that they apply to coastal, estuarine and marine areas irrespective of land tenure (public or private).[1666]

Climate change presents a clear threat to coastal and marine infrastructure through rising seas levels and more extreme weather events. Data compiled through the 2010s provides an estimate of potential damage costs for coastal assets (Table 59).

Table 59: Built assets at risk of inundation based on a 0.8 metre sea level rise by 2100.[1667]

Note: This table does not include costs associated with impacts on maritime assets and loss of revenue for other activities that rely on coastal assets.

Asset	Quantity	Value
Residential buildings	31,000 - 48,000	$6.5 billion to $10.3 billion
Commercial buildings	Up to 2,000	$12 million
Roads	527 km	$9.8 million
Railways	125 km	$500 million
Government-owned public facilities	87	Not known
Maritime assets	Not known	$220 million
Coastal protection structures	Over 1,000	$700 million

In response to these emerging threats, proposals for new or upgraded infrastructure are required to take climate change and sea level rise into account. This has occurred, for example in the St Kilda Marina Redevelopment.[1668]

1662. Department of Environment, Land, Water and Planning (DELWP) senior statewide coastal programs officer 12 July 2021.
1663. Victorian Auditor General's Office (VAGO) 2018, 'Protecting Victoria's coastal assets. Independent assurance report to parliament 2017–18: 14', Melbourne, Victoria, p. 8.
1664. Senior coastal programs officer, Department of Environment, Land, Water and Planning (DELWP), personal communication, 9 July 2021.
1665. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Siting and design guidelines for structures on the Victorian coast', East Melbourne, Victoria.
1666. Ibid.
1667. Victorian Auditor General's Office (VAGO) 2018, 'Protecting Victoria's coastal assets. Independent assurance report to parliament 2017–18: 14', Melbourne, Victoria, p. 23, incorporating data from NCCARF 2011.

Indicator 72: Recreational boating infrastructure

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		↗			N/A	N/A

Data source:	Better Boating Victoria, DELWP, VEAC
Measures:	Boating infrastructure upgrades | Boating infrastructure with proximity to marine and coastal assets Climate change impacts on boating infrastructure

Why this indicator?

Boating infrastructure is being reviewed across the state and identified for upgrade. Fish cleaning tables are a contentious issue as fish scraps effect the habitat balance in immediate are (for example, problem seals, pelicans) whilst boat cleaning facilities often facilitate run-off of oils and fuels into local water. The location of boat ramps around the bay and proximity to protected areas (for example, Ramsar sites) will give an indication of current and future human interaction with sensitive areas.

Justification for assessment ratings:

- With the establishment of the Better Boating Fund, there is a funding mechanism to enable upgrading of boating facilities along the Victorian Coast.
- Investment is being undertaken to improve boating infrastructure across Victoria. Over time, the effectiveness of this program will be able to be tracked.
- In some cases, the location of boat ramps is in proximity to significant protected areas (for example, Ramsar sites or national parks) and this requires heightened attention being given to the management issues.
- Nevertheless, coastal boating infrastructure remains under threat from climate change due to sea level rise and increasing frequency of severe weather events. This is now being taken into consideration in new proposals dealing with boating infrastructure.
- Government policy is encouraging expansion of boating and fishing. The impact of this increase will require mitigation efforts to minimise negative environmental, social or cultural impacts.

The upgrading and modernisation of recreational boating facilities tends to increase use levels through increased capacity and improved access, thus increasing boating, angling and on-water activities surrounding the facility.

In 2019, Better Boating Victoria (BBV) was tasked with overseeing a program of recreational boating reforms. An investment of $47.2 million was made through the Victorian Budget 2019/20 to deliver upgrades to six of the state's busiest boat ramps. The program has been expanded and upgrades are now occurring at 10 locations (Table 60).

Table 60: Boat Ramp Upgrades under the Better Boating Program, as at May 2021.[1669]

Location	Stage
Maribyrnong River	Consultation
Cape Conran	Consultation
Mahers Landing	Consultation
Rhyll	Planning
Cowes Boat Ramp	Planning
Werribee South	Planning
Point Richards	Planning
Queenscliff	Planning
Mordialloc	Planning
Hastings	In Construction
Cowes Jetty	In Construction

1668. Aecom Australia 2019, 'St Kilda marina redevelopment. environmental and coastal requirements', prepared for Port Phillip City Council, p. 12.
1669. Better Boating Victoria (BBV) 2021, 'Boat ramp upgrades' https://betterboating.vic.gov.au/priority-boat-ramp-upgrades/ Accessed 10 May 2021.

Legislation to establish the Better Boating Fund was passed in November 2020 in the Victorian Parliament. The Better Boating Fund uses marine licensing and boat registration fees to improve boating safety and facilities. The Better Boating Fund will commence on 1 July 2021.[1670]

The improvement of boating infrastructure and facilities can have both positive and negative impacts on the environment. Improved infrastructure is likely to lead to an increase in use which means higher numbers of visitor populations, potentially increasing human impacts (for example, litter, waste, trampling of sensitive ecosystems). Fish cleaning tables are a contentious issue as fish scraps effect the habitat balance in the immediate area (for example, problem seals, pelicans) whilst boat cleaning facilities often facilitate runoff of oils and fuels into local water.

However, better infrastructure and facilities can also reduce litter through the provision of bins, improve visitor behaviour through educational signage, and even limit the impact of fish tables through good design and waste management. Hard infrastructure such as paved boat ramps can change runoff patterns but also limit erosion and turbidity. In short, careful planning, design and visitor management strategies are all important to minimise any negative impacts of boating infrastructure upgrades.

In some cases, the location of boat ramps is in proximity to significant protected areas (for example, Ramsar sites or national parks) and this requires heightened attention being given to the management issues outlined above. Of the 266 boat access points across coastal Victoria (i.e. within 5 km of the coast), 66 (25%) are within 1 kilometre of a Ramsar site[1671] and 18 (7%) are within 1 kilometre of a marine and coastal national park or sanctuary.[1672,1673] A total of 172 access points (65%) are located within a kilometre of a marine asset of local, bioregional or state significance.[1674] The majority of these boat access structures are made of concrete (44%) or sand (20%).

Better Boating Victoria is currently reviewing management arrangements for boating facilities in Victoria. Some of these assets along the Victorian coast will be subject to the impacts of climate change such as sea level rise (Table 61). Further discussion of the impacts of climate change on infrastructure is provided in the discussion for Indicator 71: Built and public benefit infrastructure.

1670. Department of Transport (DoT) 2021, 'Better boating fund', Melbourne, Victoria https://transport.vic.gov.au/fishing-and-boating/better-boating-fund Accessed 10 May 2021.
1671. DataVic 2021, 'RAMSAR wetland areas in Victoria at 1:25 000', map layer https://discover.data.vic.gov.au/dataset/ramsar-wetland-areas-in-victoria-at-1-25-000 Accessed 27 July 2021.
1672. DataVic 2020, 'Marine national park - public land management', map layer.
1673. DataVic 2020, 'Marine sanctuary - public land management', map layer.
1674. DataVic 2020, 'Marine assets' map layer https://discover.data.vic.gov.au/dataset/marine-assets Accessed 26 July 2021.

Table 61: Crown Land reserves with boating facilities at risk of sea level rise from climate change.[1675]

Crown Reserve	Region	Ha	Proportion (%) of land unit affected by projected sea level rise of 20cm by 2040
The Anchorage Jetty (French Island)	Western Port	0.1	31.8
Warneet South Jetty	Western Port	0.7	26.0
San Remo Jetty	Western Port	1.3	22.4
Hastings Pier	Western Port	0.9	21.3
Rhyll Jetty	Western Port	0.2	20.9
Lang Lang Jetty	Western Port	0.2	18.7
Port Campbell Jetty and Coastal Reserve	West Coast	2.0	14.3
Sorrento Pier and Coastal Reserve	Port Phillip Bay	3.3	13.3
Seabrae Boat Club Jetty	Port Phillip Bay	0.1	11.6
Werribee South Jetty	Port Phillip Bay	0.3	11.3
Warneet North Jetty	Western Port	0.4	9.7
Tankerton Jetty (French Island)	Western Port	7.5	9.2
Portsea Pier	Port Phillip Bay	0.3	6.8
Portarlington Pier	Port Phillip Bay	7.6	3.4
Seaford Pier	Port Phillip Bay	0.2	2.6
Rye Pier	Port Phillip Bay	0.4	2.1
Frankston Pier	Port Phillip Bay	0.4	2.0
Rosebud Pier	Port Phillip Bay	0.8	1.3
Beaumaris Motor Yacht Squadron	Port Phillip Bay	1.2	0.5

1675. Victorian Environmental Assessment Council (VEAC) 2020, 'Assessment of Victoria's coastal reserves - inventory of coastal reserves', Melbourne, Victoria https://www.veac.vic.gov.au/investigations-assessments/current-assessments/investigation/assessment-of-victoria-s-coastal-reserves Accessed 30 June 2021.

Theme 8: Communities

Indicator 73: Illegal activities

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide					N/A	N/A

Data source:	EPA, Maritime Safety Victoria, Victorian Fisheries Authority, DELWP, Office of the Conservation Regulator
Measures:	Number of boating infringements | Number of fishing infringements | Number of environmental infringements; Point source discharges – non-compliance

Why this indicator?

This indicator highlights levels of compliance with environmental protection regulations. Illegal activities related to fishing, boating, litter and pollution and environmental damage are examined.

Justification for assessment ratings:

- Illegal activities affecting marine and coastal environments fall within the responsibility of many different agencies depending on whether they relate to fishing, boating, or environmental damage. It is therefore difficult to gain an overall picture of compliance or environmental impact even where data are available.
- While good data are available for some illegal activities (for example for boating and fishing infringements) other compliance data are affected by when and where compliance activities are undertaken. Hence, they may provide an incomplete picture of the character and prevalence of illegal activities.
- An important factor in achieving compliance is the role of engagement and education. Parks Victoria found that rules affecting Marine National Parks and Sanctuaries are not always understood by visitors. This finding suggests the need for further communication and engagement with users to explain, not only the existence of these rules, but the purpose behind them.

This indicator is designed to inform compliance and enforcement of activities like illegal fishing, illegal dumping of waste in coastal vegetation, recreational activities such as kiteboarding or jet skis that are inconsistent with management plans, illegal clearing and vandalism of vegetation (Table 62).

The analysis should help to target priority marine national parks and sanctuaries to patrol and monitor illegal activities, in addition to the community knowing how they be active players in reporting illegal fishing. It can also provide an indication of how current government recreational fishing numbers are impacting on marine protected areas.

Table 62: Selected illegal activities affecting marine and coastal areas.

Sector	Examples of regulated and illegal activities	Responsible agency/agencies
Boating (recreational)	vessel and driver licencing vessel and driver safety	Maritime Safety Victoria
Fishing (recreational, commercial, aquaculture)	fishing licences breaches of fishing regulations	Victorian Fishing Authority
Environment (DELWP)	wildlife licences breaches of campfire regulations, illegal vehicle use on public land, illegal taking of firewood, wildlife crimes (smuggling, injury, destruction).	Office of the Conservation Regulator
Environment (EPA)	Litter	EPA

Boating compliance

Maritime Safety Victoria (MSV) is responsible for licencing and compliance of boats in Victoria. Both the vessels and their operators are required to be licenced (see earlier discussion under Indicator 64: Recreational boating). Inspections are undertaken on a regular basis to check the validity of licences and whether there are any breaches of other regulations such as the carrying of safety equipment. For the 2019 calendar year, 82% of all inspections (coastal and inland waterways) found no offences by vessel operators. Figure 139 shows data for coastal waterways while Figure 140 shows infringements by vessel type. Compliance was highest in the Gippsland Lakes region (North Arm, Lake King, Lake Tyers, Mitchell River and Bancroft Bay), while lower levels of compliance were found in Corner Inlet and Anderson Inlet during 2019. More than 80% of inspections in Western Port and Port Phillip Bay resulted in no offences being found.

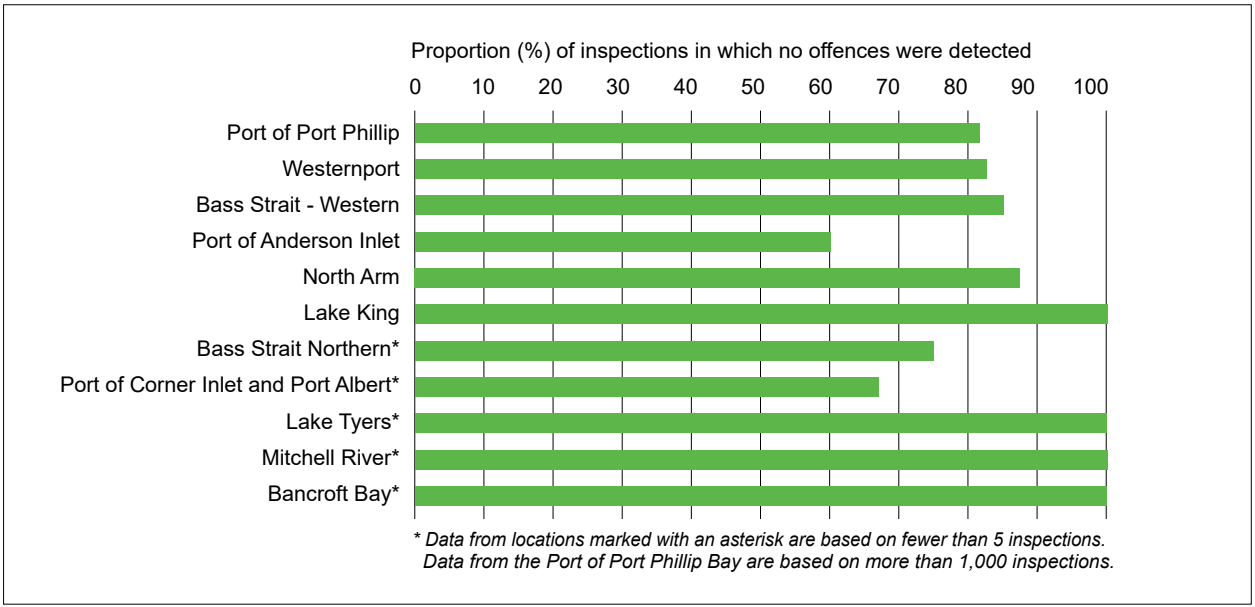


Figure 139: Outcomes of Maritime Safety Victoria (MSV) inspections of Victorian coastal waterways, 1 January to 31 December, 2019.[1676]

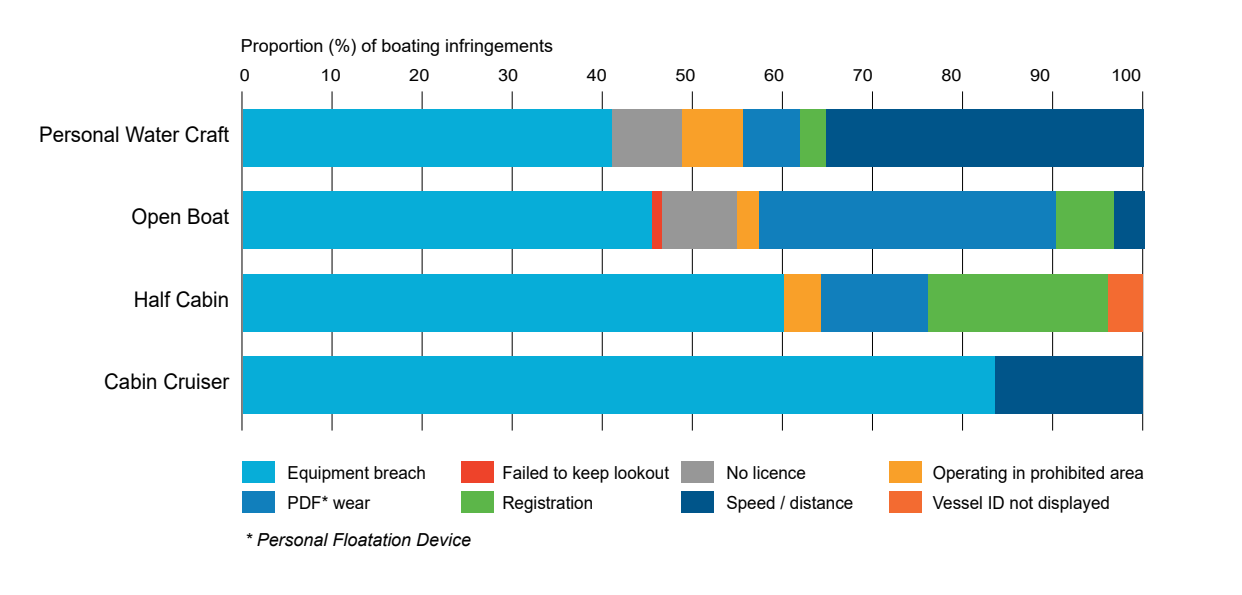


Figure 140: Maritime Safety Victoria (MSV) Infringements by Vessel Type, 1 Jan to 31 Dec, 2019.[1677]

1676. Maritime Safety Victoria 2021, 'Maritime Safety Victoria, data extract 2019', Transport Safety Victoria, Melbourne, Victoria, p. 3.
1677. Maritime Safety Victoria 2020, 'On deck. Maritime Safety Victoria stakeholder update, Data extract – July 2020', Transport Safety Victoria, Melbourne, Victoria, p. 4.

Fishing compliance

In the year ending 30 June 2020, Victorian fisheries inspectors carried out nearly 54,400 inspections across the state (inland and maritime waters). Details of these and their outcomes are provided in Table 63. Relatively small proportions of inspections resulted in verbal warnings (2.2%) official warnings (3.7%) or infringement notices (3.2%) being issued. This represented an overall compliance rate of 91% for all fishing sectors.

Table 63: Fishing infringements and outcomes, Victoria, 2019-20.[1678]

Sector	Inspections	Offenders	Verbal Warning	Official warning	Infringements	Brief
Recreational Fishing	49,940	3,807	873	1,661	1,482	30
Maritime Safety	3,449	605	261	306	192	1
Marine Parks	222	119	9	39	74	0
Commercial Fishing	755	74	50	17	16	3
Aquaculture	29	6	5	2	1	0
TOTAL	54395	4611	1198	2025	1765	34

To increase compliance, the VFA undertakes education programs to increase awareness and understanding of fisheries regulations. Education involves a number of activities including promotion of regulations, production and distribution of the Victorian Recreational Fishing Guide, provision of fish rulers and other measuring equipment, and schools' education programs. On-site education by fisheries officers on patrol is also undertaken. The VFA also hosts events with a focus on fishing promotion and education about the regulations.[1679]

Environmental compliance

The Department of Environment, Water, Planning and Environment (DELWP) has responsibility for a range of environmental regulations. In 2019, it established the Office of the Conservation Regulator (OCR) to oversee compliance against these regulations in relation to:[1680]

- timber harvesting in state forests
- fire prevention
- public land use
- wildlife and biodiversity

Four statewide compliance priorities were set by the OCR for the 2019- 2020 financial year.[1681] These were:

- illegal campfires
- illegal take of firewood
- illegal vehicle use on public land
- unauthorised timber harvesting in native forests

Table 64 shows the results of compliance activities carried out by the OCR in relation to these four priorities in the year ending 30 June 2020.

1678. Victorian Fisheries Authority (VFA) 2021, 'Compliance statistics 2019-2020' https://vfa.vic.gov.au/enforcement/enforcement-outcomes Accessed 12 March 2021.
1679. Victorian Fisheries Authority (VFA) 2021, 'Promoting stewardship' https://vfa.vic.gov.au/education Accessed 12 March 2021.
1680. Department of Environment, Water, Planning and Environment (DELWP) 2019, 'Regulatory framework', East Melbourne, Victoria.
1681. Office of the Conservation Regulator (OCR) 2020, 'Year in review 2019–2020' Melbourne, Victoria.

Table 64: Compliance outcomes for selected priority areas of the Office of the Conservation Regulator (OCR), 2019-20.[1682]

OCR Priority area	Compliance outcomes
Illegal campfires	31 people prosecuted for a total of 64 offences for lighting a fire on a total fire ban day or allowing a fire to remain alight on a total fire ban day 25 infringement notices issued for illegal campfires 19 official warnings given for leaving a campfire unattended
Illegal take of firewood	2 prosecutions undertaken with 3 charges for unauthorised firewood collection 41 infringements issued 13 warnings issued
Illegal vehicle use on public land	2 prosecutions for 7 offences for illegal vehicle use 100 infringements issued 25 official warnings issued

Regulatory priorities for 2020-21 include a continued focus on the four priorities above plus an increased focus on regulating the use, keeping, trade, treatment and control of wildlife.[1683] In 2019–20, there were 6 prosecutions consisting of 27 offences for illegal possession and trade of wildlife along with 14 infringements and 39 warnings issued. Five prosecutions with 45 charges for cruelty to or disturbance of wildlife were also undertaken by the OCR.

The total number of compliance outcomes for 2019-20 are shown in Figure 141. The significant increase in the issuing of infringements during May-June 2020 was due to an increase in high public land visitation levels due to COVID-19 travel restrictions and the associated increased patrols of Operation Guardian undertaken by the OCR.

1682. Ibid.
1683. Office of the Conservation Regulator (OCR) 2020, 'Regulatory priorities 2020–2021', Melbourne, Victoria.
1684. Office of the Conservation Regulator (OCR) 2020, 'Year in review 2019–2020', p. 16, Melbourne, Victoria.

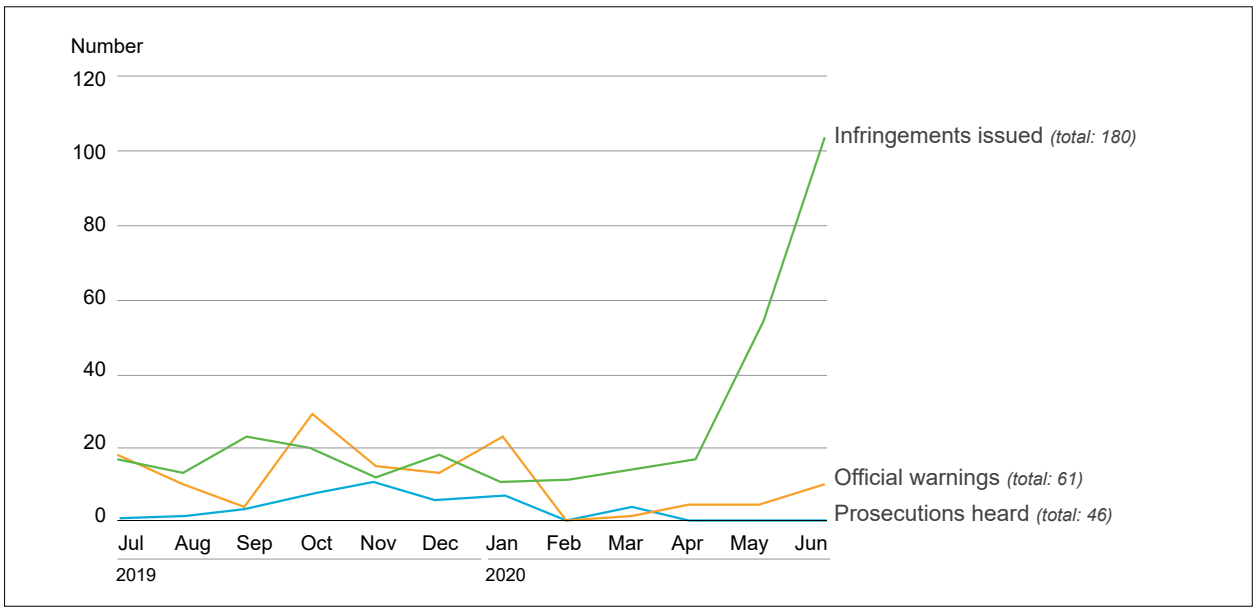


Figure 141: Summary of compliance outcomes for the Office of the Conservation Regulator (OCR), 2019-2020.[1684]

As part of its regulatory compliance program the OCR provides various educational resources to inform the community about regulatory requirements and obligations. This helps to enhance compliance outcomes. For example, in 2019-20, Operation Campfire raised community awareness about when and where a campfire can be lit and the risks of them escaping. DELWP and the Transport Accident Commission undertook a Trail Bike Initiative to promote safe, compliant, and environmentally sustainable trail riding practices.[1685]

An important factor in achieving compliance is the role of engagement and education. A Parks Victoria survey undertaken in 2021 found that rules affecting Marine National Parks and Sanctuaries are not always understood by visitors. Whilst visitors think they are doing the right thing when visiting the marine national park system, there was found to be low awareness of the rules and regulations governing behaviour with only a third of site-specific visitors being found to be fully aware of the onsite rules and permitted activities.[1686] Table 65 shows the activities which were found to cause misunderstanding among some visitors. This finding suggests the need for further communication and engagement with users to explain, not only the existence of these rules, but the purpose behind them.

Table 65: Visitor perception of allowable activities in Victorian Marine National Parks and Sanctuaries.[1687]

Activity not allowed in Park	% of Park visitors who thought activity was allowed
Beachcombing/collecting	13
Commercial fishing	9
Horse riding	6
Recreational fishing	12
Walking dogs off-lead	8

1685. Ibid. pp. 7, 9.
1686. Parks Victoria 2021, 'Victorian community usage, awareness and perceptions of marine parks and sanctuaries', written by Jacky Heath, Lonergan, Sydney, pp. 52, 54.
1687. Ibid. p. 58.

Theme 9
Stewardship and Collaborative Management

Commissioner *for* Environmental Sustainability Victoria

Wilsons Promontory National Park - Friends of the Prom volunteers
© Parks Victoria

Background

Stewardship and Collaborative Management

This Stewardship and Collaborative Management theme includes participation in stewardship activities at the local level, through to Victorian Government legislative and policy frameworks. Engagement and partnerships between agencies and communities enable co-creation of policy which can deliver stewardship outcomes on the ground.

While it is relatively easy to measure numbers of participants involved in relevant programs, it is more difficult to measure institutional characteristics or policy processes and effectiveness. For this reason, there are indicators in this chapter of the SMCE which provide a narrative exploration and assessment rather than specific or precise measurements. It is intended that this approach can raise issues and lead to new ways of measuring these aspects of stewardship and collaborative management for future State of Environment reporting.

There is a growing recognition of the importance of people being connected to nature. There are many participants involved in stewardship activities. At the community level this includes farmers and other land managers, fishers and others who rely on marine industries, traditional owners caring for country and various volunteer groups involved in environmental protection and enhancement. Many government departments and agencies are also involved in stewardship activities through funding processes, policy making and management of programs. Although defining and measuring stewardship is difficult, there has been recent progress through the development of a Marine and Coastal Stewardship Index by DELWP. Although it is too early to measure trends using this index, benchmark data are starting to be collected for Port Phillip Bay programs and this should provide a model for future data collection and indicator assessment.

Volunteering is one example where data are available. These data show that, although there are many committed volunteer groups that contribute to protecting, conserving and improving marine and coastal environments, less than 6% of Australians who volunteer are involved in environmental activities.

The Ipsos survey of community attitudes examined community participation in relation to Victoria's coast and potential financial contributions to the preservation of the Victorian coast and marine environments. The survey undertaken in 2018 found that 42% of surveyed respondents indicated an interest in joining a coastal volunteer group while 39% indicated their willingness to contribute financially to improve coastal management.

Coastcare Victoria is a community-based program which supports community stewardship of Victoria's marine and coastal environments. Volunteering is a key element of Coastcare's activities, and it aims to foster community appreciation of marine and coastal areas. The Coastcare program supports hundreds of community groups and volunteers working to protect and enhance Victoria's coastline. Activities include revegetating coastal areas, building boardwalks and tracks, fencing, monitoring native shorebirds and animals, presenting education and awareness raising sessions, plantings, landscaping and protecting cultural sites.[1688] A total of 13,444 people participated in Coastcare activities during 2019-20[1689], an increase from 10,500 recorded in the previous financial year.[1690]

Citizen scientists have been involved in marine and coastal programs, even during COVID lockdown when virtual projects enabled seal counts (via webcam) and other activities to continue. The range of these programs is broad and they can provide important data for scientific analysis where appropriate levels of rigour are applied to data collection and analytical methods. It is important for the DELWP Marine and Coastal Knowledge Framework to identify the role of, and restraints on, volunteers and citizen scientists in contributing to the evidence base of critical marine and coastal scientific knowledge. The current development of a citizen science framework for Victoria is a promising development that can help address some of these requirements and challenges to expand citizen science activities.

1688. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Draft Coastcare Victoria strategy 2020-2025', Victorian Government, Melbourne https://engage.vic.gov.au/coastcare-victoria-strategy-2020-2025 Accessed 24 February 2021.
1689. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Annual report 2020', Melbourne, Victoria, p. 52 https://www.delwp.vic.gov.au/__data/assets/pdf_file/0025/494134/Annual-Report-2019-20-3.pdf
1690. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Annual report 2019', Melbourne, Victoria, p. 42 https://www.delwp.vic.gov.au/__data/assets/pdf_file/0032/438188/DELWP-Annual-Report-2018-19-web.pdf

Theme 9: Stewardship and Collaborative Management

The assessment of the Victorian Government role in stewardship activities takes a narrative approach to explore Victoria's marine and coastal planning regimes and implementation strategies. In the past, Victoria's marine and coastal planning and policy arrangements have been criticised for being overly complex and multi-layered, thus limiting policy coherence. The introduction of the *Marine and Coastal Act 2018* and the subsequent Marine and Coastal Policy 2020 have helped to streamline and clarify aspects of coastal policy.

Institutional knowledge and capacity are acknowledged as critical for effective environmental policy. At the aggregate level, a meaningful assessment of institutional knowledge and capacity is unrealistic because of the large number, variety and complexity of institutions which have responsibilities for marine and coastal management. Following findings from the State of the Bays 2016 Report, Victoria has put in place a Marine and Coastal Knowledge Framework to support the knowledge needs of planning for Victoria's marine and coastal areas. One outcome has been Coastkit - an online system for marine and coastal spatial data. While the development of data systems for marine and coastal management is welcome, analysis of what the data tell us and the degree to which such intelligence is being used in decision making is still unclear and unable to be fully assessed yet. It is important that the Marine and Coastal Knowledge Framework considers the supply of analysis and interpretation to complement data sets to provide clarity for future state of the environment reporting.

Indicator 74: Stewardship

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		?			N/A	N/A

Data source:	DELWP
Measures:	Marine and Coastal Stewardship Index (comprising: environmental objectives, effort, outcome, accountability and adaptive management)

Why this indicator?

This indicator will recognise the fundamentally important role of communities in promoting sustainable practices through their stewardship of marine and coastal areas.

Justification for assessment ratings:

- Many policies and on-ground activities represent actions of stewardship however measurement protocols have been limited to date.
- Although defining and measuring stewardship is difficult there has been recent progress through the development of a stewardship Index by DELWP.
- Although it is too early to measure trends using this index, benchmark data are starting to be collected for Port Phillip Bay programs and this should provide a model for future data collection and indicator assessment.
- At a more disaggregated level, stewardship activities can also be assessed through measures provided for Indicator 75: Community connection to the coast, Indicator 76: Volunteering, and Indicator 77: Citizen science.

At a basic level, environmental stewardship refers to an ethic of taking care of the natural environment. It can include efforts to manage and protect land through the nurturing of responsibility in landowners and resource users.[1691] At a more fundamental level it relates to a particular relationship with the environment – a shift from a perspective of humans dominating or conquering the natural world to one in which humans are essentially part of the environment.[1692]

1691. Plieninger T and Bieling C 2017, 'The emergence of landscape stewardship in practice, policy and research', chapter 1 in C Bieling and T Plieninger (eds), 'The Science and Practice of Landscape Stewardship', Cambridge University Press, Cambridge, UK, pp. 1–17 https://doi.org/10.1017/9781316499016.007
1692. Leopold A 1949, 'A Sand County Almanac', excerpt reproduced in Peterson Del Mar D 2011, 'Environmentalism', Taylor and Francis, p 118.

Theme 9: Stewardship and Collaborative Management

The term 'landscape stewardship' is commonly used in the literature and is grounded in sustainability concepts as it seeks to sustain ecosystem services to support human wellbeing.[1693] It 'seeks to simultaneously improve heritage, food production, biodiversity and/or ecosystem conservation and rural livelihoods and particularly acknowledges the interconnections between social justice and environmental health'. Landscape stewardship may focus on the many individuals and groups that are involved in care of the environment and may also include other responsible players such as government or business.[1694]

These definitions tend to emphasise the land-based environment, yet stewardship is as important for marine and coastal areas as it is for adjacent land areas and catchments. The emphasis of landscape stewardship in terms of taking a broader landscape scale approach is important when considering marine areas because, even though people do not live in the ocean, their activities affect the marine environment and resources are drawn from the sea to sustain human populations.

Stewardship of the coast is undertaken by thousands of volunteers and local groups. These include Aboriginal Victorians, volunteers, committees of management, Coastcare, Landcare, citizen science groups, coastal advisory groups, conservation management networks, community groups, boating and fishing groups, industry groups, management agencies, farmers, individuals, local councils and state government.[1695]

Community-based groups are funded through various agencies at local, state and federal scale as well as from non-government agencies and private business. Collaboration is important so that local efforts may be harnessed to meet broader strategic objectives. Where broader objectives are aligned with local action then benefits can be maximised. This chapter therefore considers issues of governance and institutional arrangements as well as documenting the stewardship activities being undertaken at the local scale.

The Victorian Marine and Coastal Policy outlines the following outcomes for stewardship and collaborative management:

Traditional Owners, marine and coastal managers, community groups and user groups:

- are actively engaged and empowered to care for, protect and improve the health of the marine and coastal environment
- collaborate, as stewards, to take care of and deliver integrated and coordinated planning and management of the marine and coastal environment
- have the knowledge, skills and capacity to manage current and future challenges.[1696]

Stewardship embodies a responsibility that may be held at different levels of government, within communities, or by individuals. For this reason, it is worth identifying the types of stewardship activities that might occur across the private and public sectors. For State Government, many stewardship responsibilities are enshrined in legislation such as the *Environmental Protection Act 1970*, *Catchment and Land Protection Act 1994* or *Marine and Coastal Act 2018*, among others. Policies and programs flow from these laws which aim to protect Victoria's environmental assets. Some state laws such as the *Planning and Environment Act 1987* establish systems to coordinate the use and development of land at a local scale. Objectives relating to environmental protection are included within these systems and are taken into consideration by local government decision makers.

Many stewardship activities take place at the community scale. While some of these may be related to or funded by government programs, many are delivered through non-government organisations, not for profit agencies and local groups of volunteers who care for and protect local beaches, bushland, flora and fauna. Many are also involved in citizen science activities which monitor and assess environmental condition at the local scale.

1693. Chapin F, Carpenter S, Kofinas G, Folke C, Abel N, Clark W, Olsson P, Smith D, Walker B, Young O, Berkes F, Biggs R, Grove J, Naylor R, Pinkerton E, Steffen W and Swanson F 2010, 'Ecosystem stewardship: sustainability strategies for a rapidly changing planet', *Trends in Ecology and Evolution*, 25(4), pp.241–249 https://doi.org/10.1016/j.tree.2009.10.008
1694. Buck L, Scherr S, Planicka C and Heiner K 2017, 'Building partnerships for landscape stewardship', chapter 4 in C Bieling and T Plieninger (eds), 'The science and practice of landscape stewardship', Cambridge University Press, Cambridge, UK, pp. 57–77 https://doi.org/10.1017/9781316499016.007
1695. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Marine and coastal policy', East Melbourne, Victoria.
1696. Ibid.

Particular groups such as recreational fishers have an interest in maintaining a healthy environment which sustains the fish they catch. Programs such as the Angler Riparian Partnerships Program which ran from 2016/17 to 2019/20 enabled recreational fishers to partner with local CMAs, landowners and local communities to improve riverside environments. Healthy riversides can improve water quality, stabilise water temperatures, filter nutrients and sediments from catchment run-off, stabilise riverbanks, reduce erosion, and provide shade, food and shelter for fish.[1697]

In many ways, stewardship is the responsibility of all rather than of a particular agency or community group. This makes it potentially complex and thus difficult to get a complete picture of its characteristics and outcomes. The complexity also suggests that collaborative management approaches are of particular importance so that the combined outcomes of many stewardship activities can be aligned and achieve the environmental benefits being sought.

Acts of stewardship may have different objectives. Ultimately the protection of the environment is sought, but the relationship can also involve the social benefits of acting within nature and on behalf of nature. For the individual, this may be revealed in mental and spiritual health and wellbeing; for groups it may bring an enhancement of social capital – of connectedness and inclusion. For government, it may fulfil the requirement of custodianship – something which itself benefits society.

This multifaceted character makes measuring the success (or otherwise) of stewardship challenging:

SCALE: at what scale is stewardship occurring? How do we measure the different scales of activity?

OBJECTIVE: What objective(s) is/are we measuring stewardship activities against?

OUTCOME: What outcome(s) are we measuring? For example, organisational effectiveness/efficiency or achieving an environmental outcome?

Intermittent funding for stewardship activities may also make it difficult to assess effectiveness and the inevitable variability in peoples' involvement in volunteering activities can make it difficult to document numbers involved or hours devoted to environmental stewardship. Again, the scale at which we choose to measure activity is important and whether we are measuring individual satisfaction, community benefit or environmental improvement. Individual programs may be evaluated but understanding the cumulative impact of many different activities remains elusive in terms of assessing ultimate outcomes. While a program may end at a specific point in time, the ongoing environmental benefits may increase (for example, vegetation planted may ultimately grow into a more complex habitat) or decrease (invasive species may return and degrade an area where vegetation was planted).

Despite the challenges in measuring stewardship, the Victorian Government has developed an approach to creating a stewardship index. The Marine and Coastal Stewardship Index (MCSI) was developed as part of the Port Philip Bay Environmental Management Plan 2017-2027 which states, 'Stewardship of the Bay is fostered across community, industry and government as an overarching goal.'[1698] The MCSI seeks to identify different aspects of stewardship which can be monitored. These range from programs that emphasise capacity building and knowledge sharing, to community activity, to the enhancement and restoration of marine and coastal environments. All these activities are important and meet different objectives of stewardship. The 4-part categorisation of activities from supporting through to comprehensive represents an increasing confidence in delivering environmental benefits (Table 66). In this schema, supporting activities are the foundation that is required to enable communities and individuals to understand and undertake stewardship work in the future.

1697. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Angler riparian partnerships program. Statewide achievements in 2019/20 and program finale', East Melbourne, Victoria, p. 1. https://www.water.vic.gov.au/__data/assets/pdf_file/0027/491643/Angler-Riparian-Partnerships-Program-2019-20-achievements-report.pdf Accessed 18 March 2021.

1698. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Port Phillip Bay environmental management plan 2017–2027', East Melbourne, Victoria.

Table 66: Definitions used in the Victorian Government Marine and Coastal Stewardship Index (MCSI).[1699]

Category	Definition
Comprehensive	Activity is highly targeted and delivers protection, enhancement and restoration of the marine and coastal environment
Focused	Activity contributes to the protection, enhancement and restoration of the marine and coastal environment
Enterprising	Untargeted on-ground activity is occurring, but its contribution to the protection, enhancement and restoration of the marine and coastal environment is small or unknown
Supporting	Programs that develop skills and knowledge vital for effective stewardship

The MSCI has been used to assess stewardship activities in Port Phillip Bay. Figure 142 presents the results of this assessment for two time periods.

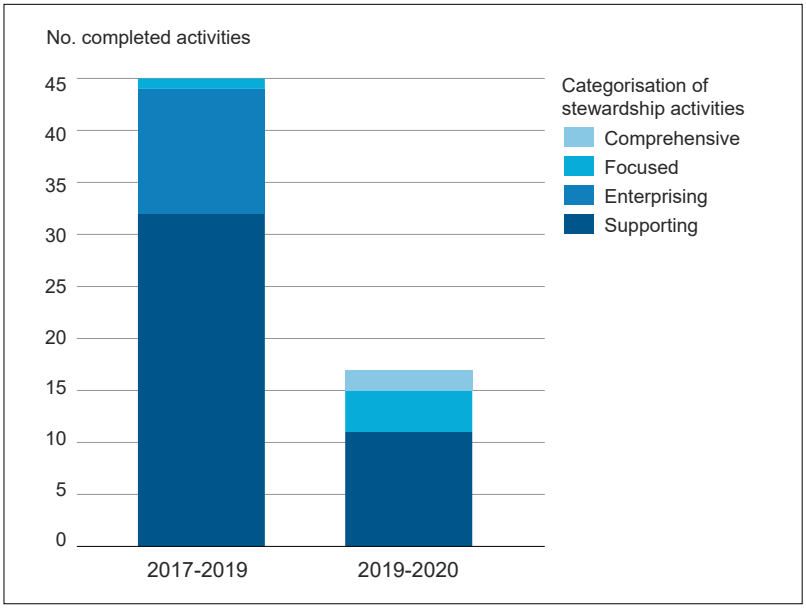


Figure 142: Marine and Coastal Stewardship Index assessment for Port Phillip Bay 2017-19 and 2019-20.[1700]

In 2017-19, the first batch of single-year Port Phillip Bay funded activities were completed. In 2019-20 new single-year activities were completed along with activities that had been funded earlier for a 2-year period. In the first time period, the majority of activities were in the supporting or enterprising categories which shows the foundations of stewardship activities being laid.

The second time period shows supporting, focused and comprehensive categories being represented indicating that targeting of environmental activities and outcomes of environmental enhancement are being attained. The involvement of organisations with long experience in stewardship activities also increases the likelihood that activities will span the four categories, thus achieving a range of environmental policy objectives.

1699. East R 2021, 'Marine and coastal stewardship index', Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria, available on request.
1700. Department of Environment, Land, Water and Planning (DELWP) environment and climate change division special data request.

Theme 9: Stewardship and Collaborative Management

Indicator 75: Community connection to the coast

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide					N/A	N/A

Data source:	Ipsos Marine and Coastal Community Attitudes and Behaviour Report, VFA Creel Surveys
Measures:	Values held in relation to marine and coastal environment; Reasons for involvement in coastal activities like fishing

Why this indicator?

There is a growing recognition of the importance of people being connected to nature. This indicator will analyse how people are connected to the marine and coastal environments and how that connection informs their sense of identity and sense of belonging. Community attitudes and behaviours shape how coastal and marine environments are managed.

Justification for assessment ratings:

- Surveys provide clear evidence that many Victorians value marine and coastal areas. This suggests a strong sense of connection with such environments.
- Australia has long had coastal environments as part of its cultural heritage - both for Indigenous and non-Indigenous Australians.
- One challenge this raises is how to maintain important cultural aspects of the ocean or beach experience while protecting coastal and marine environments from being 'loved to death'.

There is a growing recognition of the importance of people being connected to nature.[1701] Victoria's Biodiversity Plan acknowledges the connections within and between ecological, social, cultural and economic systems as well as the fact that ecosystem services delivered through biodiversity are a foundation for economic prosperity and the physical and mental health of Victorians.[1702]

Enhancing people's understanding of coastal and marine environments can assist in strengthening peoples' connection to them. Educational signage is often used to provide information on native flora and fauna, Aboriginal and non-Aboriginal cultural heritage, geological and ecological processes and ways in which people can avoid damage to natural environments. Educational initiatives can also involve the use of trained guides who can enhance the visitor experience through value-adding to their experience, while ensuring that visitors maintain the right behaviours to minimise environmental damage to the areas visited

In the Marine and Coastal Community Attitudes and Behaviour Survey,[1703] respondents were asked about what they most valued about the Victorian coast and marine environment. Unprompted answers indicate the importance of the natural environment (Figure 143). The highest proportion of mentions are for elements associated with the natural environment such as scenery, pristine beaches and wildlife. The category of 'other' responses includes those which represented less than 2% of total mentions. The fact that these in total account for 45% of responses indicates the diversity of experience of coastal and marine assets by the community.

1701. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Protecting Victoria's environment – biodiversity 2037', East Melbourne, Victoria.
1702. Ibid. p. 8.
1703. Ipsos 2018, 'Wave 5 marine and coastal community attitudes and behaviour report', prepared for the Victorian Marine and Coastal Council (VMaCC), Parks Victoria and Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria.

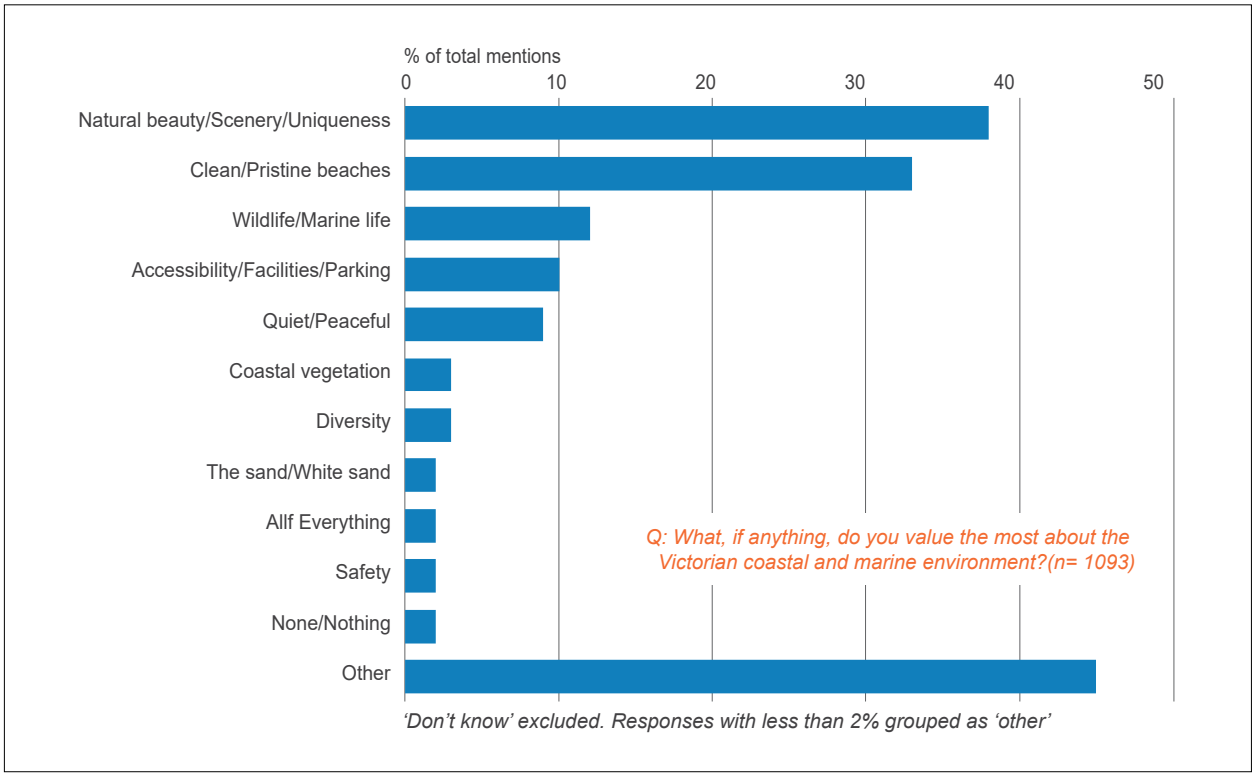


Figure 143: Victorian coast and marine environment values held by the Victorian community.[1704]

Parks Victoria have undertaken research on community awareness of Victoria's Marine National Parks and Sanctuaries. The most recent survey comprised 1,009 online surveys and 15 qualitative phone interviews. The survey found that 66% of Victorians were aware of the marine national park system and 88% agreed that marine environments should be protected.[1705]

Many of the values expressed in these surveys can be related to individual and community wellbeing. Research has found that coastal and marine environments contribute to peoples' physical, social and mental health and wellbeing.

Physical health

As noted previously, the Victorian coast and ocean offer opportunities for various recreational activities which support the improved physical health of individuals. Coastal and ocean environments can also be physically challenging, providing deeply satisfying and therapeutic experiences. The depth of experience we can have in coastal settings across the environmental, social and spiritual spectrum can contribute to moments of great happiness and fulfilment. Ongoing fondness and admiration of this environment can be linked to these types of experiences. The dynamic nature of marine and coastal environment allows individuals to experience the mental state of being challenged and completely immersed in activities that test their ability.[1706] Aside from personal benefits to the individual, the health benefits of physical activity and stress reduction are important in improving the overall health of the community which in turn brings economic savings to the wider health care system.[1707]

1704. Ibid. p. 19.
1705. Parks Victoria 2021, 'Victorian community usage, awareness and perceptions of marine parks and sanctuaries', written by Jacky Heath, Lonergan, Sydney, p. 6.
1706. Bell S, Phoenix C, Lovell R, and Wheeler B 2015, 'Seeking everyday wellbeing: the coast as a therapeutic landscape', *Social Science and Medicine*, 142(C), pp. 56-67.
1707. Papathanasopoulou E, White M, Hattam C, Lannin A, Harvey A and Spencer A 2016, 'Valuing the health benefits of physical activities in the marine environment and their importance for marine spatial planning', *Marine Policy*, 63 pp. 144-152.

Social well-being

Our coasts foster a sense of place, supporting community identity and social well-being. Victoria's coastal and marine environments are home to many public spaces where important shared experiences and relationships can occur. A sense of place can incorporate various components such as:

- Place attachment: emotional attachments to a setting.
- Place identity: the cognitive component of settings that provide opportunities for individuals to express and affirm the sense of who they are and what defines them.
- Place dependence: the behavioural component, referring to a functional reliance on a setting in which activities are undertaken.
- Social bonding: a social component, highlighting that settings can become meaningful through social relationships and shared experiences over time.[1708]

Accessible and inclusive places with a positive social atmosphere are invaluable for developing social well-being within a community.

Mental well-being

Coasts and marine environment can provide restorative, therapeutic experiences which can enhance mental well-being. The rhythms of the tides, swell, wind and wildlife and broad horizons can afford individuals a sense of spaciousness and cognitive release. These settings can allow for contemplation and the opportunity to reflect. Coastal settings with higher perceived biodiversity may also offer greater restorative potential.[1709]

Conceptual understanding of wellbeing has progressed in academic debates over the past 20 years with fundamental elements of life quality being identified. For example, wellbeing is determined by both external factors in the environment as well as internal factors that affect our experience of that external environment.[1710] The therapeutic experience of interacting with natural environments is summarised by Bell et al. (2015) in the diagram shown in Figure 144.

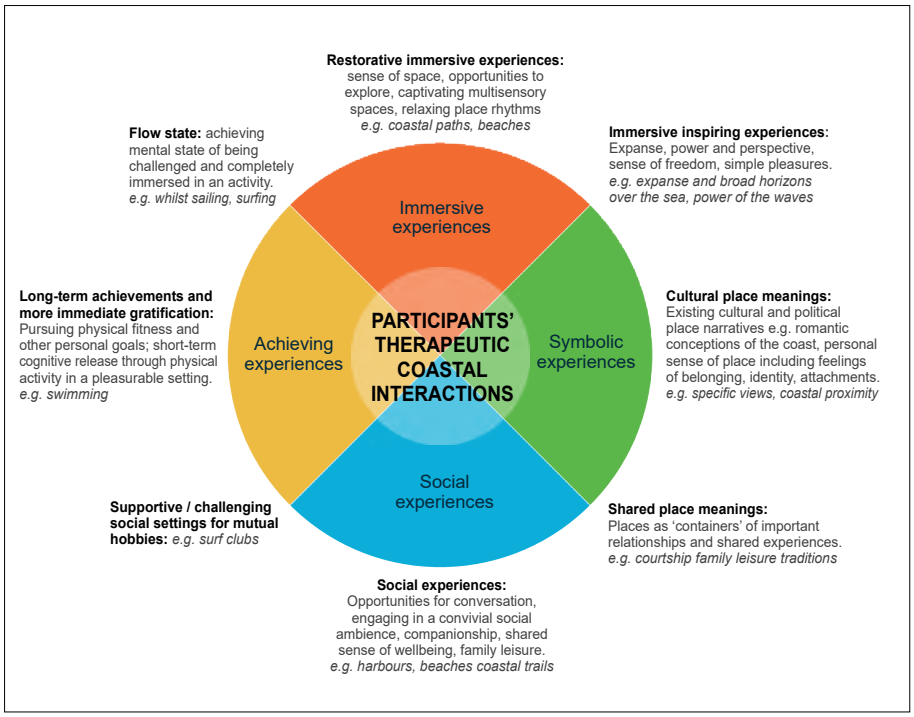


Figure 144: Four dimensions of therapeutic experience related to coastal interactions.[1711]

1708. Bell S, Phoenix C, Lovell R, and Wheeler B 2015, 'Seeking everyday wellbeing: the coast as a therapeutic landscape', *Social Science and Medicine*, 142(C), pp. 56-67, p. 57.
1709. White M, Weeks A, Hooper T, Bleakley L Cracknell D, Lovell R and Jefferson R 2017, 'Marine wildlife as an important component of coastal visits: the role of perceived biodiversity and species behaviour', *Marine Policy*, 78, pp. 80-89.
1710. Pacione M 2003, 'Urban environmental quality of human wellbeing – a social geographical perspective', *Landscape and Urban Planning*, 65(1-2), pp. 19-30.
1711. Bell S, Phoenix C, Lovell R, and Wheeler B 2015, 'Seeking everyday wellbeing: the coast as a therapeutic landscape', *Social Science and Medicine*, 142(C), pp. 56-67, p. 65.

Theme 9: Stewardship and Collaborative Management

Even with an agreed understanding of how wellbeing might be conceptualised, there are difficulties in measurement. As stated by Loveridge et al. (2020), '[d]espite conceptual progress towards agreement of universally relevant dimensions of wellbeing, consensus is still lacking on how to translate these dimensions into locally appropriate indicators to measure wellbeing in different contexts'.[1712] Surveys of self-reported wellbeing of individuals are one of the more direct ways in which this can be achieved in the sense that what people report is their reality – if they report their wellbeing is enhanced through contact with natural environments, this is a piece of factual information that can be aggregated and analysed as quantitative data, even though it is subjective rather than objective in nature.

Fishing is a good example of an activity which brings a range of physical, social and mental benefits to participants. Victorian angler surveys have highlighted the key drivers for their involvement in fishing (Figure 145). The opportunity to relax, unwind and enjoy the experience of catching fish are consistently rated as key reasons, while spending time with family and friends is also a factor.

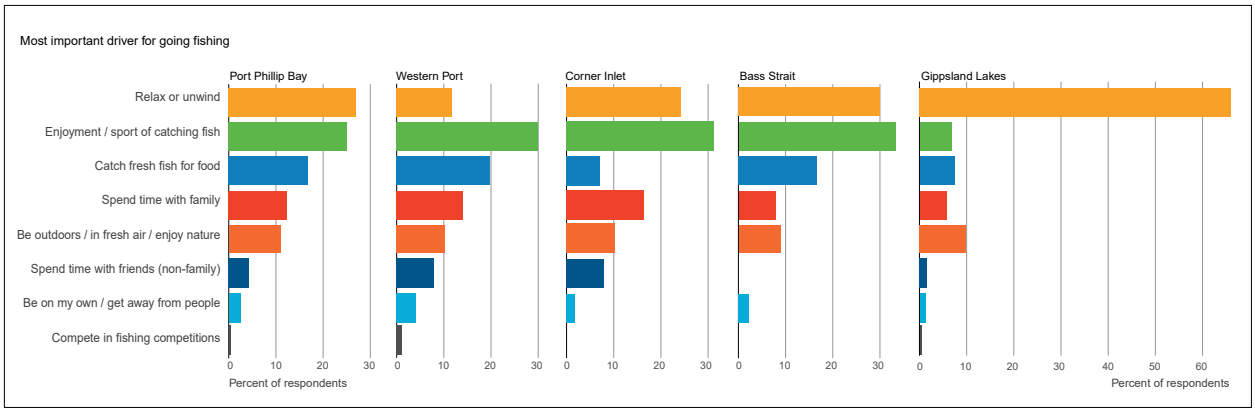


Figure 145: Most important driver for going fishing, selected Victorian regions, 2019.[1713]

Surfing is another example of a marine and coastal activity which has many health benefits. These can be seen through the types of programs which incorporate surfing activity for the benefit and wellbeing of diverse groups of people. Examples include:

The Victorian Indigenous Surfing Program has been running for more than 20 years – one of the longest running Indigenous engagement programs in the country. It uses surfing to connect Indigenous Victorians with the ocean while learning new skills, water safety and healthy habits. Programs are run across the state between October to May with locations including the regions of the Surf Coast, Metro Melbourne, Bass Coast, Lakes Entrance and Cape Conran. In 2020-2021 over 650 Indigenous people participated.[1714] The program culminates in two key events each year, the Woorangalook Koori Surfing Titles at Urquhart Bluff (Anglesea) and the Australian Indigenous Surfing Titles at Bells Beach (Torquay).[1715]

Waves of Wellness is a NSW-based surf therapy organisation that runs programs for people experiencing mental health challenges. It uses trained mental health professionals as surf coaches and participants learn how to use surfing as a coping strategy for mental health challenges.[1716]

OneWave is a non-profit group which raises community awareness of mental health through surfing. Starting in 2013 at Bondi Beach, its 'Fluro Friday' sessions of surfing, yoga and group discussion have now been held at more than 200 beaches globally.[1717]

1712. Loveridge R, Sallu S, Pesha I and Marshall A 2020, 'Measuring human wellbeing: a protocol for selecting local indicators', Environmental Science and Policy, 114, pp. 461–469.
1713. Victorian Fisheries Authority (VFA), 'Creel surveys 2018' special data request.
1714. Surfing Victoria, 'Victorian Indigenous surfing program' https://surfingvic.com/indigenous/ Accessed 18 November 2021.
1715. Australasian Leisure Management 2019, ' Australasian Leisure Management 2019, 'Victorian Indigenous surfing program receives additional support from Kieser Australia' https://www.ausleisure.com.au/news/victorian-indigenous-surfing-program-receives-additional-support-from-kieser-australia/ Accessed 7 September 2020.
1716. Waves of Wellness https://www.foundationwow.org Accessed 4 March 2021.
1717. Who is OneWave? https://www.onewaveisallittakes.com/about Accessed 4 March 2021.

Theme 9: Stewardship and Collaborative Management

Appreciation of parks and other natural spaces increased during the COVID-19 lockdowns in Melbourne. An opinion poll commissioned by the Victorian National Parks Association in 2020 found more than half of the 1,009 Melburnians polled indicated that COVID-19 restrictions have made them value access to natural areas (56%), and national parks (52%), across Victoria more.

Eighty-six percent supported Victoria having a comprehensive network of National Parks and conservation reserves across land and sea.[1718] While not specifically focused on coastal areas, the survey nevertheless highlights the importance of natural areas for peoples' wellbeing, especially during times of stress.

Indicator 76: Volunteering

	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		→			N/A	N/A

Data source:	ABS, DELWP, Parks Victoria
Measures:	Participation

Why this indicator?

Volunteers have various motivations and levels of capacity to protect, care for and responsibly use the marine and coastal environment. This indicator will highlight the importance of their work in achieving the vision of a healthy, dynamic and biodiverse marine and coastal environment.

Justification for assessment ratings:

- There are many committed volunteer groups that contribute to protecting, conserving and improving marine and coastal environments.
- However, less than 6% of Australians who volunteer are involved in environmental activities. There is an opportunity to draw from the broader community to increase the number of environmental volunteers.
- Maintaining and attracting volunteers is challenging in the modern era due to competing demands on peoples' time and changing lifestyles and expectations.

It has been estimated that there were 186,508 Victorians working as volunteers in environmental groups during 2020. These volunteers were involved in 2,166 groups and represented an economic contribution of approximately $101.36 million.[1719] The types of activities undertaken by these groups is shown in Table 67. Data for 2019 and 2020 is presented because 2020 was affected by COVID-19 pandemic lockdowns. While the pandemic had little impact on the relative importance of volunteer groups, it did have impacts on the types of activities that volunteers could undertake. The profile of volunteer activities showed some shifts as a result, for example, volunteers being more involved in sustainable living and citizen science but less involved in landscape activities due to constraints on being able to undertake travel or fieldwork in 2020.

1718. Lonergan Research 2020, 'VNPA polling 2020', prepared for Matt Ruchel, Victorian National Parks Association (VNPA), October 2020 https://vnpa.org.au/publications/covid_parks_polling/ Accessed 12 February 2021.
1719. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Volunteering naturally. Understanding Victoria's environmental volunteers 2020', East Melbourne, Victoria, p. 7.

Table 67: Activities undertaken by environmental groups in Victoria, 2019 and 2020.[1720,1721]

Activity	% of groups		% of volunteers		% of hours	
	2019	2020	2019	2020	2019	2020
Caring for landscapes	64	63	34	15	53	14
Sustainable living	20	21	36	63	14	15
Recreation/nature experience	<5	<5	12	<5	12	6
Citizen science	<5	<5	<5	13	<5	38
Wildlife rescue/ rehabilitation	<5	<5	<5	<5	<5	16
Advocacy	<5	<5	<5	<5	<5	<5
Networks/other	8	7	13	6	15	10

At a broader level, volunteering data for Australia are available from the ABS General Social Survey (most recent data 2019), and more geographically specific data from the Australian Census of Population and Housing (most recent data 2016). Both sources record whether individuals (aged 15 years and over) had undertaken volunteering in the previous 12 months.

According to 2016 Census data, regional Victorians show higher rates of volunteering than people in metropolitan Melbourne. This may be partly due to rural support networks and the need for more isolated communities to provide some of their own local services through volunteer efforts. Middle-aged and older Victorians are more likely to be volunteers than younger people and women are more likely to be volunteers than men. Areas of relatively low volunteering rates include outer metropolitan areas and peri-urban regions.

These areas tend to attract young families and commuters. Volunteering participation may be lower due to competing time demands such as commuting or looking after young families. Increasingly, many Victorians are looking for event-based volunteering opportunities which allow them to make short-term commitments rather than ongoing membership of a group.[1722]

The ABS General Social Survey (2019) found that almost a third (29.5%) of Australians aged 15 years and over participated in unpaid voluntary work through an organisation in 2019. These data provide a different perspective on environmental volunteering, showing that less than 6% of those who volunteer are involved in environmental activities. It is much more common for Australians to volunteer in sporting (39%), religious (23%) or educational (22%) activities (Figure 146).

1720. Ibid.
1721. Ibid.
1722. State Government of Victoria 2014, 'Victorian coastal strategy 2014', Melbourne, Victoria.

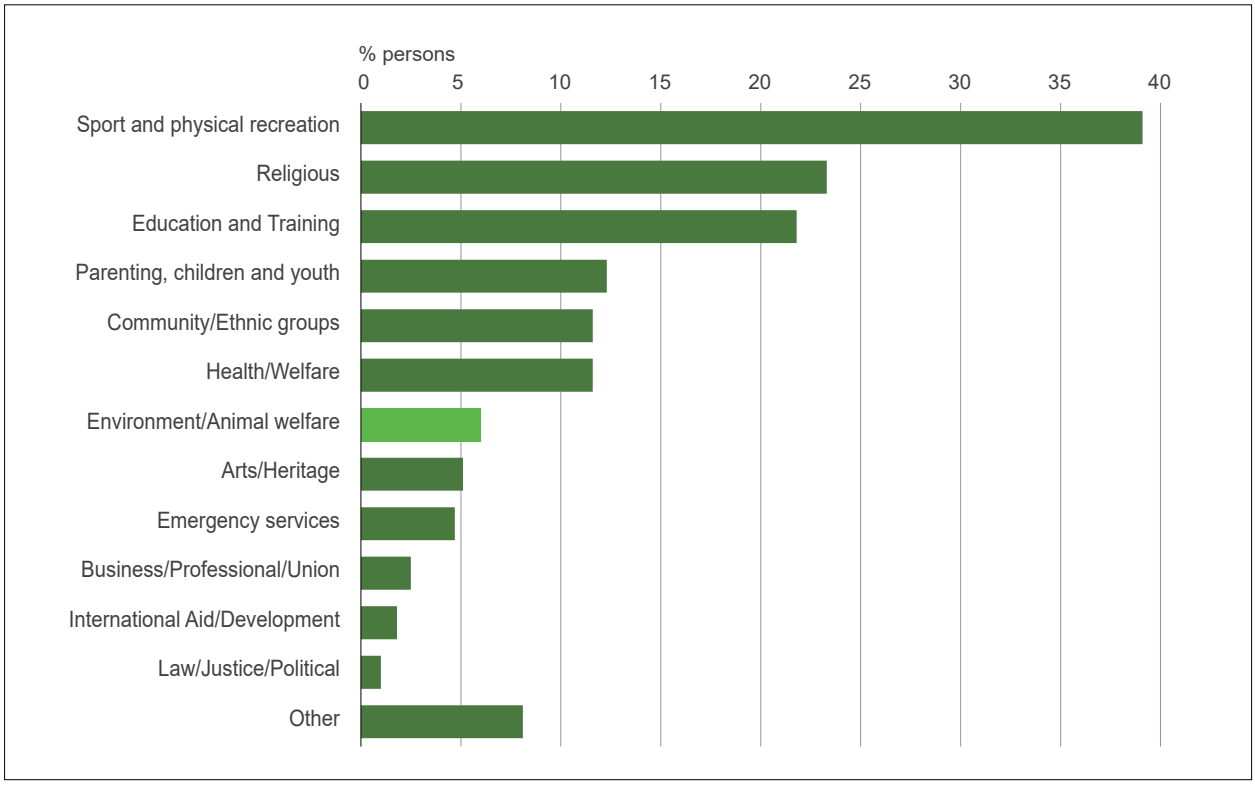


Figure 146: Type of organisation in which voluntary work was undertaken, Australia, 2019.[1723]

The relatively small proportion who undertake environmental volunteering highlights the opportunity for increasing the number of people who might become involved. The same social survey indicated that the main motivations for becoming involved in volunteering were to help others (indicated by 73% of respondents), personal satisfaction/doing something worthwhile (67%) and to use skills and experience (38%). These motivations could provide a basis for encouraging people to volunteer for environmental purposes.

In terms of coastal areas, volunteers are involved in Committees of Management of Crown Land Reserves whose role under the *Crown Land Reserves Act 1978* is to 'manage, improve, maintain and control' Crown land reserves (refer Indicator 79: Committees and Councils).

Some environmental programs like Coastcare and Estuary Watch necessarily involve coastal and marine areas. Other volunteer-based groups may have a more general environmental scope which in some cases is of relevance to marine and coastal areas.

These include:

- Land for Wildlife
- Landcare
- Waterwatch
- Victoria Environment Friends Network
- State Wide Integrated Flora and Fauna Teams (SWIFFT)
- Conservation Volunteers Australia
- Australian Citizen Science Association

The Ipsos survey of community attitudes examined community participation in relation to Victoria's coast and potential financial contributions to the preservation of the Victorian coast and marine environments. The survey undertaken in 2018 found that 42% of surveyed respondents indicated an interest in joining a coastal volunteer group while 39% indicated their willingness to contribute financially to improve coastal management (Figure 147).

1723. Australian Bureau of Statistics (ABS) 2020, 'General social survey, summary results, Australia, 2019', cat. 4159.0.

Those who visited the coast more frequently (at least monthly) were more likely to be willing to volunteer (61%) or contribute financially (51%). The proportion interested in volunteering or willing to make a financial contribution increased between the 2011 survey (Wave 4) and the 2018 survey (Wave 5).

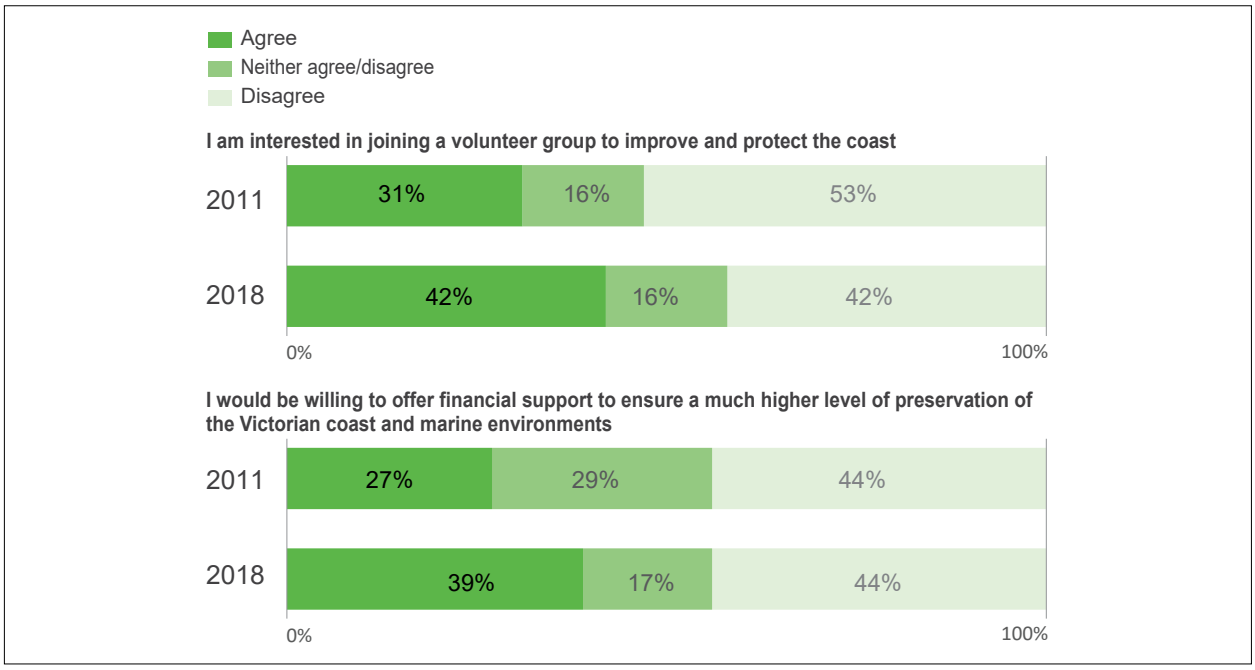


Figure 147: Respondents' interest in volunteering and providing financial support for coastal improvement, 2011 and 2018.[1724]

Coastcare

Coastcare Victoria is a community-based program which supports community stewardship of Victoria's marine and coastal environments. Volunteering is a key element of Coastcare's activities and it aims to foster community appreciation of marine and coastal areas. The Coastcare program supports hundreds of community groups and volunteers working to protect and enhance Victoria's coastline. Activities include revegetating coastal areas, building boardwalks and tracks, fencing, monitoring native shorebirds and animals, presenting education and awareness raising sessions, plantings, landscaping and protecting cultural sites.[1725]

Victoria was the first state in Australia to formally support coastal volunteers through the Coast Action program in 1994. Volunteers have helped with the management of coastal reserves in Victoria for more than 100 years. St Kilda's first foreshore committee was declared in 1905. Currently, there are around 250 community-based organisations involved in coastal conservation and protection in Victoria, up from approximately 150 in 2011.[1726] Coastcare supports Coast Action and Coastcare groups, Friends groups, volunteer Committees of Management, citizen science, and special interest groups, for example, threatened species groups and beach clean-up events.

A total of 13,444 people participated in Coastcare activities during 2019-20[1727], an increase from 10,500 recorded in the previous financial year.[1728] This was despite the cancellation of 93 activities, mostly in East Gippsland, due to bushfires, smoke and unfavourable weather conditions. During COVID-19 pandemic restrictions Coastcare introduced a Winter by the Sea online program in partnership with Parks Victoria. Coastcare has run its Summer by the Sea program for more than 25 years.

1724. Ipsos 2018, 'Wave 5 marine and coastal community attitudes and behaviour report'. Prepared for the Victorian Marine and Coastal Council, Parks Victoria and Department of Environment, Land, Water and Planning, Victorian Government Melbourne.
1725. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Draft Coastcare Victoria strategy 2020-2025', East Melbourne, Victoria https://engage.vic.gov.au/coastcare-victoria-strategy-2020-2025 Accessed 24 February 2021.
1726. Ibid. p. 7.
1727. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Annual report 2020', East Melbourne, Victoria, p. 52 https://www.delwp.vic.gov.au/__data/assets/pdf_file/0025/494134/Annual-Report-2019-20-3.pdf
1728. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Annual report 2019', East Melbourne, Victoria, p. 42 https://www.delwp.vic.gov.au/__data/assets/pdf_file/0032/438188/DELWP-Annual-Report-2018-19-web.pdf

Theme 9: Stewardship and Collaborative Management

The National Landcare Program supports Coastcare through funding to regional Natural Resource Management Authorities (NRMAs) (including CMAs in Victoria) and grants to community organisations. Table 68 shows outcomes of Coastcare activities reported for 2019 to May 2021.

Table 68: Coastcare activities in Victoria, 2019-21.[1729]

Activity	2019	2020	2021
Participants in Coastcare-funded volunteer capacity-building during the reporting period		564 (total registered for 2 online workshops) 252 Parks Victoria YouTube views (post live event).	140 (total registered for 6 online workshops)
Participants provided support by Coastcare in the funding period	21,700		

1729. Department of Environment, Land, Water and Planning (DELWP) unpublished data provided by Coastcare coordinator, 13 May 2021, Melbourne, Victoria.

Theme 9: Stewardship and Collaborative Management

Indicator 77: Citizen science

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		↗			N/A	N/A

Data source:	DELWP, Parks Victoria, VFA, VNPA, Tangaroa Blue Foundation, Estuary Watch, RedMap, Atlas of Living Australia.
Measures:	Citizen Science participation | Citizen science coastal programs

Why this indicator?

Citizen science involves community participation and collaboration in scientific research with the aim to increase scientific knowledge. This indicator will examine the many types of citizen science activities which are contributing to knowledge and management of marine and coastal environments.

Justification for assessment ratings:

- Citizen scientists have been involved in marine and coastal programs, even during COVID lockdown when virtual projects enabled seal counts (via webcam) and other activities to continue.
- While there can be challenges in ensuring scientific rigour, there are models available such as ReefWatch (with photo identification of species required) Sea Search (with supervision from park rangers and photo identification of species) or Redmap (with expert coordinators) which provide examples of how rigour can be achieved and maintained.
- Nevertheless, ensuring rigorous citizen science is not costless and funding is required to support coordination, equipment, communications and web platforms to be maintained.
- Current development of a citizen science framework for Victoria is a promising development that can help address some of these requirements and challenges in order to expand citizen science activities.

Citizen science involves community participation and collaboration in scientific research with the aim to increase scientific knowledge. It usually includes non-experts – that is, people who do not have formal science training. Citizen science is not a new phenomenon – in earlier centuries, amateur scientists contributed to many scientific disciplines. However, with the professionalisation of science, the role of citizen scientists has emerged as distinct.

Citizen science can have benefits both to the volunteers involved and to the agencies responsible for managing the environment. Many long-term monitoring programs are run by citizen science groups, supporting a greater understanding of the marine and coastal environmental condition.

Citizen science projects offer the following benefits:

- collection of data to support a diversity of scientific research investigations
- engagement with the community on scientific issues
- contribution to changes in community knowledge, attitudes and behaviours
- expansion (temporal or geographical) of data collections
- providing local knowledge which may be unattainable to higher levels of government or centralised academic institutions
- involvement in collecting and analysing environmental data that can strengthen citizens' connection to the environment.[1730]

1730. Pecl G, Stuart-Smith J, Walsh P, Bray D, Kusetic M, Burgess M, Frusher S, Gledhill D, George O, Jackson G, Keane J, Martin V, Nursey-Bray M, Pender A, Robinson L, Rowling K, Sheaves M and Moltschaniwskyj N 2019, 'Redmap Australia: challenges and successes with a large-scale citizen science-based approach to ecological monitoring and community engagement on climate change', *Frontiers in Marine Science*, 6(349) DOI: 10.3389/fmars.2019.00349.

In 2020, citizen scientists made up 13% of Victoria's environmental volunteers. This equated to around 24,250 people involved in citizen science activities. In terms of hours, however, citizen scientists accounted for 38% of total environmental volunteer hours – around 920,000 hours reported in 2020.[1731] Examples of citizen science programs which include Victorian marine and coastal areas are provided below.

The **Australian Marine Debris Initiative (AMDI)**, established by the Tangaroa Blue Foundation, comprises a national network of volunteers, communities and organisations that collect data on plastic pollution which finds its way to marine and coastal areas. Collected data are added to the AMDI Database. Responses are then developed on the basis of this evidence to stop the flow of litter at the source. The AMDI provides resources for local communities to look after their coastal environment and collaborates with industry and government to create larger scale policy change. In Victoria, the Let's Strain the Drains program was undertaken in 2019-20 through a collaborative partnership with Sustainability Victoria and the Cleanwater Group, to address the increasing amount of litter being found on Port Phillip Bay beaches. A total of 120 stormwater drain traps were installed in six municipal areas and captured contents were analysed. A total of 87,536 litter items and in more than 586,368 pieces of microplastic were captured and prevented from reaching the ocean while data collected through the project is being used by councils and state government for litter prevention and monitoring projects.[1732]

Reefwatch, coordinated by the Victorian National Parks Association, is a marine citizen-science program which trains participants to collect photos and information about fish, invertebrates and algae at various diving locations across Victoria. Specific Reefwatch projects involve volunteer citizen scientists and include the Great Victorian Fish Count, Sea Slug Census; Dragon Quest OysterWatch and ReefCam.[1733] **Sea Search** is coordinated by Parks Victoria and involves identifying flora and fauna in Victoria's Marine and Coastal Parks. Participants require permission and supervision from a Parks Victoria ranger to be part of the program and, like Reefwatch, photo identification is used to verify sightings of marine plants and animals. Identification guidelines, user manual and an App for recording sightings are also used as part of the program.[1734,1735,1736]

EstuaryWatch, like its sister program Waterwatch, is a citizen science-based volunteer program which monitors Victoria's coastal estuaries. Established in 2006, there are now 18 estuaries monitored by EstuaryWatch groups in Victoria. These groups are supported by Coordinators working for the Glenelg Hopkins CMA, Corangamite CMA, Melbourne Water, and West Gippsland CMA. Water quality data collected by these volunteers has been used to inform better estuary management.[1737] It is worth noting that most EstuaryWatch sites are located in the central and western areas of the Victorian coast. Estuaries in East Gippsland are mostly unmonitored by the program (Figure 148).

Figure 148: Location of EstuaryWatch sites.[1738]

1731. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Volunteering naturally. Understanding Victoria's environmental volunteers 2020', East Melbourne, Victoria, p. 7.
1732. Tangaroa Blue Foundation 2020, 'Annual report' 2020, p. 7 https://www.tangaroablue.org/about-us/annual-reports/ Accessed 19 July 2021.
1733. Victorian National Parks Association (VNPA), 'ReefWatch' https://vnpa.org.au/programs/reefwatch/ Accessed 12 February 2021.
1734. For example, Parks Victoria, 'Seagrass identification sheet' https://www.parks.vic.gov.au/get-into-nature/volunteering/sea-search Accessed 14 July 2021.
1735. Parks Victoria 2021, 'Sea search' https://www.parks.vic.gov.au/get-into-nature/volunteering/sea-search Accessed 14 July 2021.
1736. Parks Victoria 2018, 'Sea search manual. A guide for community based monitoring of Victoria's marine national parks and marine sanctuaries', Melbourne, Victoria https://www.parks.vic.gov.au/get-into-nature/volunteering/sea-search Accessed 14 July 2021.
1737. Estuary Watch website. http://www.estuarywatch.org.au/cb_pages/about_estuarywatch.php Accessed 1 March 2021.
1738. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Coastkit' https://mapshare.vic.gov.au/coastkit/

Citizen scientists are also involved in providing incidental data on **Southern Right Whale** sightings in Victoria. Photo-identifications are collected by citizen scientists via an online portal established by DELWP and hosted by the State Wide Integrated Flora and Fauna Teams (SWIFFT). This data are validated by DELWP and added to the DELWP whale sightings database and Victorian Biodiversity Atlas.[1739]

The **Citizen Science Drone Program**, part of the Victorian Coastal Monitoring Program (VCMP), involves citizen scientists from local communities to monitor the process of coastal erosion. Such erosion can be difficult to predict at the local level, yet many impacts may be felt at this scale, for example, loss of beaches and damage to coastal infrastructure.

To help land managers better understand these natural processes and the impact of storms, DELWP, Deakin University and Melbourne University have developed a program of coastal monitoring using drones. These drones enable surveying of beaches with the resultant data being analysed to analyse changes in volume, height and extent of sediment. Between 2018 and 2019, 16 sites were established across Victoria (Figure 149) with an additional 22 sites added in 2020 with the VCMP Port Phillip Bay Expansion. These have involved more than 100 community members and 25 local and state government employees. Each monitoring group is provided with equipment and training. More than a year's worth of data has already been collected at most sites.

Figure 149: Citizen Science Drone Program sites, 2018-2021.[1740]

Redmap (the Range Extension Database and Mapping Project) is an Australian citizen science project which involves the community submitting photos and data about unusual sightings of marine species. These sightings occur as people undertake marine activities like fishing, diving, or boating. Such data collection is made rigorous through verification processes. For example, sightings of species may require photo identification to be confirmed by trained scientists. Redmap started in Tasmania in 2009 and expanded nationwide in 2012. The project has two key aims: monitoring the environment to provide an indication of possible changes in species' range; and engaging the community on issues related to marine climate change.[1741]

Citizen scientists may also include people who regularly use the environment – for example fishers or farmers. Since the late 1990s the Victorian Fisheries Authority (VFA) has maintained a **volunteer angler fishing diary** program which is used to assess the status of a number of fish stocks.

1739. State Wide Integrated Flora and Fauna Teams (SWIFFT), 'Southern right whale photo identification project' https://www.swifft.net.au/srwsmp/ Accessed 15 March 2021.
1740. Department of Environment Land Water and Planning (DELWP) 2020, 'Citizen science drones factsheet', Victorian Government, Deakin University and University of Melbourne.
1741. Pecl G, Stuart-Smith J, Walsh P, Bray D, Kusetic M, Burgess M, Frusher S, Gledhill D, George O, Jackson G, Keane J, Martin V, Nursey-Bray M, Pender A, Robinson L, Rowling K, Sheaves M and Moltschaniwskyj N 2019, 'Redmap Australia: challenges and successes with a large-scale citizen science-based approach to ecological monitoring and community engagement on climate change', *Frontiers in Marine Science*, 6(349) DOI: 10.3389/fmars.2019.00349.

The **Victorian rock lobster tagging program**, which commenced in 2017, requires recreational fishers to tag and report on the rock lobsters they catch and keep.[1742] The data are collected via an app and is used by government to ensure ongoing access to the resource for both commercial and recreational fishing sectors. Anglers can also opt in to provide additional data as part of the VFA Citizen Science Data program. In the first season of the program (2017-18), more than 5,000 recreational fishers registered and this increased to 5,586 in the following season ((2018-19). Most participants were based in larger coastal centres including Portland, Warrnambool, Geelong, Mornington and San Remo.[1743]

At a broader scale, the **Atlas of Living Australia** brings together many scientific and citizen science data resources. It is funded by the Australian Government through the National Collaborative Research Infrastructure Strategy (NCRIS) and hosted by the Commonwealth Scientific and Industrial Research Organisation (CSIRO).[1744]

Collection of data through citizen science can fill gaps in coverage which arise due to changing funding or policy priorities. However, some regions will have small numbers of people and therefore, citizen science may have its own gaps, for example in remote areas which may have important environmental qualities and may face specific threats. The ubiquity of climate change impacts challenges us to develop a wide coverage of environmental assets, conditions and trends in order to fully understand environmental changes that may be occurring. Remote sensing offers some opportunities in this regard.

Citizen Science has drawn some criticism in relation to quality assurance, burden on government data custodians, managing and regulating the impact of drones and technologies used by citizen scientists. These criticisms can be addressed through appropriate management, for example scientific rigour has been brought to a number of programs through the use of photo identification of species and involvement of scientists as coordinators, and guidelines and education for volunteers. The regulation of drones is a broader community issue and one common to many new technologies which is addressed over time.

1742. Victorian Fisheries Corporation (VFA) 2021, 'Rock lobster tagging program' https://vfa.vic.gov.au/recreational-fishing/tagging-of-recreationally-caught-rock-lobsters Accessed 4 March 2021.
1743. Victorian Fisheries Corporation (VFA) 2020, 'Recreational rock lobster tagging program summary report 2020', Melbourne, Victoria, p. 5.
1744. Atlas of Living Australia https://www.ala.org.au/ Accessed 15 March 2021.

Theme 9: Stewardship and Collaborative Management

Indicator 78: Planning and implementation

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide	N	N	N	●	N/A	N/A

Data source:	VEAC, GeoScience Australia, DELWP
Measures:	Effectiveness of marine and coastal plans and policies

Why this indicator?

This indicator will provide an assessment of the legislative, regulatory and policy context in which marine and coastal areas are managed.

Justification for assessment ratings:

- Policy frameworks affecting marine and coastal planning may operate at international, national or state levels. Those involved in local marine and coastal management may be from local government, catchment management authorities, not for profit entities and. This makes a single assessment of planning and implementation unrealistic.
- This section therefore takes a narrative approach to explore Victoria's marine and coastal planning regimes and implementation strategies.
- In the past, Victoria's marine and coastal planning and policy arrangements have been criticised for being overly complex and multi-layered, thus limiting policy coherence.
- The introduction of the Marine and Coastal Act 2018 and the subsequent Marine and Coastal Policy 2020 have helped to streamline and clarify aspects of coastal policy. The identification and documentation of various legislation and policies relevant to Victoria's marine and coastal environments has provided a level of coherence.
- Victoria's first Marine Spatial Planning Framework is currently being developed as part of the Marine and Coastal Policy 2020. This is intended to provide overarching guidance and a process for achieving integrated and coordinated planning and management of the marine environment.
- Inventories and assessments by the Victorian Environmental Assessment Council have also contributed to valuable benchmark data from which planning and implementation can be undertaken.
- However, marine and coastal planning remains a somewhat crowded and contested space suggesting that ongoing monitoring and assessment will be important to maintain the benefits of recent work. In particular, the effectiveness of recent initiatives will be important to evaluate over time so that a process of continuous improvement and sustained clarity and coherence can be achieved.
- One way of assessing the effectiveness of policies is through community surveys such as that done by Parks Victoria for the system of Marine Parks which they manage. The parks are perceived by a majority of Victorians as successful. Importantly, this success is evident across a number of environmental, social and economic criteria, suggesting that sustainability objectives which aim to balance the interests of different users while protecting the environment are being achieved.

Governance

Marine and coastal environments are complex – environmentally, socially and economically. The Victorian coastline contains high-density urban development as well as agricultural lands; modified environments and pristine natural ecosystems; areas of population growth and others experiencing decline. Good governance arrangements for marine and coastal areas facilitate good management and creates the conditions which enable policies and plans to be effectively resourced and delivered.

Theme 9: Stewardship and Collaborative Management

Principles of good governance have been discussed by several academic writers. Key principles of good governance include:[1745,1746]

Legitimacy: the validity of an organisation's authority to govern.

Transparency: visibility of decision-making process and clarity about how such decisions have been reached.

Accountability: allocation and acceptance of responsibility for actions and showing how these responsibilities have been met.

Inclusiveness: enabling stakeholders to participate in, and influence, decision-making.

Fairness: consistency and absence of personal bias in decision-making and consideration given to the distribution of costs and benefits of decisions.

Integration: connection and coordination across different governance levels or organisations at the same level of governance and the alignment of priorities, plans, and activities across such organisations.

Capability: Systems, plans, resources, skills, leadership, knowledge, and experience that enable organisations to effectively deliver on their responsibilities.

Adaptability: the incorporation of new knowledge and learning into decision-making and implementation; anticipation and management of risks and opportunities; and systematic reflection on individual, organisational, and system performance.

The International Union for Conservation of Nature have prepared a Best Practice Guideline which outlines the principles of good governance for protected areas (Table 69).

Table 69: Good governance principles with examples.[1747]

Principle	Example
Legitimacy and voice	Ensuring stakeholders receive appropriate and sufficient information, can be represented and can have a say in advising and/or making decisions
Direction	Developing and following an inspiring and consistent strategic vision (broad, long-term perspective)
Performance	Achieving objectives as planned and monitored, including through on-going evaluation of management effectiveness
Accountability	Ensuing that the financial and human resources allocated to manage the protected areas are properly targeted according to stated objectives and plans
Fairness and rights	Striving towards an equitable sharing of the costs and benefits of establishing and managing protected areas

Although there is some agreement on the principles of good governance, there are difficulties in measuring the degree to which such principles have been attained. Performance reporting can ascertain aspects of these principles but qualitative aspects of governance such as the effectiveness of management processes can be more elusive. Despite these difficulties, some of the indicators presented in this section provide insights into various aspects of governance, for example,

1745. Coffey B, Bush J, Mumaw L, DeKleyn L, Furlong C, and Cretney R 2020, 'Towards good governance of urban greening: insights from four initiatives in Melbourne, Australia', *Australian Geographer*, DOI:10.1080/00049182.2019.1708552.
1746. Lockwood M, Davidson J, Curtis A, Stratford E, Griffith R 2010, 'Governance principles for natural resource management', *Society and Natural Resources*, 23(10), pp. 986–1001.
1747. Borrini-Feyerabend G, Dudley N, Jaeger T, Lassen B, Pathak Broome N, Phillips A and Sandwith T 2013, 'Governance of protected areas: from understanding to action'. Best practice protected area guidelines series no. 20, International Union for Conservation of Nature (IUCN) Gland, Switzerland https://portals.iucn.org/library/node/29138 Accessed 14 July 2021.

Indicator 80 (Institutional knowledge and capacity) which examines capability, Indicator 81 (Engagement and inclusiveness) which includes fairness and Indicator 82 (Delivery and accountability) which concerns accountability.

This section provides an overview of some of the jurisdictional arrangements for marine and coastal areas, then looks at planning and management arrangements and the types of organisations involved in them.

Maritime jurisdiction

Maritime jurisdiction is formalised in a series of Commonwealth Acts, notably the *Sea and Submerged Lands Act 1973* which follow conventions laid out in the International Law of the Sea. Jurisdictional limits are measured from a territorial sea baseline which, in general, aligns with the Lowest Astronomical Tide (LAT). From this baseline, several jurisdictional areas are defined including:

Coastal Waters – a band of water seawards from the territorial sea baseline (LAT) to 3 nautical miles distance offshore. The seabed and water in this region are managed by State Government with arrangements for the management of offshore resources like fisheries and petroleum defined by the Offshore Constitutional Settlement (OCS). This arrangement is outlined in the *OCS Coastal Water (State Powers) Act 1980* and the *Coastal Waters (State Title) Act 1980*.

Territorial Sea – a band of water seawards from the territorial sea baseline to 12 nautical miles distance offshore. Australia has sovereignty over this region (seabed, water and air rights) in line with the International Convention on the Law of the Sea. Foreign ships have the right of innocent passage through this region.

Contiguous Zone – a band of water contiguous to the territorial sea, extending to 24 nautical miles from the territorial sea baseline. Within this zone, Australia can exercise certain controls, for example, customs and immigration.

Exclusive Economic Zone – an area adjacent to the Territorial sea, extending up to 200 nautical miles seawards. Within this maritime area Australia has sovereign rights of exploring, exploiting, conserving and managing natural resources of the waters and seabed. It may also undertake activities relating to energy generation (from water, wind, waves or currents). It can also undertake activities such as marine scientific research and the protection of the marine environment.[1748]

Under the *Marine and Coastal Act 2018*, a definition is provided for the marine and coastal environment. This is defined as:

... the following between the outer limit of Victorian coastal waters and 5 km inland of the high-water mark of the sea—

(a) the land (whether or not covered by water) to a depth of 200 metres below the surface of that land;

(b) any water covering the land referred to in paragraph (a) from time to time;

(c) the biodiversity associated with the land and water referred to in paragraphs (a) and (b)[1749]

Within Victoria's coastal waters there are currently 24 protected areas in which resource extraction (such as fishing and mining) are prohibited (Figure 150). These 'no-take' areas include 13 marine national parks and 11 marine sanctuaries and account for 63,000 hectares or 5.3% of Victorian coastal waters. Marine National Parks are managed primarily for ecosystem protection, conservation of natural features and recreation while Marine Sanctuaries are smaller, designed to protect special features such as typical or outstanding examples of habitats, areas of special scientific significance, or areas that provide important opportunities for recreation and education.[1750] Additional protected areas include marine and coastal parks and reserves. While these areas may have significant environmental features, recreational and commercial fishing are allowed. An example is the whale calving area of Logans Beach, Warrnambool. Thus, management of Victoria's marine environment ranges from mixed-use management regimes through to full protection from human activities.

1748. GeoScience Australia, 'Maritime boundary definitions' http://www.ga.gov.au/scientific-topics/marine/jurisdiction/maritime-boundary-definitions Accessed 8 February 2021.
1749. Victorian Government, 'Marine and Coastal Act 2018', no. 26 of 2018, authorised version incorporating amendments as at 1 July 2021.
1750. Victorian Environmental Assessment Council (VEAC) 2019, 'Assessment of the values of Victoria's marine environment', Melbourne, Victoria, p. 35.

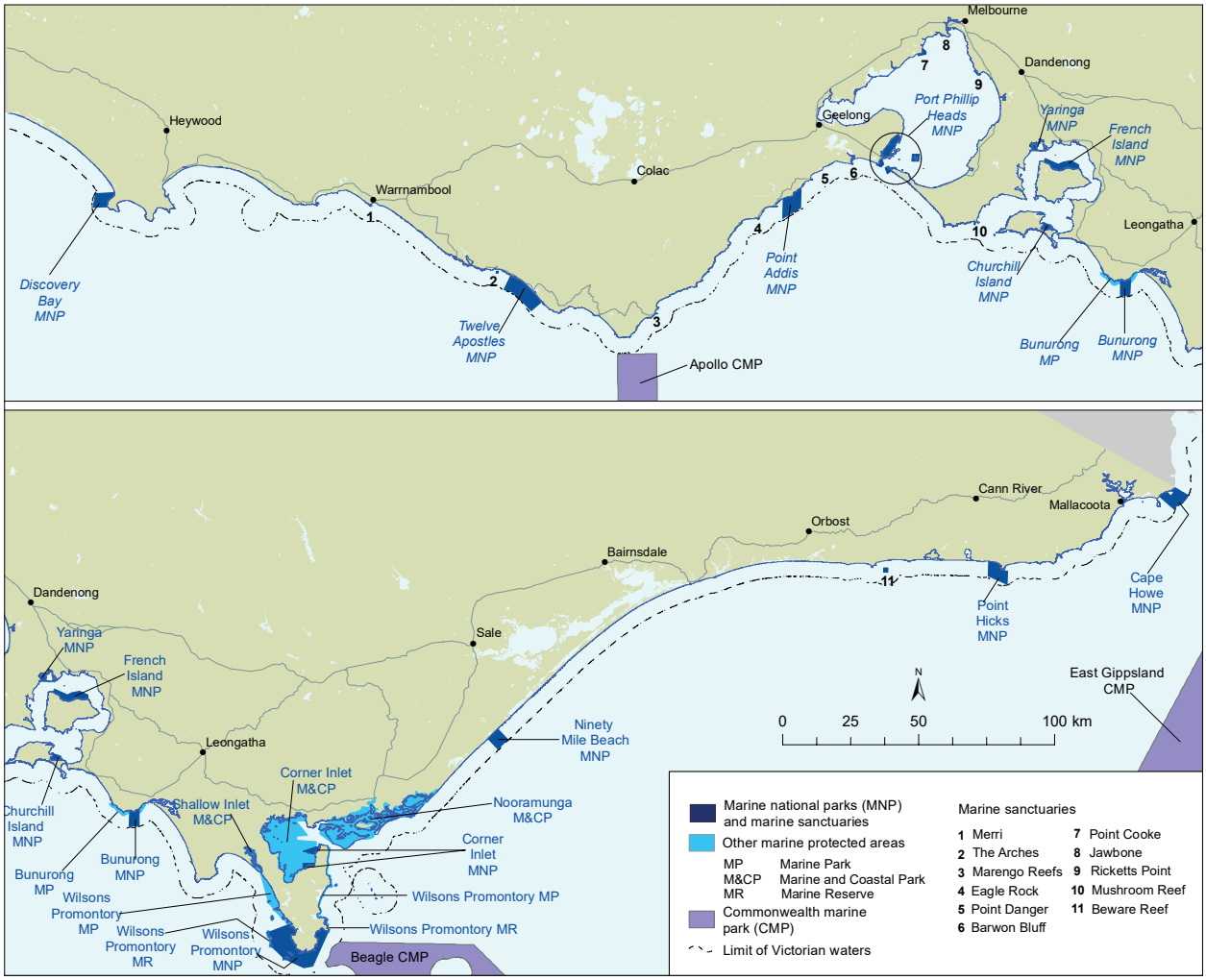


Figure 150: Victoria's marine reserves.[1751]

Coastal jurisdiction

It has been estimated that 94% of Victoria's coastline is Crown land in public ownership.[1752] Around 27% of the coastline is in coastal reserves, with most of the remaining coastal Crown land in protected areas reserved for conservation. A small proportion are designated for specific uses such as ports. Freehold land makes up a relatively small proportion of the Victorian coastal foreshore (Figure 151).

1751. Ibid.
1752. Ibid. p. 48.

Figure 151: Victoria's coastal protected areas.[1753]

Coastal reserves are often used intensively by the community for recreational activities and organised events. This is particularly the case in urban areas or popular holiday destinations. Such reserves may include foreshore reserves, parks or campgrounds and may contain buildings or infrastructure.

The Victorian Environmental Assessment Council (VEAC) have identified 61,770 hectares of coastal reserves along Victoria's open coast, an additional 21,445 hectares along the foreshores of bays and inlets and 40,315 hectares within the Gippsland Lakes.[1754] The water bodies and adjacent onshore areas of the Gippsland Lakes Reserves comprise round 65% of Victoria's total coastal reserve area. Management of coastal reserves is undertaken by the Victorian Government (DELWP or Parks Victoria), local government or public committees of management.

Issues in marine and coastal jurisdiction

Sea level rise and coastal erosion have the potential to alter coastlines and foreshores. This is an issue for land managers and communities as coastlines change shape and some areas become more frequently or permanently inundated. Issues of jurisdictional boundaries and responsibilities as well as potential property loss and questions of liability or compensation in the face of losses raise a very broad set of legal, jurisdictional and management issues. While these are not direct environmental threats in themselves, the indirect impact of land having ambiguous or changing legal status does matter for the environment as it affects the ways in which land management and public policy is implemented and by whom.

An example of how environmental change can create jurisdictional complexity can be found in Waters, et al. 2010 who examined the community impacts of a drying lake during the millennium drought as a proxy for assessing the potential impacts of a climate change event. One finding from the study was the difficulty of maintaining a clear and coherent jurisdictional framework in the face of an environmental change:

As the lake dried it became clear to the interviewees that there was significant confusion about the responsibilities of the multiple agencies involved in the management of the lake. At the time the lake dried, a different authority was responsible for each of the following aspects: the foreshore; the water; the dry lakebed; the native fish; the introduced fish; the smell of the rotting fish and the cleanup of the lakebed. The issue of insects breeding in the mud (which became a plague of gnats) was one that was not covered as a specific responsibility of any agency.[1755]

1753. Ibid. p. 36.
1754. Ibid.
1755. Waters E, McKenzie F, McCarthy C and Pendergast S 2010, 'The drying lake. Lake Boga's experience of change and uncertainty', Department of Planning and Community Development (DPCD), Melbourne, Victoria, p. 42.

While this example is from an inland setting, it could be envisaged that the complexity of coastal management systems and multiple agency involvement is likely to raise a similar risk. Furthermore, climate change poses some fundamental implications for jurisdictional boundaries as these may be altered by sea level rise and erosion. As jurisdictional boundaries are affected, so too are management arrangements. This in turn may undermine effective responses to those very changes as was highlighted in the Lake Boga example above.

Around the world, issues of changing coastal boundaries are increasingly being experienced. VEAC in their 2020 Assessment of Victoria's Coastal Reserves noted that in some locations along the Victorian coastline, the Crown land boundary, as presented in official cadastral maps, is no longer aligned with the coastline ue to erosion or accretion.[1756]

In Australia, debates on climate change and property rights have tended to focus on the impacts of higher sea levels and greater coastal erosion on private property. However, these impacts will also affect publicly owned coastal lands. The implications of changing shorelines on property law is complex. For Crown land, some aspects extend back to English common law from centuries ago. For private land, an individual landowner does not have recourse to compensation if their private property is lost to the sea through 'gradual' erosion.[1757] However, the impacts of climate change may see many of these legal technicalities tested through litigation. It is also likely to raise issues of environmental justice as those with fewer resources may have less access to legal or political resources to ameliorate their experience of climate change impacts. They are also likely to have lower levels of private insurance. Further discussion of environmental justice is provided under Indicator 81: Engagement and inclusiveness.

Planning and Implementation

Planning and implementation can help guide collaborative management of marine and coastal environments. In 2018, the Victorian Government passed the *Marine and Coastal Act* which sets out guiding principles to provide long-term direction on planning and decision making, irrespective of changes in strategies and government focus. This Act authorised the Victorian Marine and Coastal Policy which provides a framework for marine and coastal planning. It is connected to many other legislative instruments, strategies and plans to give coherence to the complex web of responsibilities and issues found within marine and coastal environments (Figure 152).

Figure 152: Examples of policies, plans, strategies and decisions that the Marine and Coastal Policy takes into account.[1758]

1756. Victorian Environmental Assessment Council (VEAC) 2020, 'Assessment of Victoria's coastal reserves final report', Melbourne, Victoria, p. 46.
1757. Corkill J 2012, 'Principles and problems of shoreline law', ACCARNSI discussion paper – node 1 coastal settlements, Australian Climate Change Adaptation Research Network for Settlements and Infrastructure, National Climate Change Adaptation Research Facility (NCCARF), p. 10.
1758. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Marine and coastal policy', East Melbourne, Victoria, pp. 80-81.

Theme 9: Stewardship and Collaborative Management

Regional and Strategic Partnerships (RASPs) are one part of the planning hierarchy of documents, decision making, and advice under the *Marine and Coastal Act 2018*. The purpose of RASPs is to produce a response to an identified regional issue affecting the marine and coastal environment. As at January 2021, one RASP had been established at Inverloch. This partnership has the following objectives:

- understand the erosion impacting the Inverloch coast
- oversee and coordinate the delivery of outputs and collaborate to develop agreed strategic approaches to enable Inverloch to be a resilient coastal community
- ensure outputs and decisions of the RASP are communicated to each partner agency
- seek the formal acceptance and support of each partner agency as determined by the partnership.

The Inverloch RASP has 10 partner agencies: DELWP (lead agency), Bass Coast and South Gippsland Shire Councils, Bunurong Land Council Aboriginal Corporation, Department of Transport, Gippsland Ports, Heritage Victoria, Parks Victoria, South Gippsland Water and West Gippsland CMA.

A second RASP is proposed for the north-western shorelines of Port Phillip Bay. The intent is for this partnership to focus on the projected impacts of climate change and sea level rise on the natural systems of the north-western corner of Port Phillip Bay. The partnership aims to work towards ensuring that this area can support a healthy, dynamic and biodiverse marine and coastal environment in the face of climate change.

While these initiatives focus on coastal areas, planning for marine environments is also envisaged under the *Marine and Coastal Act 2018*. The Marine and Coastal Policy 2020 includes Victoria's first Marine Spatial Planning Framework that sets out guidance and a process for achieving integrated and coordinated planning and management of the marine environment. A key challenge for marine policy is that issues are often addressed on a sectoral or issue-specific basis. Fisheries, shipping, recreational fishing and boating, renewable energy, and marine resources are some examples of policy focus. This limits the ability to attain a holistic view of the marine environment and its management. The intent of the marine spatial planning framework is to support and provide a process for integrated planning and management across sectors.

Marine spatial planning considers how various activities and uses of the marine environment are spatially organised. It provides a structure for integrated management and, by identifying current or potential conflicts, can deliver an approach to manage these through policies, management interventions and governance arrangements.

Undertaking marine spatial planning can have significant benefits that include:

- identifying those marine habitats that can be recovered or enhanced
- supporting the growth of Victoria's blue economy
- promoting environmental and socio-economic resilience
- supporting climate adaptation planning.

The framework sets out Victoria's approach to marine spatial planning. Implementation of the framework is being progressed through a statewide assessment to determine marine planning areas and identify priorities for more detailed marine spatial planning. Guidelines on how to undertake marine spatial planning in identified priority areas are also being prepared.

One of the challenges in monitoring or assessing governance is that there are several different aspects on which we can focus. For organisations, such as local government councils or legislatively-enabled groups such as Committees of Management, assessment of governance often focuses on organisational aspects such as whether it has met legislative obligations regarding probity, financial accountability, conflict of interest, OHS requirements and so forth. Another level at which monitoring and evaluation may be undertaken includes output measures. This may include activities (seminars, workshops, site visits, etc.) or tangible products (publications, etc.). Organisational and output reporting can usually be found in annual reports which highlight annual achievements against legal, business and strategic objectives.

A much more difficult element to measure is the external outcome of an organisation's activities. For state of environment reporting, the ultimate objective is to determine the degree to which governance structures and activities are having, or are likely to have, a positive impact on environmental condition. Issues of measurement and attribution arise in terms of the which part of an organisation's activity or structure should be measured, whether it can be measured quantitatively or qualitatively, and the degree to which a positive environmental outcome is due to the policies, activities or structure of a particular organisational entity. Good governance and good policy settings are both required, but it may be difficult to determine the relative importance of each of these in delivering good environmental outcomes. Both may need to be assessed to gain a full picture of management effectiveness

The inherent complexity of human systems (let alone their interaction with complex natural systems) may make scientific measurement impossible. However, it may be possible to find case studies where the links between good governance, good policy and positive outcomes are relatively clear. It may be useful to seek such examples rather than attempting to measure all the elements of governance for which we can find data.

An important component of the indicator assessment for this indicator, and many of the other indicators for the stewardship and collaborative management theme, is that a lot of work will need to be done to determine appropriate assessment methods to judge effectiveness. Furthermore, there may not be a lot of data available to determine whether many of the marine and coastal plans and policies have been effective or not (it is too early to tell).

Another reason why it is important to determine effectiveness of policies and government structures is that a numerical count of agencies, groups or plans cannot reveal positive or negative outcomes. In fact, the existence of too many agencies or plans may create confusion rather than clarity or effectiveness.[1759] Monitoring the number of agencies or plans suggests a focus on levels of activity rather than effective outcomes. This raises the need to consider coordination and alignment of effort. Some authors have explored how such effectiveness might be measured – network analysis has highlighted the degree to which environmental agencies are connected to, and communicating with, each other.

One way of testing policy effectiveness on the ground is through specific evaluative research. The survey of Marine National Parks and Sanctuaries undertaken by Parks Victoria in early 2021 asked respondents to rate the success of the Marine Park System against a set of their objectives. Respondents included people who had visited such parks in the previous 12 months (n=360) as well as those who had not (n=510). Figure 153 shows that the parks were deemed to have made a big impact or a very big impact by respondents, more so among those who had visited such areas. Of interest also is the perceived success across a number of environmental, social and economic criteria, suggesting that sustainability objectives which aim to balance the interests of different users while protecting the environment are being achieved.

1759. Coastal governance in Victoria has drawn criticism for its complexity – for example see Victorian Auditor-General's Office (VAGO) 2018, 'Protecting Victoria's coastal assets. Independent assurance report to parliament 2017–18: 14'', chapter 5, Melbourne, Victoria.

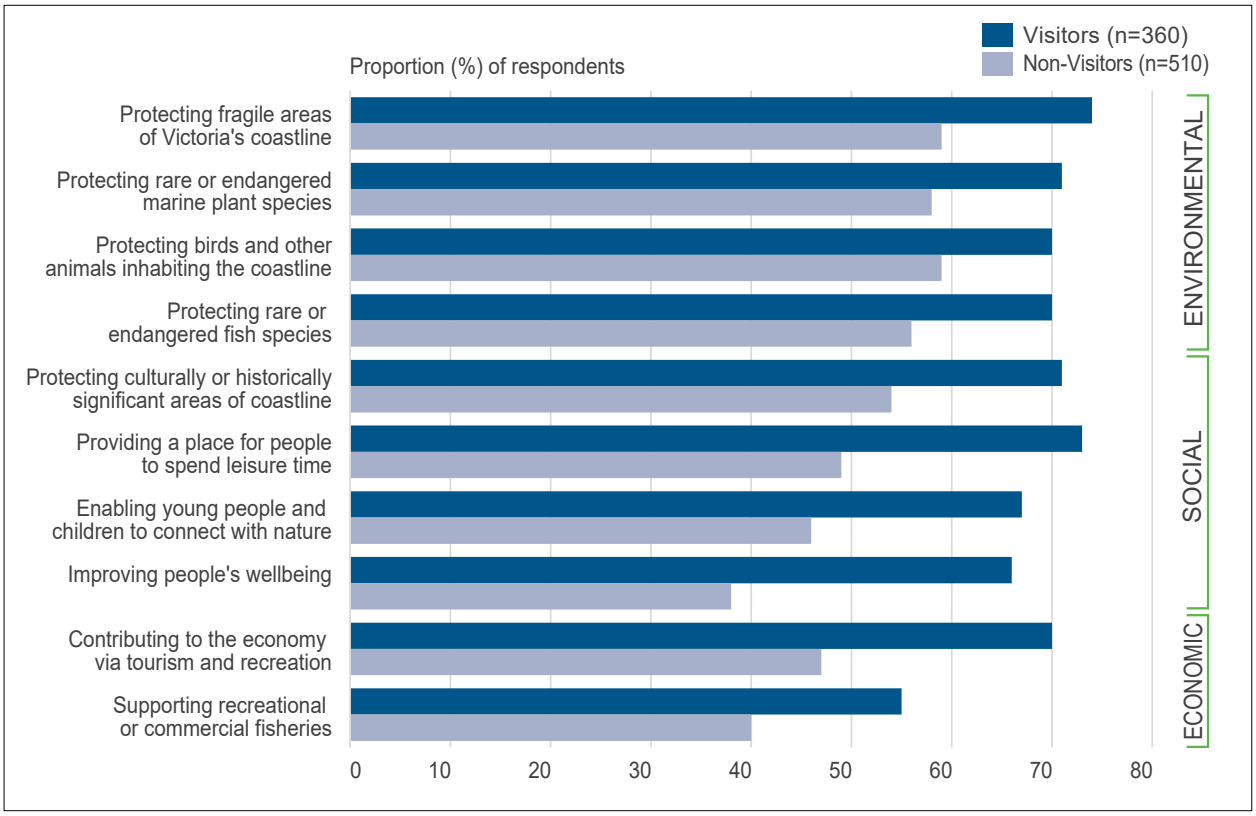


Figure 153: Ways in which the Victorian Marine Park System is deemed to be successful, 2021.[1760]

Further discussion on the delivery of effective policy outcomes is provided under Indicator 82: Delivery and accountability.

1760. Parks Victoria 2021, 'Victorian community usage, awareness and perceptions of marine parks and sanctuaries', written by Jacky Heath, Lonergan, Sydney, p. 71.

Indicator 79: Committees and Councils

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide	N	N	N	●	N/A	N/A

Data source:	VEAC, VAGO, DELWP
Measures:	Area managed by coastal CoMs | Effectiveness of coastal CoMs

Why this indicator?

Committees and Councils enable constructive debate and collective decision making concerning the management and protection of coastal and marine environments. This indicator will highlight the role and responsibilities of such groups.

Justification for assessment ratings:

- Marine and coastal planning and policy arrangements involve Committees and Councils. In the past, the variety of different entities has attracted criticism, including from Victoria's Auditor General for being overly complex and lacking coherence for their purpose and governance arrangements.
- The introduction of the *Marine and Coastal Act 2018* and the subsequent Marine and Coastal Policy 2020 have helped to streamline and clarify some aspects of coastal governance while inventories and assessments by the Victorian Environmental Assessment Council (VEAC) have also contributed to clarification about the number and nature of public land governing bodies and land managers.
- Because these changes have been recent, it is too early to fully assess their level of effectiveness and success in achieving their intended environmental outcomes. For this reason, this section provides a narrative approach to explore the nature and purpose of relevant marine and coastal management agencies.
- Ongoing monitoring and assessment will be important to maintain a coherent and workable system of governance which can support greater coordination and alignment of effort for marine and coastal environments. Such alignment may be further enhanced with the current preparation of a Marine Spatial Planning Framework.

Victorian Marine and Coastal Council

The Victorian Marine and Coastal Council (VMaCC) is the peak advisory body for coastal and marine issues in Victoria. It was established under the *Marine and Coastal Act 2018* to provide independent advice to the Minister for Energy, Environment and Climate Change. Members are appointed by the Minister for a three-year term with current members appointed from August 2018 to July 2021.[1761]

The VMaCC is supported by a 35-member Science Panel which was established to provide independent, strategic, scientific advice to the Council on marine and coastal issues. The Panel comprises members from many disciplines and enables the development of evidence-informed policy.[1762]

1761. Victorian Marine and Coastal Council (VMaCC) 2021, 'About us', Melbourne, Victoria https://www.marineandcoastalcouncil.vic.gov.au/about-us/about-the-council Accessed 19 March 2021.
1762. Victorian Marine and Coastal Council (VMaCC) 2021, 'Science panel' Melbourne, Victoria https://www.marineandcoastalcouncil.vic.gov.au/about-us/science-panel Accessed 19 March 2021.

Theme 9: Stewardship and Collaborative Management

Committees of Management

Committees and Councils enable constructive debate and collective decision making in the management and protection of marine and coastal environments. Committees of Management are responsible for the management of Victoria's Coastal Crown Land under the *Crown Land (Reserves) Act 1978*. Many Crown land reserves are managed by members of the community through formal appointment to a Committee of Management (CoM). These committees are responsible for managing, improving and maintaining the reserve on behalf of the Minister for Energy, Environment and Climate Change and are overseen by DELWP.

Across Victoria, approximately 1,200 Committees of Management work on behalf of the Minister for Environment and Climate Change to manage 1,500 Crown land reserves across Victoria. These include reserves which support a broad range of amenities and uses such as bushland, caravan parks, foreshores, walking tracks and rail trails. Thirty-two coastal Committees of Management have members appointed by DELWP (Table 70).

Shoreham Foreshore Reserve
© Film Victoria

Table 70: Victorian coastal Committees of Management where members are appointed by DELWP.[1763]

Principle	Members	Appointed	Expiry
Barwon Coast Committee of Management Inc.	9	1/07/2019	30/06/2022
Bellarine Bayside Foreshore Committee of Management Inc.	10	1/07/2019	30/06/2022
Great Ocean Road Coast Committee Inc.	12	1/07/2019	30/06/2022
Otway Coast Committee Inc.	8	1/07/2019	30/06/2022
Fitzroy River Public Purposes Reserve Inc.	8	10/03/2018	9/03/2021
Nelson Public Reserves Committee of Management Inc.	8	16/01/2020	15/01/2023
Point Danger Committee of Management Inc.	7	17/05/2019	16/05/2022
Lakes Entrance Recreation Reserve Committee of Management Inc.	8	1/10/2018	30/09/2021
Lakes Entrance Rescue Squad Reserve Committee Inc.	5	1/02/2019	31/01/2022
Loch Sport Foreshore Committee of Management Inc.	5	14/11/2019	13/11/2022
Marlay Point Public Purposes Reserve Committee of Management Inc.	9	23/07/2018	22/07/2021
Seaspray Reserves Committee of Management Inc.	7	5/06/2018	4/06/2021
Corinella Foreshore Reserve Committee of Management Inc.	8	27/11/2019	26/11/2022
Grantville & District Foreshore Reserve Committee of Management Inc.	7	26/03/2020	25/03/2023
Lang Lang Foreshore Reserve Committee Inc.	9	27/11/2019	26/11/2022
Port Franklin Public Purposes & Recreation Reserve Inc.	7	28/11/2019	27/11/2022
San Remo Foreshore Committee of Management Inc.	3	1/04/2020	31/03/2021
Sandy Point Foreshore Committee of Management Inc.	7	14/11/2019	13/11/2022
Shallow Inlet Camping & Recreation Reserve Inc.	9	26/11/2019	25/11/2022
Walkerville Foreshore Committee Inc.	11	14/11/2019	13/11/2022
Balnarring Beach Foreshore & Parks Reserve Committee of Management Inc.	6	1/08/2018	31/07/2021
Cannons Creek Foreshore Reserve Committee Inc.	5	1/08/2020	31/07/2023
Capel Sound Foreshores Committee of Management Inc.	8	1/05/2018	30/04/2021
Crib Point Stony Point Foreshore Com Inc.	5	1/01/2017	31/12/2019
Dromana Foreshore Committee of Management Inc.	8	31/07/2017	30/07/2020
Merricks Beach Foreshore Reserve Committee of Management Inc.	9	1/01/2017	31/12/2019
Point King Foreshore Reserve Committee of Management Inc.	3	27/07/2017	26/07/2020
Point Leo Foreshore & Public Park Reserves Inc.	9	1/01/2017	31/12/2019
Shoreham Foreshore Reserve Com Inc.	5	1/01/2020	31/12/2021
Tooradin Foreshore Committee of Management Inc.	10	26/03/2016	25/03/2019
Warneet Foreshore Reserve Committee of Management Inc.	7	30/03/2019	29/03/2022
White Cliffs to Camerons Bight Foreshore Reserves Committee of Management Inc.	12	31/08/2019	30/08/2022

1763. Data provided by Julie Gale, senior technical support officer (Crown land), land management policy division, environment and climate change, Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria, 14 December 2020.

Table 71 sets out the management arrangements for the 61,771 hectares of coastal public land reserve. While the largest area is managed by State Government agencies like DELWP and Parks Victoria, Committees of Management are responsible for 29 reserves covering 7,594 hectares. Category 1 CoMs are larger with formal governance arrangements and annual revenue of more than $1 million or responsibility for Crown land of statewide significance or community interest. There are four coastal CoMs in this category. There are 25 additional coastal CoMs which are included as Category Two.

Table 71: Area of coastal reserve managed by different agencies or bodies.[1764]

* management arrangements between DELWP and Parks Victoria are not accurately recorded in Crown parcel-based information.

Coastal reserve land manager(s)	Area (hectares)
Government agencies and TO Organisations	
DELWP/Parks Victoria*	38,612
Local government	3,959
Gunaikurnai Joint Management (incl. transitional arrangements with other land managers)	413
Water Authority/Melbourne Water	141
Other government depts or agencies (DTF, Victrack, Gippsland Ports, Port of Melbourne)	72
Part DELWP/part local government	666
Part Parks Victoria/part local government	224
Total (Ha) **% of total coastal reserve area**	**44,087** **71.4%**
Committees of Management (COMs) – Category 1	
Barwon Coast	236
Bellarine Bayside	126
Great Ocean Road Coast	125
Otway Coast	225
Part DELWP/part CoM	2,142
Part other i.e. government bodies/part COM	566
Total (Ha) **% of total coastal reserve area**	**3,420** **5.5%**
Committees of Management (COMs) – Category 2	
Local CoM (20 CoMs)	566
Part DELWP/part CoM	2,159
Other bodies and part CoM	1,449
Total (Ha) **% of total coastal reserve area**	**4,174** **6.8%**
Other shared management arrangements	
Various shared arrangements (multiple managers)	10,090
Total (Ha) **% of total coastal reserve area**	**10,090** **16.3%**
Total coastal public land	**61,771**

1764. Victorian Environmental Assessment Council (VEAC) 2020, 'Assessment of Victoria's coastal reserves final report', Melbourne, Victoria, p. 53.

There are a number of programs currently looking at the roles and responsibilities of CoMs, including those that manage coastal reserves along the Great Ocean Road and Western Port. A CoM Reform Program has been established by DELWP in response to the Victorian Auditor General's Office (VAGO) audits of 2014 and 2018 which examined the oversight and accountability of such committees.[1765,1766]

One theme that has arisen in several reviews of coastal governance is limitations on information which is required to adequately plan for and manage coastal reserves.

VEAC, in their Assessment of Victoria's Coastal Reserves, found that:

Information on the number and types of reservations for coastal reserves is technically complex, inconsistent and fragmented leading to significant on ground issues for land managers and the community. ... Much of the Crown land information is not readily available to the public and does not always inform management. The complexity of legislative and planning processes together with the number and variety of land and infrastructure managers further complicates management responsibilities and decision making.[1767]

The introduction of the *Marine and Coastal Act 2018* and the subsequent Marine and Coastal Policy 2020 have helped to streamline and clarify some aspects of coastal governance while inventories and assessments by the Victorian Environmental Assessment Council (VEAC) have also contributed to clarification about the number and nature of public land governing bodies and land managers. The inventory of coastal reserves offers a good baseline for monitoring a range of issues around the natural and built environment as well as climate change impacts.[1768]

Marine and coastal governance nevertheless remains complex suggesting that ongoing monitoring and assessment will be important to maintain a coherent and workable system of governance which can support greater coordination and alignment of effort for marine and coastal environments. Such alignment may be further enhanced with the current preparation of a Marine Spatial Planning Framework (refer Indicator 78: Planning and implementation).

1765. Victorian Auditor-General's Office (VAGO) 2014, 'Oversight and accountability of committees of management', Melbourne, Victoria.
1766. Victorian Auditor-General's Office (VAGO) 2018, 'Follow up of oversight and accountability of committees of management', Melbourne, Victoria.
1767. Victorian Environmental Assessment Council (VEAC) 2020, 'Assessment of Victoria's coastal reserves final report', Melbourne, Victoria, p. 15.
1768. Victorian Environmental Assessment Council (VEAC) 2020, 'Assessment of Victoria's coastal reserves - inventory of coastal reserves', Melbourne, Victoria.

Theme 9: Stewardship and Collaborative Management

Indicator 80: Institutional knowledge and capacity

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide		?			N/A	N/A

Data source:	N/A
Measures:	Number of applied scientists employed by marine and coastal management agencies; Government funding for marine and coastal research or monitoring projects in Victoria

Why this indicator?

To be effective, management arrangements need to align responsibility with institutional capacity and expertise. Institutions also need to be appropriately resourced so they can fulfil their obligations. This indicator will explore the ways in which knowledge and capacity affect the outcomes for marine and coastal management.

Justification for assessment ratings:

- Knowledge and capacity are acknowledged as critical for effective environmental policy.
- Following findings from the State of the Bays 2016 Report, Victoria has put in place a Marine and Coastal Knowledge Framework to support the knowledge needs of planning for Victoria's marine and coastal areas. One outcome has been Coastkit - an online system for marine and coastal spatial data. While the development of data systems for marine and coastal management is welcome, analysis of what the data tell us and the degree to which such intelligence is being used in decision making is still unclear and unable to be fully assessed yet.
- At the aggregate level, a meaningful assessment of institutional knowledge and capacity is unrealistic because of the large number, variety and complexity of institutions which have responsibilities for marine and coastal management.
- Measures which aim to capture educational qualifications or skill levels within organisations are not suitable for judging the qualitative aspects of how such knowledge and skills are being applied.
- Although assumptions about the positive role of funding on institutional capacity make intuitive sense, there are issues in trying to measure this quantitatively. This is partly because of the complexity of unravelling public funding streams but also because of causal ambiguities in assessing capacity. Qualitative approaches may prove more reliable for future assessments.

Marine and coastal managers face pressures from climate change, population growth, ageing infrastructure, habitat loss and fragmentation, and changing community management expectations. Managing these issues requires a range of knowledge and skills. This capacity varies – by place, organisation and specific circumstances of various locations and issues. In many cases, coastal management requires effective partnerships and this requires skills and capacity within organisations.[1769] The concept of integration can also be considered in relation to institutional knowledge and capacity.

Integration includes:

- the connection between, and coordination across, different governance levels
- the connection between, and coordination across, organisations at the same level of governance
- the alignment of priorities, plans, and activities across governance organisations.[1770]

1769. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Marine and coastal policy', East Melbourne, Victoria, p. 57.
1770. Lockwood M, Davidson J, Curtis A, Stratford E, Griffith R 2010, 'Governance principles for natural resource management', *Society and Natural Resources*, 23(10), pp. 986–1001.

The Victorian Government has developed a Marine and Coastal Knowledge Framework to support the knowledge needs of planning for Victoria's marine and coastal areas,[1771] This initiative followed findings of the State of the Bays 2016 Report which identified 30 knowledge gaps and grouped these into eight future priorities which would form the basis of a Marine and Coastal Knowledge Framework and provide the evidence base for adaptive management and future marine and coastal indicators.[1772] Figure 154 shows an overview of the framework. The framework is interconnected within CoastKit which provides an online Knowledge Management System for marine and coastal spatial data.[1773]

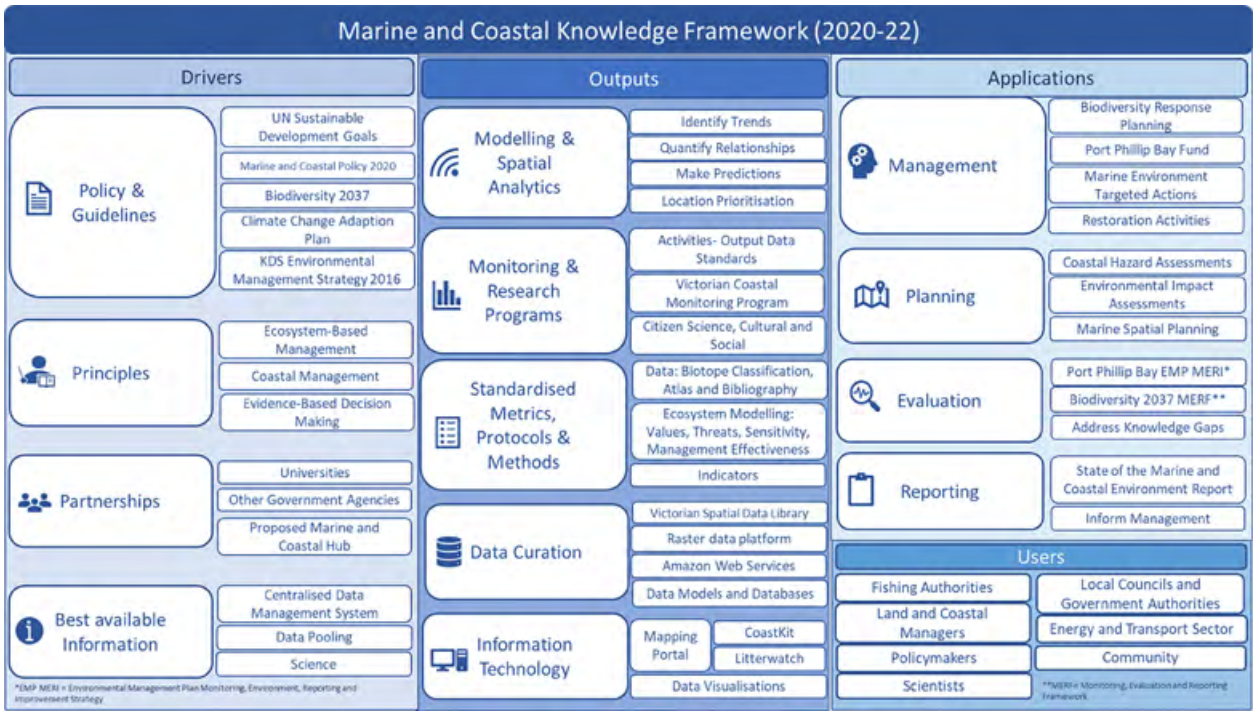


Figure 154: Victoria's Marine and Coastal Knowledge Framework 2021.[1774]

Building knowledge and understanding of the marine and coastal environment can improve the ways in which it is managed. Such knowledge can also assist in identifying threats, initiating responses and monitoring the effectiveness of those responses in an ongoing process of adaptive management. Predictive analysis, such as the modelling of climate change scenarios, can also enable trigger points for action to be set for coastal managers.[1775]

The concept of 'ecological literacy' is relevant to institutional knowledge and capacity. In 1989, UNESCO defined the term as 'a basic functional education for all people which provides them with the necessary knowledge, skills, and motives to cope with environmental needs and contribute to sustainable development.'[1776] Because public managers and policy makers are involved in developing and implementing policies that may affect the environment, it has been argued that they 'need to be ecologically literate if they are to be capable of advising and acting in ecologically responsible ways.'[1777] There are also flow-on effects for the organisations in which such decision-makers are employed. Without ecological literacy, the models and frameworks developed by such organisations may not be fit for the task of environmental governance.

1771. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Marine and coastal knowledge framework' East Melbourne, Victoria https://www.marineandcoasts.vic.gov.au/coastal-programs/marine-and-coastal-knowledge-framework Accessed 10 August 2021.
1772. Commissioner for Environmental Sustainability (CES) 2016, 'State of the Bays 2016', p. 12, Melbourne, Victoria.
1773. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Coastkit' https://mapshare.vic.gov.au/coastkit/ Accessed 10 August 2021.
1774. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Marine and coastal knowledge framework' East Melbourne, Victoria https://www.marineandcoasts.vic.gov.au/coastal-programs/marine-and-coastal-knowledge-framework Accessed 10 August 2021.
1775. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Marine and coastal policy', East Melbourne, Victoria, p. 57.
1776. United Nations Educational Scientific and Cultural Organization (UNESCO) 1989, 'Environmental literacy for all', Connect, UNESCO-UNEP environmental education newsletter, 14(2), pp. 1-2, UNESDOC Digital Library https://unesdoc.unesco.org/ark:/48223/pf0000153577 Accessed 19 July 2021.
1777. Coffey B 2021, 'Environmental challenges for public value theory and practice', *International Journal of Public Administration*, 44(10), pp. 818-825.

Theme 9: Stewardship and Collaborative Management

Environmental capacity has been defined as 'the development and strengthening of institutions able to manage current environmental problems and to facilitate a precautionary, ecologically sensitive culture in everyday life and the realm of industrial activity'.[1778] Christoff (1998) suggests several criteria for assessing environmental governance capacity (Table 72).

Table 72: Criteria for assessing capacity for environmental governance.[1779]

Criteria	Description
Consensus-building capacity	the existence of styles and forums for agenda setting and policy development, which enable open deliberation of options and encourage widely accepted, enduring and ecologically sound outcomes in both public and private sectors
Strategic capacity	the state's ability to recognise environmental problems and develop rational policy responses that would lead to ecologically sustainable outcomes in implemented effectively
Implementation capacity	staffing levels and a skill base which can react to new challenges and learn from previous experiences, and budgets appropriate for effective implementation of policy initiatives. This includes capacity for research, monitoring, community reporting and review
Integrative capacity	the existence of agencies, laws and decision-making processes which enable the state to integrate ecological principles, practices and goals into (whole-of-government) public and private sector activity

The link between knowledge and capacity is important because an organisation needs capacity (money or skills) to obtain, generate or maintain knowledge. Organisations with limited resources or capacity deficits (such as a lack of technical skills to collect, analyse and interpret data) may face a limited capacity to increase their knowledge and effectiveness. While there are alternative models which aim to overcome cost barriers – for example using citizen science to crowd source scientific data, there is still a need to coordinate, verify and host such data which requires funding and skills (technical, management and coordination). Likewise, the opportunities offered by remote sensing and earth observation technology still requires an organisation to have the skills of downloading and using that data in ways which can be directed towards effective environmental management.[1780] There is also a geographical aspect to organisational capacity with more remote or less-populated regions often facing deficits of human or financial capital. The need to support organisations in developing their capacity and knowledge levels is therefore a fundamental one to support positive environmental policy outcomes.

Availability of data may be less of a problem than having the analytical capacity to understand what the data are telling us. Part of the challenge is a technical one – having the skills to manage, organise and synthesise data in order to transform it into information. Another challenge is one of foresight – knowing what questions to ask of the data so that efforts to organise it are made efficient. Having a balance between exploratory strategies (analysis to understand emerging issues) and responsive strategies (analysis to monitor known issues) is important.

1778. Christoff P 1998, 'Degreening government in the garden state: environmental policy under the Kennett Government 1992-1997', *Environment Planning and Law Journal*, 15(1), pp. 10-32.
1779. Based on Christoff 1998, presented in Coffey B 2021, 'Environmental challenges for public value theory and practice', *International Journal of Public Administration*, 44(10), pp. 818-825.
1780. Patole M 2018, 'Localization of SDGs through disaggregation of KPIs', Economies, 6(15).

One issue relating to institutional knowledge and capacity is that dynamic and changing situations may require new or innovative responses. This can be challenging within the constraints of our existing institutions and processes of gathering and sharing knowledge. Path dependence is a feature of how decisions are made – they are reliant on previous decisions or experiences from the past. One negative outcome of path dependence is that decision making processes may not reflect current conditions but may instead be embedded in past practices. In the face of an emerging problem like climate change, we may be collecting and analysing real time data, but the processes embedded in our institutions may take time to absorb or respond to such data.

One way that knowledge and capacity in organisations might be measured is by looking at the education and skills profile of an organisation. This might include the number of scientists employed or the number of staff with particular scientific qualifications. Another potential measure might be to identify the number of staff involved in research. Yet these measures are generally not collected in a way that is comparable. For instance, the DELWP Annual Report provides a breakdown of staff by level of seniority. This includes categories of: Science Adaptives, Senior Technical Specialist, and Principal Scientist. However, these specific titles do not represent the total number of departmental staff who may be involved in scientific activity or research, nor are they generally used for social science researchers or experts. And titles alone do not provide a qualitative assessment of the knowledge and skills held within an organisation. The nomenclature used by departments may also vary.

Institutions need to be appropriately resourced so they can fulfil their obligations. University-based research also provides critical support to government and the broader community. Funding is a critical component in supporting the work of government and non-government organisations. It is in many ways the fuel that drives institutional knowledge and capacity through adequate staffing, technology and information exchange.

It is nevertheless complex to map the purpose and pathways of funding and to tie this to institutional capacity, let alone environmental outcomes. Many aspects of funding efficiency and effectiveness arise in public administration, for example, and a vast literature could be brought to bear on these matters. The source of financial data would ultimately be found within budgets and business plans, but again, a large amount of time would be needed to sort such information and, even the, a simple answer may remain elusive, By way of example, the Climate Policy Initiative and the United Nations has sought to track the effectiveness of climate change funding, yet these organisations highlight the limitations of their estimates given data gaps and lack of agreed accounting definitions.[1781]

It might be expected that reviewing accounts at a national or state level would be an easier task, yet the measure initially intended to be used in this report, 'government funding for marine and coastal research or monitoring projects in Victoria', raises its own challenges in terms of data collection. First, budget allocations may be broad with disaggregation of funds occurring at a Departmental level through specific business plans and program budgets. Second, funding may be given to agencies or programs or used for community grants thus creating a complex process if trying to account for a single activity such as research or monitoring. Third, research or monitoring projects may be defined broadly or narrowly, making consistent measurement across different projects or funding streams difficult. Finally, the fact of funding does not guarantee that institutional knowledge or capacity has been enhanced to a large or small degree.

At a broader scale, trying to follow causal links from the funding, through capacity building, to positive environmental outcomes is arguably unattainable. Whether there are other ways to measure institutional knowledge and capacity (perhaps through qualitative or case study methods) is nevertheless worth exploring.

1781. Climate Policy Initiative 2018, 'Global climate finance: an updated view 2018', prepared by P Oliver, A Clark and C Meattle.

Theme 9: Stewardship and Collaborative Management

Indicator 81: Engagement and inclusiveness

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide	N	N	N	●	N/A	N/A

Data source:	Engage Victoria
Measures:	Engagement processes undertaken for marine and coastal policies | Environmental justice

Why this indicator?

This indicator recognises that transparent engagement allows for sound policy and strategies to be developed. Broad engagement also ensures that the final deliverables are representative of the diverse stakeholder voices.

Justification for assessment ratings:

- Engagement processes are increasingly documented as part of policy development. Evaluation of engagement processes is sometimes undertaken and can provide a good basis for continuous improvement.
- Different parts of government and different professions may take a different approach to engagement and this can make a single assessment of engagement processes difficult.
- Because engagement processes are undertaken by different agencies for many different policies affecting marine and coastal planning, a single assessment of engagement and inclusiveness is unrealistic. This section therefore takes a narrative approach to explore engagement and inclusiveness more broadly.
- The impacts of environmental degradation may disproportionally affect certain groups within society (such as the elderly or the poor) and may also have varying spatial outcomes. The impacts of climate change along Victoria's coastline may be similar in terms of physical effects but coastal communities vary greatly in their capacity to respond. Environmental policies themselves may have disproportionate effects across different populations, for example, transition to a low carbon economy can mean increased energy prices which has a greater impact on those with low incomes.

Good engagement provides a basis for successful policies and programs. The process of engaging with communities affected by policies enables their voices and perspectives to be considered. Ultimately this can help to shape policies that have a higher level of potential success. Broad engagement also ensures that the final deliverables are representative of the diverse stakeholder voices and not being monopolised by only a few powerful stakeholder groups.

Community consultation is a legislative requirement for development of the following policies and plans under the Victorian *Marine and Coastal Act 2018*:

1. the Marine and Coastal Policy (cl. 26)
2. the Marine and Coastal Strategy (cl. 33)
3. products under regional and strategic partnerships (cl. 47)
4. environmental management plans (cl. 52)
5. coastal and marine management plans (cl. 60).

Submissions received must be considered by the Minister (for points 1, 2 and 4 in the preceding list) or parties to the regional and strategic partnership (point 3) or Crown land managers (point 5). These processes ensure that engagement with the community is carried out during the development of policies through to the activities of land management for Victorian coastal and marine areas. At the local level, Committees of Management and other land management agencies are undertaking engagement activities on a regular basis as part of their activities. Local government is also required to engage with local communities under the *Planning and Environment Act 1989* for changes in land use zoning or assessment of permits for a range of land use activities.

Other forms of engagement and inclusion as communities take part in implementation or monitoring activities. This chapter has already outlined the ways in which environmental volunteers may be involved in government supported programs or citizen science. This involvement enables a virtuous circle of information–policy–improvement to occur with engagement and inclusiveness being a factor at each stage.

If engagement is done well, the following outcomes may be achieved:

- improving decision making by having informed decision- making (with all relevant factors and views considered)
- educating the community and getting 'buy-in' for policies or programs
- ensuring decision makers can be held to account,
- enhancing the transparency of decision making.

At one level, engagement can be measured relatively easily. Most planning and policy development processes have a phase of community engagement and a process of calling for, receiving, and analysing submissions from stakeholders. Such processes are documented with a selection of examples shown in Table 73 below. These selected examples have engagement processes which can be assessed in terms of compliance with best practice engagement principles. Offering people the opportunity to have input into decision making processes is an important part of good governance. Nevertheless, qualitative aspects of the process would require additional research methods: was the engagement effective, who was engaged and who was not, and were the views of those engaged reflected in the final report or policy? Such questions are sometimes addressed in evaluation processes and reflected in consultation summaries and other documentation.

Table 73: Engagement processes for selected policies or programs related to marine and coastal areas in Victoria.[1782,1783,1784,1785]

Department/ Agency	Policy/Program/ investigation	Engagement	Documentation of engagement outcomes
VEAC Victorian Environmental Assessment Council	Assessment of Victoria's Coastal Reserves	1-month submission period for draft report (11 submissions received) Community information sessions in five coastal locations Media channels used: VEAC website Facebook Letters to public land licence holders Regional newspapers. email news bulletin	Consultation summary published – included summary of feedback received
DELWP Department of Environment, Land, Water and Planning	Marine and Coastal Strategy	2-month submission period for draft policy (>200 submissions received)	Consultation summary published – included clear outline of how feedback was being incorporated into final policy
DELWP (Planning) Department of Environment, Land, Water and Planning	Point Lonsdale Groyne investigations	6 options presented for coastal protection Media channels used: Engage Vic Website Emails Social media Regional newspapers (2 written submissions received) Open house events (126 attendees) Online survey (7 responses)	Consultation summary published – included summary of feedback received on each option Final report recommended preferred option

1782. Victorian Environmental Assessment Council (VEAC) 2019, 'Assessment of Victoria's coastal reserves consultation summary', Melbourne, Victoria.
1783. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Summary of consultation draft marine and coastal policy', East Melbourne, Victoria.
1784. Department of Environment, Land, Water and Planning (DELWP) 2018, 'Lonsdale Bight coastal processes, engagement summary' East Melbourne, Victoria https://engage.vic.gov.au/lonsdale-bight Accessed 23 March 2021.
1785. Department of Environment, Land, Water and Planning (DELWP) 2018, 'Lonsdale Bight groyne options - summary of feedback', East Melbourne, Victoria.

It is also worth noting in relation to the previous table that land-use planning has a somewhat different professional culture in how it undertakes consultation. The term 'consultation' is somewhat distinct from engagement and this reflects the fact that specific expertise, such as engineering or urban design, forms part of many planning projects. Hence, in the case of the Point Lonsdale coastal protection, the consultation is not open ended – it is directed towards six options. And the final design is a product of the engineer (albeit taking on board community comments) rather than a community-led design.

Environmental Justice

The impacts of environmental degradation may disproportionally affect certain groups within society (such as the elderly or the poor) and may also have varying spatial outcomes. For example, communities which have been economically reliant on fossil fuel industries (such as the Latrobe Valley) will be likely to experience greater effects of transition to a low carbon economy while communities located in areas where wind or solar power generation is expanding may have new economic opportunities. The impacts of climate change along Victoria's coastline may be similar in terms of physical effects but coastal communities vary greatly in their capacity to respond. This may be due to demographic factors (for example an elderly population), economic factors (such as income level) or political influence. In many cases, a combination of all these factors creates a greater level of disadvantage or advantage.

An example is the impact of heatwaves which disproportionally affect the elderly population. These events cause more deaths than any other natural disaster in Victoria and this is likely to increase with climate change.[1786] In addition, there is structural ageing of Victoria's population which means that the number and proportion of people aged 65 years in our population is increasing. Research has found that, without adaptation, there will be an additional 6,214 deaths in Victoria by 2050 from heatwaves caused by climate change.[1787]

Environmental policies themselves may have disproportionate effects across different populations. Remediation responses at a household level are easier for families with higher levels of disposable income. Changes to energy prices due to transition to a low carbon economy can also have greater impacts on those with low incomes. And with the increasing frequency and severity of heatwaves, the capacity of households to invest in greater levels of insulation or use of cooling technologies may be restricted. In other words, those already disadvantaged may then suffer a greater level of risk from climate change events like heatwaves.[1788]

Following recommendations of an independent inquiry into the Victorian Environmental Protection Authority (EPA),[1789] the State Government directed DELWP to lead work which would 'determine the best whole of government approach to improving environmental justice, including integration into existing decision making.'[1790] In response to this, principles of environmental justice have been outlined by Environmental Justice Australia.[1791] These inter-related principles include:

Recognition – the rights and aspirations of individuals, communities and future generations (including Traditional Owners) need to be respected in relation to the environment. This includes people being able to access and enjoy nature as well as be protected from environmental harms.

Distributive Justice – the uneven distribution of Victoria's environmental benefits and harms need to be identified. For example, many Victorians have limited access to natural spaces.

Procedural Justice – Victorians, especially those who suffer environmental risk or harm should be able to participate meaningfully in decisions which affect the environment, being treated as equal and important stakeholders.

Substantive Justice – people need to be able to access justice without barriers or obstacles preventing them from so doing. Being able to appeal decisions and take part in procedural justice should not be prevented by bureaucratic or cost barriers.

1786. Steffen W, Hughes L and Perkins S 2014, 'Heatwaves: hotter, longer, more often', Climate Council of Australia, Potts Point, New South Wales, p. 20.
1787. Keating A and Handmer J 2013, 'Future potential losses from extremes under climate change: the case of Victoria, Australia', Victorian Centre for Climate Change Adaptation Research (VCCAR), Melbourne, Victoria, p. 26.
1788. Organisation for Economic Development and Cooperation (OECD) 2021, 'The inequality-environment nexus: towards a people-centred green transition', OECD green growth papers, 2021-01, OECD Publishing, Paris https://doi.org/10.1787/ca9d8479-en
1789. Victorian Government 2016 'Independent Inquiry into the Environment Protection Authority', prepared for the Minister for Environment, Climate Change and Water, Melbourne, Victoria.
1790. Victorian Government 2017, 'Andrews Labor Government response to the Independent Inquiry into the Environment Protection Authority', Melbourne, Victoria, p. 13.
1791. Environmental Justice Australia 2018, 'An environmental justice strategy for Victoria'.

Indicator 82: Delivery and accountability

Region	2021 status	2021 trend	2021 data	2018 status	2018 trend	2018 data
Statewide					N/A	N/A

Data source:	Parks Victoria, Victorian Auditor-General's Office
Measures:	Effectiveness of delivery

Why this indicator?

This indicator examines the delivery of marine and coastal policy and highlights the important role of both internal and external assessments of effectiveness to ensure organisational accountability for implementation.

Justification for assessment ratings:

- Delivery and implementation are critical aspects of any policy or program. While the fact of delivery is often reported through corporate annual reporting processes, the evaluation of policy effectiveness is more difficult to determine.
- Assessment of policy effectiveness has been undertaken by Parks Victoria, based on expert judgement of land managers. While such assessment might be criticised for being subject to subjective bias of individuals or institutional pressures for positive outcomes, it nevertheless provides valuable insights that are generally unavailable.
- Victoria has a number of systems to ensure accountability for government performance and spending. Government Inquiries such as that undertaken to review the Environmental Protection Authority is one example. The Auditor-General also has an ongoing role to review the effectiveness of government activity and spending on behalf of the Victorian Community.
- The existence of these systems of accountability have led to the assessment of good for this indicator, while the improving trend reflects the fact that departments are seeking to develop monitoring and evaluation systems which include policy effectiveness as part of their reporting.

The provision for Monitoring, Evaluation, Reporting and Improvement (MERI) in the Marine and Coastal Policy is of key importance for state of environment reporting as it can track the effectiveness of governance and collaborative management processes over time. MERI provides an adaptive process that includes performance monitoring and evaluation. Relevant elements for SoE may include:

- impact and effectiveness of management approaches on environmental condition
- collaboration and stakeholder engagement (number of stakeholders, nature of collaboration, effectiveness of engagement in terms of environmental outcomes)
- evidence that monitoring, evaluation and reporting is leading to adjustments and improvements in policy or management approach.

This final point is an important element of determining whether the MERI approach is achieving what is envisaged in the Marine and Coastal Policy, namely:

... reporting and evaluation of information from the outcomes of past operational programs to inform changes to policies and practices to improve future outcomes.[1792]

1792. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Marine and coastal policy', East Melbourne, Victoria, p. 19.

Theme 9: Stewardship and Collaborative Management

For environmental reporting to feed into decision making there are a series of steps, and agencies involved. Each may have specific expertise in parts of the process – data analysis, policy design, implementation and assessment of impact. The agencies, and those working within them will have specific thematic expertise (land management, marine science) or skills-based expertise (research, data mining, ICT). Alignment of effort and expertise is an achievement in governance and organisational operation. Yet the actors within those agencies are human and the organisational structures themselves may have legacy systems and path dependencies that act as barriers or turbulence to the flow of evidence-based policy and effective implementation. In effect, this chain of required steps is only as strong as its weakest link.

Agencies which have horizontal or vertical integration may have potential to make such links work well. An organisation like Melbourne Water, for example, has jurisdiction over many parts of the water system in Melbourne. This enables a coherent approach that can connect land use policy (for example, rural land use policy to minimise pollution inputs to the stormwater system) through to infrastructure planning (placement and maintenance of stormwater pipes). In other words, it has control over a process in an end-to-end fashion. An agency with horizontal integration may control one part of a system, but over a wide area, potentially crossing many jurisdictions. The land use planning system in Victoria is one that is implemented by 78 Local Government Areas across the state, yet it conforms to a centrally defined standard – the Victorian Planning Provisions (VPPs).

Nevertheless, no agency operates in isolation. Melbourne Water is not the only agency dealing with Melbourne's infrastructure and the VPPs are not the only policy that affects land use in Victoria. Thus, coordination and partnerships are needed to connect elements of the policy-implementation-evaluation chain.

The OECD has conducted a review of the impact of natural capital information on policy reform. In their review of case studies, they found that:

- potential policy impact was discussed in most of the case study literature however it was difficult to assess
- impact pathways were also discussed in some of the case studies however this 'pathway' was often limited to a set of recommendations for action
- engagement with stakeholders was also frequently discussed but it was not possible to assess from the literature whether there was a relationship between project impact and stakeholder involvement.[1793]

The common element in these observations is a break in the link between information, policy and on-the-ground impact. In turn, this makes it difficult to ascertain whether the broken or missing link is between information and policy, policy and implementation, or implementation and assessment of impact. Indeed, the missing link may exist within a single agency if processes and governance are less than optimal.

There are local examples of these incomplete linkages. The link between land use activities and contaminated runoff is a recognised one. The example of Melbourne Water's Rural Land Program is one that has already been mentioned.[1794] In the Corner Inlet region, links between agricultural runoff of fertiliser chemicals such as Phosphorus and Nitrogen is one which has long been recognised as having implications for the water quality of the marine environment (see discussion for Indicator 70: Agriculture). The Corner Inlet Water Quality Improvement Plan 2013 addressed this issue and presented a program logic to address the problem, complete with targets to reduce Nitrogen and Phosphorus levels flowing from land use activities such as farming into the marine waters of Corner Inlet and the Ramsar wetland it contains (Figure 155).

1793. Organisation for Economic Development and Cooperation (OECD) 2020, 'GSDD forum issue paper - practical policy use cases for natural capital information. a review of evidence for the policy reform and impact of natural capital information', report by the GGKP Expert Group on Natural Capital, OECD, Paris.
1794. Melbourne Water 2012, 'Rural land program: a guide to reducing the impact of runoff to waterways'.

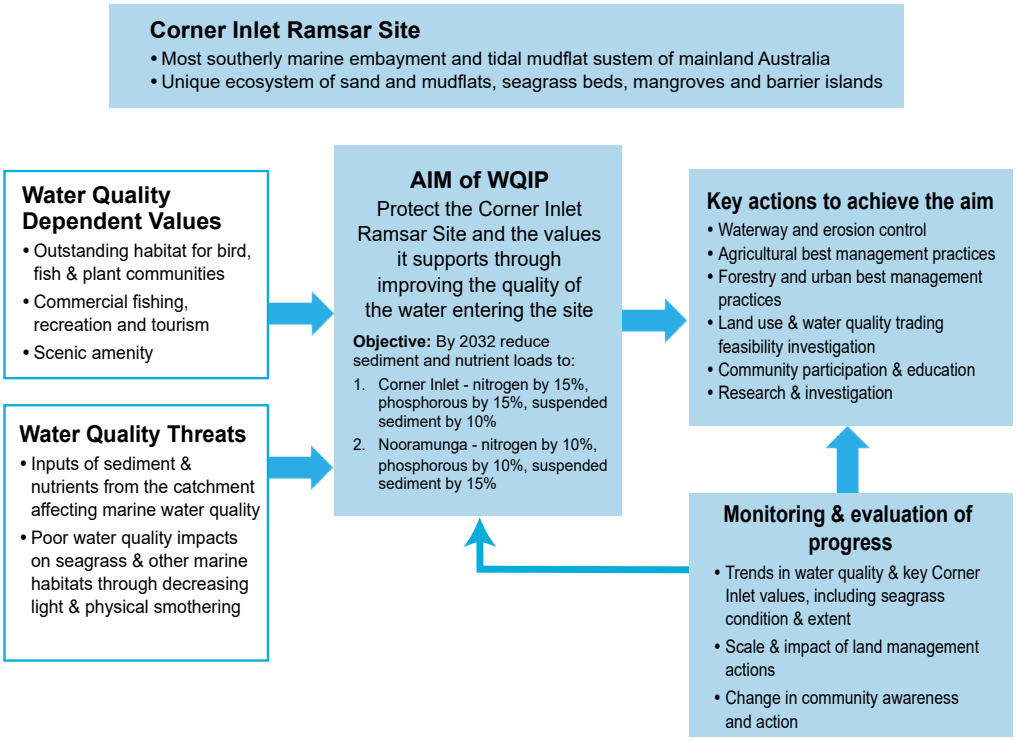


Figure 155: Simplified Program Logic for Corner Inlet Water Quality Improvement Plan.[1795]

Nearly halfway to the 2033 timeline for achieving the targets in the 2013 Water Quality Improvement Plan, it is unclear the degree to which progress has been made toward meeting those targets. As noted by Ford et al. (2016):

The absence of a water quality monitoring program in Corner Inlet is a challenge to quantifying any water quality gains made through the actions of this project. Similarly, observing actual seagrass regrowth resulting from improvements may takes years or decades to manifest.[1796]

This is just one example which highlights the long chain of actions required before an outcome can be determined or successfully achieved. In the case of the Water Quality Improvement Plan outlined above, one could argue that the following elements of the process were highly effective:

- examining scientific evidence to identify and articulate the problem
- developing a plan with sound program logic
- effectively undertaking collaborative catchment management through engagement (the farmer-fisher day) including evaluation of before and after awareness of issues.

However, maintaining consistent processes (and funding) across a 10-year timeframe is inherently difficult. In the chain of data collection, policy development, engagement, implementation, assessment and achieving outcomes, there only needs to be a single weak link for outcomes to be unclear, unmeasurable, or unachieved. In many cases, organisations may display strong and weak links across their processes and particularly at those points where another agency or agencies are required to effectively move the process forward. In

1795. West Gippsland Catchment Management Authority (WGCMA) 2013, 'Corner Inlet water quality improvement plan 2013', Traralgon, Victoria, p. 46.
1796. Ford J, Barclay K, and Day R 2016, 'Using local knowledge to understand and manage ecosystem-related decline in fisheries productivity', Fisheries Research and Development Corporation (FRDC) final project report, no. 2013-021, Melbourne, Victoria, p. 68.

the examples reviewed for this report some agencies were found to be good at analysing their management effectiveness (Parks Victoria) or reporting on their sustainability actions (Port of Melbourne) or applying their strategic intelligence (OCR) but, given the complexity of policies and actions, and the different scales at which they are being applied, it would be unrealistic to expect that every action and every outcome can be neatly linked.

One agency which has reported on the effectiveness of their work is Parks Victoria. Assessments are undertaken by senior public land managers who report against program objectives for a range of outcomes such as heritage values, park assets and natural values (Table 74). While such assessments might entail a risk of subjective bias or institutional pressures for positive outcomes, when used appropriately they provide a different kind of insight into the effectiveness of management actions in meeting agreed goals. The data in the table highlight several matters such as the degree to which objectives are met; while these are often met partially or substantially, there are fewer cases of objectives being fully met. Further investigation would be needed to understand whether this was due to limited capacity or resources, external events, or outcome expectations being overly high. Another pattern in the data appears to be the limited success in achieving objectives related to Aboriginal Heritage. The consistency of this objective not being met is also worthy of investigation so that barriers to achieving the goals can be better understood and addressed.

Table 74: Extent to which objectives were effectively met for selected outcomes, Parks Victoria, 2018.[1797]

Marine Parks			Management Plans		Degree to which Management Objectives were met			
Name	Type	Area (Ha)	Number of plans approved or in prep	Number of plans with significant influence	Natural Values	Aboriginal Heritage	Historic Heritage	Visitor assets
Barwon Bluff	MS	15.72	5	1	Substantially	Fully	Substantially	Substantially
Beware Reef	MS	219.95	2	0	Partially	Not assessed	Partially	Not assessed
Bunurong	MP	1260.74	6	1	Partially	Not at all	Partially	Not assessed
Bunurong	MNP	2049.14	7	4	Partially	Not at all	Not assessed	Not assessed
Cape Howe	MNP	4052.72	9	6	Partially	Partially	Partially	Not assessed
Churchill Island	MNP	670.33	6	1	Partially	Not assessed	Not assessed	Not assessed
Corner Inlet	MNP	1415.17	7	1	Substantially	Not at all	Not assessed	Not assessed
Corner Inlet	MCP	28585.7	3	0	Partially	Not at all	Not assessed	Partially
Discovery Bay	MNP	2833.43	5	3	Substantially	Partially	Not assessed	Not assessed
Eagle Rock	MS	17.74	5	0	Substantially	Not at all	Not assessed	Not assessed
French Island	MNP	2980.02	4	1	Partially	Not at all	Not assessed	Not assessed
Jawbone	MS	30.43	4	3	Partially	Not at all	Not at all	Partially
Marengo Reefs	MS	12.53	3	0	Substantially	Partially	Not at all	Partially
Merri	MS	29.01	7	2	Partially	Not assessed	Not assessed	Substantially
Mushroom Reef	MS	56.65	5	5	Partially	Not assessed	Not assessed	Partially
Ninety Mile Beach	MNP	2653.08	3	3	Not at all	Not assessed	Not assessed	Not assessed
Nooramunga	MCP	30091.5	4	0	Partially	Partially	Partially	Partially
Point Addis	MNP	4416.55	6	3	Substantially	Substantially	Not at all	Not assessed
Point Cooke	MS	291.91	4	0	Partially	Not assessed	Not at all	Partially
Point Danger	MS	21.71	5	1	Substantially	Substantially	Not at all	Not assessed
Point Hicks	MNP	3802.58	9	3	Partially	Not at all	Partially	Not assessed
Port Philip Heads	MNP	3473.99	7	3	Fully	Fully	Substantially	Substantially
Ricketts Point	MS	120.67	5	2	Partially	Not assessed	Not assessed	Partially
Shallow Inlet	MCP	1973.74	6	1	Not at all	Not at all	Not assessed	Partially
The Arches	MS	47.95	8	7	Substantially	Not assessed	Substantially	Not assessed
Twelve Apostles	MNP	7515.78	8	7	Partially	Not assessed	Not assessed	Not assessed
Wilsons Promontory	MR	627.43	2	2	Partially	Not at all	Partially	Not at all
Wilsons Promontory	MP	5565.98	2	2	Partially	Not at all	Partially	Not at all
Wilsons Promontory	MNP	15604.4	3	2	Partially	Not at all	Partially	Not at all
Yaringa	MNP	776.13	4	2	Fully	Not assessed	Not assessed	Not assessed

KEY

MNP Marine National Park
MCP Marine and Coastal Park
MS Marine Sanctuary
MR Marine Reserve

Management Objectives met

- Not at all
- Partially
- Substantially
- Fully
- Not assessed

1797. Parks Victoria 2018, 'State of the parks assessments'.

Delivery and effectiveness of policy and programs may be assessed internally through monitoring or surveys such as that shown above. Accountability and transparency of government activities can further be examined by independent agencies such as the Victorian Auditor-General's Office (VAGO) or through various types of Independent Inquiries (such as the Inquiry into EPA Victoria discussed in Indicator 81: Engagement and inclusiveness).

The Auditor-General is an independent officer of the Victorian Parliament. The role of VAGO is to provide assurance to Parliament and the Victorian community about how effectively public sector agencies are providing services and using public money.[1798] It does this through conducting annual reviews on a wide range of topics including those related to the environment and natural resources (Table 75).

Table 75: VAGO audits related to the environment and natural resources, 2014 to 2018.[1799]

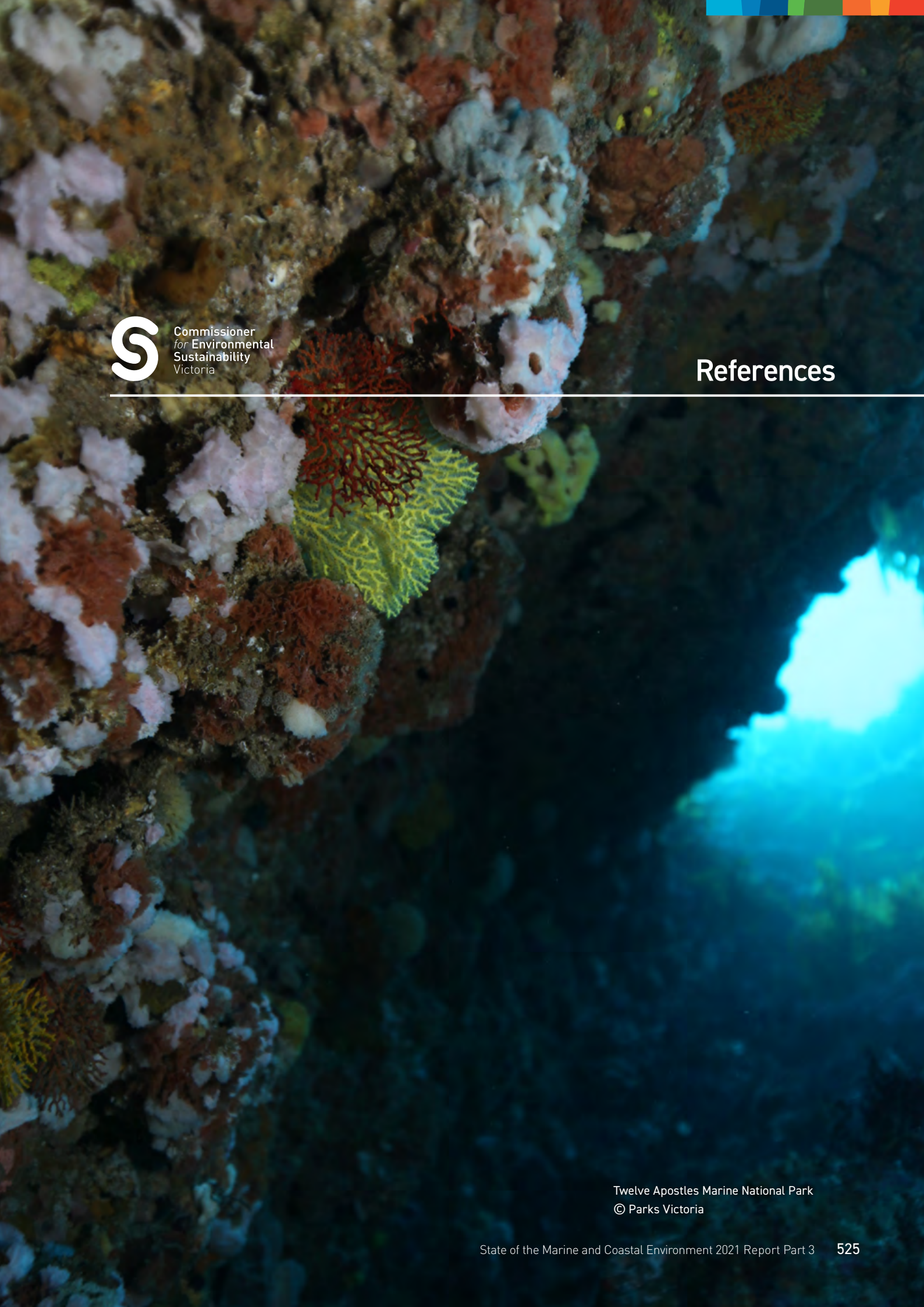
Year	VAGO Audit
2021	Delivering the Solar Homes Program
2020	Reducing Bushfire Risks Rehabilitating Mines Protecting Critically Endangered Grasslands
2019	Recovering and Reprocessing Resources from Waste Security of Water Infrastructure Control Systems
2018	Managing the Environmental Impacts of Domestic Wastewater Follow up of Oversight and Accountability of Committees of Management Managing the Municipal and Industrial Landfill Levy Protecting Victoria's Coastal Assets Improving Victoria's Air Quality

VAGO also monitors responses to their recommendations. Agencies are not legislatively required to accept, complete or publicly report on recommendations, so this monitoring process highlights where recommendations remain unresolved where responses are not able to be measured. Nevertheless, insight is provided, for example, in 2021 VAGO was able to report on outcomes of the recommendations from their 2018 audit, Protecting Victoria's Coastal Assets.[1800] All 20 recommendations were accepted by the Victorian Government. Eight had been completed by June 2021 with 12 still in progress. Those completed had taken an average of 23 months to complete (with a range from 15 months to 35 months).[1801]

1798. Victorian Auditor-General's Office (VAGO) 2021, 'Our role' https://www.audit.vic.gov.au/our-role Accessed 15 July 2021.
1799. Victorian Auditor-General's Office (VAGO) 2021, 'Victorian Auditor-General's office' https://www.audit.vic.gov.au/ Accessed 15 July 2021.
1800. Victorian Auditor-General's Office (VAGO) 2021, 'Responses to performance audit recommendations: annual status update', tabled 23 June https://www.audit.vic.gov.au/report/responses-performance-audit-recommendations-annual-status-update Accessed 16 July 2021.
1801. Victorian Auditor-General's Office (VAGO) 2021, 'Responses to performance audit recommendations dashboard' https://www.audit.vic.gov.au/report/responses-performance-audit-recommendations-annual-status-update#data-dashboard Accessed 16 July 2021.

Commissioner *for* Environmental Sustainability Victoria

References



Twelve Apostles Marine National Park
© Parks Victoria

References

AAA Tourist accommodation data 2012.

Abernethy K, Barclay K, McIlgorm A, Gilmour P, McClean N, Davey J 2020, 'Victoria's fisheries and aquaculture: economic and social contributions', Fisheries Research and Development Corporation (FRDC) 2017-092, University of Technology Sydney, Sydney https://www.frdc.com.au/Archived-Reports/FRDC%20Projects/2017-092-DLD.pdf Accessed 28 September 2020.

Aboriginal Victoria 2019, 'Fact sheet: Aboriginal coastal shell middens' https://www.aboriginalvictoria.vic.gov.au/fact-sheet-aboriginal-coastal-shell-middens Accessed 21 September 2020.

Aboriginal Victoria 2021, 'Cultural heritage sensitivity' https://www.aboriginalvictoria.vic.gov.au/cultural-heritage-sensitivity Accessed 23 March 2021.

Aboriginal Victoria, 'Aboriginal Cultural Heritage Register and Information System (ACHRIS)' https://achris.vic.gov.au/#/onlinemap Accessed 23 March 2021.

Aecom Australia 2019, 'St Kilda marina redevelopment. environmental and coastal requirements', prepared for Port Phillip City Council https://www.portphillip.vic.gov.au/media/rendykrt/st-kilda-marina-environmental-and-coastal-report-aecom-mar-2019.pdf Accessed 2 July 2021.

Agriculture Victoria 2020, 'Strategic agricultural land and development in Victoria. final report', prepared by Price Waterhouse Coopers (PwC) for the Department of Jobs, Precincts and Regions (DJPR), Melbourne, Victoria.

Agriculture Victoria 2021, 'Abalone disease' https://agriculture.vic.gov.au/biosecurity/animal-diseases/abalone-disease Accessed 22 July 2021.

Agriculture Victoria, 'Asian shore crab suspected in Mount Martha and Rickett's Point' https://agriculture.vic.gov.au/about/media-centre/media-releases/asian-shore-crab-suspected-in-mount-martha-and-ricketts-point Accessed 13 July 2021.

Agriculture Victoria, 'Invasive animal classifications' https://agriculture.vic.gov.au/biosecurity/pest-animals/invasive-animal-classifications Accessed 2 August 2021.

Agriculture Victoria, 'Invasive plant classifications' https://agriculture.vic.gov.au/biosecurity/weeds/invasive-plant-classifications Accessed 2 August 2021.

Agriculture Victoria, 'Marine pests in Victoria' https://agriculture.vic.gov.au/biosecurity/marine-pests/marine-pests-in-victoria Accessed 3 August 2021.

Agriculture Victoria, 'Northern pacific seastar die-off detected at Carrum', https://agriculture.vic.gov.au/about/media-centre/media-releases/northern-pacific-seastar-die-off-detected-at-carrum Accessed 29 March 2021.

Allen S, Allen D, Phoenix V, Le Roux G, Durántez Jiménez P, Simonneau A, Binet S and Galop D 2019, 'Atmospheric transport and deposition of microplastics in a remote mountain catchment', *Nature Geoscience*, 12, pp. 339–344.

Allinson M, Yamashita N, Taniyasu S, Yamazaki E, Allinson G 2019, 'Occurrence of perfluoroalkyl substances in selected Victorian rivers and estuaries: an historical snapshot', *Heliyon*, 5(9), e02472.

Amélineau F, Saraux C, Ropert-Coudert Y, Kato A, Hobson KA, Raymond B, Zimmer I and Chiaradia A 2021, 'Intra- and inter-individual changes in little penguin diving and isotopic composition over the breeding season', *Marine Biology*, 168(5), pp. 62.

Amtstaetter F, Yen J, Hale R, Koster W, O'Connor J, Stuart I, Tonkin Z 2021, 'Elevated river discharge enhances the immigration of juvenile catadromous and amphidromous fishes into temperate coastal rivers', *Journal of Fish Biology*, 99(1), pp. 61-72.

Anderson DJ 2017, 'Coastal groundwater and climate change', WRL technical report 2017/04, technical monograph prepared for the National Climate Change Adaptation Research Facility (NCCARF), Water Research Laboratory of the School of Civil and Environmental Engineering, UNSW, Sydney.

Atlas of Living Australia https://www.ala.org.au/ Accessed 15 March 2021.

Australasian Leisure Management 2019, ' Australasian Leisure Management 2019, 'Victorian Indigenous surfing program receives additional support from Kieser Australia' https://www.ausleisure.com.au/news/victorian-indigenous-surfing-program-receives-additional-support-from-kieser-australia/ Accessed 7 September 2020.

References

Australian Government 2019, 'Towards an emissions reduction fund method for blue carbon', Canberra, Australia, Department of the Environment and Energy https://www.industry.gov.au/sites/default/files/2020-08/erf-blue-carbon-2019.pdf Accessed 9 March 2021.

Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000, 'Australian and New Zealand guidelines for fresh and marine water quality' https://www.waterquality.gov.au/sites/default/files/documents/anzecc-armcanz-2000-guidelines-vol1.pdf Accessed 19 July 2021.

Australian and New Zealand Environment and Conservation Council (ANZECC) Task Force on Marine Protected Areas 1998, 'Guidelines for establishing the national representative system of marine protected areas', Canberra, Australia.

Australian Broadcasting Corporation (ABC) 2018, 'Great Ocean Road erosion prompts call for plant to preserve tourist destination's future' https://www.abc.net.au/news/2018-08-26/erosion-threatening-greatocean-road/10147918 Accessed 9 March 2021.

Australian Broadcasting Corporation (ABC) 2019, 'Sea urchins devastate broadleaf seagrass: industry and environmentalists team up to restore it' https://www.abc.net.au/news/2019-11-01/fighting-urchin-induced-seagrass-devastation/11658504?fbclid=IwAR3g79dZy7FK-lTR-GytnZJFs3q3mqQMH7NR3MCPt7UJU-HT4rTuNmaQ-8s Accessed 13 July 2020.

Australian Broadcasting Corporation (ABC) 2021, 'Australian seabird rescue says wildlife is paying the price for fishing boom', written by Hannah Ross and Bruce Mackenzie, posted 15 July https://www.abc.net.au/news/2021-07-15/anglers-create-a-nightmare-for-seabirds/100294268 Accessed 19 July 2021.

Australian Bureau of Statistics (ABS) 2020, 'General social survey, summary results, Australia, 2019', cat. 4159.0.

Australian Bureau of Statistics (ABS) 'Census of population and housing 2016'.

Australian Bureau of Statistics (ABS) 'Regional population growth', cat. 3218.0.

Australian Bureau of Statistics (ABS), 'Building approvals', cat. 8731.0.

Australian Government 'Climate ready natural resource management planning in Victoria' https://www.nrmclimate.vic.gov.au/ Accessed 27 July 2021.

Australian Government, *Biosecurity Act 2015*, no. 61, compilation no. 8 incorporating amendments up to 25 March 2020 https://www.legislation.gov.au/Details/C2020C00127 Accessed 6 July 2021.

Australian Government Inspector-General of Biosecurity 2019, 'Pest and disease interceptions and incursions in Australia', p. 53, Mascot, NSW https://www.igb.gov.au/sites/default/files/documents/qid52819_igb_interceptions_and_incursions_report_-_final.docx Accessed 8 October 2021.

Australian Heritage Database, 'Great Ocean Road and scenic environs listed place 105875', Department of Agriculture, Water and Environment, Canberra https://www.environment.gov.au/cgi-bin/ahdb/search.pl Accessed 1 July 2021.

Australian Marine Conservation Society 2020, 'The impacts of bushfires on coastal and marine environments, https://www.marineconservation.org.au/wp-content/uploads/2020/03/Bushfire-Report_February-2020_Final-full-for-web-1.pdf Accessed 07 July 2020.

Australian Maritime Safety Authority (AMSA) 2021, 'Major historical incidents - a summary list of major historical oil spill incidents' https://www.amsa.gov.au/marine-environment/incidents-and-exercises/major-historical-incidents Accessed 10 March 2021.

Australian Maritime Safety Authority (AMSA) 2021, 'National standard for commercial vessels (NSCV)', Australian Government, Canberra https://www.amsa.gov.au/about/regulations-and-standards/national-standard-commercial-vessels-nscv Accessed 1 July 2021.

Australian Pesticides and Veterinary Medicines Authority (APVMA) 2020, 'Spray drift management', Australian Government, Canberra https://apvma.gov.au/node/10796 Accessed 20 July 2021.

Australian Standard: AS ISO 20121-2013, 'Event sustainability management systems – requirements with guidance for use'.

Australian Urban Research Infrastructure Network (AURIN) 2021, 'State of the marine and coastal environment 2021 data gap 1 - preliminary investigation', unpublished report prepared by Lachlan Ng, University of Melbourne.

References

Ball D, Hirst A, Parry G, Heislers S, Blake S, Werner G, Young P and Coots A 2010, 'Victorian multi-regional seagrass health assessment 2004–07', Fisheries Victoria technical report no. 66, Department of Primary Industries (DPI), Queenscliff, Victoria.

Ball D, Soto-Berelov M and Young P 2014, 'Historical seagrass mapping in Port Phillip Bay', *Journal of Coastal Conservation*, 18, pp. 257–72.

Ball D, Soto-Berelov M, Young P and Coots A. 2009, 'Baywide seagrass monitoring program – historical seagrass mapping', Fisheries Victoria technical report series no. 70, Department of Primary Industries (DPI), Queenscliff, Victoria.

Barbee N, Longmore A, Townsend K, Pettigrove V and Swearer S 2016, 'Technical knowledge synthesis for nutrient cycling, marine pests and pollutants in Port Phillip Bay: informing the development of the new Port Phillip Bay environmental management plan', Centre for Aquatic Pollution Identification and Management (CAPIM) technical report no. 60, University of Melbourne, Parkville, Victoria.

Barman S, Goodsell K, Yardley D and Kowalczyk N 2020, 'Polystyrene pollution in the Yarra River: sources and solutions', Yarra Riverkeeper Association.

Barreau E, Kato A, Chiaradia A and Ropert-Coudert Y 2021, 'The consequences of chaos: foraging activity of a marine predator remains impacted several days after the end of a storm', *PLOS ONE*, 16(7), e0254269.

Barrett J, Chase Z, Zhang J, Banaszak Holl M, and Willis K, Williams A, Hardesty B and Wilcox C 2020, 'Microplastic pollution in deep-sea sediments from the Great Australian Bight', *Frontiers in Marine Science*, 7, 808, https://doi.org/10.3389/fmars.2020.576170.

Barton J, Pope A, Howe S, 2012, 'Marine natural values study vol 2: marine protected areas of the Victorian embayments bioregion, part 1 Port Phillip Bay', Parks Victoria technical series no. 77, Melbourne, Victoria.

Bass Coast Shire, 'Foreshore erosion response' https://www.basscoast.vic.gov.au/services/environment/foreshore-erosion-control Accessed 9 March 2021.

Bass Coast Shire, 'Targeting erosion at Cowes' https://www.basscoast.vic.gov.au/about-council/news-listing/targeting-erosion-at-cowes Accessed 9 March 2021.

Bell S, Phoenix C, Lovell R, and Wheeler B 2015, 'Seeking everyday wellbeing: the coast as a therapeutic landscape', *Social Science and Medicine*, 142(C), pp. 56-67.

Bennett S, Wernberg T, Connell S, Hobday A, Johnson C and Poloczanska E 2015, 'The 'Great Southern Reef': social, ecological and economic value of Australia's neglected kelp forests', *Marine and Freshwater Research,* 67, pp. 47-56.

Better Boating Victoria (BBV) 2021, 'Boat ramp upgrades' https://betterboating.vic.gov.au/priority-boat-ramp-upgrades/ Accessed 10 May 2021.

Better Boating Victoria (BBV) and Victorian Fisheries Authority (VFA) 2020, 'The economic value of recreational fishing and boating in Victoria', prepared by Ernst and Young.

Better Boating Victoria (BBV) https://betterboating.vic.gov.au/ Accessed 5 October 2020.

Bird E 1966, 'The impact of man on the Gippsland Lakes, Australia', in 'Geography as human ecology. methodology by example', S Eyre and G Jones (eds), Edward Arnold, London, pp. 55–73.

BirdLife International 2021, 'Important bird areas factsheet: Corner Inlet' http://datazone.birdlife.org/site/factsheet/corner-inlet-iba-australia Accessed 19 May 2021.

Black KP, Jenkins GP 2020, 'Model bubbles validation', technical report no. 2020-6, School of BioSciences, University of Melbourne and Sanctuary Beach Pte. Ltd.

Black KP, Longmore AR and Jenkins GP 2019, 'Model bubbles refinements and calibration', technical report no. 2019-2, School of BioSciences, University of Melbourne and Sanctuary Beach Pte. Ltd.

Black KP, Longmore AR, Hamer PA, Lee R, Swearer SE and Jenkins GP 2016, 'Linking nutrient inputs, phytoplankton composition, zooplankton dynamics and the recruitment of pink snapper, *Chrysophrys auratus*, in a temperate bay', *Estuarine, Coastal and Shelf Science*, 183, pp. 150-162.

Blue Carbon Lab 2019, 'Scientists find historical declines in kelp forest of southeast Australia' https://www.bluecarbonlab.org/kelp-forest-declines/ Accessed 6 April 2021.

References

BMT WBM 2011, 'Ecological character description of the Gippsland Lakes Ramsar site – final report', prepared for the Department of Sustainability, Environment, Water, Population and Communities (DSEWPC), Australian Government, Canberra https://www.environment.gov.au/system/files/resources/0c0185c8-8e0b-4194-a6ca-d0f795bef410/files/21-ecd.pdf Accessed 15 March 2021.

Boon P 2017, 'Are mangroves in Victoria (south-eastern Australia) already responding to climate change?', *Marine and Freshwater Research*, 68(12), pp. 2366–2374.

Boon PI, Allen T, Brook J, Carr, G, Frood, D, Hoye J, Harty C, McMahon A, Mathews S, Rosengren N, Sinclair S, White, M and Yogovic J 2011, 'Mangroves and coastal saltmarsh of Victoria: distribution, condition, threats and management', technical report, Victoria University, Melbourne.

Boon PI, Allen T, Carr G, Frood D, Harty C, McMahon A, Mathews S, Rosengren N, Sinclair S, White M and Yugovic J 2015, 'Coastal wetlands of Victoria, south-eastern Australia: providing the inventory and condition information needed for their effective management and conservation', *Aquatic Conservation: Marine and Freshwater Ecosystems*, 25, pp. 454–479.

Boon P, Cook P and Woodland R 2015, 'The Gippsland Lakes: management challenges posed by long-term environmental change', *Marine and Freshwater Research*, 67(6), pp. 721-737.

Boon P, Cook P and Woodland R 2016, 'The challenges posed by chronic environmental change in the Gippsland Lakes Ramsar site', *Marine and Freshwater Research,* 67(6), pp. 721-737.

Boon P, Frood D, Oates A, Reside J and Rosengren N 2019, 'Why has *Phragmites australis* persisted in the increasingly saline Gippsland Lakes? A test of three competing hypotheses', *Marine and Freshwater Research*, 70(4), pp. 469-492

Boon P, Rosengren N, Frood D, Oates A and Reside J 2015, 'Shoreline geomorphology and fringing vegetation of the Gippsland Lakes. Volume 1: a literature review', report to Gippsland Lakes Ministerial Advisory Committee, Bairnsdale.

Borrelle S, Ringma J, Law K, Monnahan C, Lebreton L, McGivern A, Murphy E, Jambeck J, Leonard G, Hilleary M, Eriksen M, Possingham H, De Frond H, Gerber L, Polidoro B, Tahir A, Bernard M, Mallos N, Barnes M and Rochman C 2020, 'Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution', *Science,* 369, 1515.

Borrini-Feyerabend G, Dudley N, Jaeger T, Lassen B, Pathak Broome N, Phillips A and Sandwith T 2013, 'Governance of protected areas: from understanding to action'. Best practice protected area guidelines series no. 20, International Union for Conservation of Nature (IUCN) Gland, Switzerland https://portals.iucn.org/library/node/29138 Accessed 14 July 2021.

Bowen A 2012, 'Archaeology of the Chinese fishing industry in colonial Victoria', *Studies in Australian Historical Archaeology*, Australasian Society for Historical Archaeology, Sydney.

Brooks S and Hale J 2020, 'Corner Inlet Ramsar habitat mapping', report for West Gippsland Catchment Management Authority (WGCMA), Traralgon, Victoria.

Bruce B, Griffin D and Bradford R 2007, 'Larval transport and recruitment processes of southern rock lobster', Fisheries Research and Development Corporation Project 2002/007, CSIRO Marine and Atmospheric Research, Hobart.

Buck L, Scherr S, Planicka C and Heiner K 2017, 'Building partnerships for landscape stewardship', chapter 4 in C Bieling and T Plieninger (eds), 'The science and practice of landscape stewardship', Cambridge University Press, Cambridge, UK, pp. 57–77 https://doi.org/10.1017/9781316499016.007

Bulthuis D 1983, 'Effects of in situ light reduction on density and growth of the seagrass *Heterozostera tasmanica* (Martens ex Aschers.) den Hartog in Western Port Victoria Australia', *Journal of Experimental Marine Biology and Ecology*, 67, pp. 91–103.

Bureau of Infrastructure and Transport Research Economics (BITRE) 2020, 'Australian infrastructure statistics—yearbook 2020', Department of Infrastructure, Transport, Regional Development and Communications, Canberra. Data are BITRE estimates based on Lloyds List Intelligence data.

Bureau of Infrastructure and Transport Research Economics (BITRE) 2019, 'Australian sea freight 2016-17', Department of Infrastructure, Transport, Regional Development and Communications, Canberra.

References

Bureau of Meteorology (BoM), 'Climate data online' http://www.bom.gov.au/climate/data

Bureau of Meteorology (BoM) 2011, 'Tide height assessment in Port Phillip Bay report 9: quarter ending 31 December 2011'.

Bureau of Meteorology (BoM) and CSIRO 2020, 'State of the climate 2020' http://www.bom.gov.au/state-of-the-climate/documents/State-of-the-Climate-2020.pdf

Bureau of Meteorology (BoM) 2021, 'Long-term temperature record' http://www.bom.gov.au/climate/data/acorn-sat/ Accessed 25 January 2021.

Bureau of Meteorology (BoM) and CSIRO 2016, 'State of the climate 2016'.

Bureau of Meteorology (BoM), 'Tide gauge metadata and observed monthly sea levels and statistics' http://www.bom.gov.au/oceanography/projects/ntc/monthly/ Accessed 22 May 2021.

Bureau of Meteorology (BoM), ACORN-SAT Australia v2 (snapshot v.2.1.0.1), Australian Climate Observations Reference Network - surface air temperature (1910-May 2019).

Business Victoria 2020, 'Regional visitation, regional market summaries' https://www.business.vic.gov.au/tourism-industry-resources/research/regional-visitation Accessed 25 September 2020.

Business Victoria 2021, 'Regional visitation. regional market summaries' https://business.vic.gov.au/business-information/tourism-industry-resources/tourism-industry-research/regional-visitation Accessed 9 August 2021.

Business Victoria 2020, 'Victoria's tourism regions' https://www.business.vic.gov.au/__data/assets/pdf_file/0008/1615562/Victorias_Tourism_Regions_map_2017.pdf Accessed 25 September 2020.

Business Victoria 2020, 'Victoria's visitor economy 2018-19 state tourism satellite account results' https://www.business.vic.gov.au/__data/assets/pdf_file/0010/1855603/Value-of-Tourism-to-Victoria-summary-2018-19.pdf Accessed 25 September 2020.

Butler CL, Lucieer VL, Wotherspoon SJ, Johnson CR 2020, 'Multi-decadal decline in cover of giant kelp *Macrocystis pyrifera* at the southern limit of its Australian range', *Marine Ecology Progress Series*, 653, pp. 1-18.

Campbell S and Burridge T 1998, 'Occurrence of *Undaria pinnatifida* (Phaeophyta: Laminariales) in Port Phillip Bay', Victoria, Australia. *Marine and Freshwater Research*, 49, pp. 379-381.

Canterford S 2011, 'Locating people spatially: 2006, 2010 and 2.36pm on Friday', *Australasian Journal of Regional Studies*, 17(1), pp. 46-59.

Carnell PE and Keough MJ 2019, 'Reconstructing historical marine populations reveals major decline of a kelp forest ecosystem in Australia', *Estuaries and Coasts*, 42, pp. 765–778 https://doi.org/10.1007/s12237-019-00525-1

Carnell PE and Keough MJ 2014, 'Spatially variable synergistic effects of disturbance and additional nutrients on kelp recruitment and recovery', *Oecologia*, 175(1), pp. 409-416.

Carnell PE, Reeves SE, Nicholson E, Macreadie P, Ierodiaconou D, Young M, Kelvin J, Janes H, Navarro A, Fitzsimons J and Gillies CL 2019, 'Mapping ocean wealth Australia: the value of coastal wetlands to people and nature', The Nature Conservancy, Melbourne https://www.natureaustralia.org.au/content/dam/tnc/nature/en/documents/australia/MOW_Report_Web.pdf Accessed 30 August 2021.

Casas G, Scrosati R and Luz Piriz M 2004, 'The invasive kelp *Undaria pinnatifida* (Phaeophyceae, Laminariales) reduces native seaweed diversity in Nuevo Gulf (Patagonia, Argentina)', *Biological Invasions*, 6, pp. 411-416.

Casey Seals Masters Swimming Club '2020/21 Open water swim calendar' updated 23 August 2020 https://www.caseyseals.com.au/misc/swim_calendar_cutdown_2020_21.pdf Accessed 27 August 2020.

Castro L, Cetina-Heredia P, Roughan M, Dworjanyn S, Thibaut L, Chamberlain M, Feng M and Verges A 2020, 'Combined mechanistic modelling predicts changes in species distribution and increased co-occurrence of a tropical urchin herbivore and a habitat-forming temperate kelp', *Diversity and Distributions*, 26, pp. 1211–1226 https://doi.org/10.1111/ddi.13073 Accessed 30 March 2021.

Centre for eResearch and Digital Innovation, 'Soil health knowledge base' https://www.ccmaknowledgebase.vic.gov.au/soilhealth/soils_map.php?visible=true&restore_map=true&layer_id=258# Accessed 17 May 2021.

References

Chamberlain K 1997, 'Carrying capacity', UNEP Industry and environment no. 8, UNEP, Paris.

Chapin F, Carpenter S, Kofinas G, Folke C, Abel N, Clark W, Olsson P, Smith D, Walker B, Young O, Berkes F, Biggs R, Grove J, Naylor R, Pinkerton E, Steffen W and Swanson F 2010, 'Ecosystem stewardship: sustainability strategies for a rapidly changing planet', *Trends in Ecology and Evolution*, 25(4), pp.241–249 https://doi.org/10.1016/j.tree.2009.10.008

Charko F, Blake N, Seymore A, Johnstone C, Barnett E, Kowalczyk N and Pattison M 2020, 'Clean bay blueprint – microplastics in Melbourne', Port Phillip EcoCentre.

Charlton-Robb K, Gershwin L, Thompson R, Austin J, Owen K and McKechnie S 2011, 'A new dolphin species, the burrunan dolphin *Tursiops australis sp. nov.,* endemic to southern Australian coastal waters', *PLOS ONE*, 6(9), e24047.

Charlton-Robb, K., Taylor A and McKechnie S 2015, 'Population genetic structure of the burrunan dolphin (*Tursiops australis*) in coastal waters of south-eastern Australia: conservation implications', *Conservation Genetics*, 16(1), pp. 195-207 https://doi.org/10.1007/s10592-014-0652-6 Accessed 11 April 2021.

Chassot E, Bonhommeau S, Dulvy N, Mélin F, Watson R, Gascuel D and Le Pape O 2010, 'Global marine primary production constrains fisheries catches', *Ecology Letters*, 13(4), pp. 495-505.

Chiaradia A, Forero MG, Hobson KA and Cullen JM 2010, 'Changes in diet and trophic position of a top predator ten years after a mass mortality of a key prey', *ICES Journal of Marine Science*, 67, pp. 1710-1720.

Chiaradia A, Forero MG, Hobson KA, Swearer SE, Hume F, Renwick L, Dann P 2012, 'Diet segregation between two colonies of little penguins *Eudyptula minor* in southeast Australia', *Austral Ecology*, 37(5), pp. 610-619.

Chiaradia A, Ramirez F, Forero MG and Hobson KA 2016, 'Stable isotopes (δ13C, δ15N) combined with conventional dietary approaches reveal plasticity in central-place foraging behaviour of little penguins (*Eudyptula minor*)' *Frontiers in Ecology and Evolution*, 3, 154.

Chidgey S and Crockett P 2010, 'Stony Point to Cowes vehicular ferry: marine ecosystem preliminary considerations', CEE Consultants Pty Ltd and Meinhardt Infrastructure and Environment.

Christoff P 1998, 'Degreening government in the garden state: environmental policy under the Kennett Government 1992-1997', *Environment Planning and Law Journal,* 15(1), pp. 10-32.

City of Melbourne, 'What is water sensitive urban design?' http://urbanwater.melbourne.vic.gov.au/melbournes-water-story/water-sensitive-urban-design-wsud/ Accessed 4 May 2021.

Clarke JM, Grose M, Thatcher M, Hernaman V, Heady C, Round V, Rafter T, Trenham C and Wilson L 2019, 'Victorian climate projections 2019 technical report', CSIRO, Melbourne, Australia https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0029/442964/Victorias-Climate-Science-Report-2019.pdf Accessed 21 January 2021.

Clarke JM, Grose M, Thatcher M, Round V and Heady C 2019, 'Barwon climate projections 2019', CSIRO, Melbourne Australia https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0037/429868/Barwon-Climate-Projections-2019-20200219.pdf Accessed 7 July 2021.

Clarke JM, Grose M, Thatcher M, Round V and Heady C 2019, 'Greater Melbourne climate projections 2019', CSIRO, Melbourne Australia https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0038/429878/Greater-Melbourne-Climate-Projections-2019_20200219.pdf Accessed 1 February 2021.

Clemens, R, Rogers D, Hansen B, Gosbell K, Minton C, Straw P, Bamford M, Woehler E, Milton D, Weston M, Venables B, Weller D, Hassell C, Rutherford B, Onton K, Herrod A, Studds C, Choi C, Dhanjal-Adams K, Murray N, Skilleter G and Fuller R 2016, 'Continental-scale decreases in shorebird populations in Australia', *Emu*, 116, pp. 199-135.

Climate Council of Australia Limited 2021, 'Game, set, match: calling time on climate inaction' https://www.climatecouncil.org.au/wp-content/uploads/2021/02/Game-Set-Match-Calling-Time-on-Climate-Inaction-Climate-Council-Sports-Report.pdf Accessed 5 March 2021.

Climate Policy Initiative 2018, 'Global climate finance: an updated view 2018', prepared by P Oliver, A Clark and C Meattle https://www.climatepolicyinitiative.org/wp-content/uploads/2018/11/Global-Climate-Finance-_-An-Updated-View-2018.pdf Accessed 15 July 2021.

References

Coastal Environmental Consultants 2008, 'Corner Inlet sediment characterisation study final report', report prepared in collaboration with Geomax for the Department of the Environment, Water, Heritage and the Arts (DEWHA), Australian Government, Canberra.

Coffey B 2021, 'Environmental challenges for public value theory and practice', *International Journal of Public Administration*, 44(10), pp. 818-825.

Coffey B, Bush J, Mumaw L, DeKleyn L, Furlong C, and Cretney R 2020, 'Towards good governance of urban greening: insights from four initiatives in Melbourne, Australia', *Australian Geographer*, DOI:10.1080/00049182.2019.1708552.

Cohen B, Currie D and Mcarthur M 2000, 'Epibenthic community structure in Port Phillip Bay, Victoria, Australia', *Marine and Freshwater Research*, 51, pp. 689–702.

Cohen B, McArthur M and Parry G 2000, 'Exotic marine pests in Westernport', Marine and Freshwater Resources Institute, Queenscliff, Victoria.

Collier C and Waycott M 2014, 'Temperature extremes reduce seagrass growth and induce mortality', *Marine Pollution Bulletin*, 83(2), pp. 483–490.

Collier C, Waycott M and McKenzie L 2012, 'Light thresholds derived from seagrass loss in the coastal zone of the northern Great Barrier Reef, Australia', *Ecological Indicators*, 23, pp. 211-219.

Colton MA, Swearer SE 2010, 'A comparison of two survey methods: differences between underwater visual census and baited remote underwater video', *Marine Ecology Progress Series*, 400, pp. 19-36.

Commissioner for Environmental Sustainability (CES) 2016, 'State of the Bays 2016', Melbourne, Victoria.

Commissioner for Environmental Sustainability (CES) 2018, 'Victorian State of the Environment 2018', Melbourne, Victoria.

Commissioner for Environmental Sustainability (CES) 2018, 'Victorian State of the Environment 2018, scientific assessments', Melbourne, Victoria.

Commonwealth of Australia 2009, 'Climate change risks to Australia's coast: a first pass national assessment', Department of Climate Change, Canberra.

Commonwealth of Australia 2013, 'The critical decade: impacts for Gippsland, Victoria' Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education (DIICCSRTE), Canberra.

Commonwealth of Australia 2020, 'National light pollution guidelines for wildlife including marine turtles, seabirds and migratory shorebirds' https://www.environment.gov.au/system/files/resources/2eb379de-931b-4547-8bcc-f96c73065f54/files/national-light-pollution-guidelines-wildlife.pdf Accessed 22 March 2021.

Connolly R 2009, 'Seagrass', in E Poloczanska, A Hobday and A Richardson (eds), 'Marine climate change impacts and adaptation report card for Australia', National Climate Change Adaptation Research Facility (NCCARF) Publication 2009, Southport, Queensland.

Convention on Biological Diversity, 'Quick guide to the Aichi biodiversity targets' https://www.cbd.int/doc/strategic-plan/targets/T11-quick-guide-en.pdf.

Cook P and Holland D 2012, 'Long term nutrient loads and chlorophyll dynamics in a large temperate Australian lagoon system affected by recurring blooms of cyanobacteria', *Biogeochemistry*, 107(1–3), pp. 261–274.

Cook P, Evrard V and Woodland R 2015, 'Factors controlling nitrogen fixation in temperate seagrass beds', *Marine Ecology Progress Series*, 525, pp. 41–51.

Cook P, Holland D and Longmore A 2008, 'Interactions between phytoplankton dynamics, nutrient loads and the biogeochemistry of the Gippsland Lakes', report prepared for the Gippsland Lakes Taskforce, Water Studies Centre, Monash University, Clayton.

Cooke S, Venturelli P, Twardek W, Lennox R, Brownscombe J, Skov C, Hyder K, Suski C, Diggles B, Arlinghaus R and Danylchuk A 2021, 'Technological innovations in the recreational fishing sector: implications for fisheries management and policy', *Reviews in Fish Biology and Fisheries*, 31, pp. 253–288.

Cooperative Research Centre for Spatial Information and NGIS, 'Coastal risk Australia' http://www.coastalrisk.com.au/ Accessed 26 September 2021.

Corkill J 2012, 'Principles and problems of shoreline law', ACCARNSI discussion paper – node 1 coastal settlements, Australian Climate Change Adaptation Research Network for Settlements and Infrastructure, National Climate Change Adaptation Research Facility (NCCARF).

Crockett P, Johnson K, Brenker M, Ierodiacanou D and Carnell P 2017, 'Undaria pinnatifida in Port Phillip Bay marine sanctuaries: removal strategies and interactions with the native algal canopy', Parks Victoria technical series no. 113, Melbourne, Victoria.

References

CSIRO 2005, 'Corner Inlet environmental audit CSIRO Land and Water Client Report'.

CSIRO 2021, 'Waves' https://research.csiro.au/slrwavescoast/waves/ Accessed 22 January 2021.

CSIRO and Bureau of Meteorology (BoM) 2015, 'Climate change in Australia: information for Australia's natural resource management regions: technical report', Australia https://apo.org.au/sites/default/files/resource-files/2015-01/apo-nid52475.pdf Accessed 15 November 2021.

Currie D and Crookes D 1997, 'Exotic marine pests in the Port of Hastings, Victoria', Marine and Freshwater Resources Institute, Queenscliff, Victoria.

Dann P 1996, 'The distribution and abundance of Australian fur seals Arctocephalus pusillus and bottlenose dolphins Tursiops truncatus in Western Port, Victoria', *Victorian Naturalist*, 113, pp. 306-310.

Dann P 2011, 'Birds and marine mammals', in 'Understanding the Western Port Environment: A summary of current knowledge and priorities for future research', edited by Melbourne Water, Melbourne, pp. 156–169.

DataVic 2020, 'Marine assets' map layer https://discover.data.vic.gov.au/dataset/marine-assets Accessed 26 July 2021.

DataVic 2020, 'Marine national park - public land management', map layer.

DataVic 2020, 'Marine sanctuary - public land management', map layer.

DataVic 2021, 'RAMSAR wetland areas in Victoria at 1:25 000', map layer https://discover.data.vic.gov.au/dataset/ramsar-wetland-areas-in-victoria-at-1-25-000 Accessed 27 July 2021.

Davis S, Pritchard K and Edmunds M 2011, 'Victorian subtidal reef monitoring program: the reef biota at Bunurong marine national park', Parks Victoria technical series no. 84, Melbourne, Victoria.

Day P 2018, 'Lake Wellington science review', report commissioned by the West Gippsland Catchment Management Authority (WGCMA) to inform the development of the Lake Wellington Land and Water Management Plan https://wgcma.vic.gov.au/wp-content/uploads/2018/02/Lake-Wellington-Science-Review_Feb-2018.pdf Accessed 15 March 2021.

Deloitte Access Economics 2013, 'Economic Value of Groundwater in Australia' https://www2.deloitte.com/content/dam/Deloitte/au/Documents/finance/deloitte-au-fas-ncgrt-economic-value-groundwater-31-oct-2013-250914.pdf Accessed 6 March 2021.

Deloitte Access Economics 2020, 'Visitor demand and accommodation forecast – final report. Great Ocean Road' https://www.planning.vic.gov.au/__data/assets/pdf_file/0025/510964/DAE_DELWP_Visitor-demand-and-accommodation_forecast_FINAL_report_4JUN2020.pdf Accessed 6 July 2021.

Department of Agriculture and Water Resources (DAWR) 2018, 'MarinePestPlan 2018-2023: the national strategic plan for marine pest biosecurity', Canberra, Australia.

Department of Agriculture, Fisheries and Forestry (DAFF) 2010, 'The relative contribution of vectors to the introduction and translocation of invasive marine species', Australian Government, Canberra https://www.marinepests.gov.au/sites/default/files/Documents/relative-contribution-vectors-introduction-translocation-invasive-marine-species.pdf Accessed 11 May 2021.

Department of Agriculture, Water and the Environment (DAWE) 2015, 'Anti-fouling and in-water cleaning guidelines', Australian Government, Canberra https://www.agriculture.gov.au/sites/default/files/sitecollectiondocuments/animal-plant/pests-diseases/marine-pests/antifouling-consultation/antifouling-guidelines.pdf Accessed 1 July 2021.

Department of Agriculture, Water and the Environment (DAWE) 2020, 'Australian ballast water management requirements version 8', Australian Government, Canberra https://www.agriculture.gov.au/sites/default/files/documents/australian-ballast-water-management-requirements.pdf Accessed 6 July 2021.

Department of Agriculture, Water and the Environment (DAWE) 2021, 'The introduction of marine pests to the Australian environment via shipping', Australian Government, Canberra https://www.environment.gov.au/biodiversity/threatened/nominations/ineligible-ktp/introduction-marine-pests-via-shipping Accessed 23 February 2021.

Department of Agriculture, Water and the Environment (DAWE), 'National introduced marine pest information system', Australian Government, Canberra https://www.marinepests.gov.au/pests/nimpis Accessed 29 March 2021.

References

Department of Economic Development, Jobs, Transport and Resources (DEDJTR) 2015, 'Victorian wild harvest abalone fishery management plan' Melbourne, Victoria.

Department of Economic Development, Jobs, Transport and Resources (DEDJTR) 2016, 'Victorian visitor economy strategy', Melbourne, Victoria https://economicdevelopment.vic.gov.au/__data/assets/pdf_file/0006/1340979/Visitor_Economy_Strategy.pdf Accessed 21 September 2020.

Department of Environment and Primary Industries (DEPI) 2013, 'Improving our waterways: Victorian waterway management strategy', Melbourne, Victoria.

Department of Environment Land Water and Planning (DELWP) 2020, 'Citizen science drones factsheet', Victorian Government, Deakin University and University of Melbourne https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0030/444684/Citizen-science-drones-factsheet.pdf Accessed 8 February 2021.

Department of Environment, Land Water and Planning (DELWP) 2020, 'Marine and coastal policy', East Melbourne, Victoria https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0027/456534/Marine-and-Coastal-Policy_Full.pdf Accessed 4 November 2020.

Department of Environment, Land, Water and Planning (DELWP) 'Climate change adaptation resources', https://www.climatechange.vic.gov.au/climate-change-adaptation-resources Accessed 9 May 2021.

Department of Environment, Land, Water and Planning (DELWP) 2015, 'Managing coastal hazards and the coastal impacts of climate change – planning practice note 53', East Melbourne, Victoria https://www.planning.vic.gov.au/__data/assets/pdf_file/0028/97309/PPN53-Managing-coastal-hazards-and-the-coastal-impacts-of-climate-change_August-2015.pdf Accessed 9 March 2021.

Department of Environment, Land, Water and Planning (DELWP) 2016, 'Water for Victoria – water plan', East Melbourne, Victoria https://www.water.vic.gov.au/__data/assets/pdf_file/0030/58827/Water-Plan-strategy2.pdf Accessed 17 May 2021.

Department of Environment, Land, Water and Planning (DELWP) 2017, 'Port Phillip Bay environmental management plan 2017-2027', East Melbourne, Victoria https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0024/88710/PPB-EMP-2017-Main-Doc.pdf Accessed 19 February 2021.

Department of Environment, Land, Water and Planning (DELWP) 2017, 'Index of estuary condition', East Melbourne, Victoria https://www.ari.vic.gov.au/__data/assets/pdf_file/0033/74769/Index-Estuary-Condition_fact-sheet_May2017.pdf Accessed 17 July 2020.

Department of Environment, Land, Water and Planning (DELWP) 2017, 'Port Phillip Bay environmental management plan 2017–2027 supporting document', East Melbourne, Victoria.

Department of Environment, Land, Water and Planning (DELWP) 2017, 'Western Port Ramsar site management plan', East Melbourne, Victoria https://www.water.vic.gov.au/__data/assets/pdf_file/0021/66270/Western-Port-Ramsar-Site-Management-Plan_revised.pdf Accessed 22 March 2021.

Department of Environment, Land, Water and Planning (DELWP) 2017, 'VEFMAP stage 6 part b: program design and monitoring methods', a report by Arthur Rylah Institute for Environmental Research (ARI) and Integrated Water and Catchments Division, Department of Environment, Land, Water and Planning (DELWP), Victoria https://www.ari.vic.gov.au/__data/assets/pdf_file/0028/91783/VEFMAP-Stage-6-Part-B-manual-Program-design-and-monitoring-methods.pdf Accessed 14 July 2020.

Department of Environment, Land, Water and Planning (DELWP) 2017, 'Climate change risks to local government', East Melbourne, Victoria https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0023/73049/Climate-Change-Risks-to-Local-Government_FINAL.pdf Accessed 9 March 2021.

Department of Environment, Land, Water and Planning (DELWP) 2017, 'Guidelines for the removal, destruction or lopping of native vegetation' East Melbourne, Victoria.

Department of Environment, Land, Water and Planning (DELWP) 2017, 'Protecting Victoria's environment – biodiversity 2037', East Melbourne, Victoria https://www.environment.vic.gov.au/__data/assets/pdf_file/0022/51259/Protecting-Victorias-Environment-Biodiversity-2037.pdf Accessed 21 July 2020.

References

Department of Environment, Land, Water and Planning (DELWP) 2018, 'Improving stormwater management advisory committee: final report', East Melbourne, Victoria https://www.water.vic.gov.au/__data/assets/pdf_file/0035/394685/Improving_Stormwater_Management_Report_PUBLIC_V4.pdf Accessed 19 February 2021.

Department of Environment, Land, Water and Planning (DELWP) 2018, 'Dandenong strategic directions statement 2018', East Melbourne, Victoria https://www.water.vic.gov.au/__data/assets/pdf_file/0017/412442/Dandenong_SDS_web_UPDATED-FEB-2019.pdf Accessed 9 June 2021.

Department of Environment, Land, Water and Planning (DELWP) 2018, 'Western Port strategic directions statement September 2018', East Melbourne, Victoria https://www.water.vic.gov.au/__data/assets/pdf_file/0019/417412/IWM_Western-Port_web_Updated-April-2019.pdf Accessed 22 February 2021.

Department of Environment, Land, Water and Planning (DELWP) 2018, 'Threatened plants and animals', Arthur Rylah Institute (ARI), Heidelberg, Victoria https://www.ari.vic.gov.au/research/threatened-plants-and-animals Accessed 11 April 2021.

Department of Environment, Land, Water and Planning (DELWP) 2018, 'Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar site management plan', East Melbourne, Victoria.

Department of Environment, Land, Water and Planning (DELWP) 2018, 'Towns in time', based on ABS census data, East Melbourne, Victoria.

Department of Environment, Land, Water and Planning (DELWP) 2018, 'Victoria's marine and coastal reforms final transition plan', East Melbourne, Victoria.

Department of Environment, Land, Water and Planning (DELWP) 2018, 'Lonsdale Bight coastal processes, engagement summary' East Melbourne, Victoria https://engage.vic.gov.au/lonsdale-bight Accessed 23 March 2021.

Department of Environment, Land, Water and Planning (DELWP) 2018, 'Lonsdale Bight groyne options - summary of feedback', East Melbourne, Victoria https://s3.ap-southeast-2.amazonaws.com/hdp.au.prod.app.vic-engage.files/3515/4985/7499/Lonsdale_Bight_groyne_options_summary_of_feedback_August_2018.pdf Accessed 22 March 2021.

Department of Environment, Land, Water and Planning (DELWP) 2020, 'Annual report 2019', Melbourne, Victoria, p. 42 https://www.delwp.vic.gov.au/__data/assets/pdf_file/0032/438188/DELWP-Annual-Report-2018-19-web.pdf Accessed 13 July 2021.

Department of Environment, Land, Water and Planning (DELWP) 2019 'Great Ocean Road coast and parks authority fact sheet', East Melbourne, Victoria https://s3.ap-southeast-2.amazonaws.com/hdp.au.prod.app.vic-engage.files/6715/5927/2048/Fact_Sheet_Authority.pdf Accessed 20 August 2020.

Department of Environment, Land, Water and Planning (DELWP) 2019, 'East Gippsland strategic directions statement September 2018', East Melbourne, Victoria https://www.water.vic.gov.au/__data/assets/pdf_file/0029/395462/East-Gippsland-SDS-web-version.pdf Accessed 15 March 2021.

Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria Unearthed', East Melbourne, Victoria https://www.environment.vic.gov.au/__data/assets/pdf_file/0019/430471/VictoriaUnearthed_FactSheet_v2.1_Aug2019.pdf Accessed 06 July 2020.

Department of Environment, Land, Water and Planning (DELWP) 2019, 'NaturePrint's strategic management prospects - transformer weeds', East Melbourne, Victoria https://www.environment.vic.gov.au/__data/assets/pdf_file/0030/412959/NaturePrints-Strategic-Management-Prospects-Transformer-Weeds.pdf Accessed 2 August 2021.

Department of Environment, Land, Water and Planning (DELWP) 2019, 'Biodiversity 2037 monitoring, evaluation, reporting and improvements framework (MERF) Version 2.0', East Melbourne, Victoria https://www.environment.vic.gov.au/__data/assets/pdf_file/0020/462341/Biodiverstiy-2037-MERI-v2.pdf Accessed 3 August 2021.

Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019' https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0029/442964/Victorias-Climate-Science-Report-2019.pdf Accessed 21 January 2021.

Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria in future 2019: population projections 2016 to 2056', East Melbourne, Victoria https://www.planning.vic.gov.au/__data/assets/pdf_file/0032/332996/Victoria_in_Future_2019.pdf Accessed 5 March 2021.

References

Department of Environment, Land, Water and Planning (DELWP) 2019, 'Port Phillip Bay coastal hazard assessment project overview', East Melbourne, Victoria https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0018/423513/Port-Phillip-Bay-Coastal-Hazard-Assessment-fact-sheet-for-web.pdf Accessed 2 August 2021.

Department of Environment, Land, Water and Planning (DELWP) 2019, 'Improving coastal erosion assessments for Victoria: embayments and living shorelines research project summaries - August 2019' https://www.marineandcoasts.vic.gov.au/coastal-programs/victorian-coastal-monitoring-program?a=436223 Accessed 7 July 2020.

Department of Environment, Land, Water and Planning (DELWP) 2019, 'Planning and Environment Amendment (Distinctive Areas and Landscapes) Act 2018 fact sheet' https://s3.ap-southeast-2.amazonaws.com/hdp.au.prod.app.vic-engage.files/2815/5547/6847/DALs_Legislation_Fact_Sheet_.pdf Accessed 20 July 2020.

Department of Environment, Land, Water and Planning (DELWP) 2019, 'Draft Coastcare Victoria strategy 2020-2025', East Melbourne, Victoria https://engage.vic.gov.au/coastcare-victoria-strategy-2020-2025 Accessed 24 February 2021.

Department of Environment, Land, Water and Planning (DELWP) 2020, 'Port Phillip Bay coastal hazard assessment – decision support system', East Melbourne, Victoria https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0016/450124/PPBCHA-DSS-General-Fact-Sheet-January-2020.pdf Accessed 7 July 2020.

Department of Environment, Land, Water and Planning (DELWP) 2020, 'Annual report', East Melbourne, Victoria https://www.delwp.vic.gov.au/__data/assets/pdf_file/0025/494134/Annual-Report-2019-20-3.pdf Accessed 13 July 2021.

Department of Environment, Land, Water and Planning (DELWP) 2020, 'Urban development program metropolitan Melbourne – industrial', East Melbourne, Victoria https://www.planning.vic.gov.au/__data/assets/pdf_file/0027/508194/Metropolitan-Melbourne-Industrial-2019.pdf Accessed 22 July 2021.

Department of Environment, Land, Water and Planning (DELWP) 2020, 'Wind energy projects, as at 08/10/20' https://www.planning.vic.gov.au/permits-and-applications/specific-permit-topics/wind-energy-facilities/wind-energy-projects-planning?_ga=2.189197033.318809511.1602653626-245237306.1598233448 Accessed 14 October 2020.

Department of Environment, Land, Water and Planning (DELWP) 2020, 'Siting and design guidelines for structures on the Victorian coast', East Melbourne, Victoria https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0027/478413/Siting-and-Design-Guidelines_May2020_WEB.pdf Accessed 15 July 2021.

Department of Environment, Land, Water and Planning (DELWP) 2020, 'Angler riparian partnerships program. Statewide achievements in 2019/20 and program finale', East Melbourne, Victoria. https://www.water.vic.gov.au/__data/assets/pdf_file/0027/491643/Angler-Riparian-Partnerships-Program-2019-20-achievements-report.pdf Accessed 18 March 2021.

Department of Environment, Land, Water and Planning (DELWP) 2020, 'Volunteering naturally. Understanding Victoria's environmental volunteers 2020', East Melbourne, Victoria, https://www.environment.vic.gov.au/__data/assets/pdf_file/0029/494813/Volunteering-Naturally-2020-FINAL.pdf Accessed 15 March 2021.

Department of Environment, Land, Water and Planning (DELWP) 2020, 'Summary of consultation draft marine and coastal policy', East Melbourne, Victoria https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0029/456536/Consultation-Summary_Draft-Marine-and-Coastal-Policy.pdf Accessed 22 March 2021.

Department of Environment, Land, Water and Planning (DELWP) 2021, 'Flora and Fauna Guarantee Act 1988 - threatened list June 2021', East Melbourne, Victoria.

Department of Environment, Land, Water and Planning (DELWP) 2021, 'Threatened list and processes list' East Melbourne, Victoria https://www.environment.vic.gov.au/conserving-threatened-species/threatened-list Accessed 17 August 2021.

References

Department of Environment, Land, Water and Planning (DELWP) 2021, 'Port Phillip Bay environmental management plan 2017-2027. 2019-2020 annual report and 2020 delivery plan update', East Melbourne, Victoria https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0023/511844/PPB-EMP-2019-2020-Annual-Report-and-2020-Delivery-Plan-Update-1.pdf Accessed 12 March 2021.

Department of Environment, Land, Water and Planning (DELWP) 2021, 'Draft marine and coastal strategy', East Melbourne, Victoria.

Department of Environment, Land, Water and Planning (DELWP) 2021, 'Coastkit' https://mapshare.vic.gov.au/coastkit/ Accessed 10 August 2021.

Department of Environment, Land, Water and Planning (DELWP) 2021, 'Integrated water management forums' https://www.water.vic.gov.au/liveable/integrated-water-management-program/forums Accessed 22 July 2021.

Department of Environment, Land, Water and Planning (DELWP) 2021, 'Marine and coastal knowledge framework' East Melbourne, Victoria https://www.marineandcoasts.vic.gov.au/coastal-programs/marine-and-coastal-knowledge-framework Accessed 10 August 2021.

Department of Environment, Land, Water and Planning (DELWP), 'Climate Change Act 2017', East Melbourne https://www.climatechange.vic.gov.au/legislation/climate-change-act-2017 Accessed 9 March 2021.

Department of Environment, Land, Water and Planning (DELWP), 'Gippsland Lakes algae update January 2021', East Melbourne, Victoria https://www.water.vic.gov.au/waterways-and-catchments/rivers-estuaries-and-waterways/blue-green-algae/gippsland-lakes-algae-update-january-2021 Accessed 15 March 2021.

Department of Environment, Land, Water and Planning (DELWP), 'Improving stormwater management', East Melbourne, Victoria https://www.water.vic.gov.au/liveable/stormwater Accessed 19 February 2021.

Department of Environment, Land, Water and Planning (DELWP), 'Managing nitrogen loads in Port Phillip Bay: towards better water quality (3060)', East Melbourne, Victoria https://www.marineandcoasts.vic.gov.au/grants/port-phillip-bay-fund/managing-nitrogen-loads-in-port-phillip-bay-towards-better-water-quality Accessed 22 February 2021.

Department of Environment, Land, Water and Planning (DELWP), 'Marine algal bloom detected in Hobsons Bay', East Melbourne, Victoria https://www.marineandcoasts.vic.gov.au/media-releases/marine-algal-bloom-detected-in-hobsons-bay Accessed 12 July 2021.

Department of Environment, Land, Water and Planning (DELWP), 'Migratory shorebirds', East Melbourne, Victoria https://www.water.vic.gov.au/waterways-and-catchments/rivers-estuaries-and-waterways/wetlands/migratory-shorebirds Accessed 13 July 2020.

Department of Environment, Land, Water and Planning (DELWP), 'NatureKit layers and datasets' https://www.environment.vic.gov.au/biodiversity/naturekit/nk-datalists#toc__id_1_biodiversity Accessed 2 August 2021.

Department of Environment, Land, Water and Planning (DELWP), 'NatureKit' https://maps2.biodiversity.vic.gov.au/Html5viewer/index.html?viewer=NatureKit Accessed 2 August 2021.

Department of Environment, Land, Water and Planning (DELWP), 'Port Phillip Bay coastal hazard assessment' https://www.marineandcoasts.vic.gov.au/coastal-programs/port-phillip-bay-coastal-hazard-assessment Accessed 7 July 2020.

Department of Environment, Land, Water and Planning (DELWP), 'The coast and planning in Victoria', East Melbourne, Victoria www.planning.vic.gov.au/policy-and-strategy/coastal-planning-in-victoria#overview Accessed 9 March 2021.

Department of Environment, Land, Water and Planning (DELWP), 'Tracking eel migration using satellites' https://www.ari.vic.gov.au/research/field-techniques-and-monitoring/tracking-eel-migration-using-satellites Accessed 14 July 2021.

Department of Environment, Land, Water and Planning (DELWP), 'Water measurement information system', East Melbourne, Victoria https://data.water.vic.gov.au/static.htm Accessed 20 July 2021.

References

Department of Environment, Land, Water and Planning (DELWP), 'Whales, dolphins and seals' https://www.wildlife.vic.gov.au/our-wildlife/whales,-dolphins-and-seals Accessed 30 July 2021.

Department of Environment, Land, Water and Planning (DELWP), 'Distinctive areas and landscapes' https://www.planning.vic.gov.au/policy-and-strategy/distinctive-areas-and-landscapes Accessed 20 August 2020.

Department of Environment, Land, Water, and Planning (DELWP) 2021, 'Victorian heritage register', map layer ANZVI0803004621, 3 July 2021.

Department of Environment, Water, Planning and Environment (DELWP) 2019, 'Regulatory framework', East Melbourne, Victoria.

Department of Health and Human Services (DHHS), 'Gippsland Lakes seafood' https://www2.health.vic.gov.au/public-health/water/blue-green-algae-cyanobacteria/gippsland-lakes-seafood Accessed 15 March 2021.

Department of Jobs, Precincts and Regions (DJPR) 2020, 'Earth resources – Victoria', Melbourne, Victoria https://earthresources.vic.gov.au/__data/assets/pdf_file/0007/461608/Earth-Resources-Victoria-July-2020-Web.pdf Accessed 6 October 2020.

Department of Jobs, Precincts and Regions (DJPR) 2020, 'Oil and gas in Victoria' https://earthresources.vic.gov.au/geology-exploration/oil-gas/oil-and-gas-in-victoria Accessed 6 October 2020.

Department of Jobs, Precincts and Regions (DJPR), 'Coastal acid sulfate soils', Melbourne, Victoria http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/soil_acid_sulfate_soils Accessed 22 July 2020.

Department of Jobs, Precincts and Regions (DJPR), 'Coastal acid sulfate soils distribution - Map 5 for the Gippsland Lakes of Victoria' Melbourne, Victoria http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/soil_coastal-acid-sulfate-soils_documents/$FILE/CASS_map5.pdf Accessed 22 July 2020.

Department of Natural Resources and Environment (DNRE) 1996, 'Draft abalone management plan', Victorian Fisheries Program, Melbourne, Victoria.

Department of Primary Industries (DPI) 2010, 'Open water', Melbourne, Victoria http://agriculture.vic.gov.au/__data/assets/pdf_file/0014/213152/Habitat-Series-Posters.pdf Accessed 10 July 2020.

Department of Primary Industries (DPI) 2012, 'Abalone recovery review workshop', Fisheries Victoria Management report series no. 83, Melbourne, Victoria.

Department of Sustainability and Environment (DSE) 2003, 'Western Port Ramsar site strategic management plan', East Melbourne, Victoria.

Department of Sustainability and Environment (DSE) 2006, 'Coastal spaces landscape assessment study', Melbourne, Victoria.

Department of Sustainability and Environment (DSE) 2012, 'A cleaner Yarra River and Port Phillip Bay – a plan of action', Melbourne, Victoria.

Department of Sustainability, Environment, Water, Population and Communities (DSEWPC) 2001, 'Corner Inlet Ramsar site ecological character description', Australian Government, Canberra https://www.environment.gov.au/system/files/resources/97f19db6-cc7c-429b-9431-7577f1d99907/files/13-ecd-ch-5-6.pdf Accessed 16 March 2021.

Department of the Environment and Energy 2017, 'Australian energy statistics', Australian Government, Canberra.

Department of Transport (DoT) 2021, 'About Victoria's commercial ports' https://transport.vic.gov.au/ports-and-freight/commercial-ports Accessed 1 July 2021.

Department of Transport (DoT) 2021, 'Better boating fund', Melbourne, Victoria https://transport.vic.gov.au/fishing-and-boating/better-boating-fund Accessed 10 May 2021.

Department of Transport (DoT) 2021, 'Commercial shipping' https://www.portofmelbourne.com/port-operations/commercial-shipping/ Accessed 1 July 2021.

Department of Transport (DoT) 2021, 'Independent review of the Victorian ports system – initial government response', Melbourne, Victoria https://transport.vic.gov.au/ports-and-freight/commercial-ports Accessed 1 July 2021.

Dixon CD and Dichmont CM 2019, 'Draft stock assessment for the central zone of the Victorian abalone fishery 2018/19', MRAG Asia Pacific, Brisbane, Australia.

Dugdale TM, Hunt TD and Clements D 2013, 'Aquatic weeds in Victoria: where and why are they a problem, and how are they being controlled?' *Plant Protection Quarterly*, 28(2), pp. 35-40.

References

Duignan PJ, Stephens NS and Robb K 2020, 'Fresh water skin disease in dolphins: a case definition based on pathology and environmental factors in Australia', *Scientific Reports*, 10(21979).

Earth Systems and Climate Change Hub 2021, 'Wind-wave climate change along Australia's coast' https://nespclimate.com.au/wp-content/uploads/2021/04/ESCC_Wind-wave-climate-change_Factsheet.pdf Accessed 7 July 2021.

Earth Systems and Climate Change Hub, 'Coastal erosion under a changing climate' https://nespclimate.com.au/wp-content/uploads/2019/05/2.11_1_A4_4pp_Brochure_Coastal_Erosion_NCCC_ESCC_Feb26_2020_WEB.pdf Accessed 14 July 2021.

Earthcare St Kilda 2018, 'Penguin report 2016-17', St Kilda, Victoria.

East Gippsland Catchment Management Authority (EGCMA) 2015, 'Gippsland Lakes Ramsar site management plan', Bairnsdale, Victoria.

East R 2021, 'Marine and coastal stewardship index', Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria, available on request.

Ecological Associates 2014, 'Reedy Lake vegetation monitoring final report', Ecological Associates report BX010-2-B prepared for Corangamite Catchment Management Authority (CCMA), Colac.

Ecology Australia 2014, 'Western Port (Bass River and the inlets): 10 year *Spartina anglica* (common cordgrass) management plan', Fairfield, Victoria.

Edgar G, Ward T, Stuart-Smith R 2018, 'Rapid declines across Australian fishery stocks indicate global sustainability targets will not be achieved without an expanded network of "no-fishing" reserves', *Aquatic Conservation: Marine and Freshwater Ecosystems,* 28, pp. 1337-1350 https://doi.org/10.1002/aqc.2934 Accessed 9 April 2021.

Edmunds M 2017, 'Victorian subtidal reef monitoring program: Popes Eye – Port Phillip Heads, January 2015', Parks Victoria technical series no. 103, Melbourne, Victoria.

Edmunds M and Woods B 2014, 'Victorian subtidal reef monitoring program: the reef biota at Cape Howe marine national park', Parks Victoria technical series no. 99, Melbourne, Victoria.

Edmunds M, Brown H and Woods B 2014, 'Victorian subtidal reef monitoring program: the reef biota at Eagle Rock marine sanctuary', Parks Victoria technical series no. 89, Melbourne, Victoria.

Edmunds M, Hallein E and Flynn A 2014, 'Victorian subtidal reef monitoring program: the reef biota at Beware Reef marine sanctuary', Parks Victoria technical series no. 88, Melbourne, Victoria.

Edmunds M, Stewart K and Pritchard K 2010, 'Victorian subtidal reef monitoring program: the reef biota at Port Phillip Heads marine national park', Volume 4, Parks Victoria technical series no. 63, Melbourne, Victoria.

Edmunds M, Stewart K, Pritchard K and Zavalas R 2010, 'Victorian intertidal reef monitoring program: the reef biota of central Victoria's marine protected areas. Volume 3', Parks Victoria technical series no. 61, Melbourne, Victoria.

Edmunds M, Woods B and Donnelly D 2014, 'Intertidal reef monitoring program: Central Victoria marine protected areas March 2014', Parks Victoria technical series no. 97, Melbourne, Victoria.

Emergency Management Victoria (EMV) 'Roles and responsibilities', Melbourne, Victoria https://www.emv.vic.gov.au/responsibilities/semp/roles-and-responsibilities Accessed 9 May 2021.

Emergency Management Victoria (EMV) 2016, 'State maritime emergencies (non-search and rescue) plan, a subplan within the State Emergency Management Plan (SEMP) 2020', Melbourne, Victoria https://www.emv.vic.gov.au/responsibilities/semp-sub-plans/state-maritime-emergencies-non-search-and-rescue-plan Accessed 1 July 2021.

Emergency Management Victoria (EMV) 2018, 'State emergency response plan. biosecurity sub-plan, edition 1.1'.

Emergency Management Victoria (EMV) 2020, 'Victorian state emergency management plan', Melbourne, Victoria.

Emergency Management Victoria (EMV) 2020, 'Role statement - Department of Transport (including Head, Transport for Victoria)' https://www.emv.vic.gov.au/responsibilities/semp/roles-and-responsibilities/role-statements/dot Accessed 10 March 2021.

References

Emergency Management Victoria (EMV) 2020, Role statement - National Offshore Petroleum Safety and Environmental Management Authority' https://www.emv.vic.gov.au/responsibilities/semp/roles-and-responsibilities/role-statements/nopsema Accessed 10 March 2021.

Emergency Management Victoria (EMV), 'State emergency management plan sub-plans', Melbourne, Victoria https://www.emv.vic.gov.au/responsibilities/state-emergency-management-plan-sub-plans Accessed 9 May 2021.

Emergency Management Victoria, 'roles and responsibilities', Melbourne, Victoria https://www.emv.vic.gov.au/responsibilities/semp/roles-and-responsibilities Accessed 9 May 2021.

Emphron Informatics 2008, 'Channel deeping project: bay-wide monitoring programme - water quality', CSIRO Mathematical and Information Sciences, Melbourne.

Environment, Natural Resources and Regional Development Committee 2017, 'Inquiry into the control of invasive animals on Crown land', Parliament of Victoria, Melbourne, Victoria.

Environmental Justice Australia 2018, 'An environmental justice strategy for Victoria' https://www.envirojustice.org.au/wp-content/uploads/2018/04/An-Environmental-Justice-Strategy-for-Victoria.pdf Accessed 15 July 2021.

EPA Victoria 2011, 'Western Port condition report – 2009' https://www.vgls.vic.gov.au/client/en_AU/search/asset/1159472/0 Accessed 17 November 2021.

EPA Victoria 2015, 'Gippsland Lakes and catchment literature review', Carlton, Victoria https://www.epa.vic.gov.au/-/media/epa/files/publications/1585.pdf Accessed 14 March 2021.

EPA Victoria 2017, '1674.1: Fact sheet: Fishermans Bend groundwater studies 2015-2017', Carlton, Victoria https://www.epa.vic.gov.au/-/media/epa/files/publications/1674-1.pdf Accessed 23 March 2021.

EPA Victoria 2019, 'Development of environmental quality indicators and objectives for SEPP (Waters)', Carlton, Victoria https://www.epa.vic.gov.au/-/media/epa/files/publications/1733.pdf Accessed 17 July 2021.

EPA Victoria 2019, 'Development of indicators and objectives for SEPP (Waters)', Carlton, Victoria https://www.epa.vic.gov.au/-/media/epa/files/publications/1733.pdf Accessed 17 August 2021.

EPA Victoria 2020, 'Air monitoring report 2019 – Compliance with the national environment protection (ambient air quality) measure', Carlton, Victoria https://www.epa.vic.gov.au/-/media/epa/files/publications/1875.pdf Accessed 24 March 2021.

EPA Victoria 2020, 'Beach report and Yarra watch results, 2019–20', Carlton, Victoria https://www.epa.vic.gov.au/-/media/epa/files/publications/1882.pdf Accessed 12 March 2021.

EPA Victoria 2020, 'Report card 2019-20', Carlton, Victoria https://www.epa.vic.gov.au/about-epa/publications/1923 Accessed 17 May 2021.

EPA Victoria 2020, 'Report card 2019–20', Carlton, Victoria https://www.epa.vic.gov.au/-/media/epa/files/publications/1923.pdf Accessed 8 March 2021.

EPA Victoria 2021, 'Permissions scheme policy', publication 1799.2, Carlton, Victoria https://www.epa.vic.gov.au/-/media/epa/files/publications/1799-2.pdf Accessed 13 July 2021.

EPA Victoria 2021, 'Guide to the Environment reference standard', Carlton, Victoria https://www.epa.vic.gov.au/-/media/epa/files/publications/1992.pdf Accessed 17 August 2021.

EPA Victoria, 'About PFAS', Carlton, Victoria https://www.epa.vic.gov.au/for-community/environmental-information/pfas Accessed 10 March 2021.

EPA Victoria, 'About stormwater', Carlton, Victoria https://www.epa.vic.gov.au/for-community/environmental-information/water/stormwater/about-stormwater Accessed 19 February 2021.

EPA Victoria, 'Beach report and Yarra watch season 2019-2020 summary', Carlton, Victoria https://www.epa.vic.gov.au/for-community/summer-water-quality/beach-report-and-yarra-watch-season-2019-2020-summary Accessed 12 March 2021.

EPA Victoria, 'EPA AirWatch', Carlton, Victoria https://www.epa.vic.gov.au/for-community/airwatch Accessed 13 July 2021.

EPA Victoria, 'Marine monitoring', Carlton, Victoria https://www.epa.vic.gov.au/for-community/monitoring-your-environment/monitoring-victorias-water-quality/marine-monitoring Accessed 17 July 2021.

References

EPA Victoria, 'Priority sites register', Carlton, Victoria https://www.epa.vic.gov.au/your-environment/land-and-groundwater/priority-sites-register Accessed 3 December 2018.

EPA Victoria, 'Report card', Carlton, Victoria https://www.epa.vic.gov.au/for-community/monitoring-your-environment/monitoring-victorias-water-quality/report-card Accessed 12 July 2021.

EPA Victoria, 'Report helium balloon releases', Carlton, Victoria https://www.epa.vic.gov.au/report-pollution/report-balloon-releases Accessed 13 August 2021.

EPA Victoria, 'Search for a licence, approval or APS', Carlton, Victoria https://www.epa.vic.gov.au/for-business/permissions/search-for-licence Accessed 15 November 2021.

EPA Victoria, 'Environmental audits', Carlton, Victoria.

Eriksen R, Davies C, Bonham P, Coman F, Edgar S McEnnulty F, McLeod D, Miller M, Rochester W, Slotwinski A, Tonks M, Uribe-Palomino J, Richardson A, 2019, 'Australia's long-term plankton observations: the integrated marine observing system national reference station network', *Frontiers in Marine Science*, 6(161) DOI:10.3389/fmars.2019.00161.

Erisman B, Allen L, Claisse J, Pondella D, Miller E, Murray J and Walters C 2011, 'The illusion of plenty: Hyperstability masks collapses in two recreational fisheries that target fish spawning aggregations', *Canadian Journal of Fisheries and Aquatic Sciences*, 68(10), pp. 1705–1716 https://doi.org/10.1139/f2011-090

Estuary Watch website. http://www.estuarywatch.org.au/cb_pages/about_estuarywatch.php Accessed 1 March 2021.

EthosNRM 2019, 'Gippsland Lakes ocean access maintenance dredging 2018: independent audit of environmental management plan. Final audit report Gippsland Ports' http://www.gippslandports.vic.gov.au/wp-content/uploads/2017/05/2018-gloa-dredging-independent-emp-audit-final-report-v3.0.pdf Accessed 20 July 2021:

Evrard V, Eate V, Woodland R, Ross D, O'Brien A, Keough M, Longmore A, Wilson R, and Cook P 2013, 'Nutrient processing on tidal flats in Western Port: interactions with ecology and implications for bay-wide nutrient budgets', report prepared for Melbourne Water, Water Studies Centre, Monash University.

Evrard V, Huettel M, Cook P, Soetaert K, Heip C and Middelburg J 2012, 'Importance of phytodetritus and microphytobenthos for heterotrophs in a shallow subtidal sandy sediment', *Marine Ecology Progress Series*, 455, pp. 13–31.

Fabris G, Theodoropoulos T, Sheehan A and Abbott B 1999, 'Mercury and organochlorines in black bream, (*Acanthopagrus butcheri*), from the Gippsland Lakes, Victoria, Australia: evidence for temporal increases in mercury levels', *Marine Pollution Bulletin*, 38(11), pp. 970–976.

Fathom Pacific, 'Western Port bryozoan reef project' https://fathompacific.com/project-spotlight/western-port-bryozoan-reef-project/ Accessed 25 July 2021.

Fisheries Research and Development Corporation (FRDC) 2018, 'Status of Australian fish stocks' https://www.fish.gov.tstock?kw=sand+flathead&page=1&sort=LatestFirst Accessed 29 March 2021.

Fisheries Research and Development Corporation (FRDC), 'Blacklip abalone (2020)' https://www.fish.gov.au/report/286-Blacklip-Abalone-2020 Accessed 29 August 2021.

Fisheries Research and Development Corporation (FRDC), 'Glossary' https://www.fish.gov.au/about/glossary Accessed 10 February 2021.

Fisheries Research and Development Corporation (FRDC), 'Greenlip abalone (2020)' https://www.fish.gov.au/report/284-Greenlip-Abalone-2020 Accessed 30 July 2020.

Fisheries Research and Development Corporation (FRDC), 'Southern rock lobster (2020)' https://www.fish.gov.au/report/294-Southern-Rock-Lobster-2020 Accessed 30 July 2020.

Fisheries Research and Development Corporation (FRDC), 'What are the status of Australian fish stock reports?' https://www.fish.gov.au/about/what-are-the-status-of-australian-fish-stock-reports Accessed 10 February 2021.

Fitzsimons, J, Branigan S, Brumbaugh R, McDonald T and zu Ermgassen P 2019, 'Restoration guidelines for shellfish reefs', The Nature Conservancy, Arlington VA, USA https://www.natureaustralia.org.au/content/dam/tnc/nature/en/documents/australia/TNC_Shellfish_Reef_Restoration_Guidelines_WEB.pdf Accessed 30 March 2021.

References

Fobert E, Burke da Silva K and Swearer SE 2019, 'Artificial light at night causes reproductive failure in clownfish', *Biology Letters,* 15 e20190272.

Ford J 2018, '2018 Seagrass mapping of the Corner Inlet basin (preliminary report)', report to West Gippsland Catchment Management Authority (WGCMA), Traralgon, Victoria.

Ford J and Gilmour P 2013, 'The state of recreational fishing in Victoria: a review of ecological sustainability and management options, a report to the Victorian National Parks Association, Melbourne'.

Ford J and Hamer P 2016, 'The forgotten shellfish reefs of coastal Victoria: documenting the loss of marine ecosystem over 200 years since European settlement', *Proceedings of the Royal Society of Victoria,* 128, pp. 87-105.

Ford J, Barclay K and Day R 2016, 'Using local knowledge to understand and manage ecosystem-related decline in fisheries productivity', Fisheries Research and Development Corporation (FRDC), final project report, no. 2013-021, Melbourne, Victoria.

Fraser M, Kendrick, G, Statton J, Hovey R, Zavala-Perez A and Walker D 2014, 'Extreme climate events lower resilience of foundation seagrass at edge of biogeographical range', *Journal of Ecology,* 102(6), pp. 1528–1536.

Frijlink S and Lyle J 2010, 'An evaluation of motivations, attitudes and awareness of Tasmanian recreational fishers', Tasmanian Aquaculture and Fisheries Institute, University of Tasmania, Hobart.

GeelongPort 2019, 'GeelongPort environmental strategy' http://geelongport.com.au/wp-content/uploads/2019/05/LCC8781_GP_Enviro_StrategyA4Brochure_v6_FILM_noversioncontrol.pdf Accessed 2 July 2021.

GeelongPort 2021, 'GeelongPort environment policy' https://geelongport.com.au/hseq/environment/#:~:text=GeelongPort%20is%20committed%20to%20ensuring,Nurturing%20our%20port%20land Accessed 2 July 2021.

Gemmill J, Fischer A, Rohmana QA 2021, 'Towards a national outfall standard and guidelines for reporting wastewater treatment plant outfall data', report to the National Environmental Science Program, Marine Biodiversity Hub, Clean Ocean Foundation and University of Tasmania.

Gemmill J, Rohmana QA, Fischer A, Blackwell B and Cumming J 2019, 'National outfall database: prospectus report 2019, report to the National Environmental Science Program', Marine Biodiversity Hub, Clean Ocean Foundation.

Geoscience Australia, 'Seawater intrusion', Canberra, Australia http://www.ga.gov.au/scientific-topics/water/groundwater/understanding-groundwater-resources/seawater-intrusion Accessed 07 July 2020.

GeoScience Australia, 'Maritime boundary definitions' http://www.ga.gov.au/scientific-topics/marine/jurisdiction/maritime-boundary-definitions Accessed 8 February 2021.

Geyer R, Jambeck J and Law K 2017, 'Production, use, and fate of all plastics ever made', *Science Advances*, 3(7), e1700782.

Gippsland Coastal Board 2008, 'Climate Change, Sea level rise and coastal subsidence along the Gippsland Coast'.

Gippsland Ports 2015, 'Gippsland Lakes ocean access environmental management plan' https://www.gippslandports.vic.gov.au/wp-content/uploads/2019/11/2015-gloa-emp-version-4.2.3-2015-11-05.pdf Accessed 16 July 2021.

Gippsland Ports 2020, 'Environment' https://www.gippslandports.vic.gov.au/ports-and-waterways/environment/ Accessed 24 August 2020.

Gippsland Ports 2021, 'History of dredging the entrance to Gippsland Lakes, fact sheet' http://www.gippslandports.vic.gov.au/wp-content/uploads/2020/06/dredging-facts-sheet_apr2021.pdf Accessed 16 July 2021.

Gippsland Ports 2021, 'Sand management' https://www.gippslandports.vic.gov.au/ports-and-waterways/sand-management/ Accessed 16 July 2021.

Gippsland Ports, 'Marine pest found at Port Welshpool' https://www.gippslandports.vic.gov.au/news/marine-pest-found-port-welshpool/ Accessed 29 March 2021.

Gippsland Times 2015, 'Pacific seastar found in Gippsland Lakes' https://www.gippslandtimes.com.au/story/3283646/pacific-seastar-found-in-gippsland-lakes/ Accessed 29 March 2021.

References

Gorfine H, Bell J, Mills K, Lewis Z 2012, 'Removing sea urchins (*Centrostephanus rodgersii*) to recover abalone (*Haliotis rubra*) habitat', Department of Primary Industries (DPI), Queenscliff, Victoria.

Great Ocean Road Coast and Parks Authority (GORCC) https://www.gorcc.com.au/gorcapa/ Accessed 10 May 2021.

Griffiths S, Bryant J, Raymond H and Newcombe P 2017, 'Quantifying subjective human dimensions of recreational fishing: does good health come to those who bait?' *Fish and Fisheries*, 18, pp. 171-184.

Gunaikurnai Land and Waters Aboriginal Corporation, 'Working together to build a new wetland' https://gunaikurnai.org.au/working-together-to-build-a-new-wetland/ Accessed 15 March 2021.

Gurrna N, Zhang Y and Shrestha P 2020, ''Pop-up' tourism or 'invasion'? Airbnb in coastal Australia', *Annals of Tourism Research*, 81, 102845.

Hale J 2011, 'Baywide monitoring program: Ramsar listed wetlands – monitoring of saltmarsh health and extent and intertidal mudflat extent (2008 to 2011)', Port of Melbourne Corporation, Melbourne, Australia.

Hale J 2016, 'Ecological character description addendum - Corner Inlet Ramsar site', Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria.

Hale J 2017, 'Addendum to the ecological character description for the Corner Inlet Ramsar site', Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria.

Hale J 2020, 'Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar site ecological character description, for catchments, waterways cities and towns', Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria.

Hancock G, Wilkinson S and Read A 2007, 'Sources of sediment and nutrients to the Gippsland Lakes assessed using catchment modelling and sediment tracers', CSIRO Land and Water Science Report 70/07 https://publications.csiro.au/rpr/download?pid=procite:07c9be40-4aad-402c-993a-6d253a2c15cb&dsid=DS1 Accessed 15 March 2021.

Hannan H and Bennett B 2010, 'Western Port fishermen', published by Hannan and Bennett, Melbourne Victoria.

Hansen B, Menkhorst P, Moloney P and Loyn R 2015, 'Long-term waterbird monitoring in Western Port, Victoria, reveals significant declines in multiple species', *Austral Ecology*, 40, pp. 513-527.

Hardesty B, Schuyler Q, Lawson T, Opie K and Wilcox C 2016, 'Understanding debris sources and transport from the coastal margin to the ocean'. CSIRO: EP165651.

Hardy N, Berry T, Kelaher BP, Goldsworthy SD, Bunce M, Coleman MA, Gillanders BM, Connell SD, Blewitt M and Figueira W 2017, 'Assessing the trophic ecology of top predators across a recolonisation frontier using DNA metabarcoding of diets', *Marine Ecology Progress Series*, 573, pp. 237-254.

Harris J 1984, 'Impoundment of coastal drainages of south-eastern Australia, and a review of its relevance to fish migrations', *Australian Zoologist*, 21, pp. 235-250.

Harrison A 1996, 'The fisheries savant: William Saville-Kent in Victoria, 1887–8', *Historical Records of Australian Science,* 11(3), pp. 419–429.

Harty C 2011, 'Mangroves of Victoria information kit', Parks Victoria, Melbourne.

Hazelwood Mine Fire Inquiry 2014, 'Hazelwood mine fire inquiry report 2014'.

Helidoniotis F and Haddon M 2014, 'Modelling the potential for recovery of western victorian abalone stocks: The Crags', interim report to 2012/225, CSIRO, Hobart.

Henry G and Lyle J (eds) 2003, 'The national recreational and Indigenous fishing survey', Fisheries Research and Development Corporation (FRDC) project no. 99/158, Commonwealth of Australia, Canberra https://eprints.utas.edu.au/2526/1/Henry_Lyle_Nationalsurvey.pdf Accessed 6 August 2021.

Heritage Council of Victoria 2021, 'The Victorian heritage database - the Great Ocean Road', VHR no. H2261 https://vhd.heritagecouncil.vic.gov.au/search?kw=great+ocean+road&aut_off=1 Accessed 1 July 2021.

References

Heritage Victoria 'Maritime heritage' https://www.heritage.vic.gov.au/heritage-listings/maritime-heritage Accessed 18 November 2021.

Heritage Victoria 2020, 'Victorian heritage database' https://vhd.heritagecouncil.vic.gov.au/ Accessed 23 September 2020.

Herpich D 2020, 'Corner Inlet and Nooramunga marine and coastal parks – seagrass change detection and urchin barren assessment', Parks Victoria, Melbourne.

HESC 2018, 'Hydrogen energy supply chain factsheet' https://hydrogenenergysupplychain.com/wp-content/uploads/2018/04/HESC-Fact-Sheet-FINAL.pdf Accessed 2 July 2021.

HESC 2021, 'Supply chain - Latrobe Valley' https://hydrogenenergysupplychain.com/latrobe-valley/ Accessed 2 July 2021.

HESC 2021, 'Supply chain - Port of Hastings' https://hydrogenenergysupplychain.com/port-of-hastings/ Accessed 2 July 2021.

Hewitt C, Campbell M, McEnnulty F, Moore K, Murfet N, Robertson B and Schaffelke B 2005, 'Efficacy of physical removal of a marine pest: the introduced kelp *Undaria pinnatifida* in a Tasmanian marine reserve', *Biological Invasions*, 7, pp. 251-263.

Hewitt C, Gollasch S and Minchin D 2009, 'The vessel as a vector – biofouling, ballast water and sediments', pp. 117-131 in G Rilov and J Crooks (eds), 'Biological invasions in marine ecosystems, ecological, management, and geographic perspectives', Ecological Studies 204, p 127.

Hicks T, Kopf R and Humphries P 2015, 'Fecundity and egg quality of dusky flathead (*Platycephalus fuscus)* in East Gippsland, Victoria', Institute for Land Water and Society, Charles Sturt University, report no. 94, prepared for the recreational fishing grants program, Fisheries Victoria, Department of Economic Development, Jobs, Transport and Resources (DEDJTR), Melbourne, Victoria, pp. 1–34.

Hirst A and Bott N 2016, 'Marine pests in the Gippsland Lakes: existing threats and future monitoring', Centre for Environmental Sustainability and Remediation, RMIT, Melbourne, Victoria.

Hirst A, Giri K, Ball D and Lee R 2017, 'Determination of the physical drivers of Zostera seagrass distribution using a spatial autoregressive lag model', *Marine and Freshwater Research*, 68, pp. 1752-1763.

Hirst A, Longmore A, Ball D, Cook P and Jenkins G 2016, 'Linking nitrogen sources utilised by seagrass in a temperate marine embayment to patterns of seagrass change during drought', *Marine Ecology Progress Series*, 549, pp. 79–88.

Hirst A, Rees C, Hamer P, Conron S and Kemp J 2014, 'The decline of sand flathead stocks in Port Phillip Bay: magnitude, causes and future prospects', Fisheries Victoria Recreational Fishing Grant Program Research Report, Queenscliff, Victoria.

Hirst AJ, Giri K, Ball D and Lee RS 2017, 'Determination of the physical drivers of Zostera seagrass distribution using a spatial autoregressive lag model', *Marine and Freshwater Research*, 68, 1752-1763.

Hoegh-Guldberg O, Jacob D, Taylor M, Bindi M, Brown S, Camilloni I, Diedhiou A, Djalante R, Ebi KL, Engelbrecht F, Guiot J, Hijioka Y, Mehrotra S, Payne A, Seneviratne SI, Thomas A, Warren R and Zhou G 2018, 'Impacts of 1.5°C global warming on natural and human systems', in 'Global warming of 1.5°C', an IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.

Hoffman J 2006, 'The diet and foraging movements of the little penguin at Rabbit Island, Victoria' Honours thesis, Monash University, Melbourne.

Holbrook NJ, Sen Gupta A, Oliver ECJ, Hobday AJ, Benthuysen JA, Scannell HA, Smale DA and Wernberg T 2020, 'Keeping pace with marine heatwaves', *Nature Reviews Earth and Environment*, 1, pp. 482–493 https://doi.org/10.1038/s43017-020-0068-4 Accessed 2 February 2021.

Hölker F, Wolter C, Perkin E, Tockner K 2010, 'Light pollution as a biodiversity threat', *Trends in Ecology and Evolution,* 25, pp. 681–682.

Holland D, Cook P, Mac Nally R, Thomson J, Womersley B, Ball D, Longmore A, Keough M, Lee R, Martinez G, Greer D 2013, 'Preliminary assessment of water quality requirements of seagrasses in Western Port', report prepared for Melbourne Water, December 2013.

References

Holland D, Jennings M, Beardall J, Gell P, Doan P, Mills K, Briles C, Zawadzki A and Cook P 2013, 'Two hundred years of blue-green algae blooms in the Gippsland Lakes', Gippsland Lakes Ministerial Advisory Committee.

Hurst T and Boon P 2016, 'Agricultural weeds and coastal saltmarsh in south-eastern Australia: an insurmountable problem?', *Australian Journal of Botany*, 64, pp. 308-324.

Ierodiaconou D, Wines S, Carnell P, Tinkler P, Allan B, Carey J, Young M, Howe S, Pocklington J 2020, 'An enhanced signs of healthy parks monitoring program for Victoria's marine national parks and marine sanctuaries: Point Addis marine national park', Parks Victoria technical series no. 114, Melbourne, Victoria.

Infrastructure Victoria 2020, 'Victoria's draft infrastructure strategy volume 1' https://www.infrastructurevictoria.com.au/wp-content/uploads/2020/12/Victorias-Draft-30-Year-Infrastructure-Strategy-Volume-1-1.pdf Accessed 9 March 2021.

Intergovernmental Panel on Climate Change (IPCC) 2013, 'Climate change 2013: the physical science basis', Working Group I contribution to the IPCC Fifth Assessment Report, Cambridge University Press, Cambridge, United Kingdom.

Intergovernmental Panel on Climate Change (IPCC) 2014, 'Climate change 2014: synthesis report', contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) by RK Pachauri and LA Meyer (eds), Geneva, Switzerland.

Intergovernmental Panel on Climate Change (IPCC) 2018, 'Global warming of 1.5°C. An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty', by V Masson-Delmotte, P Zhai, HO Pörtner, D Roberts, J Skea, PR Shukla, A Pirani, W Moufouma-Okia, C Péan, R Pidcock, S Connors, JBR Matthews, Y Chen, X Zhou, MI Gomis, E Lonnoy, T Maycock, M Tignor, and T Waterfield (eds), in press.

Intergovernmental Panel on Climate Change (IPCC) 2019, 'Summary for policymakers', in IPCC 'Special report on the ocean and cryosphere in a changing climate' prepared by HO Pörtner, DCRV Masson-Delmotte, P Zhai, M Tignor, E Poloczanska, K Mintenbeck, M Nicolai, A Okem, J Petzold, B Rama and N Weyer (eds).

International Maritime Organisation 2004, 'The international convention for the control and management of ships' ballast water and sediments', adopted: 13 February 2004, entry into force 8 September 2017 https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Control-and-Management-of-Ships%27-Ballast-Water-and-Sediments-(BWM).aspx Accessed 6 July 2021.

International Standard: ISO 20121, 'International standard on sustainable event management'.

International Union for Conservation of Nature (IUCN), 'The IUCN red list of threatened species' https://www.iucnredlist.org/ Accessed 14 July 2021.

Ipsos 2018, 'Wave 5 marine and coastal community attitudes and behaviour report', prepared for the Victorian Marine and Coastal Council (VMaCC), Parks Victoria and Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria.

Ivkovic KM, Marshall SK, Morgan LK, Werner AD, Carey H, Cook S, Sundaram B, Norman R, Wallace L, Caruana L, Dixon-Jain P and Simon D 2012, 'National-scale vulnerability assessment of seawater intrusion: summary report', National Water Commission, Canberra.

Jambeck J, Geyer R, Wilcox C, Siegler T, Perryman M, Andrady A, Narayan R and Lavender Law K 2015, 'Plastic waste inputs from land into the ocean', *Science*, 347(6223), pp. 768-71, DOI:10.1126/science.1260352.

Jayaratne R, Kuhn T, Christensen B, Liu X, Zing I, Lamont R, Dunbabin M, Maddox J, Fisher G and Morawska L 2020, 'Using a network of low-cost particle sensors to assess the impact of ship emissions on a residential community', *Aerosol and Air Quality Research*, 20(12), pp. 2754-2764.

Jedensjö M, Kemper C, Milella M, Willems E and Krützen M 2020, 'Taxonomy and distribution of bottlenose dolphins in Australian waters: an osteological clarification', *Canadian Journal of Zoology*, 98.

Jenkins G, Black K and Hamer P 2000, 'Determination of spawning areas and larval advection pathways for King George whiting in southeastern Australia using otolith microstructure and hydrodynamic modelling', *Marine Ecology Progress Series*, 199, pp. 231-242.

Jenkins G, Edgar G, May H and Shaw C 1993, 'Ecological basis for parallel declines in seagrass habitat and catches of commercial fish in Western Port Bay, Victoria', in DA Hancock (ed) 'Sustainable fisheries through sustaining fish habitat', Australian Society for Fish Biology Workshop Proceedings, Victor Harbour, South Australia, 12–13 August, Bureau of Resource Sciences (BRS), Canberra.

Jenkins G, Keough M, Ball D, Cook P, Ferguson A, Gay J, Hirst A, Lee R, Longmore A, Macreadie P, Nayar S, Sherman C, Smith T, Ross D and York P 2015, 'Seagrass resilience in Port Phillip Bay', final report to the seagrass and reefs program for Port Phillip Bay, University of Melbourne, Melbourne.

Jenkins GP and Black KP 2019, 'Contrasting impact of diatoms on dominant calanoid and cyclopoid copepods in a temperate bay', *Estuarine, Coastal and Shelf Science*, 217, pp. 211-217.

Jenkins GP and Conron S 2015, 'Characterising the status of the Western Port recreational fishery in relation to biodiversity value: phase 1', technical report, School of Biosciences. Melbourne University.

Jeppe KJ, Kellar CR, Marshall S, Colombo V, Sinclair GM, Pettigrove VJ 2017, 'Bifenthrin causes toxicity in urban stormwater wetlands: field and laboratory assessment using *Austrochiltonia* (Amphipoda)', *Environmental Science and Technology*, 51(12), pp. 7254-7262.

Johnson C, Swearer S, Ling S, Reeves S, Kriegisch N, Treml E, Ford J, Fobert E, Black K, Weston K, and Sherman C 2015, 'The Reef Ecosystem Evaluation Framework (REEF): managing resilience in temperate environments', Melbourne, Victoria, pp. 1-39.

Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection 2015, 'Sources, fate and effects of microplastics in the marine environment: a global assessment'.

Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection 2019, 'Guidelines for the monitoring and assessment of plastic litter in the ocean'.

Jung C, Swearer S, Jenkins G 2010, 'Changes in diversity in the fish assemblage of a southern Australian embayment: consistent spatial structuring at decadal scales', *Marine and Freshwater Research*, 61, pp. 1425–143.

Jurij Stare 'Light pollution map' https://www.lightpollutionmap.info/ Accessed 19 May 2021.

Jurij Stare 'Light pollution map' https://www.lightpollutionmap.info/help.html Accessed 19 May 2021.

Keating A and Handmer J 2013, 'Future potential losses from extremes under climate change: the case of Victoria, Australia', Victorian Centre for Climate Change Adaptation Research (VCCAR), Melbourne, Victoria.

Keith D, Simpson C, Tozer M and Rodoreda S 2007, 'Contemporary and historical descriptions of the vegetation of brundee and saltwater swamps on the lower Shoalhaven River floodplain, southeastern Australia', *Proceedings of the Linnean Society of New South Wales,* 128, pp. 123–153.

Kennedy M, McInness K and Ierodiaconou D 2019, 'Understanding coastal erosion on beaches', Earth Systems and Climate Change Hub. https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0029/444683/Understanding-coastal-erosion-on-beaches-booklet.pdf Accessed 07 July 2020.

Kinrade P and Preston B 2008, 'Impacts of climate change on settlements in the Western Port region: people, property and places', Australian Department of Climate Change and Victorian Department of Sustainability and Environment https://www.seccca.org.au/wp-content/uploads/2020/12/Socio-Economic-Impacts-Report-_web-version_.pdf

Kirezci E, Young IR, Ranasinghe R, Muis S, Nicholls RJ, Lincke D and Hinkel J 2020, 'Projections of global-scale extreme sea levels and resulting episodic coastal flooding over the 21st century', *Scientific Reports*, 10, 11629 https://doi.org/10.1038/s41598-020-67736-6 Accessed 9 March 2021.

Kirkwood R, Pemberton D, Gales R, Hoskins A, Mitchell T, Shaughnessy P and Arnould J 2010, 'Continued population recovery by Australian fur seals', *Marine and Freshwater Research*, 61, pp. 695-701.

Kitchingman A 2016, 'Gippsland Lakes seagrass mapping', Arthur Rylah Institute for Environmental Research (ARI), Department of Environment, Land, Water and Planning (DELWP), Heidelberg, Victoria.

References

Kliska K 2015, 'Environmental correlates of temporal variation in the diet of Australian fur seals', Master of Science, Department of Biological Sciences, MSc, Macquarie University.

Knuckey IA, Eayrs S and Bosschietter B 2002, 'Options for reducing 659 incidental catch of seals on wet-boats in the SETF: a preliminary assessment', Final Report to the Australian Fisheries Management Authority, ARF Project R01/0887, Marine and Freshwater Resources Institute.

Konlechner TM, Kennedy DM, O'Grady JJ, Leach C, Ranasinghe R, Carvalho RC and Ierodiaconou D 2020, 'Mapping spatial variability in shoreline change hotspots from satellite data; a case study in southeast Australia', *Estuarine, Coastal and Shelf Science*, 246, 107018.

Koster W, Aarestrup K, Birnie-Gauvin K, Church B, Dawson D, Lyon J, O'Connor J, Righton D, Rose D, Westerberg H and Stuart I 2021, 'First tracking of the oceanic spawning migrations of Australasian short- finned eels (*Anguilla Australis*)', 22 June 2021, preprint (Version 1) available at Research Square https://doi.org/10.21203/rs.3.rs-622777/v1 Accessed 17 August 2021.

Kowalczyk ND, Chiaradia A, Preston TJ, Reina RD 2015, 'Fine-scale dietary changes between the breeding and non-breeding diet of a resident seabird', *Royal Society Open Science*, 2(4), https://doi.org/10.3389/fmars.2015.00042.

Kowalczyk ND, Reina RD, Preston TJ, Chiaradia A 2015, 'Environmental variability drives shifts in the foraging behaviour and reproductive success of an inshore seabird', *Oecologia*, 178(4), pp. 967-979.

Kowalczyk ND, Reina RD, Preston TJ, Chiaradia A 2015, 'Selective foraging within estuarine plume fronts by an inshore resident seabird', *Frontiers in Marine Science,* 2(42), DOI:10.3389/fmars.2015.00042.

Kyba C, Kuester T, Sánchez de Miguel A, Baugh K, Jechow A, Hölker F, Bennie J, Elvidge C, Gaston K and Guanter L 2017, 'Artificially lit surface of Earth at night increasing in radiance and extent', *Science Advances*, 3 (11), e1701528.

Landcare Victoria 2020, 'Community leads restoration of seagrass at Corner Inlet', *Victorian Landcare and Catchment Management Magazine*, 77, pp. 20-21.

Last P, White W, Gledhill D, Hobday A, Brown R, Edgar G and Pecl G 2011, 'Long-term shifts in abundance and distribution of a temperate fish fauna: a response to climate change and fishing practices', *Global Ecology and Biogeography*, 20, pp. 58-72.

Leach C, Hague B, Kennedy DM, Carvalho RC, Ierodiaconou D 2021, 'Identifying oceanographic conditions conducive to coastal impacts on temperate open coastal beaches and the importance of empirical impact data', *Natural Hazards* https://doi.org/10.1007/s11069-021-04845-z Accessed 7 July 2021.

Lennox RJ, Paukert CP, Aarestrup K, Auger-Méthé M, Baumgartner L, Birnie-Gauvin K, Bøe K, Brink K, Brownscombe JW and Chen Y 2019, 'One hundred pressing questions on the future of global fish migration science, conservation, and policy', *Frontiers in Ecology and Evolution*, 7 https://doi.org/10.3389/fevo.2019.00286.

Leo KL, Gillies CL, Fitzsimons JA, Hale LZ, Beck MW 2019, 'Coastal habitat squeeze: a review of adaptation solutions for saltmarsh, mangrove and beach habitats', *Ocean and Coastal Management*, 175, pp. 180-190.

Leopold A 1949, 'A Sand County Almanac', excerpt reproduced in Peterson Del Mar D 2011, 'Environmentalism', Taylor and Francis, p 118.

Lewis PJ, McGrath TJ, Chiaradia A, McMahon CR, Emmerson L, Allinson G and Shimeta J 2020, 'A baseline for POPs contamination in Australian seabirds: little penguins vs. short-tailed shearwaters', *Marine Pollution Bulletin*, 159, DOI:10.1016/j.marpolbul.2020.111488.

Life Saving Victoria 2020, 'Join a life saving club' https://lsv.com.au/clubs-members/support/join-a-life-saving-club/#:~:text=Life%20Saving%20Victoria%20has%2057,all%20the%20way%20to%20Mallacoota Accessed 4 September 2020.

Limburg KE and Waldman JR 2009, 'Dramatic declines in North Atlantic diadromous fishes', *BioScience*, 59, pp. 955-965.

Ling S 2008, 'Range expansion of a habitat-modifying species leads to loss of taxonomic diversity: a new and impoverished reef state', *Oecologia*, 156, pp. 883-894.

References

Lockwood M, Davidson J, Curtis A, Stratford E, Griffith R 2010, 'Governance principles for natural resource management', *Society and Natural Resources*, 23(10), pp. 986–1001.

Lonergan Research 2020, 'VNPA polling 2020', prepared for Matt Ruchel, Victorian National Parks Association (VNPA), October 2020 https://vnpa.org.au/publications/covid_parks_polling/ Accessed 12 February 2021.

Longmore A 2014, 'Spatial and temporal scales of key ecological processes in marine protected areas', Fisheries Victoria science report series no. 4.

Longmore A and Roberts S 2006, 'Importance of sediment nutrients in the Gippsland Lakes', Gippsland Lakes Task Force.

Loveridge R, Sallu S, Pesha I and Marshall A 2020, 'Measuring human wellbeing: a protocol for selecting local indicators', *Environmental Science and Policy*, 114, pp. 461–469.

Lowry M, Folpp H, Gregson M, Suthers I 2012, 'Comparison of baited remote underwater video (BRUV) and underwater visual census (UVC) for assessment of artificial reefs in estuaries', *Journal of Experimental Marine Biology and Ecology*, 416, pp. 243-253.

Loyn R, Rogers DI, Swindley RJ, Stamation K, Macak P and Menkhorst P 2014, 'Waterbird monitoring at the Western Treatment Plant 2000-2012: the effects of climate and sewage treatment processes on waterbird populations', Arthur Rylah Institute for Environmental Research (ARI) technical report series no. 256, Department of Environment, Land, Water and Planning (DELWP), Heidelberg, Victoria.

Lynch D 1966, 'Port Phillip survey 1957–63 - the fisheries', *Memoirs of the National Museum of Victoria*, 27, pp. 7–18.

MacKinnon J, Verkuil Y, Murray N 2012, 'IUCN situation analysis on East and Southeast Asian intertidal habitats, with particular reference to the Yellow Sea (including the Bohai Sea)', International Union for Conservation of Nature (IUCN), occasional paper of the IUCN species survival commission no. 47, Gland, Switzerland and Cambridge.

Manasseh R, McInnes K and Hemer M 2017, 'Pioneering developments of marine renewable energy in Australia', *The International Journal of Ocean and Climate Systems,* 8(1), pp. 50-67. DOI: 10.1177/1759313116684525.

Marion J 2016, 'A review and synthesis of recreation ecology research supporting carrying capacity and visitor use management decision-making', *Journal of Forestry*, 114(3), pp. 339-351.

Maritime Safety Victoria 2020, 'On deck. Maritime Safety Victoria stakeholder update, Data extract – July 2020', Transport Safety Victoria, Melbourne, Victoria.

Maritime Safety Victoria 2021, 'Maritime Safety Victoria, data extract 2019', Transport Safety Victoria, Melbourne, Victoria.

Maritime Safety Victoria 2021, 'On deck. Maritime Safety Victoria stakeholder update, Data extract April 2021' https://transportsafety.vic.gov.au/maritime-safety/recreational-vessel-operators/report-a-rec-boating-incident/maritime-incident-statistics#_ga=2.71464272.27516040.1601950094-575231943.1601950094 Accessed 26 August 2021.

Maritime Safety Victoria, various years, 'On deck stakeholder update', data extracts and annual reports https://transportsafety.vic.gov.au/maritime-safety/recreational-vessel-operators/report-a-rec-boating-incident/maritime-incident-statistics#_ga=2.71464272.27516040.1601950094-575231943.1601950094 Accessed 10 August 2021.

Marsden Jacob Associates 2014, 'Valuing the water services provided by Victoria's parks', report prepared for Parks Victoria.

Marshall D, Gaines S, Warner R, Barneche D and Bode M 2019, 'Underestimating the benefits of marine protected areas for the replenishment of fished populations', *Frontiers in Ecology and the Environment*, 17, pp. 407–413.

Marshall S, Pettigrove V, Carew M and Hoffmann A 2010, 'Isolating the impact of sediment toxicity in urban streams', *Environmental Pollution*, 158, pp. 1716–1725.

References

Marshall S, Sharley DJ, Jeppe K, Sharp SM, Rose G and Pettigrove VJ 2016, 'Potentially toxic concentrations of synthetic pyrethroids associated with low density residential land use', *Frontiers in Environmental Science*, 4(75), DOI:10.3389/fenvs.2016.00075.

Mayfield S, McGarvey R, Gorfine HK, Peeters H, Burch P and Sharma S 2011, 'Survey estimates of fishable biomass following a mass mortality in an Australian molluscan fishery', *Journal of Fish Diseases*, 34, pp. 287–302.

Mayfield S, Miller KJ, and Mundy CM 2014, 'Towards understanding greenlip abalone population structure', final report to the Fisheries Research and Development Corporation (FRDC), project 2010/013, South Australia Research and Development Institute, Adelaide.

McArthur M, Smith A, Davis, S, Edmunds M and Pritchard K 2011, 'Victorian subtidal reef monitoring program: the reef biota at Marengo Reefs marine sanctuary, Parks Victoria technical series no. 85, Melbourne, Victoria.

McIntosh RR 2021, 'Australian sea lion (*Neophoca cinerea*), long-nosed fur seals (LNFS, *Arctocephalus forsteri*), Australian fur seals (AUFS, *Arctocephalus pusillus doriferus*), state and trend assessment: pinnipeds', State of the Environment 2021, marine expert assessments.

McIntosh RR, Kirkman SP, Thalmann S, Sutherland DR, Mitchell A, Arnould JPY, Salton M, Slip DJ, Dann P and Kirkwood R 2018, 'Understanding meta-population trends of the Australian fur seal, with insights for adaptive monitoring', *PLOS ONE*, 13(9), e0200253.

McIntosh RR, Kirkwood R, Sutherland DR and Dann P 2015, 'Drivers and annual estimates of marine wildlife entanglement rates: a long-term case study with Australian fur seals,' *Marine Pollution Bulletin*, 101, pp. 716-723.

McIntosh RR, Sorrell KJ, Thalmann S, Mitchell T, Gray R, Schnagl H, Arnould JPY, Dann P and Kirkwood R (in review), 'Sustained reduction in numbers of Australian fur seal pups: implications for future population monitoring'. *PLOS ONE*.

McKenzie F 2020, 'Coastal demographics in Victoria: background research paper prepared for the Victorian Marine and Coastal Council', Department of Environment, Land, Water and Planning (DELWP), East Melbourne Victoria https://www.marineandcoastalcouncil.vic.gov.au/__data/assets/pdf_file/0027/455904/Coastal-Demographics-in-Victoria.pdf Accessed 13 July 2021.

McKenzie F and Canterford S 2018, 'Demographics for bushfire risk analysis', Department of Environment, Land, Water and Planning (DELWP), East Melbourne, Victoria.

McLean E and Jones B 2011, 'Corner Inlet sediment study – trace elements' final report by the University of Wollongong to the West Gippsland Catchment Management Authority (WGCMA).

McLean LJ, George S, Ierodiaconou D, Kirkwood RJ, Arnould JPY 2018, 'Impact of rising sea levels on Australian fur seals', *PeerJ*, 6, e5786.

McManus A, Hunt W, McManus J, and Creegan R 2011, 'Investigating the health and well-being benefits of recreational fishing in Western Australia', Centre of Excellence for Science Seafood and Health (CESSH), Curtin Health Innovation Research Institute, Perth, Western Australia.

McNeil M 2019, 'Port Fairy wave energy project decommissioned after technical challenges in "harsh marine environment"', *The Standard,* Warrnambool, April 5 https://www.standard.net.au/story/5989332/challenging-victorian-wave-energy-project-pilot-goes-under/#:~:text=A%20%2424%20million%20pilot%20wave,any%20electricity%2C%20has%20been%20decommissioned.&text=Ongoing%20technical%20problems%20and%20uncertainties,was%20deployed%20in%20December%202015 Accessed 8 October 2020.

McSweeney S 2020, 'Temporal and spatial variability of the open coast wave climate of Victoria, Australia', *Marine and Freshwater Research,* 71, pp. 394-413.

Melbourne Water (unpublished report) 2021, 'Interim report on modelled annual loads to Port Phillip Bay and Western Port'.

References

Melbourne Water 2011, 'Understanding the Western Port environment – a summary of current knowledge and priorities for future research' https://www.melbournewater.com.au/sites/default/files/2018-02/Understanding_the_Western_Port_Environment_0.pdf Accessed 28 March 2021.

Melbourne Water 2012, 'Rural land program. a guide to reducing the impact of runoff to waterways'.

Melbourne Water 2017, 'Planning for sea level rise guidelines February 2017' https://www.melbournewater.com.au/sites/default/files/Planning-for-sea-levels.pdf Accessed 4 August 2021.

Melbourne Water 2018, 'Co-designed catchment program for the Werribee catchment region' https://healthywaterways.com.au/sites/default/files/2021-03/HWS-werribee-co-designed-catchment-program.pdf Accessed 26 July 2021.

Melbourne Water 2018, 'Healthy waterways strategy 2018' https://www.melbournewater.com.au/media/6976/download Accessed 22 February 2021.

Melbourne Water 2018, 'Healthy waterways strategy 2018', Melbourne, Victoria https://www.melbournewater.com.au/about/strategies-and-reports/healthy-waterways-strategy Accessed 22 July 2021.

Melbourne Water 2018, 'Healthy waterways strategy 2018-2028, Port Phillip and Westernport, Victoria, Stormwater condition baseline and targets' https://healthywaterways.com.au/waterway-conditions/stormwater Accessed 22 July 2021.

Melbourne Water 2018, 'Understanding the Western Port environment 2018. A summary of research findings from the Western Port environment research program 2011-2017 and priorities for future research' https://www.melbournewater.com.au/media/6686/download Accessed 20 July 2021.

Melbourne Water and CSIRO 2021, 'Westernport catchment planning tool' https://www.flowmatters.com.au/viz/#/mw-cpt?_page=0 Accessed 20 July 2021.

Melbourne Water, 'Spartina management in Western Port estuaries' https://www.melbournewater.com.au/building-and-works/projects/spartina-management-western-port-estuaries Accessed 29 March 2021.

Melbourne Water, 'Waterways report card' https://healthywaterways.com.au/report-card?suId=PPW&tabId=river& Accessed 14 March 2021.

Melville D, Chen Y, Ma Z, 2016, 'Shorebirds along the Yellow Sea coast of China face an uncertain future - a review of threats', *Emu*, 116, pp. 100–110.

Menkhorst P 2010, 'A survey of colonially-breeding birds on mud islands, Port Phillip, Victoria; with an annotated list of all terrestrial vertebrates', Arthur Rylah Institute for Environmental Research (ARI), Department of Environment, Land, Water and Planning (DELWP), Heidelberg, Victoria.

Menkhorst P, Loyn R, Liu C, Hansen B, Mackay M and Dann P 2015, 'Trends in numbers of piscivorous birds in Western Port and West Corner Inlet, Victoria, 1987–2012', Arthur Rylah Institute for Environmental Research (ARI), unpublished client report for Melbourne Water, Department of Environment, Land, Water and Planning (DELWP), Heidelberg, Victoria.

Menkhorst P, Macak P, Rogers D, Stamation K and Fansen B 2020, 'Monitoring waterbird populations at the Western Treatment Plant – 2020 annual report', unpublished Client Report for Melbourne Water', Arthur Rylah Institute for Environmental Research (ARI), Department of Environment, Land, Water and Planning (DELWP), Heidelberg, Victoria.

Miles N, Walsh C, Butler G, Ueda H, West R 2013, 'Australian diadromous fishes – challenges and solutions for understanding migrations in the 21st century', *Marine and Freshwater Research*, 65, pp. 12-24 https://doi.org/10.1071/MF12340 Accessed 14 July 2020.

Miller KJ, Maynard BT and Mundy CN 2009, 'Genetic diversity and gene flow in collapsed and healthy abalone fisheries', *Molecular Ecology,* 18, pp. 200–211.

Ministerial Advisory Committee 2016, 'Independent Inquiry into the EPA' http://www.epa-inquiry.vic.gov.au/__data/assets/file/0008/336698/Inquiry-report-EPA_June.pdf Accessed 19 May 2021.

Minton C, Dann P, Ewing A, Taylor S, Jessop R, Anton P and Clemens R 2012, 'Trends of shorebirds in Corner Inlet, Victoria, 1982–2011', *Stilt*, 61, pp. 3–18.

Molloy R, Chidgey S, Webster I, Hancock G, Fox D 2005, 'Corner Inlet environmental audit', CSIRO Land and Water client report, Canberra, Australia.

References

Morgan G 1986, 'A survey of macrobenthos in the waters of Corner Inlet and the Nooramunga, southern Victoria, with an assessment of the extent of Posidonia seagrass', Victorian Fisheries and Wildlife paper no. 31, Museum of Victoria.

Morgan LK and Werner AD 2015, 'A national inventory of seawater intrusion vulnerability for Australia,' *Journal of Hydrology: Regional Studies*, 4, pp. 686-698 http://dx.doi.org/10.1016/j.ejrh.2015.10.005 Accessed 7 July 2020.

Morim J, Hemer M, Wang XL, Cartwright N, Trenham C, Semedo A, Young I, Bricheno L, Camus P, Casas-Prat M, Erikson L, Mentaschi L, Mori N, Shimura T, Timmermans B, Aarnes O, Breivik Ø, Behrens A, Dobrynin M, Menendez M, Staneva J, Wehner M, Wolf J, Kamranzad B, Webb A, Stopa J and Andutta F 2019, 'Robustness and uncertainties in global multivariate wind-wave climate projections', *Nature Climate Change,* 9, pp. 711-718 https://doi.org/10.1038/s41558-019-0542-5 Accessed 5 February 2021.

Murfitt, S, Allan B, Bellgrove A, Rattray A, Young M, Ierodiaconou D 2017, 'Applications of unmanned aerial vehicles in intertidal reef monitoring', *Scientific Reports*, 7(10259) https://doi.org/10.1038/s41598-017-10818-9 Accessed 9 April 2021.

Murphy H, Jenkins G, Hamer P and Swearer S 2011, 'Interannual variation in larval survival of snapper (*Chrosophrys auratus*, Sparidae) is linked to diet breadth and prey availability', *Canadian Journal of Fisheries and Aquatic Sciences*, 69, pp. 1340-1351.

Murray A and Parslow J 1999, 'Modelling of nutrient impacts in Port Phillip Bay – a semi-enclosed marine Australian ecosystem', *Marine and Freshwater Research*, 50, pp. 597–611.

Murray N, Ma Z, Fuller R 2015, 'Tidal flats of the Yellow Sea: a review of ecosystem status and anthropogenic threats', *Austral Ecology*, 40, pp. 472-481.

Myers, JH, Sharp S, Long S, Kellar C and Pettigrove V 2018, 'Final report Western Port toxicant study stage 4: assessment of pesticide risks in catchments of north-eastern Western Port', Aquatic Pollution Prevention Partnership, technical report no. 2, RMIT University, Victoria, Australia.

National Environmental Science Programme (NESP) 2020, 'Science webinar: impacts of climate change and variability on ocean waves' http://nespclimate.com.au/impacts-of-climate-change-and-variability-on-ocean-waves/ Accessed 22 January 2021.

National Environmental Science Programme (NESP), 'Marine heatwaves: changes, causes and impacts' http://nespclimate.com.au/marine-heatwaves-changes-causes-and-impacts/ Accessed 2 February 2021.

National Oceanic and Atmospheric Administration (NOAA) Earth observation group, 'Visible infrared imaging radiometer suite (VIIRS)' National Geophysical Data Center https://ngdc.noaa.gov/eog/viirs/index.html Accessed 06 July 2020.

National Outfall Database, 'Toora outfall' https://www.outfalls.info/detail/locations/50 Accessed 29 July 2021.

Northcote J 2020, 'Sustainable visitation index: a new visitor management framework for assessing destination sustainability', *Journal of Ecotourism*, DOI: 10.1080/14724049.2020.1715417.

Nowicki R, Thomson J, Burkholder D, Fourqurean J and Heithaus M 2017, 'Predicting seagrass recovery times and their implications following an extreme climate event,' *Marine Ecology Progress Series*, 567, pp. 79–93.

O'Hara T and Barmby V 2000, 'Victorian marine species of conservation concern: molluscs, echinoderms and decapod crustaceans,' Parks, Flora and Fauna Division, Department of Natural Resources and Environment (DNRE), East Melbourne, Victoria.

O'Hara T, Norman M and Staples D 2002, 'Baseline monitoring of Posidonia seagrass beds in Corner Inlet, Victoria', *Museum Victoria Science Reports*, 1, pp. 1–44.

O'Connor JJ, Fest B J, Sievers M and Swearer SE 2020, 'Impacts of land management practices on blue carbon stocks and greenhouse gas fluxes in coastal ecosystems - a meta-analysis', *Global Change Biology,* 26(3), pp. 1354-1366.

Office of the Conservation Regulator (OCR) 2020, 'Regulatory priorities 2020–2021', Melbourne, Victoria.

References

Office of the Conservation Regulator (OCR) 2020, 'Year in review 2019–2020' Melbourne, Victoria.

Organisation for Economic Development and Cooperation (OECD) 2020, 'GSDD forum issue paper - practical policy use cases for natural capital information. a review of evidence for the policy reform and impact of natural capital information', report by the GGKP Expert Group on Natural Capital, OECD, Paris.

Organisation for Economic Development and Cooperation (OECD) 2021, 'The inequality-environment nexus: towards a people-centred green transition', OECD green growth papers, 2021-01, OECD Publishing, Paris https://doi.org/10.1787/ca9d8479-en

Orth R, Carruthers T, Dennison W, Duarte C, Fourqurean J, Heck K, Hughes A, Kendrick G, Kenworthy W, Olyarnik S, Short F, Waycott M and Williams SL 2006, 'A global crisis for seagrass ecosystems', *BioScience*, 56, pp. 987–96.

Ovenden JR, Brasher DJ and White R 1992, 'Mitochondrial DNA analyses of the red rock lobster *Jasus edwardsii* supports an apparent absence of population subdivision throughout Australasia', Marine Biology, 112: 319–326.

Pacific Hydro 2020, 'Codrington wind farm' https://www.pacifichydro.com.au/projects/operations/codrington-wind-farm/ Accessed 14 October 2020.

Pacione M 2003, 'Urban environmental quality of human wellbeing – a social geographical perspective', *Landscape and Urban Planning*, 65(1-2), pp. 19-30.

Papas, P, Downe J, Osler D 2020, 'WetMAP observations and results for Reedy Lake (February 2020 update)' Arthur Rylah Institute for Environmental Research (ARI), Department of Environment, Land, Water and Planning (DELWP), Heidelberg, Victoria.

Papathanasopoulou E, White M, Hattam C, Lannin A, Harvey A and Spencer A 2016, 'Valuing the health benefits of physical activities in the marine environment and their importance for marine spatial planning', *Marine Policy*, 63 pp. 144-152.

Parks Australia, 'Reef life survey' https://parksaustralia.gov.au/marine/science/reef-life-survey/ Accessed 9 April 2021.

Parks Victoria 2003, 'Victoria's system of marine national parks and marine sanctuaries management strategy 2003 – 2010', Parks Victoria and the Department of Sustainability and Environment (DSE), Melbourne, Victoria.

Parks Victoria 2005, 'Corner Inlet marine national park management plan', Melbourne, Victoria.

Parks Victoria 2012, 'Marine natural values study summary', Melbourne, Victoria.

Parks Victoria 2017, 'Seagrass meadows saved from sea urchin attack', media release 28 July 2017, Melbourne, Victoria.

Parks Victoria 2018, 'Check clean dry', Melbourne, Victoria https://www.parks.vic.gov.au/-/media/project/pv/main/parks/documents/get-into-nature/conservation-and-science/marine-docs/check-clean-dry_stop-the-spread-marine-pests.=en&hash=91C478C9982B8EAE17326AEFB7C52C2772920441 Accessed 03 July 2020.

Parks Victoria 2018, 'Sea search manual. A guide for community based monitoring of Victoria's marine national parks and marine sanctuaries', Melbourne, Victoria https://www.parks.vic.gov.au/get-into-nature/volunteering/sea-search Accessed 14 July 2021.

Parks Victoria 2018, 'State of the parks assessments'.

Parks Victoria 2019, 'Annual report 2018–19', Melbourne, Victoria.

Parks Victoria 2020, 'Annual report 2019-20', Melbourne, Victoria https://www.parks.vic.gov.au/-/media/f0f4aa2dfacd43948158493c6d0b7855.__=6E3FC66C70DE08527982AE1D9653B5C821B2B44E Accessed 5 April 2021.

Parks Victoria 2020, 'State of the parks 2018', Melbourne, Victoria.

Parks Victoria 2021, 'Sea search' https://www.parks.vic.gov.au/get-into-nature/volunteering/sea-search Accessed 14 July 2021.

Parks Victoria 2021, 'Victorian community usage, awareness and perceptions of marine parks and sanctuaries', written by Jacky Heath, Lonergan, Sydney.

References

Parks Victoria, 'Kelp forests recovering after urchin culls' https://www.parks.vic.gov.au/news/2021/05/21/00/23/kelp-forests-recovering-after-urchin-culls Accessed 14 August 2021.

Parks Victoria, 'Marine pests' https://www.parks.vic.gov.au/get-into-nature/conservation-and-science/conserving-our-parks/marine-pests Accessed 26 March 2021.

Parks Victoria, 'Signs of healthy parks' https://www.parks.vic.gov.au/get-into-nature/conservation-and-science/science-and-research/signs-of-healthy-parks Accessed 25 July 2021.

Parks Victoria, 'Seagrass identification sheet' https://www.parks.vic.gov.au/get-into-nature/volunteering/sea-search Accessed 14 July 2021.

Parliament of Australia, 'Submission 116', Senate inquiry into the threat of marine plastic pollution in Australia and Australian Waters https://www.aph.gov.au/DocumentStore.ashx?id=326c34c6-9093-43df-a6fc-5b7e8411430a&subId=403678 Accessed 22 March 2021.

Parry G and Cohen B 2001, 'Exotic species established in Western Port, including an assessment of the status of the exotic species *Corbula gibba, Alexandrium spp, Gymnodinium spp* and *Undaria pinnatifida*', report no. 45, Marine and Freshwater Resources Institute, Queenscliff, Victoria.

Parry G and Hirst A 2015, 'Decadal decline in demersal fish biomass coincident with a prolonged drought and the introduction of an exotic starfish', *Marine Ecology Progress Series*, 544, pp. 37–52.

Parry G, Heislers S and Werner G 2004, 'Changes in distribution and abundance of *Asterias amurensis* in Port Phillip Bay 1999-2003', Primary Industries Research Victoria, Marine and Freshwater Systems report series, no. 1, Victorian Department of Primary Industries (DPI), Queenscliff, Victoria.

Patole M 2018, 'Localization of SDGs through disaggregation of KPIs', *Economies*, 6(15).

Pecl G, Stuart-Smith J, Walsh P, Bray D, Kusetic M, Burgess M, Frusher S, Gledhill D, George O, Jackson G, Keane J, Martin V, Nursey-Bray M, Pender A, Robinson L, Rowling K, Sheaves M and Moltschaniwskyj N 2019, 'Redmap Australia: challenges and successes with a large-scale citizen science-based approach to ecological monitoring and community engagement on climate change', *Frontiers in Marine Science*, 6(349) DOI: 10.3389/fmars.2019.00349.

Perillo G, Wolanski E, Cahoon D and Hopkinson C 2019, 'Coastal wetlands: an integrated ecosystem approach', Elsevier, Amsterdam, Netherlands.

Pettigrove VJ and Hoffmann A 2005, 'A field-based microcosm method to assess the effects of polluted urban sediments on aquatic macroinvertebrates', *Environmental Toxicology and Chemistry*, 24, pp. 170–180.

Phillip Island Nature Parks, 'Penguin research' https://www.penguins.org.au/conservation/research/penguin-research/ Accessed 9 April 2021.

Phillip Island Nature Parks, 'Annual report', various years https://www.penguins.org.au/about/corporate-affairs/publications/annual-reports/ Accessed 14 May 2021.

PlasticsEurope 2019, 'Plastics - the facts 2019' https://www.plasticseurope.org/application/files/9715/7129/9584/FINAL_web_version_Plastics_the_facts2019_14102019.pdf

Plieninger T and Bieling C 2017, 'The emergence of landscape stewardship in practice, policy and research', chapter 1 in C Bieling and T Plieninger (eds), 'The Science and Practice of Landscape Stewardship', Cambridge University Press, Cambridge, UK, pp. 1–17 https://doi.org/10.1017/9781316499016.007

Plummer A, Morris L, Blake S and Ball D 2003, 'Marine natural values study, Victorian marine national parks and sanctuaries', Parks Victoria technical series no. 1, Melbourne, Victoria.

Pope A, Monk J and Ierodiaconou D 2013, 'Corner Inlet and Nooramunga marine habitat mapping project: part II', Deakin University, Warrnambool, Victoria.

References

Port of Hastings Development Authority 2019, 'Annual report 2018/19' https://static1.squarespace.com/static/592f5720f5e2317ce97cec2c/t/5dddcf6d0264c30de205e2c3/1574817677347/Annual+Report+2018+-+19+Final.pdf

Port of Melbourne 2018, 'Sustainability report' https://www.portofmelbourne.com/wp-content/uploads/Sustainability-Report-webfile.pdf.

Port of Melbourne 2020, 'Sustainability report based on financial year 2020' https://www.portofmelbourne.com/wp-content/uploads/PoM-2020-Sustainability-Report-Final-Web.pdf Accessed 2 July 2021.

Port of Melbourne Corporation, 'Port of Melbourne – facts and figures' https://www.portofmelbourne.com/about-us/factsandfigures/ Accessed 13 July 2021.

Port of Portland https://www.portofportland.com.au/ Accessed 1 July 2021.

Port Phillip and Western Port Catchment Management Authority (PPWCMA) 2008, 'Summary of changes to the bioregional conservation status ratings resulting from updated 2007 native vegetation datasets - Port Phillip and Western Port CMA region'.

Port Phillip and Westernport Catchment Management Authority (PPWCMA), 'Improving hydrology at The Spit Nature Conservation Reserve' 24 August 2021 https://www.ppwcma.vic.gov.au/improving-hydrology-at-the-spit-nature-conservation-reserve/ Accessed 15 November 2021

Preston TJ, Chiaradia A, Caarels SA, and Reina RD 2010, 'Fine scale biologging of an inshore marine animal', *Journal of Experimental Marine Biology and Ecology*, 390(2), pp. 196-202.

Preston TJ, Ropert-Coudert Y, Kato A, Chiaradia A, Kirkwood R, Dann P, and Reina RD 2008, 'Foraging behaviour of little penguins *Eudyptula minor* in an artificially modified environment', *Endangered Species Research*, 4, pp. 95-103.

Primo C, Hewitt C, and Campbell M 2010, 'Reproductive phenology of the introduced kelp *Undaria pinnatifida* (Phaeophyceae, Laminariales) in Port Phillip Bay (Victoria, Australia)', *Biological Invasions*, 12, pp. 3081-3092.

Reef Life Survey, 'About RLS' https://reeflifesurvey.com/about-rls/ Accessed 25 July 2021.

Reef Life Survey, 'Reef life explorer' https://reeflifesurvey.com/explorer/map Accessed 19 May 2021.

Reeves J and Trewarn A 2016, 'Assessment of heavy metals and other contaminants of the Gippsland Lakes', Federation University Australia, Mt Helen, Victoria.

Reisser J, Shaw J, Wilcox C, Hardesty B, Proietti M, Thums M and Pattiaratchi C 2013, 'Marine plastic pollution in waters around Australia: characteristics, concentrations, and pathways', *PLOS ONE*, 8, e80466.

Renew Economy 2021, 'Offshore wind farm map of Australia' https://reneweconomy.com.au/offshore-wind-farm-map-of-australia/ Accessed 30 June 2021.

Richardson A and Schoeman D 2004, 'Climate impact on plankton ecosystems in the northeast Atlantic', *Science*, 305(5690), pp. 1609-1612.

Richardson A, Eriksen R, Moltmann T, Hodgson-Johnston I and Wallis J 2020, 'State and trends of Australia's oceans', Integrated Marine Observing System, Hobart.

Richardson A, Eriksen R, Rochester W 2015, 'Plankton 2015: state of Australia's oceans', CSIRO Report, Canberra, Australia.

Richardson MF, Sherman CDH, Lee RS, Bott NJ, Hirst AJ 2016, 'Multiple dispersal vectors drive range expansion in an invasive marine species', *Molecular Ecology*, 25, pp. 5001–5014.

RMIT University, 'Litter, litter everywhere! How do we best assess it?', https://www.rmit.edu.au/about/schools-colleges/science/research/research-centres-groups/aquatic-environmental-stress/projects/litter-framework Accessed 26 July 2021.

References

Robert K, Lesku J, Partecke J and Chambers B 2015, 'Artificial light at night desynchronizes strictly seasonal reproduction in a wild mammal', *Proceedings of the Royal Society B*, 282 https://doi.org/10.1098/rspb.2015.1745.

Robinson R, Crick H, Learmonth J, Maclean I, Thomas C, Bairlein F, Forchhammer M, Francis C, Gill J, Godley B, Harwood J, Hays G, Huntley B, Hutson A, Pierce G, Rehfisch M, Sims D, Santos M, Sparks, T, Stroud D and Visser M 2009, 'Travelling through a warming world: climate change and migratory species', *Endangered Species Research*, 7(2), pp. 87–99.

Rodríguez A, Burgan G, Dann P, Jessop R, Negro JJ and Chiaradia A 2014, 'Fatal attraction of short-tailed shearwaters to artificial lights', *PLOS ONE*, 9(10), e110114.

Rodríguez A, Dann P and Chiaradia A 2017, 'Reducing light-induced mortality of seabirds: high pressure sodium lights decrease the fatal attraction of shearwaters', *Journal for Nature Conservation*, 39, pp. 68-72.

Rodríguez A, Holmes N, Ryan PG, Wilson K-J, Faulquier L, Murillo Y, Raine AF, Penniman J, Neves V, Rodríguez B, Negro JJ, Chiaradia A, Dann P, Anderson T, Metzger B, Shirai M, Deppe L, Wheeler J, Hodum P, Gouveia C, Carmo V, Carreira GP, Delgado-Alburqueque L, Guerra-Correa C, Couzi F-X, Travers M and Le Corre M 2017, 'A global review of seabird mortality caused by land-based artificial lights', *Conservation Biology*, 31, pp. 986-1001.

Rodríguez A, Moffett J, Revoltós A, Wasiak P, McIntosh RR, Sutherland DR, Renwick L, Dann P and Chiaradia A 2017, 'Light pollution and seabird fledglings: Targeting efforts in rescue programs', *Journal of Wildlife Management*, 81, pp. 734–741.

Rogers K, Boon PI, Branigan S, Duke NC, Field CD, Fitzsimons JA, Kirkman H, MacKenzie JR, and Saintilan N 2016, 'The state of legislation and policy protecting Australia's mangrove and salt marsh and their ecosystem Services', *Marine Policy*, 72, pp. 139–155.

Rogers K, Saintilan N and Heijnis H 2005, 'Mangrove encroachment of salt marsh in Western Port Bay, Victoria: the role of sedimentation, subsidence, and sea level rise', *Estuaries*, 28, pp. 551–559.

Roman L, Schuyler QA, Hardesty BD and Townsend KA 2016, 'Anthropogenic debris ingestion by avifauna in eastern Australia', *PLOS ONE*, 11(8), pp. 1-14 https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0158343 Accessed 19 May 2021.

Roob R and Ball D 1997, 'Victorian marine habitat database, seagrass, Gippsland Lakes', report for Fisheries Victoria, and the Department of Natural Resources and the Environment (DNRE), The Marine and Freshwater Resources Institute, Queenscliff, Victoria.

Ropert-Coudert Y, Kato A and Chiaradia A 2009, 'Impact of small-scale environmental perturbations on local marine food resources: a case study of a predator, the little penguin', *Proceedings of the Royal Society*, B276, pp. 4105-4109.

Ross J, Longmore A and Keough M 2013, 'Spatially variable effects of a marine pest on ecosystem function', *Oecologia*, 172(2), pp. 525-538.

Russart K and Nelson R 2018, 'Artificial light at night alters behavior in laboratory and wild animals', *JEZ-A Ecological and Integrative Physiology*, 329(8-9), pp. 401-408.

Russell D, Warry F and Cook P 2016, 'The balance between nitrogen fixation and denitrification on vegetated and non-vegetated intertidal sediments', *Limnology and Oceanography*, 61, pp. 2058-2075 https://doi.org/10.1002/lno.10353 Accessed 31 March 2021.

Salton M, Carr M, Tarjan LM, Clarke J, Kirkwood R, Slip D and Harcourt R 2021, 'Protected area use by two sympatric marine predators repopulating their historical range', *Endangered Species Research*, 45, pp. 181-194.

Salton M, Kirkwood R, Slip DJ and Harcourt R 2019, 'Mechanisms for sex-based segregation in foraging behaviour by a polygynous marine carnivore', *Marine Ecology Progress Series*, 624, pp. 213-226.

Sampson J, Easton A and Singh M 2005, 'Modelling the effect of proposed channel deepening on the tides in Port Phillip Bay', *Australia and New Zealand Industrial and Applied Mathematics Journal,* 46, pp. C888-C901.

Saraux C, Chiaradia A, Salton M, Dann P and Viblanc VA 2016, 'Negative effects of wind speed on individual foraging performance and breeding success in little penguins', *Ecological Monographs*, 86(1), pp. 61-77.

References

Sardain A, Sardain E and Leung B 2019, 'Global forecasts of shipping traffic and biological invasions to 2050', *Nature Sustainability*, 2, pp. 274-282.

Scarpaci C, Nugegoda D and Corkeron PJ 2005, 'Tourists swimming with Australian fur seals (*Arctocephalus Pusillus*) in Port Phillip Bay, Victoria, Australia: are tourists at risk?', *Tourism in Marine Environments*, 1(2), pp. 89-95.

Science Advice for Policy by European Academies (SAPEA) 2019, 'A scientific perspective on microplastics in nature and society' https://www.sapea.info/topics/microplastics/

Scott H 2018, 'Monitoring and evaluation of climate change adaptation by local government: the state of play in Australia', Proceedings of the 4th Practical Responses to Climate Change Conference: Climate Adaptation 2018: Learn, Collaborate, Act, 8–10 May 2018, Melbourne.

Setälä O, Lehtiniemi M, Coppock R and Cole M 2018, 'Microplastics in marine food webs', in 'Microplastic contamination in aquatic environments', Elsevier, pp.339-363.

SGS Economics and Planning 2007, 'Impacts of coastal population fluctuations', report prepared for Department of Sustainability and Environment (DSE), Melbourne, Victoria.

Sharley D, Marshall S, Mackintosh T, Coombes L, Forrester J 2020, 'Reducing stormwater pollution in the Werribee catchment: Sources, impacts and solution, Werribee River Association'.

Sharley DJ, Sharp SM, Bourgues S and Pettigrove VJ 2016, 'Detecting long-term temporal trends in sediment-bound trace metals from urbanised catchments', *Environmental Pollution*, 2016, 219, pp. 705-713.

Sharley DJ, Sharp SM, Marshall S, Jeppe K and Pettigrove VJ 2017, 'Linking urban land use to pollutants in constructed wetlands: implications for stormwater and urban planning', *Landscape and Urban Planning*, 162, pp. 80-91.

Sharp S, Myers J, Pettigrove V 2013, 'An assessment of sediment toxicants in Western Port and major tributaries', CAPIM technical report no. 27 https://www.melbournewater.com.au/sites/default/files/2017-12/Report-Sediment-toxicants-WesternPort-major-tributaries.pdf Accessed 12 March 2021.

Shears N, Grace R, Usmar N, Kerr V and Babcock R 2006, 'Long-term trends in lobster populations in a partially protected vs. no-take marine park', *Biological Conservation*, 132(2), pp. 222–231.

Shimeta JLS, Verspaandonk E, Nugegoda D, Howe S 2016, 'Long-term ecological consequences of herbicide treatment to control *Spartina anglica* in an Australian Saltmarsh', *Estuarine, Coastal and Shelf Science*, 176, pp. 58-66.

Sinclair Knight Mertz 2005, Werribee irrigation district groundwater investigations', Malvern, Victoria.

Sinclair S and Boon P 2012, 'Changes in the area of coastal marsh in Victoria since the mid 19th century', *Cunninghamia*, 12 (2), pp. 153-176.

Sinclair S and Kohout M 2018, 'Assessment of fringing vegetation for the index of estuary condition', Arthur Rylah Institute for Environmental Research (ARI), technical report series no. 290, Department of Environment, Land, Water and Planning (DELWP), Heidelberg, Victoria.

Smale DA, Wernberg T, Oliver ECJ, Thomsen M, Harvey BP, Straub SC, Burrows MT, Alexander LV, Benthuysen JA, Donat MG, Feng M, Hobday AJ, Holbrook NJ, Perkins-Kirkpatrick SE, Scannell HA, Gupta AS, Payne BL and Moore PJ 2019, 'Marine heatwaves threaten global biodiversity and the provision of ecosystem services', *Nature Climate Change*, 9, pp. 306–312 https://doi.org/10.1038/s41558-019-0412-1 Accessed 2 February 2021.

Sorte C, Williams S and Zerebecki R 2010, 'Ocean warming increases threat of invasive species in a marine fouling community', *Ecology*, 91(8), pp. 2198-2204.

Spatial Vision 2017, 'Victorian coastal hazard assessment 2017 technical report 1'. https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0021/122709/VCHA2017_R1_Victorian_Coastal_Hazard_Assessment_2017_Final_R1.compressed.pdf Accessed 5 March 2021.

Speakman CN, Hoskins AJ, Hindell MA, Costa DP, Hartog JR, Hobday AJ and Arnould JPY 2020, 'Environmental influences on foraging effort, success and efficiency in female Australian fur seals', *Scientific Reports*, 10(17710).

References

Spenceley A, Kohl J, McArthur S, Myles P, Notarianni M, Paleczny D, Pickering C and Worboys GL 2015, 'Visitor management', in GL Worboys, M Lockwood, A Kothari, S Feary and I Pulsford (eds), 'Protected area governance and management', pp. 715–750, ANU Press, Canberra.

Star of the South Wind Farm 2020, 'Star of the south – the project' https://www.staroftheseouth.com.au/the-project Accessed 14 October 2020.

State Government of Victoria 2014, 'Victorian coastal strategy 2014', Melbourne, Victoria.

State Government of Victoria 2021, 'Environment reference standard (*Environment Protection Act 2017*)' http://www.gazette.vic.gov.au/gazette/Gazettes2021/GG2021S245.pdf Accessed 16 August 2021.

State Government of Victoria, 'EPA Victoria environmental audit reports - location polygons' https://discover.data.vic.gov.au/dataset/epa-victoria-environmental-audit-reports-location-polygons Accessed 23 March 2021.

State Government of Victoria, 'EPA Victoria groundwater quality restriction use zones (GQRUZ) - location points' https://discover.data.vic.gov.au/dataset/epa-victoria-groundwater-quality-restriction-use-zones-gqruz-location-points Accessed 23 March 2021.

State Government of Victoria, 'EPA Victoria licence - location polygons' https://discover.data.vic.gov.au/dataset/epa-victoria-licence-location-polygons Accessed 23 March 2021.

State Government of Victoria, 'EPA Victoria priority sites register (PSR) - location points' https://discover.data.vic.gov.au/dataset/epa-victoria-priority-sites-register-psr-location-points Accessed 23 March 2021.

State Government of Victoria, 'EPA Victoria Victorian landfill register (VLR) - location points' https://discover.data.vic.gov.au/dataset/epa-victoria-victorian-landfill-register-vlr-location-points Accessed 23 March 2021.

State Wide Integrated Flora and Fauna Teams (SWIFFT), 'Southern right whale photo identification project' https://www.swifft.net.au/srwsmp/ Accessed 15 March 2021.

Steffen W, Hughes L and Perkins S 2014, 'Heatwaves: hotter, longer, more often', Climate Council of Australia, Potts Point, New South Wales https://www.climatecouncil.org.au/uploads/9901f6614a2cac7b2b888f55b4dff9cc.pdf Accessed 6 August 2021.

Steven A, Mobsby D and Curtotti R 2020, 'Australian fisheries and aquaculture statistics 2018', Fisheries Research and Development Corporation (FRDC) project 2019-093, ABARES, Canberra.

Steven A, Mobsby D and Curtotti R 2020, 'Australian fisheries and aquaculture statistics 2018', Fisheries Research and Development Corporation (FRDC) project 2019-093, ABARES, Canberra.

Stevenson J 2017, 'Sea searching in seagrass: 10 years of citizen science seagrass monitoring in Corner Inlet, Victoria, Australia', Parks Victoria, Melbourne.

Stock C, John J, Rykaczewski R, Asch R, Cheung W, Dunne J, Friedland K, Lam V, Sarmiento J, Watson R 2017, 'Reconciling fisheries catch and ocean productivity', *Proceedings of the National Academy of Sciences*, 114(8), pp. E1441-E1449.

Surfing Victoria, 'Victorian Indigenous surfing program' https://surfingvic.com/indigenous/ Accessed 18 November 2021.

Sustainability Victoria 2019, 'Microplastics and Port Phillip Bay', Melbourne, Victoria.

Sustainable Energy Authority 2004, 'Wave and tidal power assessment for the Victorian coastline', Water Technology technical report.

Sutherland W, Alves JA, Amano T, Chang CH, Davidson NC, Finlayson M, Gill JA, Gill RE, González PM, Gunnarsson, TG, Kleijn D, Spray CJ, Székely, T, and Thompson DBA 2012, 'A horizon scanning assessment of current and potential future threats to migratory shorebirds', *Ibis,* 154(4), pp. 663–679.

Symonds G and McInnes K 2013, 'Review of OEM assessment of potential causes of beach erosion at Portsea', CSIRO, Australia.

Tangaroa Blue Foundation 2020, 'Annual report' 2020 https://www.tangaroablue.org/about-us/annual-reports/ Accessed 19 July 2021.

References

Tangaroa Blue Foundation, 'Engaging community, industry and government to reduce plastic resin pellets flowing into Port Phillip Bay July 2018 – June 2020', Dunsborough, Western Australia https://www.tangaroablue.org/engaging-community-industry-and-government-to-reduce-plastic-resin-pellets-flowing-into-port-phillip-bay/ Accessed 3 August 2021.

Tangaroa Blue Foundation, 'Initial results – let's strain the drains, Warrnambool', Dunsborough, Western Australia https://www.tangaroablue.org/lets-strain-the-drains-warrnambool-2/ Accessed 3 August 2021.

Tangaroa Blue Foundation, 'Project Report – Let's strain the drains – monitoring land-based sources of marine debris in Port Phillip Bay', Dunsborough, Western Australia.

Taylor S, Terkildsen M, Stevenson G, de Araujo J, Yu C, Yates A, McIntosh R and Gray R 2021, 'Per and polyfluoroalkyl substances (PFAS) at high concentrations in neonatal Australian pinnipeds', *Science of the Total Environment*, e147446.

The Age, May 5, 2021, 'Divers heartbroken as virus returns, and not just for shellfish reasons', by Benjamin Preiss https://www.theage.com.au/national/victoria/divers-heartbroken-as-virus-returns-and-not-just-for-shellfish-reasons-20210505-p57p0d.html Accessed 22 July 2021.

The Centre for Australian Weather and Climate Research (CAWCR) 2014, 'A global wave hindcast focussed on the Central and South Pacific', CAWCR technical report no. 070 https://www.cawcr.gov.au/technical-reports/CTR_070.pdf Accessed 7 July 2021.

The Conversation 2019, 'No-take marine areas help fishers (and fish) far more than we thought' https://theconversation.com/no-take-marine-areas-help-fishers-and-fish-far-more-than-we-thought-119659 Accessed 6 April 2021.

The Nature Conservancy, 'Victoria's lost reefs rediscovered' https://www.natureaustralia.org.au/what-we-do/our-priorities/oceans/ocean-stories/restoring-shellfish-reefs/port-phillip-bay/ Accessed 19 May 2021.

The University of Melbourne, 'Mapping spatial variability in shoreline change hotspots from satellite data: a case study in southeast Australia' https://findanexpert.unimelb.edu.au/scholarlywork/1467937-mapping-spatial-variability-in-shoreline-change-hotspots-from-satellite-data%3B-a-case-study-in-southeast-australia Accessed 15 July 2021.

The University of Melbourne, 'Marine biology MSc projects 2021' https://biosciences.unimelb.edu.au/__data/assets/pdf_file/0008/3493880/2021_MarineProjects_Final.pdf Accessed 22 March 2021.

Thompson R, Olsen Y, Mitchell R, Davis A, Rowland S, John A, McGonigle D and Russell A 2004, 'Lost at sea: where is all the plastic?', *Science*, 304(5672), 838, DOI:10.1126/science.1094559.

Thomson J, Burkholder D, Heithaus M, Fourqurean J, Fraser M, Statton J and Kendrick G 2015, 'Extreme temperatures, foundation species, and abrupt ecosystem change: an example from an iconic seagrass ecosystem', *Global Change Biology*, 21(4), pp. 1463–1474.

Tomkins K, McLachlan G, Coleman R 2014, 'Quantification of coastal bank erosion rates in Western Port', CSIRO Water for a Healthy Country Flagship, Australia.

Tonkin Z, Jones C, Clunie P, Vivian L, Amtstaetter F, Jones M, Koster W, Mole B, O'Connor J, Brooks J, Caffrey L and Lyon J 2020, 'Victorian environmental flows monitoring and assessment program stage 6 synthesis report 2016-2020', technical report series no. 316, Arthur Rylah Institute (ARI), Department of Environment, Land, Water and Planning (DELWP), Heidelberg, Victoria.

Tran HQ, Provis D, Babanin A 2021, 'Hydrodynamic Climate of Port Phillip Bay', *Journal of Marine Science and Engineering*, 9(8), 898 https://doi.org/10.3390/jmse9080898

Transport Safety Victoria, 'Boating behaviour report 2015', Melbourne, Victoria.

Tull M 2006, 'The environmental impact of ports: an Australian case study', paper presented at the XIV International Economic History Congress (session no. 58), Helsinki, Finland, 21-25 August 2006 https://researchrepository.murdoch.edu.au/id/eprint/33124/1/environmental-impact-of-ports.pdf Accessed 6 August 2021.

References

Tulloch V, Pirotta V, Grech A, Crocetti S, Double M, How J, Kemper C, Meager J, Peddemors V, Waples K, Watson M and Harcourt R 2020, 'Long-term trends and a risk analysis of cetacean entanglements and bycatch in fisheries gear in Australian waters', *Biodiversity and Conservation*, 29, pp. 251–282 https://doi.org/10.1007/s10531-019-01881-x

Tulloch V, Pirotta V, Jonsen I, Grech A and Harcourt R 2017, 'National assessment of cetacean entanglements in fishery gear in Australia, final report', Macquarie University, Faculty of Science and Engineering.

United Nations 2015, 'Paris agreement' https://unfccc.int/sites/default/files/english_paris_agreement.pdf Accessed 06 April 2020.

United Nations Educational Scientific and Cultural Organization (UNESCO) 1989, 'Environmental literacy for all', *Connect*, UNESCO-UNEP environmental education newsletter, 14(2), pp. 1-2, UNESDOC Digital Library https://unesdoc.unesco.org/ark:/48223/pf0000153577 Accessed 19 July 2021.

United Nations, 'Sustainable Development Goal 14' https://sustainabledevelopment.un.org/sdg14 Accessed 19 May 2021.

United States National Optical Astronomy Observatory, 'Wasted lights and wasted nights: globe at night tracks light pollution' https://www.noao.edu/news/2011/pr1101.php Accessed 19 May 2021.

Valentine J and Johnson C 2004, 'Establishment of the introduced kelp Undaria pinnatifida following dieback of the native macroalga Phyllospora comosa in Tasmania, Australia', *Marine and Freshwater Research*, 55, pp. 223-230.

Valuer-General Victoria 2020, 'A guide to property values - annual analysis of property sales data from Valuer-General Victoria, January – December 2019', Department of Environment, Land, Water and Planning (DELWP), Melbourne, Victoria https://www.land.vic.gov.au/valuations/resources-and-reports/property-sales-statistics Accessed 6 May 2021.

Vergés A, McCosker E, Mayer-Pinto M, Coleman MA, Wernberg T, Ainsworth T and Steinberg PD 2019, 'Tropicalisation of temperate reefs: implications for ecosystem functions and management actions', *Functional Ecology*, 33(6), pp. 1000–1013 https://doi.org/10.1111/1365-2435.13310 Accessed 6 July 2020.

VicRoads 2015, 'Climate change risk assessment' VicRoads, Kew, Victoria.

VicRoads 2019, 'Annual report 2018-19', Melbourne, Victoria.

Victorian Aboriginal Heritage Council (VAHC) 2020, 'Aboriginal cultural heritage' https://www.aboriginalheritagecouncil.vic.gov.au/aboriginal-heritage Accessed 21 September 2020.

Victorian Auditor General's Office (VAGO) 2018, 'Protecting Victoria's coastal assets. Independent assurance report to parliament 2017–18: 14', Melbourne, Victoria https://www.audit.vic.gov.au/sites/default/files/2018-03/20180329-Coastal-Assets.pdf Accessed 21 May 2021.

Victorian Auditor-General's Office (VAGO) 2014, 'Oversight and accountability of committees of management', Melbourne, Victoria https://www.audit.vic.govau/sites/default/files/20140205-Management-Committees.pdf Accessed 6 August 2021.

Victorian Auditor-General's Office (VAGO) 2018, 'Follow up of oversight and accountability of committees of management', Melbourne, Victoria https://www.audit.vic.gov.au/sites/default/files/2018-09/20180905-Follow-Up-CoM_0.pdf Accessed 6 August 2021.

Victorian Auditor-General's Office (VAGO) 2021, 'Our role' https://www.audit.vic.gov.au/our-role Accessed 15 July 2021.

Victorian Auditor-General's Office (VAGO) 2021, 'Responses to performance audit recommendations: annual status update', tabled 23 June https://www.audit.vic.gov.au/report/responses-performance-audit-recommendations-annual-status-update Accessed 16 July 2021.

Victorian Auditor-General's Office (VAGO) 2021, 'Responses to performance audit recommendations dashboard' https://www.audit.vic.gov.au/report/responses-performance-audit-recommendations-annual-status-update#data-dashboard Accessed 16 July 2021.

References

Victorian Auditor-General's Office (VAGO) 2021, 'Victorian Auditor-General's office' https://www.audit.vic.gov.au/ Accessed 15 July 2021.

Victorian Catchment Management Authorities (CMAs) and Department of Environment, Land, Water and Planning (DELWP), 'Regional natural resource management climate change adaption Victorian priorities' https://nrmclimate.vic.gov.au/file/file/Victorian%20CMA%20Climate%20Change%20Priorities_March2020.pdf

Victorian Coastal Council (VCC) 2018, 'Victoria's coast and marine environments under projected climate change: impacts, research gaps and priorities' https://www.marineandcoastalcouncil.vic.gov.au/__data/assets/pdf_file/0022/411718/VCC_Science_Panel_Report_2018_Full_32pp_WEB.pdf.

Victorian Electoral Commission (VEC) 2017, '2016 Local government elections report', Melbourne, Victoria.

Victorian Environmental Assessment Council (VEAC) 2014, 'Marine investigation final report', Melbourne, Victoria.

Victorian Environmental Assessment Council (VEAC) 2017, 'Statewide assessment of public land', Melbourne, Victoria.

Victorian Environmental Assessment Council (VEAC) 2019, 'Assessment of the values of Victoria's marine environment', Melbourne, Victoria.

Victorian Environmental Assessment Council (VEAC) 2019, 'Assessment of Victoria's coastal reserves consultation summary', Melbourne, Victoria.

Victorian Environmental Assessment Council (VEAC) 2020, 'Assessment of Victoria's coastal reserves final report'.

Victorian Environmental Assessment Council (VEAC) 2020, 'Assessment of Victoria's coastal reserves - inventory of coastal reserves', Melbourne, Victoria https://www.veac.vic.gov.au/investigations-assessments/current-assessments/investigation/assessment-of-victoria-s-coastal-reserves Accessed 30 June 2021.

Victorian Environmental Water Holder 2016, 'Seasonal watering plan 2016-17', Melbourne, Victoria.

Victorian Fisheries Authority (VFA) 2017, '2016/17 Victorian abalone stock assessment – western zone', Victorian Fisheries Authority science report series no. 4, Melbourne, Victoria.

Victorian Fisheries Authority (VFA) 2017, '2016/17 Victorian abalone stock assessment – central zone', Victorian Fisheries Authority science report series no. 2, Melbourne, Victoria.

Victorian Fisheries Authority (VFA) 2017, 'Review of key Victorian fish stocks — 2017', Melbourne, Victoria.

Victorian Fisheries Authority (VFA) 2017, 'Victorian rock lobster fishery management plan 2017', Melbourne, Victoria.

Victorian Fisheries Authority (VFA) 2017, 'Victorian rock lobster fishery stock assessment report – 2019/20 Season', Melbourne, Victoria.

Victorian Fisheries Authority (VFA) 2018, 'Recreational fishing in Victoria. report of survey findings', Melbourne, Victoria.

Victorian Fisheries Authority (VFA) 2020, 'Review of key Victorian fish stocks — 2019'.

Victorian Fisheries Authority (VFA) 2020, 'Golden tags to lure fishers back to fire affected areas', 05 February 2020 https://vfa.vic.gov.au/about/news/golden-tags-to-lure-fishers-back-to-fire-affected-areas Accessed 18 November 2021.

Victorian Fisheries Authority (VFA) 2020, 'Recreational fishing licence trust account. a report to each house of parliament on the disbursement of recreational fishing licence revenue', Melbourne, Victoria.

Victorian Fisheries Authority (VFA) 2020, 'Target one million – phase 2', Melbourne, Victoria https://vfa.vic.gov.au/recreational-fishing/targetonemillion2/target-one-million Accessed 6 October 2020.

Victorian Fisheries Authority (VFA) 2021, 'Aquaculture' https://vfa.vic.gov.au/aquaculture Accessed 22 July 2021.

Victorian Fisheries Authority (VFA) 2021, 'Aquaculture management' https://vfa.vic.gov.au/aquaculture/aquaculture-management Accessed 22 July 2021.

Victorian Fisheries Authority (VFA) 2021, 'Compliance statistics 2019-2020' https://vfa.vic.gov.au/enforcement/enforcement-outcomes Accessed 12 March 2021.

References

Victorian Fisheries Authority (VFA) 2021, 'Promoting stewardship' https://vfa.vic.gov.au/education Accessed 12 March 2021.

Victorian Fisheries Authority (VFA) 2020, 'Gippsland Lakes is now net free' https://vfa.vic.gov.au/recreational-fishing/targetonemillion2/phase-out-of-commercial-netting-in-the-gippsland-lakes Accessed 18 August 2021.

Victorian Fisheries Authority (VFA), 'Eating your catch safely' https://vfa.vic.gov.au/recreational-fishing/recreational-fishing-guide/food-safety Accessed 19 February 2021.

Victorian Fisheries Authority (VFA), 'Scallop' https://vfa.vic.gov.au/commercial-fishing/commercial-fisheries/scallop Accessed 17 August 2021.

Victorian Fisheries Authority (VFA), various years, 'Recreational fishing licence trust account. a report to each house of parliament on the disbursement of recreational fishing licence revenue', Melbourne, Victoria.

Victorian Fisheries Corporation (VFA) 2020, 'Recreational rock lobster tagging program summary report 2020', Melbourne, Victoria https://vfa.vic.gov.au/__data/assets/pdf_file/0007/581488/FINAL_2018-19-VicRecRLTag_Summary-Report.pdf.

Victorian Fisheries Corporation (VFA) 2021, 'Rock lobster tagging program' https://vfa.vic.gov.au/recreational-fishing/tagging-of-recreationally-caught-rock-lobsters Accessed 4 March 2021.

Victorian Government 2016 'Independent Inquiry into the Environment Protection Authority', prepared for the Minister for Environment, Climate Change and Water, Melbourne, Victoria http://epa-inquiry.vic.gov.au/epa-inquiry-report Accessed 15 July 2021.

Victorian Government 2017, 'Andrews Labor Government response to the Independent Inquiry into the Environment Protection Authority', Melbourne, Victoria https://www.environment.vic.gov.au/__data/assets/pdf_file/0025/49741/Andrews-Labor-Government-Response-to-the-Independent-Inquiry-into-the-Environment-Protection-Aut.pdf.

Victorian Government 2020, 'Healthy waterways strategy 2018-2028, Port Phillip and Westernport, Victoria, Stormwater condition baseline and targets' https://healthywaterways.com.au/waterway-conditions/stormwater Accessed 22 July 2021.

Victorian Government, *Marine and Coastal Act 2018*, no. 26 of 2018, authorised version incorporating amendments as at 1 July 2021 https://content.legislation.vic.gov.au/sites/default/files/2021-06/18-26aa005%20authorised.pdf Accessed 6 July 2021.

Victorian Marine and Coastal Council (VMaCC) 2021, 'About us', Melbourne, Victoria https://www.marineandcoastalcouncil.vic.gov.au/about-us/about-the-council Accessed 19 March 2021.

Victorian Marine and Coastal Council (VMaCC) 2021, 'Science panel' Melbourne, Victoria https://www.marineandcoastalcouncil.vic.gov.au/about-us/science-panel Accessed 19 March 2021.

Victorian Marine and Coastal Council (VMaCC), 'Corner Inlet broadleaf seagrass restoration project' https://www.marineandcoastalcouncil.vic.gov.au/news-and-events/victorian-marine-and-coastal-awards/2020/corner-inlet-broadleaf-seagrass-restoration-project Accessed 14 August 2021.

Victorian National Parks Association (VNPA) 2019, 'Marine protected area review June 2019', Carlton, Victoria https://vnpa.org.au/wp-content/uploads/2020/08/VNPA-Marine-Protected-Area-Review-2019.pdf Accessed 19 May 2021.

Victorian National Parks Association (VNPA) 2020, '2019 Great Victorian fish count'.

Victorian National Parks Association (VNPA), 'ReefWatch' https://vnpa.org.au/programs/reefwatch/ Accessed 12 February 2021.

Victorian Parliament 2018, *Owners Corporations Amendment (Short-stay Accommodation) Act 2018*.

Victorian Planning Provisions 'Section 16.01-2S Housing Affordability', DELWP (Department of Environment, Land Water and Planning) East Melbourne, Victoria https://www.planning.vic.gov.au/schemes-and-amendments/browse-planning-scheme/planning-scheme?f.Scheme%7CplanningSchemeName=VPPS Accessed 6 May 2021.

Victorian Ports 2021, 'VPCM and VRCA to combine as Ports Victoria', article date 3 March 2021 https://www.vicports.vic.gov.au/News/Pages/ports-victoria-establishment.aspx Accessed 1 July 2021.

Wallbrink PJ, Hancock GJ, Olley JM, Hughes A, Prosser IP, Hunt D, Rooney G, Coleman R, Stevenson J 2003, 'The Westernport Sediment Study', Consultancy Report, CSIRO Land and Water.

Ware D and Thomson R 2005, 'Bottom-up ecosystem trophic dynamics determine fish production in the Northeast Pacific, *Science*, 308(5726), pp. 1280-1284.

Water Technology 2014, 'Report 1: summary report Gippsland Lakes/90 Mile Beach local coastal hazard assessment project', prepared for the Victorian Department of Environment and Primary Industries (DEPI) https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0015/415131/2363-01R01v09_Summary-Gipps-L.pdf Accessed 7 July 2020.

Water Technology 2014, 'Western Port local coastal hazard assessment report 1 (R01) – summary report', prepared for Melbourne Water https://www.mornpen.vic.gov.au/files/assets/public/new-website-documents/building-amp-planning/strategic-planning/docs/amendments-in-progress/c216/western-port-local-coastal-hazard-assessment-report-1-summary-report.pdf Accessed 7 July 2020.

Waters E, McKenzie F and Pendergast S 2012, 'Dealing with extremes. The Lake Boga follow-up study – report on findings', Department of Planning and Community Development (DPCD), Melbourne, Victoria.

Waters E, McKenzie F, McCarthy C and Pendergast S 2010, 'The drying lake. Lake Boga's experience of change and uncertainty', Department of Planning and Community Development (DPCD), Melbourne, Victoria.

Waves of Wellness https://www.foundationwow.org Accessed 4 March 2021.

Waycott M, Duarte C, Carruthers T, Orth R, Dennison W, Olyarnik S, Calladine A, Fourqurean J, Heck K, Hughes A, Kendrick G, Kenworthy W, Short F and Williams S 2009, 'Accelerating loss of seagrasses across the globe threatens coastal ecosystems', *Proceedings of the National Academy of Science USA*, 106, pp. 12377–81.

Webb J and Keough M 2002, 'Measurement of environmental trace-metal levels with transplanted mussels and diffusive gradients in thin films (DGT): a comparison of techniques', *Marine Pollution Bulletin*, 44, pp. 222-229.

Wernberg T, Campbell A, Coleman M, Connell S, Kendrick G, Moore P, Russell B, Smale D and Steinberg P 2009, 'Macroalgae and temperate rocky reefs', in CSIRO, 'Marine climate change in Australia. Impacts and adaptation responses. 2009 report card'.

Wernberg T, Thomsen M, Tuya F, Kendrick G, Staehr P and Toohey B 2010, 'Decreasing resilience of kelp beds along a latitudinal temperature gradient: potential implications for a warmer future', *Ecology Letters*, 13, pp. 685-694.

Werner AD 2010, 'A review of seawater intrusion and its management in Australia', *Hydrogeology Journal*, 18, pp. 281–285.

Werribee River Association 2015, 'The Werribee River – a stream of litter'.

Werribee River Association 2018, 'Our Werribee River – a water quality analysis report'.

West Gippsland Catchment Management Authority (WGCMA) 2008, 'Corner Inlet sediment and nutrient modelling final report', Traralgon, Victoria https://www.wgcma.vic.gov.au/wp-content/uploads/2019/08/Corner-Inlet-Sediment-and-Nutrient-Modelling-Final.pdf Accessed 23 February 2021.

West Gippsland Catchment Management Authority (WGCMA) 2013, 'Corner Inlet water quality improvement plan 2013', Traralgon, Victoria https://www.wgcma.vic.gov.au/wp-content/uploads/2019/08/WGCMA-Corner-Inlet-Water-Quality-Improvement-Plan-2013.pdf Accessed 20 July 2021.

West Gippsland Catchment Management Authority (WGCMA), 'Corner Inlet – a RAMSAR site, right in our backyard', Traralgon, Victoria https://www.wgcma.vic.gov.au/news/latest-news/corner-inlet-a-ramsar-site-right-in-our-backyard Accessed 19 July 2021.

West Gippsland Catchment Management Authority (WGCMA), 'Macalister farmers get serious about fertilisers', Traralgon, Victoria https://www.wgcma.vic.gov.au/news/latest-news/macalister-farmers-get-smart-about-fertilisers Accessed 20 July 2021.

Western Abalone Diver Association 2020, 'Assessment of abalone stocks in western zone Victoria: submission for the TAC setting process for 2020'.

References

Western Water 2018, 'Integrated water management developer guidance' https://www.westernwater.com.au/assets/volumes/general-downloads/iwm-developers-guidance.pdf Accessed 22 July 2021.

White M, Cheal D, Carr GW, Adair R, Blood K and Meagher D 2018, 'Advisory list of environmental weeds in Victoria', Arthur Rylah Institute for Environmental Research (ARI), technical report series no. 287, Department of Environment, Land, Water and Planning (DELWP), Heidelberg, Victoria.

White M, Weeks A, Hooper T, Bleakley L Cracknell D, Lovell R and Jefferson R 2017, 'Marine wildlife as an important component of coastal visits: the role of perceived biodiversity and species behaviour', *Marine Policy,* 78, pp. 80-89.

Who is OneWave? https://www.onewaveisallittakes.com/about Accessed 4 March 2021.

Wilkinson S, Anstee J, Joehnk K, Karim F, Lorenz Z, Glover M and Coleman R 2016, 'Western Port sediment supply and resuspension dynamics', report to Melbourne Water, CSIRO, Australia.

Winstanley R 1982, 'The fishery and stocks of blue mussel *Mytilis edulis planulatus* in Port Phillip Bay', Fisheries and Wildlife Victoria Division of Commercial Fisheries, report no. 5.

Witherington B and Martin R 2003, 'Understanding, assessing, and resolving light-pollution problems on sea turtle nesting beaches', Florida Fish and Wildlife Conservation Commission FMRI technical report TR-2, Jensen Beach, Florida.

Wong WW, Greening C, Shelley G, Lappan R, Leung PM, Kessler A, Winfrey B, Poh SC, and Cook P 2021, 'Effects of drift algae accumulation and nitrate loading on nitrogen cycling in a eutrophic coastal sediment', *Science of The Total Environment*, 790, 2021.

Woodland R, Thomson J, Mac Nally R, Reich P, Evrard V, Walker J and Cook P 2015, 'Nitrogen loads explain primary productivity in estuaries at the ecosystem scale', *Limnology and Oceanography*, 60, pp. 1751-1762.

Woods B and Edmunds M 2013, 'Victorian subtidal reef monitoring program: the reef biota at Merri marine sanctuary', Parks Victoria technical series no. 87, Melbourne, Victoria.

Woods B, Donnelly D and Edmunds M 2014, 'Victorian subtidal reef monitoring program: the reef biota at Point Cooke marine sanctuary', Parks Victoria technical paper series no. 93, Melbourne, Victoria.

Woods B, Edmunds M and Brown H 2014, 'Victorian subtidal reef monitoring program: The reef biota at Point Addis marine national park, June 2013', Parks Victoria technical series no. 94, Melbourne, Victoria.

Yang H, Chen B, Barter M, Piersma T, Zhou C, Li F, Zheng W, 2011, 'Impacts of tidal land reclamation in Bohai Bay, China: ongoing losses of critical Yellow Sea waterbird staging and wintering sites', *Bird Conservation International*, pp. 241-259.

Ziajahromi S, Neale P and Leusch F 2016, 'Wastewater treatment plant effluent as a source of microplastics: review of the fate, chemical interactions and potential risks to aquatic organisms', *Water Science and Technology,* 74, pp. 2253–2269.

Zoos Victoria 2013, 'Seal the loop 2012-2013 report', Melbourne, Victoria.

Appendix A

Commissioner *for* Environmental Sustainability Victoria

Granula seastar (U*niophora granifera*) and broadleaf seagrass (*Posidonia australis*), Corner Inlet Marine National Park
© Parks Victoria

Appendix A

In order of scientific name

Scientific name	Common Name
Acacia cupularis	Coastal umbrella-bush
Acacia longifolia	Sallow wattle
Acacia sophorae	Coastal wattle
Acanthopagrus butcheri	Black bream
Actinia tenebrosa	Red waratah anemone
Amphibolis antartica	Wire weed (aka sea nymph)
Anas castanea	Chestnut teal
Anas gracilis	Grey teal
Anas superciliosus	Pacific black duck
Anguilla australis	Short-finned eel
Anguilla reinhardtii	Long-finned eel
Anhinga novaehollandiae	Australasian darter
Anthothoe albocincta	White-striped anemone
Arctocephalus forsteri	New Zealand fur seal
Arctocephalus pusillus doriferus	Australian fur seal
Arctocephalus tropicalis	Subantarctic fur seal
Arcuatula senhousia	Asian bag mussel
Ardenna tenuirostris	Short-tailed shearwater
Arenaria interpres	Ruddy turnstone
Arripis trutta	Australian salmon
Asterias amurensis	Northern Pacific seastar
Astrostole scabra	New Zealand seastar
Aulactinia veratra	Green anemone
Austrocochlea porcata	Zebra top snail
Austromytilus rostratus	Beaked mussel
Avicennia marina	White mangrove
Avicennia marina var. australasica	Grey or white mangrove
Balaenopointera edeni	Brydes whale
Balaenopointera musculus	Blue whale
Balaenoptera acutorostrata	Minke whale
Bembicium nanum	Conniwink
Bugula neritina	Brown bryozoan (aka common bugula)
Calidris acuminata	Sharp-tailed sandpiper

Appendix A

Calidris canutus ..... Red knot
Calidris ferruginea ..... Curlew sandpiper
Calidris ruficollis ..... Red-necked stint
Caperea marginate ..... Pygmy right whale
Carcinus maenas ..... European green crab (aka European shore crab)
Caulerpa racemosa var. cylindracea ..... (species of algae)
Cellana tramoserica ..... Variegated limpet
Centrostephanus rodgersii ..... Long-spined sea urchin
Cereopsis novaehollandiae ..... Cape Barren goose
Chamaesipho tasmanica ..... Honeycomb barnacle
Charadrius bicinctus ..... Double-banded plover
Charadrius leschenaultii ..... Greater sand plover
Charadrius mongolus ..... Lesser sand plover
Charadrius ruficapillus ..... Red-capped plover
Chlidonius hybridus ..... Whiskered tern
Chroicocephalus novaehollandiae ..... Silver gull
Chrysophrys auratus ..... Snapper
Chthamalus antennatus ..... Eastern shore barnacle
Ciona intestinalis ..... Sea vase
Cladorhynchus leucocephalus ..... Banded stilt
Codium fragile subspecies fragile ..... Dead man's fingers
Cominella lineolata ..... Spotted cominella
Corymbia maculata ..... Spotted gum
Coscinasterias muricata ..... Eleven-arm seastar
Cygnus atratus ..... Black swan
Cyprinus carpio ..... European carp (aka common carp)
Delphinus delphis ..... Common dolphin
Diodon nicthemerus ..... Globefish
Donax deltoides ..... Pipi
Durvillaea potatorum ..... Bull kelp
Ecklonia radiata ..... Golden kelp
Egretta novaehollandiae ..... White-faced heron
Engraulis australis ..... Anchovy
Eubalaena australis ..... Southern right whale
Eudyptula minor ..... Little penguin

Appendix A

Galaxias brevipinnis ..... Climbing galaxias
Galaxias maculatus ..... Common galaxias
Galaxias truttaceous ..... Spotted galaxias
Galeolaria caespitosa ..... 'Sydney coral' tubeworm
Gelochelidon nilotica ..... Gull-billed tern
Girella zebra ..... Zebra fish
Goniodiscaster scaber ..... Biscuit seastar
Grateloupia turuturu ..... (species of algae)
Haematopus longirostris ..... Australian pied oystercatcher
Haliotis laevigata ..... Greenlip abalone
Haliotis rubra ..... Blacklip abalone
Heliocidaris erythrogramma ..... Short-spined sea urchin
Helmiselmis spp ..... (species of flagalette bacteria)
Hemigrapsus sanguineus ..... Asian shore crab
Hormosira banksii ..... Neptune's necklace (aka Neptune's pearls, sea grapes, bubbleweed)
Hydroprogne caspia ..... Caspian tern
Hydrurga leptonyx ..... Leopard seal
Jasus edwardsii ..... Southern rock lobster
Lagenorhynchus obscurus ..... Dusky dolphin
Larus pacificus ..... Pacific gull
Lepsiella vinosa ..... (species of shellfish)
Leptospermum laevigatum ..... Coastal tea tree
Limnoperna pulex ..... Black horse mussel (aka flea mussel, little horse mussel, little black horse mussel)
Limosa lapponica ..... Bar-tailed godwit
Lophopyrum ponticum ..... Tall wheat grass
Lunella undulata ..... Turban shell
Macroctopus maorum ..... Maori octopus
Macrocystis pyrifera ..... Giant kelp
Magallana gigas ..... Pacific oyster
Maoricolpus roseus ..... New Zealand screw shell
Megaptera novaeangliae ..... Humpback whale
Melaleuca ericifolia ..... Swamp paperbark
Meridiastra calcar ..... Carpet seastar (aka cushion seastar, eight-armed seastar)
Mirounga leonine ..... Southern elephant seal
Montfortula rugosa ..... Slit limpet

Appendix A

Myliobatis australis.....Southern eagle ray
Mytilis edulis.....Blue mussel
Neophema chrysogaster.....Orange-bellied parrot
Neophoca cinereal.....Australian sea lion
Nerita atramentosa.....Black nerite
Notolabrus fucicola.....Purple wrasse
Notoacmea spp......(species of limpet)
Notolabrus tetricus.....Blue throat wrasse
Numenius madagascariensis.....Eastern curlew
Numenius phaeopus.....Whimbrel
Octopus pallidus.....Pale octopus
Orcinus orca.....Killer whale
Ostrea angasi.....Native flat oyster
Oulactis muscosa.....Sand anemone
Parma victoriae.....Scalyfin
Patelloida alticostata.....Tall-ribbed limpet
Pecten fumatus.....Commercial scallop
Pelecanus conspicillatus.....Australian pelican
Phalacrocorax carbo.....Great cormorant
Phalacrocorax melanoleucos.....Little pied cormorant
Phalacrocorax sulcirostris.....Little black cormorant
Phalacrocorax varius.....Pied cormorant
Phragmites australis.....Common reed
Phyllospora comosa.....Crayweed
Plagioselmis prolonga.....(species of flagalette bacteria)
Platalea regla.....Royal spoonbill
Platycephalus bassensis.....Southern sand flathead
Platycephalus fuscus.....Dusky flathead
Platycephalus laevigatus.....Rock flathead
Pluvialis fulva.....Pacific golden plover
Poliocephalus poliocephalus.....Hoary-headed grebe
Porifera.....Sponges
Posidonia australis.....(species of seagrass)
Protroctes maraena.....Australian grayling
Pyura stolonifera.....Sea squirt

Appendix A

Recurvirostra novaehollandiae ..... Red-necked avocet
Ruppia spiralis ..... (species of seagrass)
Sabella spallanzanii ..... European fan worm
Sardinops sagax ..... Sardine
Sepioteuthis australis ..... Southern calamari
Sillaginodes punctatus ..... King George whiting
Siphonaria spp. ..... False limpet
Spartina anglica ..... Common cord grass (aka spartina)
Styela clava ..... Stalked ascidian
Styela plicata ..... Pleated sea squirt
Tadorna tadornides ..... Australian shelduck
Tesseropora rosea ..... Rose barnacle
Tetraclitella purpurascens ..... Purple four-plated barnacle
Thalasseus bergil ..... Crested tern
Threskiornis molucca ..... Australian white ibis
Threskiornis spinicollis ..... Straw-necked ibis
Tosia australis ..... Southern biscuit star
Trachinops caudimaculatus ..... Southern hulafish
Tringa brevipes ..... Grey-tailed tattler
Tringa nebularia ..... Common greenshank
Trygonoptera imitata ..... Eastern shovelnose stingaree
Tursiops australis ..... Burrunan dolphin
Tursiops truncates ..... Common bottlenose dolphin
Ulva spp ..... Green algae
Undaria pinnatifida ..... Wakame (aka Japanese kelp)
Vallisneria australis ..... Ribbonweed (aka eelweed)
Vanellus miles ..... Masked lapwing
Zostera mulleri ..... (species of seagrass)
Zostera nigricaulis ..... (species of eelgrass)

Appendix A

In order of common name

Common Name	Scientific name
Asian bag mussel	*Arcuatula senhousia*
Asian shore crab	*Hemigrapsus sanguineus*
Australasian darter	*Anhinga novaehollandiae*
Australian fur seal	*Arctocephalus pusillus doriferus*
Australian grayling	*Protroctes maraena*
Australian pelican	*Pelecanus conspicillatus*
Australian pied oystercatcher	*Haematopus longirostris*
Australian salmon	*Arripis trutta*
Australian sea lion	*Neophoca cinereal*
Australian shelduck	*Tadorna tadornides*
Australian white ibis	*Threskiornis molucca*
Banded stilt	*Cladorhynchus leucocephalus*
Bar-tailed godwit	*Limosa lapponica*
Beaked mussel	*Austromytilus rostratus*
Biscuit seastar	*Goniodiscaster scaber*
Black bream	*Acanthopagrus butcheri*
Black horse mussel	*Limnoperna pulex*
Black nerite	*Nerita atramentosa*
Black swan	*Cygnus atratus*
Blacklip abalone	*Haliotis rubra*
Blue mussel	*Mytilis edulis*
Blue throat wrasse	*Notolabrus tetricus*
Blue whale	*Balaenopointera musculus*
Brown bryozoan	*Bugula neritina*
Brydes whale	*Balaenopointera edeni*
Bubbleweed	see Neptune's necklace
Bull kelp	*Durvillaea potatorum*
Burrunan dolphin	*Tursiops australis*
Cape Barren goose	*Cereopsis novaehollandiae*
Carpet seastar	*Meridiastra calcar*
Caspian tern	*Hydroprogne caspia*
Chestnut teal	*Anas castanea*
Climbing galaxias	*Galaxias brevipinnis*

Appendix A

Coastal tea tree ..... *Leptospermum laevigatum*
Coastal umbrella-bush ..... *Acacia cupularis*
Coastal wattle ..... *Acacia sophorae*
Commercial scallop ..... *Pecten fumatus*
Common bottlenose dolphin ..... *Tursiops truncates*
Common bugula ..... see brown bryozoan
Common carp ..... see European carp
Common cord grass ..... *Spartina anglica*
Common dolphin ..... *Delphinus delphis*
Common galaxias ..... *Galaxias maculatus*
Common greenshank ..... *Tringa nebularia*
Common reed ..... *Phragmites australis*
Conniwink ..... *Bembicium nanum*
Crayweed ..... *Phyllospora comosa*
Crested tern ..... *Thalasseus bergil*
Curlew sandpiper ..... *Calidris ferruginea*
Cushion seastar ..... see carpet seastar
Dead man's fingers ..... *Codium fragile subspecies fragile*
Double-banded plover ..... *Charadrius bicinctus*
Dusky dolphin ..... *Lagenorhynchus obscurus*
Dusky flathead ..... *Platycephalus fuscus*
Eastern curlew ..... *Numenius madagascariensis*
Eastern shore barnacle ..... *Chthamalus antennatus*
Eastern shovelnose stingaree ..... *Trygonoptera imitate*
Eelweed ..... see ribbonweed
Eight-armed seastar ..... see carpet seastar
Eleven-arm seastar ..... *Coscinasterias muricata*
European carp ..... *Cyprinus carpio*
European fan worm ..... *Sabella spallanzanii*
European green crab ..... *Carcinus maenas*
European shore crab ..... see European green crab
False limpet ..... *Siphonaria spp.*
Flea mussel ..... see black horse mussel
Giant kelp ..... *Macrocystis pyrifera*
Globefish ..... *Diodon nicthemerus*

Appendix A

Golden kelp ..... *Ecklonia radiata*
Great cormorant ..... *Phalacrocorax carbo*
Greater sand plover ..... *Charadrius leschenaultii*
Green algae ..... *Ulva spp*
Green anemone ..... *Aulactinia veratra*
Greenlip abalone ..... *Haliotis laevigata*
Grey or white mangrove ..... *Avicennia marina var. australasica*
Grey teal ..... *Anas gracilis*
Grey-tailed tattler ..... *Tringa brevipes*
Gull-billed tern ..... *Gelochelidon nilotica*
Hoary-headed grebe ..... *Poliocephalus poliocephalus*
Honeycomb barnacle ..... *Chamaesipho tasmanica*
Humpback whale ..... *Megaptera novaeangliae*
Japanese kelp ..... see wakame
Killer whale ..... *Orcinus orca*
King George whiting ..... *Sillaginodes punctatus*
Leopard seal ..... *Hydrurga leptonyx*
Lesser sand plover ..... *Charadrius mongolus*
Little black cormorant ..... *Phalacrocorax sulcirostris*
Little black horse mussel ..... see black horse mussel
Little horse mussel ..... see black horse mussel
Little penguin ..... *Eudyptula minor*
Little pied cormorant ..... *Phalacrocorax melanoleucos*
Long-finned eel ..... *Anguilla reinhardtii*
Long-spined sea urchin ..... *Centrostephanus rodgersii*
Maori octopus ..... *Macroctopus maorum*
Masked lapwing ..... *Vanellus miles*
Minke whale ..... *Balaenoptera acutorostrata*
Native flat oyster ..... *Ostrea angasi*
Neptune's necklace ..... *Hormosira banksii*
Neptune's pearls ..... see Neptune's necklace
New Zealand fur seal ..... *Arctocephalus forsteri*
New Zealand screw shell ..... *Maoricolpus roseus*
New Zealand seastar ..... *Astrostole scabra*
Northern Pacific seastar ..... *Asterias amurensis*

Appendix A

Orange-bellied parrot ..... *Neophema chrysogaster*
Pacific black duck ..... *Anas superciliosus*
Pacific golden plover ..... *Pluvialis fulva*
Pacific gull ..... *Larus pacificus*
Pacific oyster ..... *Magallana gigas*
Pale octopus ..... *Octopus pallidus*
Pied cormorant ..... *Phalacrocorax varius*
Pipi ..... *Donax deltoides*
Pleated sea squirt ..... *Styela plicata*
Purple four-plated barnacle ..... *Tetraclitella purpurascens*
Purple wrasse ..... *Notolabrus fucicola*
Pygmy right whale ..... *Caperea marginate*
Red knot ..... *Calidris canutus*
Red waratah anemone ..... *Actinia tenebrosa*
Red-capped plover ..... *Charadrius ruficapillus*
Red-necked avocet ..... *Recurvirostra novaehollandiae*
Red-necked stint ..... *Calidris ruficollis*
Ribbonweed ..... *Vallisneria australis*
Rock flathead ..... *Platycephalus laevigatus*
Rose barnacle ..... *Tesseropora rosea*
Royal spoonbill ..... *Platalea regla*
Ruddy turnstone ..... *Arenaria interpres*
Sallow wattle ..... *Acacia longifolia*
Sand anemone ..... *Oulactis muscosa*
Sardine ..... *Sardinops sagax*
Scalyfin ..... *Parma victoriae*
Sea grapes ..... see Neptune's necklace
Sea nymph ..... see wire weed
Sea squirt ..... *Pyura stolonifera*
Sea vase ..... *Ciona intestinalis*
Sharp-tailed sandpiper ..... *Calidris acuminata*
Short-finned eel ..... *Anguilla australis*
Short-spined sea urchin ..... *Heliocidaris erythrogramma*
Short-tailed shearwater ..... *Ardenna tenuirostris*
Silver gull ..... *Chroicocephalus novaehollandiae*

Appendix A

Slit limpet ..... *Montfortula rugosa*
Snapper ..... *Chrysophrys auratus*
Southern biscuit star ..... *Tosia australis*
Southern calamari ..... *Sepioteuthis australis*
Southern eagle ray ..... *Myliobatis australis*
Southern elephant seal ..... *Mirounga leonine*
Southern hulafish ..... *Trachinops caudimaculatus*
Southern right whale ..... *Eubalaena australis*
Southern rock lobster ..... *Jasus edwardsii*
Southern sand flathead ..... *Platycephalus bassensis*
Spartina ..... see common cord grass
Sponges ..... *Porifera*
Spotted cominella ..... *Cominella lineolata*
Spotted galaxias ..... *Galaxias truttaceous*
Spotted gum ..... *Corymbia maculata*
Stalked ascidian ..... *Styela clava*
Straw-necked ibis ..... *Threskiornis spinicollis*
Subantarctic fur seal ..... *Arctocephalus tropicalis*
Swamp paperbark ..... *Melaleuca ericifolia*
'Sydney coral' tubeworm ..... *Galeolaria caespitosa*
Tall wheat grass ..... *Lophopyrum ponticum*
Tall-ribbed limpet ..... *Patelloida alticostata*
Turban shell ..... *Lunella undulata*
Variegated limpet ..... *Cellana tramoserica*
Wakame ..... *Undaria pinnatifida*
Whimbrel ..... *Numenius phaeopus*
Whiskered tern ..... *Chlidonius hybridus*
White mangrove ..... *Avicennia marina*
White-faced heron ..... *Egretta novaehollandiae*
White-striped anemone ..... *Anthothoe albocincta*
Wire weed ..... *Amphibolis antartica*
Zebra fish ..... *Girella zebra*
Zebra top snail ..... *Austrocochlea porcata*

Authorised by the Commissioner for Environmental Sustainability

Level 36, 2 Lonsdale Street
Melbourne, Victoria 3000

Accessibility

If you would like to receive this publication in an alternative format, please telephone the Commissioner for Environmental Sustainability office on 136186, email info.ces@ces.vic.gov.au or call 03 9948 2846, or via the National Relay Service on 133 677 www.relayservice.com.au. This document is also available on the internet at www.ces.vic.gov.au.

Disclaimer

This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

For further information contact:

Commissioner for Environmental Sustainability
Level 36, 2 Lonsdale Street
Melbourne Victoria 3000

Email: info.ces@ces.vic.gov.au
www.ces.vic.gov.au

ISBN (print): 978-0-6485069-5-9

ISBN (online): 978-0-6485069-7-3

Published by the Commissioner
for Environmental Sustainability,
Victoria, 2021

Level 36, 2 Lonsdale Street
Melbourne Victoria 3000

info.ces@ces.vic.gov.au
www.ces.vic.gov.au

Commissioner *for* Environmental Sustainability Victoria

VICTORIA State Government

RECYCLED CONTENT FOREST MANAGEMENT MANUFACTURED CARBON NEUTRAL ENVIRONMENTAL MANAGEMENT SYSTEMS BLEACHING PROCESS