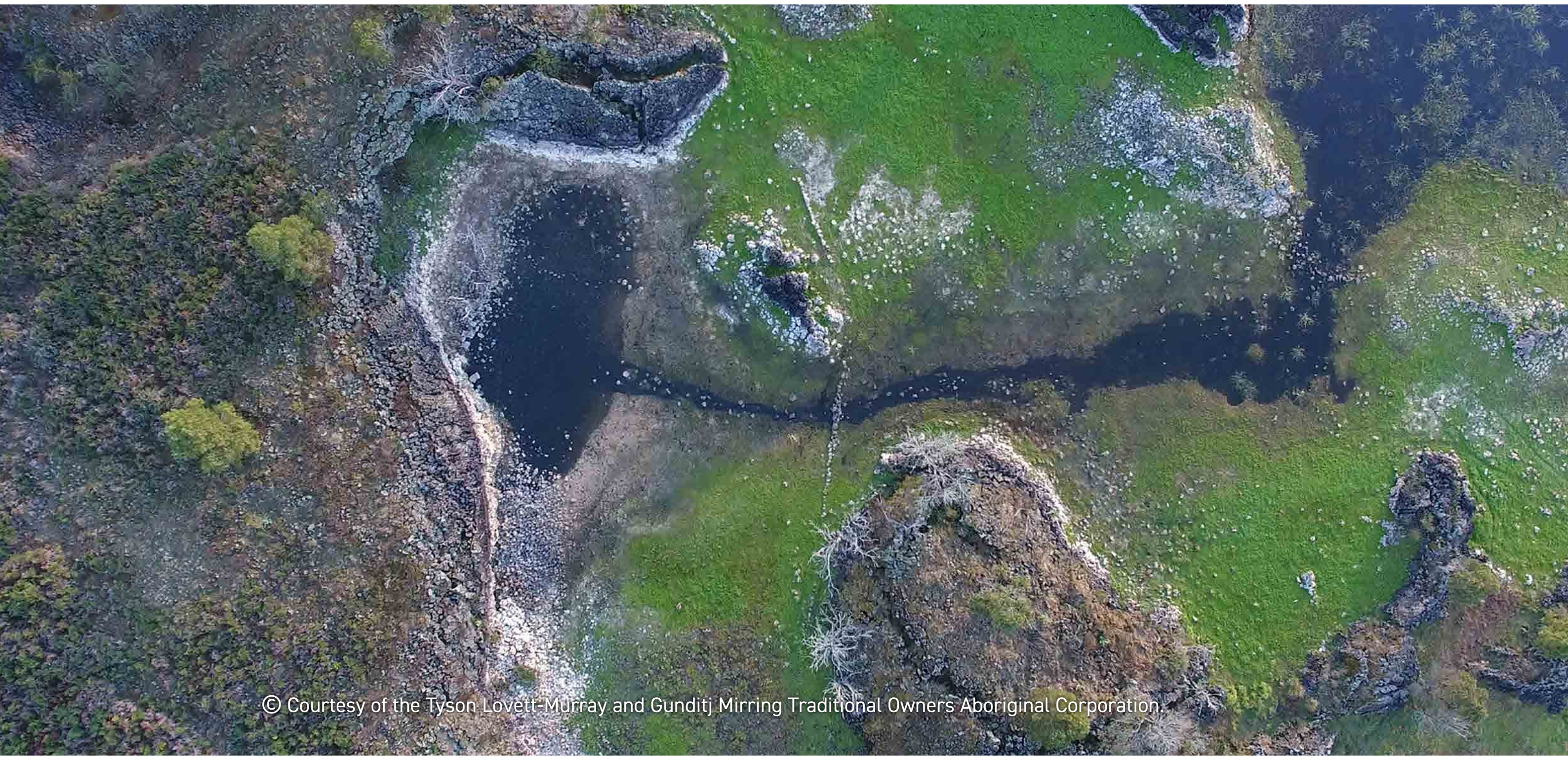
Commissioner
for Environmental
Sustainability
Victoria

Victorian State of the Environment 2023 Report
Summary Report

VICTORIA
State
Government



Aerial view of Tae Rak channel and holding pond, Budj Bim Cultural Landscape Gunditjmara Country of south-western Victoria. In 2019, Budj Bim Cultural Landscape became one of only 20 World Heritage sites in Australia listed by the United Nations Educational, Scientific and Cultural Organization (UNESCO).

The Budj Bim Cultural Landscape is the first Australian Aboriginal cultural site to be added exclusively for its cultural significance. Over the past 40 years, the Gunditjmara Traditional Owners have recovered ownership of several properties spanning the coastal aquaculture system, discovering the complexity of the network. At this site is evidence of sophisticated Aboriginal engineering practices. Budj Bim is a vast and complex aquaculture system consisting of constructed dams, ponds and channels designed to direct and store eels and other fish for routine harvesting. It is archaeologically dated at 6,600 years of continuous use. Budj Bim was built on principles of respect for Country and was constructed to support a concentrated population. It required precision in construction to manage water flow, and an in-depth understanding of natural processes. There are many known Aboriginal engineering sites around Australia.

Traditional Owners

We acknowledge and respect Victoria's Traditional Owners as the original custodians of Victoria's land and waters. We acknowledge their unique ability to care for Country and their deep spiritual connection to it.

We honour Elders past and present, whose knowledge and wisdom have ensured the continuation of culture and traditional practices.

Commissioner *for* Environmental Sustainability Victoria

COVER IMAGE © Parks Victoria.
Wilsons Promontory National Park Friends of the Prom volunteers, 2017.
Credit: Jessica Shapiro Photography.

Commissioner's foreword

Welcome to the Victorian State of the Environment (SoE) 2023 Report – Victoria's five-yearly report card on the health of our natural environment – our land, water, air and ecosystems. This report is a considered analysis of the available science and the pressures and challenges ahead. It tells three stories:

- the health of Victoria's natural environment
- the adequacy of our science
- areas for future focus.

The SoE 2023 Report marks the first time that a comprehensive scientific baseline analysis on Victoria's environment has been carried forward and re-evaluated in consecutive Victorian state of the environment reports. This continuity and maturation of state of the environment reporting in Victoria is enabling a systemic shift from reporting on 'what we know' to 'what we need to know'. The approach to reporting is authorised through the Framework for the Victorian State of the Environment 2023 Report — Science for Sustainable Development (the Framework), tabled in the Parliament of Victoria in 2020.

SoE 2023 reports on 139 indicators of environmental condition, which is fewer than the 170 indicators assessed in 2018 – due to the introduction of a standalone five-yearly Victorian State of the Marine and Coastal Environment (SMCE) Report under the *Marine and Coastal Act 2018*, negating the need for a marine and coastal environments chapter. However, and as a prelude to the first statewide SMCE report in 2024, the SMCE 2021 Report assesses five regions across Victoria and is available at www.ces.vic.gov.au/state-of-reports.

The SoE 2023 Report includes 171 trend assessments of the 139 indicators and reports that 33 are improving, 34 are stable, 60 are deteriorating and 44 are unclear. The table below provides a summary of the status, trend and data confidence assessments in this report.

The SoE 2023 Report is presented in three parts and includes 15 recommendations that are informed by the analyses presented in Parts 2 and 3 of the report. Part 1 summarises all findings and recommendations. Part 2 includes an analysis of the application of space and spatial technologies for better understanding and responses to biodiversity decline and other environmental challenges. Part 2 also delivers on my commitment to apply international frameworks – specifically the United Nations Sustainable Development Goals and System of Environmental Economic Accounting – to advance future state of environment reporting. Part 3 presents a detailed analysis of the 139 indicator assessments – the science that underpins this report card on the health of Victoria's natural environment.

The recommendations seek to support the Victorian Government to keep improving its environmental monitoring and management systems and capabilities during this decade and beyond. They build on the work underway following the SoE 2018 Report – where 19 of the report's 20 recommendations were supported in full, in part or in principle by the Victorian Government.

The SoE 2023 Report reveals that responding to biodiversity decline remains a big challenge for Victoria, with 32 of the 42 assessments either deteriorating since 2018 or unable to be assessed. The status of many indicators remains poor, deteriorating trends continue and data confidence in the assessments, including the new 'Threatened species' indicators is generally low. The 2019–20 bushfires further compounded Victoria's biodiversity challenges.

Proportion of status assessments (%)		Proportion of trend assessments (%)		Proportion of data confidence assessments (%)	
Good	12	Improving	19	High	49
Fair	32.5	Stable	20	Moderate	27
Poor	35.5	Deteriorating	35	Low	13
Unknown	20	Unclear	26	Insufficient	11

I make specific recommendations to counteract biodiversity decline and support the implementation of Victoria's biodiversity plan, Protecting Victoria's Environment – Biodiversity 2037. The recommendations include establishing safe havens to protect and restore critical habitats for nature and wildlife and exploring new ways of working, such as harnessing spatial information. Building on the success of Digital Twin Victoria - which uses data to answer new questions and make better data-led decisions related to Victoria's built assets – I recommend creating an environmental Digital Twin to better understand and manage our natural assets.

Also, in recognising the need to restore the knowledge system of Traditional Owners in Victoria and reflect the fundamental principle that traditional knowledge is owned by Traditional Owners, I recommend the Victorian Government resource and support Traditional Owners to implement a program of on-ground assessment and develop contemporary bio-cultural indicators consistent with Victorian policy and legislative obligations in, but not limited to, the *Great Ocean Road and Environs Protection Act 2020*.

The SoE 2023 Report reveals that Victoria's temperature increases, reported in the SoE 2018 Report, have continued. Victoria is getting warmer, is more fire-prone and can expect more extreme weather in the future. Only one of the 13 climate change indicators – annual net greenhouse gas emissions – has improved, and encouragingly recorded a 27% reduction for 2015 to 2020. Positive mitigation efforts are further supported by the energy indicators, with five of the six energy assessments improving compared with the 2018 assessments. Acknowledging the tools, policies and frameworks already in place, and work underway to support Victoria's response to climate change and transition to a low-carbon economy, I present a suite of potential future indicators designed as measures of improvements in climate change adaptation for SoE reporting. I also recommend the introduction of best-practice climate hazard decision support tools, better tracking to monitor progress of the development of renewable electricity, and the need to improve monitoring and reporting on Victoria's transition to a circular economy.

It is pleasing that 'Target 2: More than five million Victorians are acting for nature' in the state biodiversity plan has been achieved despite the challenges of the COVID-19 pandemic. We report that in 2021 an estimated 5.45 million Victorians acted for nature. In addition, citizen scientists continue to play a vital role in collecting biodiversity and other environmental data.

Good data, interrogated for understanding, is the foundation for evidence-based environmental policy, regulation and management. I welcome the Victorian Government's commitment to independent scientific reporting on the health of Victoria's environment, with eight new environmental condition reports tasked to the Commissioner since 2014. The next step is to develop environmental monitoring programs and capabilities commensurate with these new reporting obligations and establish a data integration strategy for state of the environment reporting.

This report has been prepared with the support and input of many talented and dedicated people. The model of reporting that I have adopted relies on codesign, consultation and collaboration with our partners and stakeholders throughout the reporting cycle – from indicator selection to data collection and expert review to stakeholder insight and feedback.

Sincere thanks to those individuals and organisations who, as members of the Commissioner's Reference Group and my government and non-government technical advisory groups, have generously volunteered their time and expertise over many years. These resolute members have consistently offered impeccable expert review of the scientific assessments in this report. Their guidance and feedback have been invaluable to delivering SoE 2023 and, indeed, the entire environmental condition reporting program since 2014. Thanks also to my exceptional team of science writers and administrative staff for a sustained effort throughout this five-yearly reporting cycle, which included the challenges we all experienced during the COVID-19 pandemic.

It is an honour to serve as Victoria's Commissioner for Environmental Sustainability. I am proud of our collective achievements to improve the impact of Victoria's state of the environment reporting program since 2014. Victoria has moved beyond traditional methods to continue to deliver independent, objective environmental condition reporting. This reporting aims to enable systemic improvement in our environment and helps facilitate ecologically sustainable development. I am pleased to present the Victorian SoE 2023 Report and hope that the findings and recommendations benefit Victoria's environment and communities for many years to come. I invite you to download the report, explore our interpretive website (www.ces.vic.gov.au) and keep in touch with our work through your preferred social media channels.

Thank you to everyone who has contributed to this report.

Dr Gillian Sparkes AM
Commissioner for Environmental Sustainability, Victoria

Salmon sun-orchid, Woowookarung Regional Park.

Acknowledgements

Sincere thanks to my dedicated team who, under the skilful guidance of Dr Scott Rawlings, Director of Science and Reporting and Michael Reid, Director of Office, have worked with me to prepare this report. I am extremely grateful for your commitment and expertise. Thanks also for your support leading our science writing and engagement teams through a collaborative reporting process where considerable effort is devoted to communicating and engaging with scientists from across the government, non-government and academic sectors and with other stakeholders and communities.

Heartfelt thanks go to the dedicated science writers and contributing authors of this report: Dr Kangmin Moon, Andy Marshall, Dr Celine Goulet, Chris Smyth, Professor Bruce Mountain, Professor Lauren Rickards, Jessica Keysers and FrontierSI colleagues, and Professor Abbas Rajabifard, Dr Soheil Sabri and team from the Centre for Spatial Data Infrastructures and Land Administration (University of Melbourne).

I am grateful to Professor Dave Griggs, Professor Rob Vertessy and Simon Molesworth AO KC for their valued expert advice.

Thanks to Claire Ruedin, Alex Warder and Emily Ross for creative and editorial support, and thanks to the many other individuals and organisations who have contributed to this SoE 2023 Report, including:

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Melbourne Water	Victorian Department of Families, Fairness and Housing
Municipal Association of Victoria	Victorian Department of Health (formerly Department of Health and Human Services)
Parks Victoria	Victorian Department of Jobs, Skills, Industry and Regions (formerly Department of Jobs, Precincts and Regions)
Recycling Victoria	Victorian Department of Transport and Planning (formerly Department of Transport)
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BirdLife Australia	Native Fish Australia
Bush Heritage Australia	The Nature Conservancy Australia
Conservation Volunteers Australia	The Royal Society of Victoria
Environment Victoria	Victorian Apiarists Association
Field Naturalists Club of Victoria	Victorian Farmers Federation
Friends of the Earth	Victorian National Parks Association
Greening Australia	Waterwatch Victoria
Invasive Species Council	Yarra Riverkeeper Association
Commonwealth agency reviewers	
Australian Bureau of Meteorology	Commonwealth Scientific and Industrial Research Organisation
Academic reviewers	
La Trobe University	University of Tasmania
University of Melbourne	

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**Part 3: Scientific Assessments consists of two volumes, each a separate document from the Summary Report.*

List of tables and figures

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About this report

Victoria's *Commissioner for Environmental Sustainability Act 2003* (CES Act) requires the Commissioner for Environmental Sustainability (CES) to 'prepare and submit to the Minister a periodical Report on the State of the Environment of Victoria prepared at intervals not exceeding five years'.

This Victorian State of the Environment (SoE) 2023 Report provides a comprehensive scientific baseline of the state of Victoria's environment, and a considered analysis of the available science on Victoria's environment and the pressures and challenges ahead. It incorporates the science and builds on the findings of the Victorian SoE 2018 Report. This evidence base enables the Commissioner to exercise the authority under the CES Act and to confidently recommend and prioritise actions to influence and inform the focus, effort and investment by the Victorian Government over the next decade and beyond to improve Victoria's environmental condition and outcomes.

SoE 2023 marks the first time that a comprehensive scientific baseline analysis on Victoria's environment has been carried forward and re-evaluated in consecutive Victorian state of the environment reports. The approach to reporting is authorised through the Framework for the Victorian State of the Environment 2023 Report Science for Sustainable Development (the Framework), tabled in the Parliament of Victoria in June 2020 as required by the CES Act.

The CES Act also requires that the Minister must, within 12 months of tabling this report in the Parliament of Victoria, cause a statement of the response by the Victorian Government to be laid before each House of the Parliament of Victoria, specifying the action (if any) proposed to be taken by the Victorian Government with respect to the recommendations.

Report structure

Indicators

This report contains scientific assessments for 139 indicators. There are fewer indicators in the SoE 2023 Report than the 170 indicators assessed in the SoE 2018 Report because the SoE 2023 Report does not report on marine and coastal environments. Victoria's *Marine and Coastal Act 2018* requires a standalone Victorian State of the Marine and Coastal Environment Report be prepared every five years, with the first report due in 2024. This accounts for a reduction of 24 indicators compared with the SoE 2018 Report.

Of the 139 SoE 2023 indicators, 99 are the same as the SoE 2018 indicators, 25 indicators from SoE 2018 were modified, and 15 are new.

Summary Report: Parts 1, 2A and 2B

Summary Report Part 1 begins with a summary of findings from the SoE 2023 Report, which includes the indicator assessment dashboard and key findings.

The dashboard provides a synopsis of the assessments for the SoE 2023 indicator suite as a whole and a summary report card for each indicator assessment by theme. The summary report card includes a traffic-light representation of the status, trend and data confidence as well as the region to which the indicator assessment applies to and the data source(s) used in the assessment.

Summary Report Part 1 also includes key findings from the scientific assessments presented in Part 3 as well as 15 recommendations that are informed by the analyses presented in Parts 2 and 3.

Summary Report Part 2A contains an analysis of the application of space and spatial technologies for better understanding and responding to biodiversity decline and other environmental challenges.

Summary Report Part 2B presents applications of two international frameworks – the United Nations (UN) Sustainable Development Goals (SDGs) and System of Environmental Economic Accounting (SEEA) – to advance future state of the environment reporting.

There are five appendices in the Summary Report:

- **Appendix A** includes more detail on spatial technologies and the opportunities they present to improve biodiversity and forests, mitigate climate change and improve air monitoring in Victoria.
- **Appendix B** is a comprehensive assessment of progress on selected UN SDG targets.
- **Appendix C** compares SoE 2018 and SoE 2023 indicator suites. It explains the modifications to the SoE 2018 indicators, which enabled:
  - a calibrated level of focus for assessing new and emerging environmental pressures
  - assessment of newly available data
  - greater alignment of indicator measures with policy targets to evaluate efficacy for improving environmental outcomes.
- **Appendix D** is a compilation of the full indicator assessment summary tables by theme.
- **Appendix E** contains the reference list for the Summary Report.

Scientific Assessments: Part 3

Part 3 consists of two volumes, each a separate document from the Summary Report, and presents the detailed scientific assessments for each of the 139 SoE 2023 indicators across 10 chapters:

- **Cultural landscape health and management**
- **Climate change**
  - Climate change impacts
  - Climate change mitigation
  - Climate change adaptation
- **Air**
- **Biodiversity**
- **Land**
- **Forests**
- **Fire**
- **Inland waters**
  - Water quality
  - Water resources
- **Energy**
- **Waste and resource recovery**

The following elements are presented in detail for each chapter:

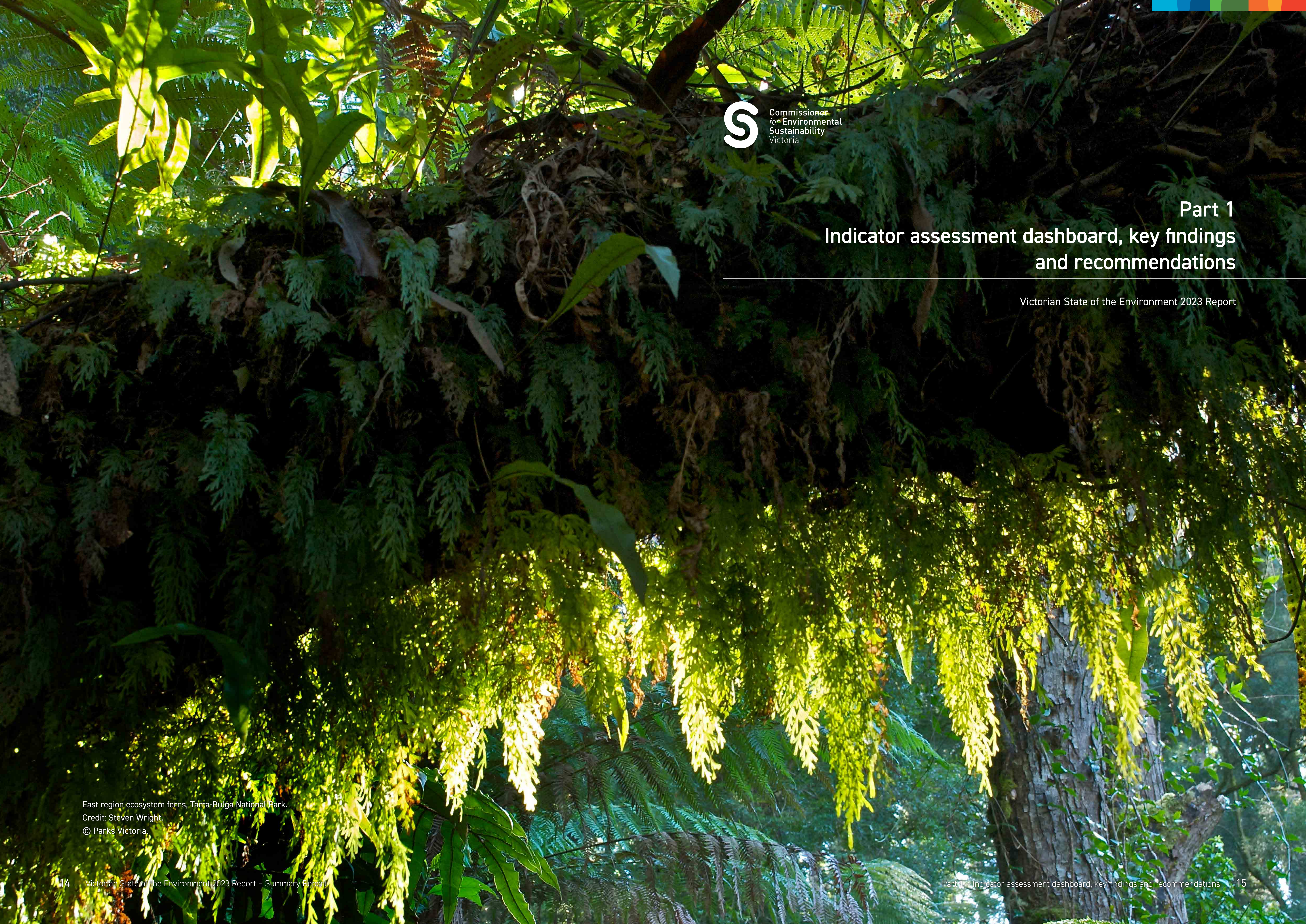
- summary and analysis of the key findings
- an overview of progress made by the Victorian Government against the SoE 2018 recommendation(s)
- background information, including relevant policy and legislative settings
- scientific assessments of the related indicators.

The scientific assessments rely on publicly available scientific data found in reports, journal articles, submissions to parliamentary and other government inquiries, citizen science projects and interviews. The data are assessed and synthesised by the CES science team, which is followed by a rigorous peer-review process by subject-area experts. The scientific assessments provide an evidence-based evaluation of Victoria's environmental health and progress on environmental sustainability, expressed through the 139 indicators.

Each indicator's scientific assessment includes:

- the indicator assessment report card, which presents:
  - the indicator's 2023 and 2018 traffic-light summary
  - the region covered by the indicator (statewide or a specific region(s))
  - the measures used to evaluate the status and trend
  - the data source(s)
  - the reason for assessing the indicator
  - the criteria used for determining the status of each indicator, where applicable
  - the rationale and summary of the indicator assessment
- a summary of the 2018 assessment
- the critical data used for the 2023 assessment
- a commentary to explain the 2023 assessment.

Koala in tree. French Island National Park.
Credit: Christian Pearson – Misheye.



Commissioner for Environmental Sustainability Victoria

Part 1
Indicator assessment dashboard, key findings and recommendations

Victorian State of the Environment 2023 Report

East region ecosystem ferns, Tarra-Bulga National Park.
Credit: Steven Wright.
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Indicator assessment dashboard

Indicator assessment overview

The indicator assessment dashboard provides a high-level overview of the status, trend and data confidence assessments for all 139 SoE 2023 indicators followed by a summary of the indicator assessment report cards detailed in Appendix D. Because some indicators have multiple assessments – for example, for multiple regions or for different environmental conditions (years with and without bushfires for instance) – the total number of assessments exceeds the total number of indicators. A total of 166 status assessments, 171 trend assessments and 172 data confidence assessments were conducted for the 139 SoE 2023 indicator suite.

Overall summary of status assessments

Table 1: Summary of status assessments for SoE 2023 indicators.

Status	Good	Fair	Poor	Unknown	Total
Climate change	0	5	6	0	11
Air	5	8	5	4	22
Biodiversity	1	6	26	9	42
Land	2	4	1	4	11
Forests	3	9	6	8	26
Fire	0	2	3	0	5
Inland waters	8	15	6	8	37
Energy	1	3	2	0	6
Waste and resource recovery	0	2	4	0	6
Total	**20**	**54**	**59**	**33**	**166**
%	**12**	**32.5**	**35.5**	**20**	**100**

Note: Six assessments have 'not applicable' as the status and are not included.

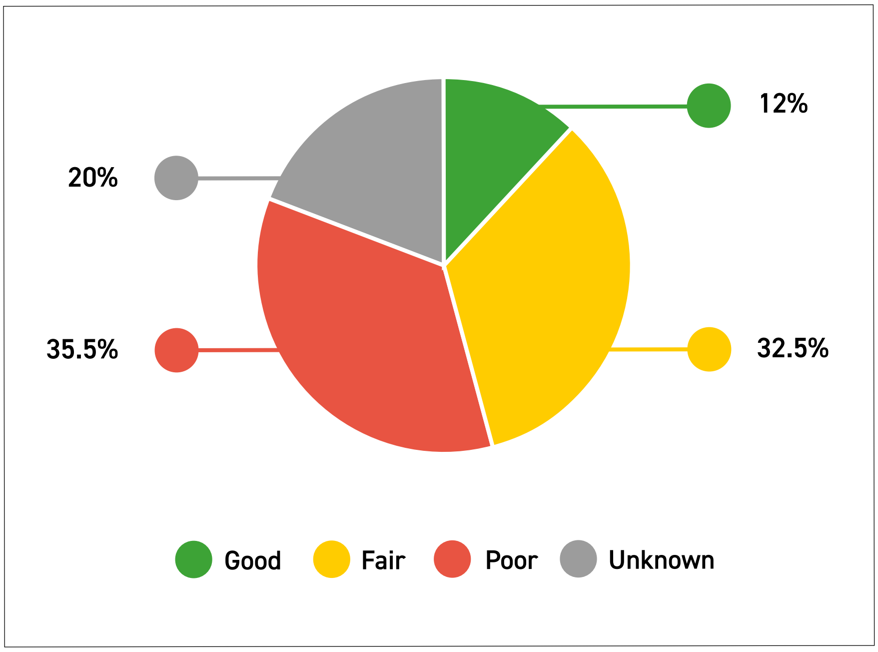

Figure 1: Breakdown of status assessments for SoE 2023 indicators.

Overall summary of trend assessments

Table 2: Summary of trend assessments for SoE 2023 indicators.

Trend	Improving	Stable	Deteriorating	Unclear	Total
Climate change	1	3	9	2	**15**
Air	1	9	3	9	**22**
Biodiversity	2	8	20	12	**42**
Land	3	1	1	7	**12**
Forests	5	1	11	9	**26**
Fire	0	1	4	0	**5**
Inland waters	16	8	10	3	**37**
Energy	5	1	0	0	**6**
Waste and resource recovery	0	2	2	2	**6**
Total	**33**	**34**	**60**	**44**	**171**
%	**19**	**20**	**35**	**26**	**100**

Note: One indicator, 'L:01 Land-cover classes in Victoria', was not applicable for a trend assessment and is not included.

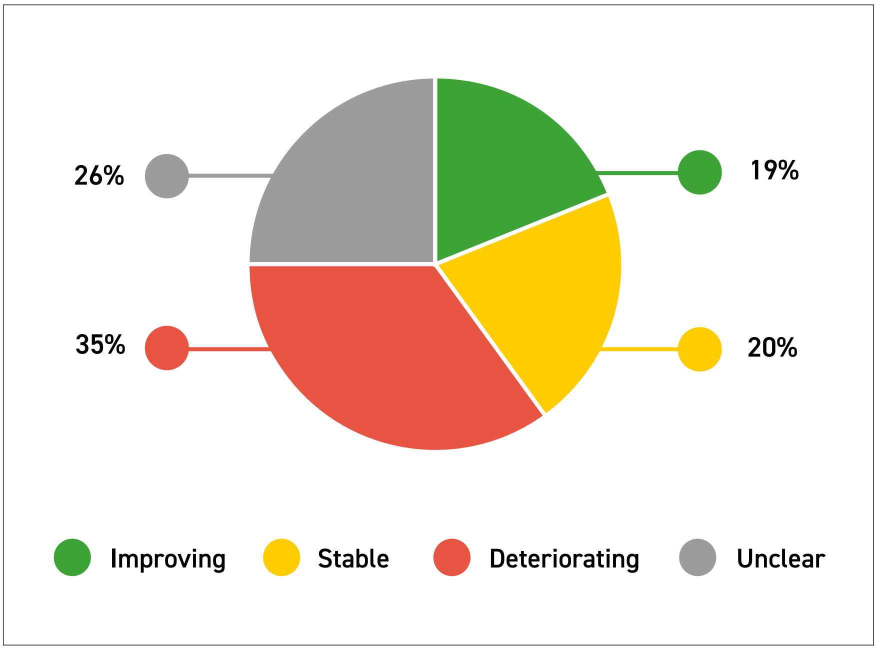

Figure 2: Breakdown of trend assessments for SoE 2023 indicators.

Overall summary of confidence assessments

Table 3: Summary of data confidence assessments for SoE 2023 indicators.

Data confidence	High	Moderate	Low	Insufficient	Total
Climate change	11	3	1	0	**15**
Air	11	6	5	0	**22**
Biodiversity	11	18	4	9	**42**
Land	2	2	3	6	**13**
Forests	10	10	6	0	**26**
Fire	4	1	0	0	**5**
Inland waters	29	4	0	4	**37**
Energy	6	0	0	0	**6**
Waste and resource recovery	0	2	4	0	**6**
Total	**84**	**46**	**23**	**19**	**172**
%	**49**	**27**	**13**	**11**	**100**

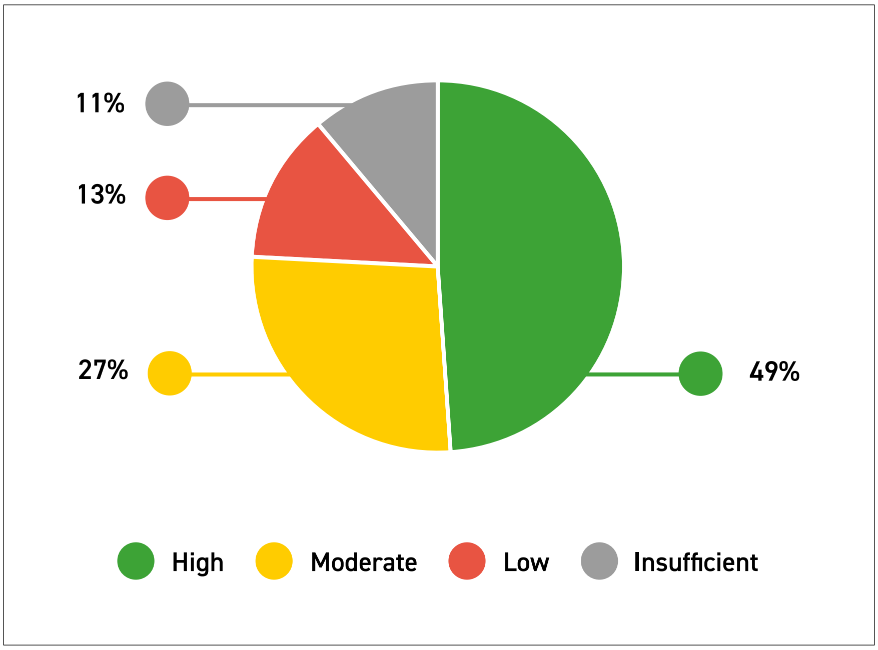

Figure 3: Breakdown of data confidence assessments for SoE 2023 indicators.

Indicator assessment report card summaries

The colour and symbol keys for the assessments are as follows:

Key to status

Good	Fair	Poor	Unknown	N/A Not applicable	N Narrative but not assessed

Key to trend

Improving	Stable	Deteriorating	? Unclear	N/A Not applicable	N Narrative but not assessed

Key to confidence

High	Moderate	Low	Insufficient	N/A Not applicable	N Narrative but not assessed

Cultural landscape health and management

No indicator assessments have been undertaken for this theme

Climate change — Impacts

CCIm:01 Observed surface temperature

Region(s)	2023 status	2023 trend	2023 confidence
Statewide		↙	
Data source(s):	BOM		

CCIm:02 Observed average rainfall

Region(s)	2023 status	2023 trend	2023 confidence
Statewide		↙	
Data source(s):	BOM		

CCIm:03 Snow cover

Region(s)	2023 status	2023 trend	2023 confidence
Falls Creek, Mount Buller, Mount Hotham		→	
Mount Baw Baw, Lake Mountain		↙	
Data source(s):	Academic researchers, DELWP		

CCIm:04 Sea level and coastal inundation

Region(s)	2023 status	2023 trend	2023 confidence
Victoria's coastline		↙	
Data source(s):	BOM		

CCIm:05 Sea-surface temperature

Region(s)	2023 status	2023 trend	2023 confidence
Victoria's marine environment		→	
Data source(s):	BOM, CSIRO		

CCIm:06 Projected changes in temperature

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	N/A	↙	
Data source(s):	BOM, CSIRO		

CCIm:07 Projected changes to average rainfall

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	N/A	↙	🟢
Data source(s):	BOM, CSIRO		

CCIm:08 Regional climate projections

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	N/A	↙	🟢
Data source(s):	BOM, CSIRO, DELWP		

CCIm:09 Projected sea level

Region(s)	2023 status	2023 trend	2023 confidence
Victoria's coastline	N/A	↙	🟢
Data source(s):	BOM, CSIRO		

CCIm:10 Occurrence and impacts of extreme weather

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🔴	↙	🟢
Data source(s):	Australian Institute for Disaster Resilience, BOM, CSIRO, Deloitte Access Economics, DOH, Insurance Council of Australia		

Climate change — Mitigation

CCM:11 Annual greenhouse gas emissions

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🟡	↗	🟢
Data source(s):	ABS, DCCEEW		

CCM:12 Victorian ecosystem carbon stocks

Region(s)	2023 status	2023 trend	2023 confidence
Land sector	🟡	?	🔴
Marine and coastal sector	🔴	?	🟡
Data source(s):	Academic researchers, DELWP		

CCM:13 Stratospheric ozone

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🟡	→	🟢
Data source(s):	BOM, CSIRO		

Climate change — Adaptation

No indicator assessments have been undertaken for this theme

Air

A:01 Particle pollution ($PM_{2.5}$ and PM_{10})

Region(s)	2023 status	2023 trend	2023 confidence
Geelong		→	
Latrobe Valley and Melbourne		→	
Elsewhere across Victoria		→	
Data source(s):	EPA Victoria		

A:02 Ambient ozone levels

Region(s)	2023 status	2023 trend	2023 confidence
Latrobe Valley		→	
Geelong and Melbourne		→	
Data source(s):	EPA Victoria		

A:03 Carbon monoxide

Region(s)	2023 status	2023 trend	2023 confidence
Statewide		→	
Data source(s):	EPA Victoria		

A:04 Nitrogen dioxide

Region(s)	2023 status	2023 trend	2023 confidence
Statewide		↗ (Melbourne)	
Statewide		→ (Geelong and Latrobe Valley)	
Data source(s):	EPA Victoria		

A:05 Sulfur dioxide

Region(s)	2023 status	2023 trend	2023 confidence
Statewide		→	
Data source(s):	EPA Victoria		

A:06 Population exposure to air pollution

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🔴 (years with significant bushfires)	?	🟢
Statewide	🟡 (other years)	?	🟢
Data source(s):	EPA Victoria		

A:07 Pollen

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🔴	↙	🟡
Data source(s):	University of Melbourne		

A:08 Odour

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🟡	→	🟡
Data source(s):	EPA Victoria		

A:09 Noise

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🟡	↙	🟡
Data source(s):	EPA Victoria		

A:10 Light pollution

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	⚪	↙	🟡
Data source(s):	Academic researchers		

A:11 Health impacts of air pollution

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🔴	?	🟢
Data source(s):	Academic researchers, EPA Victoria		

A:12 Health impacts of noise pollution

Region(s)	2023 status	2023 trend	2023 confidence
Melbourne	🟡	?	🔴
Rest of Victoria	⚪	?	🔴
Data source(s):	Academic researchers		

A:13 Indoor air quality

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🟡 (schools and aged care facilities)	?	🟡
Statewide	🔴 (residential buildings during periods of bushfire smoke)	?	🔴
Statewide	⚪ (all other scenarios)	?	🔴
Data source(s):	Academic researchers		

A:14 Health impacts from pollen

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🟡	?	🟡
Data source(s):	ABS, academic researchers		

Biodiversity

B:01 Changes in land cover

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🔴	?	🟢
Data source(s):	DELWP		

B:02 Wetlands

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🔴	↙	🟡
Data source(s):	DELWP		

B:03 Health and status of Victorian inland Ramsar wetlands

Region(s)	2023 status	2023 trend	2023 confidence
Inland Ramsar sites: Barmah Forest, Edithvale Seaford wetlands Gunbower Forest, Hattah-Kulkyne Lakes, Kerang Wetlands, Lake Albacutya, Western District Lakes	🟡	↗	🟢
Data source(s):	DELWP, PV, Melbourne Water		

B:04 Groundwater-dependent ecosystems

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	⚪	?	⚪
Data source(s):	DELWP, Melbourne Water, CSIRO		

B:05 Rivers

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🔴	→	🟡
Data source(s):	CMAs, DELWP		

B:06 Riparian vegetation

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🔴	→	🟡
CMA and local reaches level	🔴	↗	🟡
Data source(s):	DELWP, VEAC		

B:07 Floodplains

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🔴	→	🟡
Data source(s):	DELWP, VEAC		

B:08 Grasslands

Region(s)	2023 status	2023 trend	2023 confidence
Victorian Volcanic Plain, Wimmera Plain, Gippsland Plain and Warrnambool Plain bioregions	🔴	↙	🟢
Data source(s):	DELWP, Grassy Plains Network, VEAC		

B:09 Alpine

Region(s)	2023 status	2023 trend	2023 confidence
Victorian Alps bioregion	🟡	↙	🟡
Data source(s):	DELWP, VEAC		

B:10 Mallee

Region(s)	2023 status	2023 trend	2023 confidence
Lowan Mallee and Murray Mallee bioregions	🟡	→	🟡
Data source(s):	DELWP, PV, VEAC		

B:11 Heathlands

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🟡	→	🟡
Data source(s):	DELWP, VEAC		

B:12 Threatened terrestrial and freshwater mammals

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🔴	↙	🟢
Data source(s):	DELWP		

B:13 Threatened wetland-dependent species

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🔴	↙	🟡
Data source(s):	DELWP		

B:14 Threatened terrestrial bird species

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🔴	↙	🟢
Data source(s):	DELWP		

B:15 Waterbird species in the Murray–Darling Basin

Region(s)	2023 status	2023 trend	2023 confidence
Southern Murray-Darling Basin	🔴	↙	🟢
Data source(s):	DELWP, Centre for Ecosystem Science		

B:16 Threatened terrestrial and wetland reptile species

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🔴	↙	🟡
Data source(s):	DELWP		

B:17 Threatened large-bodied freshwater fish species

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🔴	↙	🟡
Data source(s):	DELWP		

B:18 Threatened small-bodied freshwater fish species

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🔴	↙	🟡
Data source(s):	DELWP		

B:19 Threatened frog species			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide	🔴	↙	🟡
Data source(s):	DELWP		

B:20 Threatened freshwater invertebrate species			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide	🔴	↙	🔴
Data source(s):	DELWP		

B:21 Threatened terrestrial invertebrate species			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide	🔴	↙	🔴
Data source(s):	DELWP		

B:22 Threatened terrestrial vascular plant species			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide	🔴	↙	🟡
Data source(s):	DELWP		

B:23 Threatened terrestrial fungi, lichen, moss and liverwort species			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide	🔴	?	🔴
Data source(s):	DELWP		

B:24 Invasive freshwater plant species			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide	⚪	?	⚪
Data source(s):	DELWP		

B:25 Invasive freshwater animal species			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide	🔴	↙	🟡
Data source(s):	AgVic, DELWP		

B:26 Trend in carp			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide	🔴	↙	🟢
Data source(s):	DELWP		

B:27 Invasive terrestrial plant species			
Region(s)	2023 status	2023 trend	2023 confidence
Statewide		↙	
Data source(s):	AgVic, DELWP		

B:28 Priority weed control			
Region(s)	2023 status	2023 trend	2023 confidence
Statewide		?	
Data source(s):	DELWP		

B:29 Invasive terrestrial herbivore species			
Region(s)	2023 status	2023 trend	2023 confidence
Statewide		↙	
Data source(s):	AgVic, DELWP		

B:30 Priority pest herbivore control			
Region(s)	2023 status	2023 trend	2023 confidence
Statewide		?	
Data source(s):	DELWP		

B:31 Invasive terrestrial predator species			
Region(s)	2023 status	2023 trend	2023 confidence
Statewide		↙	
Data source(s):	AgVic, DELWP		

B:32 Priority pest predator control			
Region(s)	2023 status	2023 trend	2023 confidence
Statewide		?	
Data source(s):	DELWP		

B:33 Net gain in the extent and condition of native vegetation			
Region(s)	2023 status	2023 trend	2023 confidence
Statewide		↙	
Data source(s):	DELWP		

B:34 Change in suitable habitat for threatened native species			
Region(s)	2023 status	2023 trend	2023 confidence
Statewide		?	
Data source(s):	DELWP		

B:35 Climate-sensitive ecosystems			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide		?	
Data source(s):	DELWP		

B:36 New, permanently protected areas on private land			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide		?	
Data source(s):	DELWP, Trust for Nature		

B:37 The conservation of Victorian ecosystems on public land			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide		→	
Data source(s):	DELWP, PV		

B:38 Priority revegetation			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide		?	
Data source(s):	DELWP		

B:39 Victorians value nature			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide	(Target 1: All Victorians are connected to nature)	→	
Statewide	(Target 2: More than 5 million Victorians acting for nature)	→	
Data source(s):	DELWP		

B:40 Number of Victorian Government organisations that manage environmental assets that contribute to DELWP Standard Output Data			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide		?	
Data source(s):	DELWP		

Land

L:01 Land-cover classes in Victoria

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	N/A	N/A	
Data source(s):	AgVic, DELWP		

L:02 Changes in Victoria's land-cover classes

Region(s)	2023 status	2023 trend	2023 confidence
Statewide		?	
Data source(s):	AgVic, DELWP		

L:03 Changes in land tenure

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	N/A	→	
Data source(s):	DELWP		

L:04 Greenfield and infill development in Melbourne

Region(s)	2023 status	2023 trend	2023 confidence
Melbourne metropolitan area		↙	
Data source(s):	DTP, IV		

L:05 Soil organic carbon storage

Region(s)	2023 status	2023 trend	2023 confidence
Statewide		?	
Data source(s):	AgVic		

L:06 Area affected by dryland salinity

Region(s)	2023 status	2023 trend	2023 confidence
Murray River catchment		↗	
Elsewhere across Victoria		?	
Data source(s):	AgVic, DELWP		

L:07 Soil acidification

Region(s)	2023 status	2023 trend	2023 confidence
Statewide		?	
Data source(s):	AgVic		

L:08 Soil erosion

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	(wind)	?	
Statewide	(water)	?	
Data source(s):	AgVic, National Landcare Project		

L:09 Contaminated sites

Region(s)	2023 status	2023 trend	2023 confidence
Statewide		?	
Data source(s):	DELWP, EPA Victoria		

L:10 Participation in natural resource management activities

Region(s)	2023 status	2023 trend	2023 confidence
Statewide		↗	
Data source(s):	CMAs, Landcare, PV		

L:11 Use of best practice for sustainability outcomes on agricultural lands

Region(s)	2023 status	2023 trend	2023 confidence
Statewide		↗	
Data source(s):	DELWP		

Forests

Fo:01A Area of forest by type and tenure — forest canopy cover

Region(s)	2023 status	2023 trend	2023 confidence
Statewide		?	
Data source(s):	DELWP		

Fo:01B Area of forest by type and tenure — forest type

Region(s)	2023 status	2023 trend	2023 confidence
Statewide		?	
Data source(s):	DELWP		

Fo:01C Area of forest by type and tenure — plantation forest

Region(s)	2023 status	2023 trend	2023 confidence
Statewide		↙	
Data source(s):	ABS		

Fo:02 Area of forest type by growth stage

Region(s)	2023 status	2023 trend	2023 confidence
Statewide		?	
Data source(s):	DELWP		

Fo:03 Area of forest type by growth stage distribution in protected zones

Region(s)	2023 status	2023 trend	2023 confidence
Statewide		↗	
Data source(s):	CAPAD, DELWP		

Fo:04 Fragmentation of native forest cover

Region(s)	2023 status	2023 trend	2023 confidence
Statewide		↙	
Data source(s):	DELWP		

Fo:05 Number of in-situ and ex-situ conservation efforts for forest-dependent species

Region(s)	2023 status	2023 trend	2023 confidence
Statewide		?	
Data source(s):	DELWP, VicForests, Zoos Victoria		

Fo:06 The status of forest-dependent species at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide	🔴	↙	🟢
Data source(s):	DELWP		

Fo:07 Degree of disturbance to native forest species caused by invasive species			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide	🟡	?	🟡
Data source(s):	DELWP		

Fo:08A Scale and impact of agents and processes affecting forest health and vitality — mortality, dieback, canopy health			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide	⚪	?	🟡
Data source(s):	DELWP		

Fo:08B Scale and impact of agents and processes affecting forest health and vitality — bushfire-affected area and climate			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide	🔴	↙	🟢
Data source(s):	DELWP		

Fo:09A Area and type of human-induced disturbance — planned burns			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide	🟡	↙	🟢
Data source(s):	DELWP		

Fo:09B Area and type of human-induced disturbance — grazing			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide	⚪	↗	🔴
Data source(s):	ABS		

Fo:10 Total forest ecosystem biomass and carbon pool by forest type, age class and successional stages			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide	⚪	?	🔴
Data source(s):	DELWP		

Fo:11 Contribution of forest ecosystems to the global greenhouse gas balance			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide	🟢	↗	🟢
Data source(s):	DCCEEW, DELWP		

Fo:12 Area and percentage of forest and net area of forest available and suitable for wood production			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide	🟡	↙	🟢
Data source(s):	DJPR		

Fo:13 Area of native forest harvested			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide	🟡	→	🟢
Data source(s):	DJPR		

Fo:14 Annual production of wood products from state forests compared to sustainable harvest levels			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide	🟢 (wood products) ⚪ (firewood)	↙ (wood products) ↙ (firewood)	🟢 (wood products) 🟡 (firewood)
Data source(s):	VicForests		

Fo:15 Proportion of timber harvest area successfully regenerated by forest type			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide	🔴	↙	🟡
Data source(s):	DJPR, VicForests		

Fo:16 Extent to which the legal framework (laws, regulations, guidelines) supports the conservation and sustainable management of forests			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide	🟡	↗	🟡
Data source(s):	ARV, DELWP, DJCS, DJPR, DPC, DTP, GORCP Authority, PV, VPC		

Fo:17 Extent to which the institutional framework supports the conservation and sustainable management of forests			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide	🟡	↙	🟢
Data source(s):	DELWP		

Fo:18 Extent to which the economic framework supports the conservation and sustainable management of forests			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide		?	
Data source(s):	DELWP		

Fo:19 Capacity to conduct and apply research and development aimed at improving forest management, including development of scientific understanding of forest ecosystem characteristics and functions			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide		↗	
Data source(s):	DELWP		

Fo:20 Investment and expenditure in forest management			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide		↙	
Data source(s):	DELWP, VicForests		

Fo:21 Value ($) of forest derived ecosystem services			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide		?	
Data source(s):	DELWP		

Fire

Fi:01 Area of native vegetation burnt in planned fires and bushfires

Region(s)	2023 status	2023 trend	2023 confidence
Statewide (bushfire)	🔴	↙	🟢
Statewide (planned burn)	🟡	→	🟢
Data source(s):	DELWP		

Fi:02 Impacts of bushfires

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🔴	↙	🟢
Data source(s):	DJPR, Inspector-General of Emergency Management, Insurance Council of Australia		

Fi:03 Actual fire regimes compared to optimal fire regimes in public forests

Region(s)	2023 status	2023 trend	2023 confidence
Statewide (public forests)	🔴	↙	🟡
Data source(s):	DELWP		

Fi:04 Bushfire risk

Region(s)	2023 status	2023 trend	2023 confidence
Statewide (public forests)	🟡	↙	🟢
Data source(s):	DELWP		

Inland waters — Water quality

WQ:01 Occurrence of algal blooms

Region(s)	2023 status	2023 trend	2023 confidence
Statewide		↙	
Data source(s):	DELWP		

WQ:02 Dissolved oxygen concentrations in rivers

Region(s)	2023 status	2023 trend	2023 confidence
CMAs		→	
Data source(s):	DELWP		

WQ:03 Salinity concentrations in rivers

Region(s)	2023 status	2023 trend	2023 confidence
CMAs	(7 CMAs)	→	
CMAs	(2 CMAs)	→	
CMAs	(1 CMA)	→	
Data source(s):	DELWP		

WQ:04 Total nitrogen concentrations in rivers

Region(s)	2023 status	2023 trend	2023 confidence
CMAs	(3-4 CMAs)*	↗	
CMAs	(3 CMAs)	↗	
CMAs	(3-2 CMAs)*	↗	
CMAs	(Mallee CMA)	↗	
Data source(s):	DELWP		

**The first figure presented in brackets refers to the number of CMAs whose status was based on 2010–17 data and the second figure presented in brackets refers to the number of CMAs based on 2018–21 data.*

WQ:05 Total phosphorus concentrations in rivers

Region(s)	2023 status	2023 trend	2023 confidence
CMAs	(2-4 CMAs)*		
CMAs	(4 CMAs)		
CMAs	(3-1 CMAs)*		
CMAs	(Mallee CMA)		
Data source(s):	DELWP		

WQ:06 Turbidity levels in rivers

Region(s)	2023 status	2023 trend	2023 confidence
CMAs	(5-10 CMAs)*		
CMAs	(5-0 CMAs)*		
Data source(s):	DELWP		

WQ:07 pH levels in rivers

Region(s)	2023 status	2023 trend	2023 confidence
CMAs	(10-7 CMAs)*		
CMAs	(0-2 CMAs)*		
CMAs	(1 CMA)		
Data source(s):	DELWP		

**The first figure presented in brackets refers to the number of CMAs whose status was based on 2010–17 data and the second figure presented in brackets refers to the number of CMAs based on 2018–21 data.*

WQ:08 Proportion of water bodies with good ambient water quality			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
CMAs	(2-1 CMAs)*		
CMAs	(3-8 CMAs)*		
CMAs	(4-0 CMAs)*		
CMAs	(Mallee CMA)		
Data source(s):	DELWP, EPA Victoria, Melbourne Water		

WQ:09 Groundwater quality			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide		?	
Data source(s):	DELWP		

WQ:10 Volume of treated and poorly treated discharges to surface waters and compliance with licence requirements			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide		?	
Data source(s):	EPA Victoria		

WQ:11 Percentage of inland water pollution reports requiring a field response by EPA Victoria			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide		?	
Data source(s):	EPA Victoria		

**The first figure presented in brackets refers to the number of CMAs whose status was based on 2010–17 data and the second figure presented in brackets refers to the number of CMAs based on 2018–21 data.*

Inland waters — Water resources

WR:01 Water resources and storage trends

Region(s)	2023 status	2023 trend	2023 confidence
Statewide		↙ (long term)	
Statewide		↗ (short term)	
Data source(s):	DELWP		

WR:02 Interception of surface water by small farm dams

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	(southern rivers)	↙	
Statewide	(northern rivers)	↙	
Data source(s):	DELWP		

WR:03 Surface water harvested for consumptive use

Region(s)	2023 status	2023 trend	2023 confidence
Statewide		↙	
Data source(s):	DELWP		

WR:04 Percentage of compliance with entitlements for the take of surface water

Region(s)	2023 status	2023 trend	2023 confidence
Statewide		→	
Data source(s):	DELWP		

WR:05 Water recycling

Region(s)	2023 status	2023 trend	2023 confidence
Statewide		↙	
Data source(s):	DELWP		

WR:06 Percentage of agricultural land with improved irrigation			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide			
Data source(s):	CMAs		

WR:07 Groundwater levels, consumption and use			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide		(most shallow aquifers)	
Statewide		(shallow aquifers in northern region; lower aquifers in Gippsland and northern region)	
Data source(s):	DELWP		

WR:08 Condition of flow regimes			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide			
Data source(s):	DELWP		

WR:09 Delivering water for the environment			
Region(s)	**2023 status**	**2023 trend**	**2023 confidence**
Statewide			
Data source(s):	VEWH		

Energy

E:01 Primary energy consumption

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🟡	↗	🟢
Data source(s):	BP, DCCEEW		

E:02 Primary energy consumption by source

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🟡	↗	🟢
Data source(s):	DCCEEW		

E:03 Electricity consumption

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🟢	↗	🟢
Data source(s):	Australian Energy Market Operator, BP, DCCEEW		

E:04 Electricity generation by fuel

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🟡	↗	🟢
Data source(s):	Australian Energy Market Operator, BP, DCCEEW		

E:05 Gas consumption

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🔴	→	🟢
Data source(s):	Australian Energy Market Operator, DCCEEW		

E:06 Energy in transport

Region(s)	2023 status	2023 trend	2023 confidence
Statewide	🔴	↗	🟢
Data source(s):	DCCEEW		

Waste and resource recovery

W:01 Total waste generation

Region(s)	2023 status	2023 trend	2023 confidence
Statewide			
Data source(s):	SV		

W:02 Generation of waste per capita

Region(s)	2023 status	2023 trend	2023 confidence
Statewide			
Data source(s):	ABS, SV		

W:03 Total food waste generated

Region(s)	2023 status	2023 trend	2023 confidence
Statewide			
Data source(s):	SV, DCCEEW		

W:04 Diversion rate

Region(s)	2023 status	2023 trend	2023 confidence
Statewide			
Data source(s):	SV		

W:05 Litter and illegal dumping

Region(s)	2023 status	2023 trend	2023 confidence
151 survey sites primarily located across Melbourne suburbs 15 rural highway survey sites			
Data source(s):	KAB, SV		

W:06 Total hazardous waste managed

Region(s)	2023 status	2023 trend	2023 confidence
Statewide			
Data source(s):	DCCEEW, EPA Victoria, SV		

Key findings

Cultural landscape health and management

Aboriginal people's existence and identity are underpinned by healthy cultural landscapes. The land that is now known as the State of Victoria, along with its water and other natural resources, was managed for thousands of years according to traditional laws, customs and practices. Shaped by a sustainable-use system and managed with a deep understanding of natural systems and an embedded lore and culture, Country (land, water, animals, plants, people, spirits and customs) has provided for the material, cultural and spiritual needs of thousands of generations of Aboriginal people.[1]

Victoria's cultural landscapes are unique. They are host to one of the oldest continuing cultures in the world, and home to a diverse array of plants, animals and places that have both symbolic and practical values for Aboriginal Victorians. Today's cultural landscapes reflect how Aboriginal people engage with their world and experience their surroundings. These landscapes are the product of generations of economic activity, material culture and settlement patterns. While colonisation resulted in the landscape being broken up into different land tenures and established different management regimes, Aboriginal people remain connected to Country, and cultural landscapes continue across these artificial boundaries.[2]

Aboriginal cultural heritage in Victoria is protected under Victoria's *Aboriginal Heritage Act 2006* (Aboriginal Heritage Act). The Aboriginal Heritage Act establishes a framework and mechanisms for the management and protection of Aboriginal cultural heritage. These mechanisms include cultural heritage management plans, cultural heritage permits, protection declarations and Aboriginal cultural heritage land management agreements. The status of 'Registered Aboriginal Parties' is provided under the Aboriginal Heritage Act to Traditional Owner organisations that hold decision-making powers under the Aboriginal Heritage Act for the protection and management of Aboriginal cultural heritage within a specified geographic area.

This report proposes an approach to cultural landscape health and management reporting that aligns with the aspirations of Victoria's Traditional Owners – as shared with the Victorian Government:

> 'Restoring the knowledge system must reflect the fundamental principle that traditional knowledge is owned by Traditional Owners. Traditional Owners as custodians of knowledge and practice continue to decide how consent to share knowledge is given.[3]
>
> We need resources for data collection, then will give the state the management objectives. The state and other [land management organisations] need to support our projects, not us supplementing theirs.'[4]

The Commissioner for Environmental Sustainability (CES) supports the aspirations of Traditional Owners and the restoration of traditional knowledge systems. Increased connection, participation and self-determination in managing and caring for Country will improve the condition of cultural landscapes. The CES acknowledges that the sharing of data, knowledge and stories to inform reporting on cultural landscape health and management is always at the discretion of Traditional Owner groups.

Climate change

Assessments of the 13 indicators in the 'Climate change' chapter are generally made with high confidence and highlight poor environmental status with a deteriorating trend. None of the 13 indicators have been assessed as having a good status. These assessments are generally similar to the results for the corresponding indicators in the State of the Environment 2018 Report (SoE 2018 Report).

Climate change impacts

The assessments of indicators CCIm:01 to CCIm:10 were generally consistent with the SoE 2018 indicator assessments, where the same 10 indicators were assessed as deteriorating.

1. Parks Victoria (PV) 2018, 'Managing country together', Melbourne, Victoria, https://www.parks.vic.gov.au/managing-country-together Accessed on 31 May 2023.
2. Ibid.
3. Federation of Victorian Traditional Owner Corporations 2021, 'The Victorian Traditional Owner cultural landscapes strategy', Melbourne, Victoria, https://www.fvtoc.com.au/cultural-landscapes Accessed on 9 June 2023.
4. Ibid.

The only change was the stable snow-cover trend for higher altitude alpine resorts based on fresh analysis completed for this report.

The temperature increases reported in the SoE 2018 Report have continued. Data from Australia's Bureau of Meteorology (BOM) show that each year since 1997 has been warmer in Victoria than the average for the period from 1961 to 1990. Furthermore, seven years during the past decade (2012-2021) have been in the top 10 warmest years on record for Victoria.

The assessment of indicator 'CCIm:01 Observed surface temperature' shows that annual average temperatures for Melbourne are approaching a 1.5°C increase from an indicative pre-industrial era temperature. Indeed, some years are now more than 1.5°C warmer than the indicative pre-industrial era baseline.[5] The results of this comparison with an indicative pre-industrial era temperature are consistent with recent Australian research that found Australia had warmed by approximately 1.5°C from 1850 to 2019.[6] The warming in Melbourne reflects both broader climate change and the impacts of urbanisation. On a decadal basis, Melbourne has warmed by 0.99°C from an average of 19.6°C (1992–2001) to 20.5°C (2012–2021). If the rate of temperature increase was to continue at its current trajectory of nearly 0.5°C per decade (Melbourne's temperatures increased by 0.99°C from the 1990s to the 2010s), temperatures in Melbourne will increase by approximately 2.5°C from pre-industrial levels by the 2040s. The Technical Report for the Victorian Climate Projections 2019 project found that, based on ACORN-SAT temperature data, the mean annual temperature across Victoria had increased by 1.2°C between 1910 and 2018.[7]

The observed temperature increase is particularly significant in the context of Australia being a signatory to the Paris Agreement, which aims to keep global temperature rise during this century well below 2°C above pre-industrial levels (the pre-industrial period was defined as 1850–1900) and to pursue efforts to limit the temperature increase even further to 1.5°C. However, it is important to note that warming assessed in this report is representative of land-based warming, while the Paris Agreement aim includes both land and ocean temperatures. Globally, land is warming faster than oceans, with Intergovernmental Panel on Climate Change (IPCC) assessments determining land warming at 1.6°C, ocean warming at 0.9°C and the combined land–ocean warming at 1.1°C.[8]

Below-average rainfall conditions have dominated the climate and extended the overall drying pattern affecting the state. Above-average rainfall (relative to the reference period 1961–1990) has been recorded for only five of the past 25 years (1997–2021) in Victoria. Further analysis is provided in indicator 'CCIm:02 Observed average rainfall'.

The number of days per year when temperatures in Victoria are unusually hot has increased significantly and is linked with increased risk of heatwaves and bushfires. Victoria has experienced a drier climate with more intense rainfall events in recent years. There are several examples of catastrophic natural disaster events associated with climate change since publication of the SoE 2018 Report, which are detailed in the assessment for indicator 'CCIm:10 Occurrence and impacts of extreme weather'.

The financial cost of natural disasters is increasing in Victoria and is projected to be at least $185 billion cumulatively between 2020 and 2060.[9] Further detail is provided in indicator 'CCIm:10 Occurrence and impacts of extreme weather'.

The climate projections synthesised and presented within indicators CCIm:06 to CCIm:09 are generally consistent with the SoE 2018 Report findings. Physical evidence, past trends and various models all suggest Victoria will continue warming this century; therefore, ongoing warming is projected with high confidence.

Inland regions of Victoria are projected to warm by a greater amount (2.4°C) compared to coastal regions (1.9°C) by the 2050s, while the number of very hot days is projected to double across the state by the 2050s, relative to the reference period 1986–2005 and under a high-emissions pathway.[10]

5. United Nations (UN) 2015, 'The Paris agreement', https://unfccc.int/process-and-meetings/the-paris-agreement Accessed 9 June 2023.
6. Grose MR, Trewin B, Ashcroft L, Hawkins E 2020, 'Australian warming: observed change and global temperature targets', *ESS Open Archive*, https://essopenarchive.org/doi/full/10.1002/essoar.10503758.1 Accessed 9 June 2023.
7. Clarke JM, Grose M, Thatcher M, Hernaman V, Heady C, Round V, Rafter T, Trenham C, Wilson L 2019, 'Victorian climate projections 2019: Technical report', CSIRO, Melbourne, Victoria.
8. Intergovernmental Panel on Climate Change (IPCC) 2021, 'Climate change 2021: The physical science basis', https://www.ipcc.ch/report/ar6/wg1 Accessed on 9 June 2023.
9. Deloitte Access Economics 2021, 'Special report: Update to the economic costs of natural disasters in Australia', Australian Business Roundtable for Disaster Resilience & Safer Communities, https://www.preventionweb.net/publication/special-report-update-economic-costs-natural-disasters-australia Accessed on 8 June 2023.
10. 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 8 June 2023.

The assessments for the 'Climate projections' indicators are generally based on results from the Victorian Climate Projections (VCP19) project. Since then, a new generation of global climate models have been developed as part of the Coupled Model Intercomparison Projects Phase 6 (CMIP6). These were featured in the IPCC Sixth Assessment Report (AR6), which included a new set of emission scenarios. The new modelling and scenarios are yet to be downscaled and applied for Victoria.

While the impact of global warming on Victoria's rainfall is expected to increase throughout the 21st century, significant natural variability will occur. In some years and decades this natural variability will exacerbate the underlying drying, while in other periods the underlying drying will be balanced out by natural climatic events such as La Niña.[11] By the 2050s, Victoria is likely to experience more extreme, short-duration rainfall despite an overall decrease in rainfall.[12, 13]

Tidal gauge data provided by BOM show that mean and maximum sea levels are gradually increasing, and this is exerting pressure on human coastal settlements and infrastructure. Future rises are projected with high confidence, with sea levels expected to rise about 12 cm by 2030 at some places along Victoria's coastline, and 40 cm by 2070.[14] These projections are based on a high-emissions scenario (RCP8.5) and are relative to the levels observed for the 1986–2005 reference period.

Climate change mitigation

Three 'Climate change mitigation' indicators were assessed as having a fair status, and none have a deteriorating trend. A distinct area of improvement since the SoE 2018 Report is that Victoria's annual net greenhouse gas (GHG) emissions have reduced by 27% over the period between 2015 to 2020, which represents the five most recent years with available data. The status assessment for indicator 'CCM:11 Annual greenhouse gas emissions' has been upgraded from poor in 2018 to fair in 2023.

Climate change adaptation

A suite of climate change adaptation indicators is presented that incorporates nine new indicators, as well as modified forms of existing Victorian state of the environment indicators. Acknowledging that positive adaptation outcomes are critical to environmental sustainability, the indicators aim to track and monitor progress against the Victorian Government's seven Adaptation Action Plans (AAPs) and guide ongoing work on the Regional Climate Change Adaptation Strategies. The AAPs emphasise that the natural environment is the foundation of all other systems, shaping the climate change risk we face and the success of our adaptation efforts. The natural environment fundamentally provides not only the context in which human systems and regions exist but also specific ecological services that enable human life and activities.

Successful climate change adaptation:

- is fundamental to our ongoing ability to function and achieve other climate goals, including GHG mitigation
- requires 'interventions that intentionally address the impacts and risks of climate change on natural and human systems'[15]
- reduces the negative consequences of interactions among existing systems and emergent climatic shifts, hazards and their flow-on effects
- includes not only the management of increasingly frequent and severe disasters, but also anticipation and prevention or mitigation of larger, longer-term, aggregate future threats.

Air

Victoria's air quality is considered good relative to international standards, although poor air quality is still measured occasionally in some circumstances, including during major incidents (e.g. bushfires, industrial fires and dust storms), near major industrial facilities, from the domestic use of wood heaters, and during periods of planned burns.[16]

11. Department of Environment, Land, Water and Planning (DELWP), BOM, CSIRO, The University of Melbourne 2020, 'Victoria's water in a changing climate', https://apo.org.au/node/312270 Accessed on 8 June 2023.
12. 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 8 June 2023.
13. Clarke JM, Grose M, Thatcher M, Hernaman V, Heady C, Round V, Rafter T, Trenham C, Wilson L 2019, 'Victorian Climate Projections 2019: Technical report', CSIRO, Melbourne.
14. 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 8 June 2023.
15. Pearce-Higgins JW, Antão LH, Bates RE, Bowgen KM, Bradshaw CD, Duffield SJ, Ffoulkes C, Franco AMA, Geschke J, Gregory RD, Harley MJ, Hodgson JA, Jenkins RLM, Kapos V, Maltby KM, Watts O, Willis SG, Morecroft MD 2022, 'A framework for climate change adaptation indicators for the natural environment', *Ecological Indicators*, 136, article no. 108690, https://www.sciencedirect.com/science/article/pii/S1470160X22001613 Accessed 9 June 2023.
16. World Health Organization, 'WHO Air Quality Database 2022', https://www.who.int/data/gho/data/themes/air-pollution/who-air-quality-database/2022#:~:text=The%202022%20update%20(Fifth%20Version,Sustainable%20Development%20Goal%20Indicator%2011.6. Accessed 17 April 2023.

Air quality, particularly particle pollution, was generally worse in this reporting period (2018–21) compared to the previous period (2013–17) due to bushfire smoke impacts.[17] However, air quality was generally better in 2020 and 2021 in Melbourne's suburbs and across areas of regional Victoria; this was likely due to increased rainfall during 2021 and less motor vehicle pollution associated with travel restrictions that formed part of the Victorian Government's response to the COVID-19 pandemic.

All monitoring stations in Melbourne and the Latrobe Valley recorded exceedances of the daily $PM_{2.5}$ air-quality standard in each year of the past five years (2017–2021) except for Footscray in 2021. PM_{10} pollution remains an issue in Brooklyn in Melbourne's inner west and is associated with dust emissions generated by industry and vehicles (A:01).

The Environment Protection Authority (EPA) Victoria has expanded its air-quality monitoring network since 2018; however, there are still significant gaps in air-quality analysis in regional Victoria (A:01 to A:05). The new monitoring in regional Victoria uses lower quality sensors; therefore, the results are deemed indicative and not available for analysis and inclusion in this report.

This report captures the important work recently undertaken to quantify population exposure to air pollution (A:06) and its health impacts in Victoria (A:11). These were previously identified as knowledge gaps. There is a significant variance from year to year in the proportion of the Victorian population exposed to annual $PM_{2.5}$ concentrations exceeding the air-quality standard. Data provided by EPA Victoria show that 79% of the Victorian population were exposed to annual $PM_{2.5}$ concentrations exceeding the air-quality standard in a year with significant bushfire smoke impacts (2020), compared with 18% in a year without significant bushfire smoke impacts (2021). In terms of health impacts, the average annual mortality burden for Victoria from exposure to anthropogenic $PM_{2.5}$, based on data from 2006 to 2016, was estimated to be more than 600 premature deaths.[18]

Following on from the recommendation in the SoE 2018 Report to establish a contemporary pollen-monitoring network, this report is the first time that pollen has been captured within state of the environment indicator assessments (A:07). Victoria has the second highest rate (23%) of hay fever in Australia.[19] Across the eight sites monitoring pollen in Victoria, there has been a generally increasing trend since 2017 in the number of days of extreme or high grass pollen during grass pollen seasons. Data provided by the University of Melbourne show that Bendigo recorded 59 days of extreme or high grass pollen in the most recently completed grass pollen season (October to December 2021). This means that grass pollen was likely impacting human health on nearly two out of every three days during the grass pollen season in Bendigo during 2021.

Most recently, a multi-year La Niña state has led to increased rainfall and grass pollen levels. However, from 2017 to 2019 (prior to the La Niña state), there was still an average of 20 to 40 days of extreme or high grass pollen per season across Victoria. The narratives for the two pollen indicators (A:07 and A:14) highlight limitations with existing pollen-monitoring arrangements and present future opportunities for monitoring, for example, developing an automated pollen-monitoring network and expanding analysis to include other pollens in addition to grass pollen.

Odour (A:08) remains generally the type of pollution most frequently reported to EPA Victoria, with the regulator receiving more than 3,000 odour reports in each of the past nine years. This report provides commentary on EPA Victoria's recent achievements to support and regulate industry to improve odour-management practices that reduce odour impacts on communities over time.

Prior to 2020–21, noise (A:09) was generally the pollution most frequently reported to EPA Victoria after odour. However, since the shift to remote working in Victoria from March 2020 due to the COVID-19 pandemic, there has been a sharp increase in the number of noise pollution reports received by EPA Victoria. Noise was the type of pollution most frequently reported to EPA Victoria in 2020–21.

17. For this indicator, the SoE 2023 reporting period represents the years when data have been available since the SoE 2018 Report. Data from 2022 will be incorporated into the assessment for the SoE 2028 Report.
18. Hanigan IC, Broome RA, Chaston TB, Cope M, Dennekamp M, Heyworth JS, Heathcote K, Horsley JA, Jalaludin B, Jegasothy E, Johnston FH, Knibbs LD, Pereira G, Vardoulakis S, Vander Hoorn S, Morgan GG 2020, 'Avoidable mortality attributable to anthropogenic fine particulate matter (PM2.5) in Australia', *International Journal of Environmental Research and Public Health,* 18(1), pp. 254, https://pubmed.ncbi.nlm.nih.gov/33396338 Accessed on 9 June 2023.
19. Australian Institute of Health and Welfare (AIHW) 2020, 'Allergic rhinitis ("hay fever")', https://www.aihw.gov.au/reports/chronic-respiratory-conditions/allergic-rhinitis-hay-fever/contents/allergic-rhinitis Accessed 8 June 2023.

As reported in 2018, there remains no systematic measurements and analysis of light pollution conducted in Victoria (A:10). Remote sensing has been used to identify and analyse light pollution, and this has been complemented by summaries of research investigating how light pollution threatens reproduction and migratory habits of insects, amphibians, fish, birds, bats and other animals. In contrast to the gradual increases in night-time light emissions observed across Melbourne's urban extent, new analyses completed for this report highlight dramatic light pollution increases in Melbourne's growth areas. For example, night-time light emissions in growth areas of Melbourne's outer western suburbs have nearly tripled from 2014 to 2021.

Biodiversity

A number of recent reviews, studies and inquiries have established that Victoria's biodiversity is in decline. These include:

- the Victorian Government's biodiversity plan Protecting Victoria's Environment – Biodiversity 2037 (Biodiversity 2037)
- the Department of Environment, Land, Water and Planning (DELWP) 2020 submission to the Parliament of Victoria Inquiry into Ecosystem Decline in Victoria
- the Royal Society of Victoria's Towards Conservation and Recovery of Victoria's Biodiversity.

Victoria's biodiversity threats include bushfires, major floods, habitat loss, fragmentation and degradation, human population growth, land-use change, the intensification of agriculture, water regulation and extractions, invasion by introduced plants, herbivores and predators, and climate change.

There has been little change in the status, trend and data confidence for the indicators assessed in the SoE 2018 and 2023 reports. The status of many indicators remains poor, deteriorating trends continue, and data confidence in the assessments is generally low. This is also the case for the new SoE 2023 'Threatened species' indicators. Assessment of the 'Ecosystem health' indicators had mixed results, with status ranging from poor for grasslands, wetlands, rivers, and riparian vegetation, to fair for mallee, heathlands and alpine ecosystems.

Through the assessment of 40 indicators, this chapter considers 'where' and 'what' is in decline and reviews data and information provided by the government and community groups in response to the ongoing threats that drive that decline.

The assessments highlight the lack of, or gaps in, monitoring, data analysis, interpretation and reporting in the following areas:

- the condition and diversity of ecosystems and ecological vegetation classes (EVCs)
- the distribution and abundance of threatened species
- time-series data for the assessment of trends
- a focus on inputs and outputs rather than analysis and reporting of outcomes in projects for threat management and biodiversity recovery and restoration
- interpretation of data and their reporting to the community
- integration and coordination of data gathering by government and community organisations
- data gathering about biodiversity management activities on private land
- timeliness in releasing data.

Ecosystem health

Indicators B:02 to B:11 assess the health of some of Victoria's key ecosystems. In general, the extent of Victoria's ecosystems has been largely stable in recent years except for grasslands and wetlands, which are both deteriorating. However, the trend in condition of wetlands, grasslands, and potentially alpine and subalpine areas, is in decline, while ecosystems in north-eastern Victoria and East Gippsland have been severely impacted by the 2019–20 bushfires. The biodiversity effects of the 2022 floods are yet to be determined.

The assessment of indicator B:01 finds that changes in land-cover classes continue in Victoria, with natural areas being replaced by other uses – such as urban and agricultural uses – in some parts of the state.

The bioregional conservation status of many of the EVCs within the ecosystems assessed is either endangered, vulnerable or depleted. Protection levels vary, with most alpine EVC extents found within protected areas, in contrast to the low levels of protection for grasslands. For some EVCs, much of their remaining extent is on private land, which means their conservation could depend on landowners establishing permanent protection for them.

Long-term surface water availability across southern Victoria has declined due to drier conditions. Ongoing human population growth and agricultural development, along with reduced river flows due to climate change, will increase pressure on water resources and impact wetlands (B:02), groundwater-dependent ecosystems (B:04), rivers (B:05), riparian vegetation (B:06), floodplain EVCs (B:07) and Ramsar sites (B:03).

A lack of data on the condition of, and diversity within, EVCs is an ongoing issue for indicator assessment.

Threatened species

Indicators B:12 to B:23 span threatened freshwater and terrestrial animal and plant species. The status for each of these indicators has been assessed as poor. Habitat loss and degradation, environmental weeds and invasive herbivores and predators remain major threats.

The 2019–20 bushfires burnt about 1.5 million hectares of Victoria, most of which was in areas of high biodiversity value including parks, reserves and state forests, where many threatened species and ecological communities were impacted. Accordingly, unburnt areas are critical as refuges and genetic storehouses for species recovery and genetic rescue.

Amendments to Victoria's *Flora and Fauna Guarantee Act 1988* (FFG Act) that came into force in 2020 led to an update of the FFG Act Threatened List in 2021. More rigorous criteria have resulted in the conservation status of many threatened animals and plant species being upgraded, for example, from vulnerable to endangered or critically endangered. Although the on-ground situation (population size and habitat) for the listed species might not have changed since their last assessment, the new conservation status provides a more robust assessment of their extinction risk than was previously available. As more species are assessed at state and federal scales, the list is expected to continue to grow, particularly if the existing imbalance in listing between vertebrate and invertebrate species is addressed, recognising that there are 30 times as many invertebrate species than vertebrate species in the Australian environment. Fungi, lichen, moss and liverwort species are also poorly represented on the list at this time.

Few of the individual species in the groups assessed in indicators B:12 to B:23 have action statements to guide their recovery, and the statements that do exist are often out of date. Many of the threatened species have high to very high genetic risk ratings.

While there may be few action statements, supporting certain threatened species is a key focus for government agencies, catchment management authorities (CMAs), research institutions, local communities, Traditional Owners and Aboriginal communities. Government and community biodiversity response and recovery actions following the 2019–20 bushfires were immediate, well resourced, well coordinated, and targeted threatened species.

Safe havens on islands and within fenced areas that exclude feral predators and herbivores are being used to conserve critically endangered species such as bandicoots, possums and wallabies across Australia. Their establishment in various parts of Australia has prevented the extinction of 13 mammal species and conserved many more.[20] Several safe havens already exist in Victoria, with more planned at Wilsons Promontory National Park and at Haining Farm. Together with improved and broad-scale management of invasive species and other threats, and the expansion of conservation reserves, they can make a significant contribution to the conservation of threatened species.

Assessment of the 'Threatened species' indicators has been hampered by the lack of data on the distribution and abundance of threatened species.

Threats and responses

Indicators B:24 to B:32 assess the threats from invasive species and the management response by government and community. Although invasive plants and animals are the major threat to many threatened species, there remains very limited data on the numbers and abundance of invasive species.

The full effect of the 2019–20 bushfires on invasive species is yet to be documented; however, concerns that they could exploit the post-fire vulnerability of native species led to significantly expanded control efforts, including aerial and ground operations to cull introduced terrestrial herbivores such as deer, goats and pigs.

20. Legge S, Dickman C, Dielenberg J, Woinarski J, Nou T 2021, 'Australia must control its killer cat problem. A major new report explains how, but doesn't go far enough', https://theconversation.com/australia-must-control-its-killer-cat-problem-a-major-new-report-explains-how-but-doesnt-go-far-enough-154931 Accessed on 17 July 2023.

Biodiversity 2037 has annual contributing targets for priority on-ground actions that, if implemented, will help deliver on the plan's longer-term outcome targets. Although the available data do not span the five years since the plan's release in 2017, they suggest that the annual targets to control pest herbivores, pest predators and weeds in priority areas are not being met.

Indicator B:33 assesses whether the state is achieving a net gain or loss in the extent and condition of native vegetation. Net losses have continued since the SoE 2018 Report. Losses are also occurring on public land, although these are to some extent counterbalanced by restoration and control of invasive species.

Habitat can be compromised by invasive species, climate change, fire, timber harvesting and other factors, and become less suitable for native species (B:34 and B:35). Change in suitable habitat (B:34) estimates the net improvement in suitable habitat for individual species in 50 years time by comparing implemented actions with a 'no action' scenario. The assessment, undertaken by DELWP, found that for more than 50% of species there was no improvement or a very small improvement. The Biodiversity 2037 target is for a 100% net positive change (on average) in suitable habitat for threatened species in 50 years.

Conservation and community engagement

Indicators B:36 to B:40 assess conservation and community engagement. Almost 90% of the EVCs that are poorly represented in parks and reserves are found on private land. About 62% of Victoria's land is privately owned, yet only 1% to 2% of private agricultural land is managed for conservation, for example, native vegetation protection, revegetation and livestock exclusion.[21, 22]

Biodiversity 2037 estimated that there was a gap of 2.1 million hectares between the existing protected area network and what was required for a comprehensive, adequate and representative reserve system. In some bioregions, such as the Victorian Volcanic Plain, Wimmera, Dundas Tablelands and Gippsland Plain, Biodiversity 2037 indicated that this would require land purchase or additional formal protection of habitat on private land. However, efforts to increase the conservation of native vegetation on private land (B:36) and revegetate both private and public land (B:38) have not progressed far in achieving statewide targets.

Priority 18 of Biodiversity 2037 is to 'maintain and enhance a world-class system of protected areas'. However, protection levels for Victoria's ecosystems have been largely stable since the plan was released, with only small additions to the protected areas network (B:37). In response to the Victorian Environmental Assessment Council (VEAC) Central West Investigation recommendations, in 2021 the Victorian Government committed to creating three new national parks, together with new conservation parks, nature reserves and bushland reserves. These are yet to be legislated and gazetted at the time of writing.

The planned cessation of timber harvesting in state forests, initially scheduled for 2030 but which has now been brought forward six years to the beginning of 2024, will provide opportunities for the expansion of the conservation estate on public land.

The 2019–20 bushfires and the COVID-19 pandemic restricted the engagement of people in nature-based activities and, accordingly, impacted the achievement of Biodiversity 2037 targets. However, surveys show that the target of more than 5 million Victorians acting for nature has been met, while there has been a shortfall in meeting the target for all 'Victorians connected to nature' (B:39).

Land

Land use and land health are inextricably linked. The types of land use, and changes in their spatial extent or management, can either improve or degrade land cover and land health. The indicators in this chapter assess land health – soil carbon storage, soil erosion, soil acidity and dryland salinity – and the natural resource management (NRM) actions being undertaken by government agencies, Traditional Owners, scientists, farmers, land managers and community organisations to maintain, restore and improve it.

Indicators L:01 to L:03 consider the mix and changing nature of land-cover classes and land tenure. In general, land-cover classes associated with human-based activities have continued to increase, while natural land-cover classes have continued to decline. There has been little change in land tenure.

21. Trust for Nature, 'Biodiversity and land tenure in Victoria', https://trustfornature.org.au/resources/statewide-conservation-plan Accessed 17 April 2023.
22. The proportion of Victorian land that is private was reported as 57.6% in the SoE 2018 Report. Trust for Nature, which focusses on the conservation of biodiversity on private land, now reports it as being 62%. This should not be interpreted as an increase; it is a recalculation of the spatial extent of private land.

The changing mix of human-based land-cover classes and natural land-cover classes is most apparent in and around Melbourne and regional growth areas. The impacts of population growth and demographic shifts are assessed in indicator L:04, which also compares the advantages and disadvantages of infill and greenfield development in metropolitan Melbourne. Although a planning boundary currently limits the extent of Melbourne's future growth, there is no clear target for the desirable mix of infill and greenfield development.

Indicators L:05 to L:08 assess the impact of agricultural land use on soil organic carbon, soil erosion, soil acidification and the extent of dryland salinity.

By changing land management to sequester carbon in soil, agriculture can help mitigate climate change. However, the science indicates that there is still much to learn about soil carbon, and how to measure, store and increase it. The Commonwealth and Victorian governments have developed carbon-farming projects to encourage farmers to sequester carbon in their soil, a process that could take at least 25 years if it is to be successful.[23]

Dryland salinity is receding in the state's northern river basins that flow into the Murray River, due to improved land management and a major reduction in groundwater levels caused by the Millennium Drought (1998–2009).

Dry years lower the groundwater levels and reduce the volume of saline groundwater discharged to the land surface. As a result, the area of dryland salinity is reduced. The reverse occurs in wet years. Although wet years have recharged much of the groundwater lost, groundwater discharges have not returned to previous levels.

The assessment of indicator L:07 finds that, over the long term, the extent of acidic soils in medium-rainfall areas has increased due to historical farm management practices, with implications for agricultural productivity and economic returns to farmers, as well as potential increases in soil erosion and salinity, and impacts on soil biodiversity. The application of lime is the main way that farmers reduce soil acidity. There are insufficient data available to determine either the current status or trend.

Indicator L:08 considers the risk of soil erosion to Victoria's land health. The threat of wind erosion is highest in the sandy plains of the Mallee and Wimmera regions in the state's north-west, whereas erosion caused by water – sheet, rill, gully and tunnel erosion – has been mostly in the sloping higher rainfall areas of the central west. The National Landcare Program has developed targets for total vegetation cover (TVC) for each NRM region. If those targets are met, the threat of wind and water erosion can be significantly reduced.

Up to 30,000 sites are estimated to be contaminated in Victoria, with half of these rated as being high risk (L:09). Land remediation is increasing across the state, although a variety of data sources indicate industrial areas in Melbourne's western and south-eastern suburbs remain hotspots for contaminated sites.

Indicators L:10 and L:11 assess volunteer engagement in NRM activities and the work of landholders to adopt best practice to progress sustainability in agriculture. Individual and community participation in NRM activities is significant, widespread and supported by government agencies, including CMAs. The agriculture sector is increasingly invested in best practice with sustainability outcomes; however, publicly available data on their extent and outcomes are limited.

Forests

Forests, and the services they provide, are essential for the health and wellbeing of all Victorians. Forests maintain Victoria's water quality, purify the air, store carbon, stabilise and nourish the soil, assist agriculture, and support economies that are vital for regional communities and businesses. Forests are critical habitats for biodiversity, especially for the conservation of many iconic threatened species in Victoria. Forests have been an essential part of the history and culture for Victoria's Traditional Owners and Aboriginal Victorians.

Various forest values deteriorated in this state of the environment reporting period (2018–22) compared to the previous period (2013–18), primarily because of the 2019–20 bushfires. Nearly 1.4 million hectares of native forest – or 18% of Victoria's public native forests – were burnt.[24, 25] This directly impacted the

23. Robertson F, Nash D 2013, 'Limited potential for soil carbon accumulation using current cropping practices in Victoria', *Agriculture, Ecosystems and Environment*, 165, pp. 130-140, https://www.sciencedirect.com/science/article/abs/pii/S0167880912004276 Accessed 9 June 2023.
24. National Emergency Management Agency, 'Bushfires – Black Summer', https://knowledge.aidr.org.au/resources/black-summer-bushfires-vic-2019-20 Accessed 19 April 2023.
25. The overall figure for the impact of the 2019-20 bushfires in Victoria is 1.5 million hectares, which includes all public and private land.

assessments for many indicators, including forest fragmentation, forest-dependent species, expansion of invasive species and timber harvest areas successfully regenerated previously.

The 2019–20 bushfires had a significant impact on forest-dependent species (Fo:06), resulting in their status changing from fair to poor with a deteriorating trend. Of the VEAC's 84 threatened forest-dependent species, 32 (DELWP's species of most concern) were directly impacted by the high-severity fires or had some of their modelled habitat within the fire extent. Fifteen species had more than 50% of their extent burnt and the following listed species were exposed to high-severity fires across more than 50% of their overall extent: Betka bottlebrush, roundsnout galaxias, East Gippsland galaxias, Mallacoota burrowing crayfish, Orbost spiny crayfish and eastern she-oak skink. Another two listed species – the diamond python and the large brown tree frog – have had at least 50% of their habitat impacted by multiple high-severity fires since 2000.

Forest fragmentation (Fo:04) is a critical indicator for monitoring biological diversity. Due to the technical difficulties in ensuring accuracy, only a state-scale comparison was possible. The state data from 2018 and 2022 demonstrate a large increase of edge (~1.3 million ha) and a decrease of interior areas (~0.7 million ha). The increase in forest edge and the decrease in the total interior area might be a result of 2019–20 bushfires as well as other factors, including change of forest extent mapping methodology and data resolution. Many species increased their genetic risk because of the 2019–20 bushfires. Because more frequent and higher intensity bushfires are expected as a result of climate change, future policy settings and interventions will be needed to tackle this trend.

In response to the 2019–20 bushfires the Victorian Government invested significantly in ex-situ and in-situ conservation efforts (Fo:05) to address the decline in the state's biodiversity. A notable conservation effort was the introduction of a variable retention harvesting method in the majority of coupes. Since 2019–20, VicForests harvested 3,281 hectares of native timber using this technique. The post-harvest monitoring program found species persist within and around harvested areas. Captive breeding programs also contributed to protecting seven threatened species released into protected habitat. These are the Leadbeater's possum, helmeted honeyeater, yellow-tufted honeyeater, plains-wanderer, eastern bristlebird, eastern barred bandicoot and orange-bellied parrot. Despite all efforts, biodiversity in forests is deteriorating.

The 2019–20 bushfires also impacted timber harvesting (Fo:12 to Fo:14). The Victorian Conservation Regulator (CR) identified 34 species of concern due to significant biodiversity loss, requiring additional protection from timber harvesting to assist recovery. These included the giant burrowing frog, greater glider, glossy black-cockatoo, Leadbeater's possum and diamond python.[26] VicForests developed an approach to protect the species of concern. The Major Event Review on the impact of the 2019–20 bushfires on the operation of Victoria's Regional Forest Agreements (RFAs), which was released in 2022, found that the precautionary principle and tailored adaptive responses to the 2019–20 bushfires was a sound approach to mitigate the risk of serious or irreversible damage from timber harvesting.[27] Although there is a reduction of the volume of D+ sawlog inventory due to the 2019–20 bushfires, the remaining sawlog volumes available under the current Allocation Order appear to be sufficient to meet the allowable harvesting levels under the Victorian Forestry Plan (VFP) for both ash and mixed species in eastern Victoria. These major changes in the timber harvesting method, along with sufficient timber resources, resulted in positive change in assessments for timber harvesting indicators. The revised timeline to end Victoria's native timber harvesting – by 1 January 2024, as opposed to 2030 – will address concerns about the adverse impact of native timber harvesting on biodiversity. However, ongoing management should be applied to successfully recover harvested areas that were previously regenerated, are still regenerating or were recently harvested.

The timber harvest area successfully regenerated (Fo:15) was impacted by the 2019–20 bushfires. Victoria's Department of Energy, Environment and Climate Action (DEECA) is responsible for the ongoing management of the regenerated areas once they are successfully regenerated after harvesting

26. Major Event Review Independent Panel 2022, 'Victorian regional forest agreements: Major event review of the 2019-20 bushfires', https://www.agriculture.gov.au/sites/default/files/documents/vic-rfa-mer-bushfires-report-2022.pdf Accessed 21 November 2022.
27. Ibid.

and removed from the Timber Release Plan (TRP). The 2019-20 bushfires impacted 82,700 hectares of ash forest; no information was available on mixed-species forest. The overall regeneration status for coupes harvested up to June 2020 that remain on the TRP shows that around 40% of 10,083 hectares that were harvested four to five years ago is yet to be finalised (i.e. regenerated). Rapid changes in the intensity and frequency of fire regimes pose significant challenges for managing and successfully regenerating forests after timber harvesting. As a result, the status of this indicator has deteriorated, from fair to poor.

The data confidence of many indicators deteriorated during this reporting period – including Fo:01B, Fo:02 and Fo:10 – due to time-series data being discontinued. Furthermore, the 2023 forest extent information was not comparable to the information in previous SoE reports (2013 and 2018), due to different analytical methods and image resolution, with 2023 data having a lower resolution.

Victoria's forest health is important for tackling GHG emissions (Fo:11). Victoria's land use, land-use change and forestry (LULUCF) sector was a net sink for GHGs of 21,054 CO2-e in 2020. This equates to around one-quarter of Victoria's total emissions, which is a significantly higher proportion than the national figure (7.8%). The LULUCF sector in Victoria has been increasing net sink contributions over the past 10 years.[28]

Fire

Fire regimes play a vital, yet complex, role in Victorian ecosystems that provide habitat for a diverse range of fire-adapted native flora and fauna species (with some plant species only germinating after stimulation by heat or smoke, for example). The beneficial effects of fire on ecosystem processes are well researched. Locally, fire catalyses plant nutrient cycles by decomposing organic materials into available nutrients that provide fertile soil conditions. Fire assists key processes within landscapes, for example, tree decay, tree collapse and stand tree germination.[29, 30, 31, 32] Unexpected or inappropriate fire regimes can jeopardise the survival of threatened flora and fauna species. These ecological complexities highlight the importance of optimising fire management in Victoria.

In terms of economic impacts, the Reserve Bank of Australia estimated that the 2019–20 bushfires would directly reduce growth in the national gross domestic product (GDP) by around 0.2% between December 2019 and March 2020.[33] Westpac indicated that the 2019–20 bushfires would result in insured and uninsured losses of around $5 billion nationally. Of this, around 8% was attributed to Victoria.[34] The economic cost of bushfires is expected to double by 2050.

About a third of listed flora and fauna species under the FFG Act were severely impacted by the 2019–20 bushfires.[35] There are 244 species that had at least 50% of their likely statewide habitat burnt, 215 of which are rare or threatened species. The unprecedented increase in the vulnerability of many species due to this single catastrophic event highlights how the 2019–20 bushfires were an ecological disaster of national and international importance. Many of Victoria's native species are vulnerable to increasing extinction risk and severe impacts of bushfire, which indicates that we need to improve strategies for prevention and response to mitigate future losses to bushfires.

28. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Victorian greenhouse gas emissions report', Melbourne, Victoria, https://www.parliament.vic.gov.au/file_uploads/Victorian_Greenhouse_Gas_Emissions_Report_2020_tH8912bV.pdf Accessed 6 January 2023.
29. Lindenmayer DB, Blanchard W, Blair D, McBurney L 2018, 'The road to oblivion – quantifying pathways in the decline of large old trees', *Forest Ecology and Management*, 430, pp. 259-264, https://www.sciencedirect.com/science/article/abs/pii/S037811271830834X Accessed 9 June 2023.
30. Lindenmayer DB, Blanchard W, Blair D, McBurney L, Banks SC 2018 'Empirical relationships between tree fall and landscape-level amounts of logging and fire', *PLOS ONE*, 13(2), e0193132, https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0193132 Accessed 9 June 2023.
31. Lindenmayer DB, Blanchard W, McBurney L, Blair D, Banks S, Likens GE, Franklin JF, Laurance WF, Stein JAR, Gibbons P 2012, 'Interacting factors driving a major loss of large trees with cavities in a forest ecosystem', *PLOS ONE*, 7, e41864, https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0041864 Accessed 9 June 2023.
32. Smith AL, Blair D, McBurney L, Banks SC, Barton PS, Blanchard W, Driscoll DA, Gill AM, Lindenmayer DB 2013, 'Dominant drivers of seedling establishment in a fire-dependent obligate seeder: climate or fire regimes?' *Ecosystems*, 17, pp. 258-270, https://link.springer.com/article/10.1007/s10021-013-9721-9 Accessed 9 June 2023.
33. Reserve Bank of Australia 2020, 'Statement of Monetary Policy – February 2020 – Box B: Macroeconomic effects of the drought and bushfires', https://www.rba.gov.au/publications/smp/2020/feb/box-b-macroeconomic-effects-of-the-drought-and-bushfires.html Accessed 24 August 2022.
34. Westpac 2020, 'Counting the cost of bushfire's fury', https://www.westpac.com.au/news/in-depth/2020/01/counting-the-cost-of-bushfires-fury Accessed 24 August 2022.
35. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Victorian Regional Forest Agreements Major Event Review of the 2019-20 bushfires – Summary report: Information and data to inform public consultation', https://nla.gov.au/nla.obj-2992111289/view Accessed 8 June 2023.

It is expected that the area of native vegetation impacted by bushfire is likely to increase because of more frequent extreme weather events.[36, 37] This is consistent with the findings of the SoE 2018 Report. A higher probability of more frequent catastrophic bushfires presents a growing risk to threatened species that are likely to become even more vulnerable. Even some fire-tolerant vegetation types and ecological communities may face changes to their structural composition as a result of recurrent severe wildfires, making them more vulnerable to structural and state changes by killing seedlings and increasing tree mortality.[38, 39]

DEECA uses a range of metrics to understand the impact of changing fire regimes on ecosystem resilience, including tolerable fire interval (TFI), growth stage structure and geometric mean of abundance. The SoE 2018 Report incorporated information on ecosystem resilience using these metrics for 2016–17, which indicated that about 54% (4,119,000 ha) of native vegetation across Victoria was below minimum TFI. In 2020–21 this had increased slightly to 55% (4,157,670 ha). However, in 2019–20, the area burnt by bushfires, while below minimum TFI (757,898 ha), was the greatest since 1980; and the long-term trend is a consistent increase in Victoria's land sitting below minimum TFI. These areas are vulnerable to major – and potentially irreversible – changes in vegetation communities if they burn again in the next few decades. These trends indicate an increasing likelihood that some areas will experience localised extinctions of plant species.

To accurately quantify and track changes in ecological resilience, DEECA and external partners have developed a new set of metrics and targets that combine empirical, field-based observations and spatial modelling. DEECA advises these will be finalised as part of a review of bushfire metrics and targets, which is due to be completed later in 2023.

36. Canadell JG, Meyer CP, Cook GD, Dowdy A, Briggs PR, Knauer J, Pepler A, Haverd V 2021, 'Multi-decadal increase of forest burned area in Australia is linked to climate change', *Nature Communications*, 12, article no. 6921, https://doi.org/10.1038/s41467-021-27225-4 Accessed 24 April 2023.
37. Collins L, Clarke H, Clarke MF, McColl Gausden, SC, Nolan RH, Penman T, Bradstock R 2022, 'Warmer and drier conditions have increased the potential for large and severe fire seasons across south-eastern Australia', *Global Ecology and Biogeography*, 31, pp. 1933–1948. https://doi.org/10.1111/geb.13514 Accessed 24 April 2023.
38. Fairman TA, Bennett LT, Tupper S, Nitschke CR 2017, 'Frequent wildfires erode tree persistence and alter stand structure and initial composition of a fire-tolerant sub-alpine forest', *Journal of Vegetation Science*, 28(6), pp. 1151–1165, https://onlinelibrary.wiley.com/doi/abs/10.1111/jvs.12575 Accessed 9 June 2023.
39. Fairman TA, Nitschke CR, Bennett LT 2015, 'Too much, too soon? A review of the effects of increasing wildfire frequency on tree mortality and regeneration in temperate eucalypt forests', *International Journal of Wildland Fire*, 25(8), pp. 831-848, https://www.publish.csiro.au/wf/wf15010 Accessed 9 June 2023.

Planned burns have been a strategic tool to reduce bushfire risk and reduce the spread and intensity of bushfires when they occur. Since 2015–16, when the hectare-based target was set at burning 5% of public land each year, a risk-based approach has been adopted to fuel management on public land. DEECA's fuel management program aims to keep bushfire risk at or below 70% of Victoria's maximum bushfire risk. Maximum bushfire risk is calculated using a model that assumes the worst conditions are present, including maximum fuel build-up and extreme bushfire conditions. Victoria has succeeded in maintaining bushfire risk below 70% of the maximum since the risk target for the fuel management program was introduced.

Forest Fire Management Victoria and partner agencies undertake joint planning at both strategic and operational levels to inform the fuel management program. The Joint Fuel Management Program (JFMP) sets out the annual schedule of fuel reduction works (planned burning, slashing, mowing and clearing). On average, planned burning accounted for more than two-thirds (70%) of the total risk reduction from July 2009 to June 2022, compared with 30% for bushfires. This is despite bushfires burning an additional 747,000 hectares compared to planned burning in that period. This is because planned burning uses best available science and data to target areas (such as those close to high-value assets) to maximise risk reduction, whereas bushfires randomly burn across locations.

Inland waters

As Victoria's population grows, demand for water is increasing and climate change is placing more pressure on the availability of fresh water. Water quality is crucial for the wellbeing of people and the environmental health of flora and fauna.

Good-quality fresh water in rivers and streams is vital for the environment and culture, agriculture, human health and recreation. Water quality can be degraded in many ways, including by vegetation loss, pollution, catchment run-off and the impacts of climate change.

Victoria's Traditional Owners and Aboriginal Victorians managed water sustainably for thousands of years. The Victorian Government is working with Traditional Owners to strengthen their role in water planning and management; and Victoria's *Water Act 1989* now includes a provision to consider Aboriginal cultural values and uses of waterways, along with social and recreational uses and values, in the management of waterways.

These important changes come at a time when Victoria's water resources are under increasing pressure from climate change, population growth and competing demands. Over recent decades, Victoria has experienced less rainfall in the cooler months of the year when most rainfall occurs. This is expected to continue, and projected increases in summer rainfall are unlikely to offset this decline.

In this context, it is critical to appropriately balance the water allocations for consumption and the environment. Environmental water is water that is managed to improve or maintain the health of rivers, floodplains, wetlands and estuaries, and the plants and animals that depend on them.

Water quality

There are several differences in the status and trend assessments for the water-quality indicators in the 2018 and 2023 SoE reports. This is due to a number of factors:

- two wet years occurring between 2018 and 2021
- the 2019–20 bushfires
- the availability of new data from the Water Measurement Information System (WMIS), which was matched to the water-quality objectives of the Environment Reference Standard (ERS).

The WMIS contains real-time data delivered hourly for all telemetered surface-water gauges (including water level, flow and water quality) and groundwater bores (for water level and water quality). As a result, water-quality data have improved significantly. The data are collected through Regional Water Monitoring Partnerships that include DEECA, BOM, the Murray–Darling Basin Authority, Victorian water corporations, Victorian CMAs and local councils.

The SoE 2018 Report used the objectives for the State Environment Protection Policy (Waters of Victoria), which was superseded by the ERS in 2021. Accordingly, for the SoE 2018 reporting period DELWP updated the water-quality data for the 2010-17 period assessed in the SoE 2018 Report to match the ERS water-quality objectives. This has enabled a comparison of the new data from the 2018-21 period with data from the 2010-17 period.

Urban development and population growth, agricultural land management, irrigation and climate change are impacting on water quality and aquatic biodiversity in Victoria.

Indicator WQ:01 shows that blue-green algal blooms are becoming more frequent, of longer duration and spread over a larger area. However, data limitations prevent an assessment of status.

Indicators WQ:02 to WQ:07 comprise the physico-chemical indicators of water quality – dissolved oxygen, salinity, nitrogen, phosphorus, turbidity and pH – and they vary considerably across Victoria's CMA regions. Water quality is generally highest in the east of the state, where forest cover is largely intact, and then declines westwards as urban and agricultural development intensify.

Indicator WQ:08 assesses water quality across CMA regions using a combined score from indicators WQ:03 to WQ:07. In the SoE 2018 Report, indicator WQ:08 was assessed on a statewide basis and was determined to be poor. In this SoE 2023 Report the assessment results are presented by CMA region, which shows that in some regions water quality has improved.

The quality of groundwater is still assessed as unknown in indicator WQ:09. So too are the assessments of status for indicators WQ:10 and WQ:11, which cover inland water pollution and the responses by EPA Victoria to pollution reports.

The SoE 2018 Report identified several critical challenges facing Victoria's management of water quality, which remain relevant five years later. They are:

- balancing the needs of catchment and waterway health with human and agricultural water consumption
- managing urban development and its impact on urban waterway health
- maintaining long-term water-quality monitoring data so that they are easily accessible and suitable for informing policy and strategy development
- mitigating against the following stressors:
    - increasing stormwater and wastewater discharges from urban areas
    - altered water regimes, salinity and algal blooms
    - an increase in catchment inflows from diffuse sources
    - localised events in which stressors on water quality, including nutrients, sediments, toxicants and pathogens, exceed objectives.

Water resources

The assessments for most water resources indicators are the same or similar in 2018 and 2023. One key difference is that 'WR:03 Surface water harvested for consumptive use' was rated as poor in 2018 and is now rated as fair in 2023.

'Indicator WR:01 Water resources and storage trends' shows that since the SoE 2018 Report water storage levels have been variable, falling to below 40% of capacity in 2020 and rising to almost 100% in late 2022. While there has been a long-term decline in storage levels, recent levels are slightly higher than the average during the Millennium Drought from 1998 to 2010.[40]

The long-term decline in inflows and storage levels, the projected growth of Victoria's population from 6.7 million to 11 million by 2056, and the anticipated impacts of climate change will increase pressure on the state's water resources.[41]

The use of groundwater and manufactured water (desalinated water, fit-for-purpose recycled wastewater and treated stormwater) is projected to increase, with one of the aims being to reduce reliance on river water and help stressed rivers recover.

Indicator WR:02 describes the important role that small farm dams play in rural communities. These dams provide water for stock, irrigation, gardens, domestic use and recreation. They provide habitat and refuges for frogs, waterbirds, invertebrates and reptiles, and can be used to support threatened species. However, farm dams also impact stream flows due to their interception of run-off, and can negatively impact aquatic life as well as downstream water consumers. Their number and storage volumes increased rapidly during the early stages of the Millennium Drought, but growth has now slowed. The limited monitoring of the smaller unlicensed farm dams limits analysis of the scale of their impacts.

Indicator WR:03 shows that waterway health is directly impacted by water diversion for human consumption. Reduced stream flows place stress on ecological functions and aquatic life in waterways. Many waterways across the state were rated poorly for hydrology in the Index of Stream Condition (ISC) released in 2013 and based on 2010 data, and the impacts of climate change on stream flows will make improvements difficult.

Indicator 'WR:04 Percentage of compliance with entitlements for the take of surface water' assesses compliance with water-extraction entitlements to support best-practice management of water resources and reduce impacts on aquatic ecosystems. Data for each of the 29 river basins show that there has been compliance with bulk entitlements, with take below the available water resource. However, the setting of entitlement caps has not included a determination of an environmentally sustainable level of take.[42]

As climate change and population growth increase pressure on Victoria's water resources, greater use of recycled water (WR:05) and treated stormwater (where fit for purpose) will be needed to help address supply shortfalls. However, the percentage of wastewater being recycled has not increased over the past decade due to several factors, including uncertainty in demand. Rainfall levels influence the volume needed for irrigation (the predominant end use of recycled water). Appropriately treated recycled water can also be used to boost environmental flows.

Irrigation agriculture is the dominant user of surface water, groundwater and recycled water in Victoria. Efforts to improve irrigation efficiency are the focus of indicator WR:06. The Australian (2009–19) and Victorian governments have been investing in the modernisation of irrigation districts to improve agricultural productivity and the efficiency of water use.[43] The saved water could be used to expand the land area under irrigation or to supplement environmental flows. While data for on-farm irrigation improvements are limited, surveys indicate that irrigators are improving the efficiency of their water use and using the gains to increase the resilience of the irrigation enterprise during dry periods when water allocations are lower.

Groundwater levels and consumption vary considerably across the state, as illustrated by the assessment for indicator WR:07. While many groundwater levels are stable, some are rising and others – in northern Victoria and Gippsland – are declining. Rising levels could indicate sustainable groundwater use; however, they could also lead to increased saline discharges and dryland salinity.

40. Department of Energy, Environment and Climate Action (DEECA), 'Current water snapshot', https://www.water.vic.gov.au/water-reporting/water-snapshot Accessed 23 February 2023.
41. Department of Environment Land, Water and Planning (DELWP) 2019, 'Victoria in future: 2019 population projections 2016 to 2056', Melbourne, Victoria, https://www.planning.vic.gov.au/land-use-and-population-research/victoria-in-future Accessed 8 June 2023.
42. The *Water Act 2007* (Cth) requires an environmentally sustainable level of take.
43. Department of Climate Change, Energy, the Environment and Water (DCCEEW), 'On-farm irrigation efficiency program', https://www.dcceew.gov.au/water/policy/programs/completed/ofiep Accessed 15 August 2022.

Declining levels could indicate unsustainable use. Groundwater levels are generally expected to decline in the longer term. Data on the outcomes of this long-term decline are limited, particularly relating to the impact on groundwater-dependent ecosystems such as wetlands.[44]

The 'Water resources' indicator assessments in the 2018 and 2023 SoE reports highlights:

- the ongoing impacts of climate change, population growth and land-use change on water storages, stream flows, groundwater and consumptive uses of water resources
- the relatively low volume of recycled water as a percentage of wastewater produced
- the lack of consistent and statewide data on improvements in irrigation
- variations in groundwater conditions and levels across the state, with many stable, some declining and several rising
- concentrations of high groundwater use in the state's north and in Gippsland.

Water for the environment

Average annual delivery of water for the environment from 2016–17 to 2020–21 (WR:09) was 743,402 ML. This was up 21% from the previous five-year period (2011–12 to 2015–16). The amount of carryover water also increased during the past five years, up by 24% in 2020–21 compared with 2015–16. This demonstrates that more water has been available and delivered for the environment during this state of the enviroment reporting period relative to the previous state of the enviroment reporting period. Water allocations are generally greater in wet years compared with dry years. Given that Victoria's total rainfall for this five-yearly state of the enviroment reporting period increased by only 2.5%, the 21% increase in delivery of water for the environment, and the 24% increase in carryover, represent a likely relative improvement in water availability for the environment. This analysis is best interpreted as an indicative guide to water availability for the environment because, even though it has been averaged across a 5-year period, environmental water allocations, delivery and carryover fluctuate from year to year.

44. Department of Environment, Land, Water and Planning (DEWLP), 'Unpublished data', Melbourne, Victoria, Accessed 2022.

A robust assessment of environmental water allocations over a longer period was completed for southern Victorian river systems in 2020 as part of the Long-Term Water Resource Assessment — Southern Victoria. That assessment found that long-term surface water availability across southern Victoria has declined by up to 21%. The decline in water availability has not always been shared equally, with the declines falling disproportionately on the environment in some basins. The assessment also found that a smaller proportion of available water is now set aside for the environment than when the last sustainable water strategies were developed between 2006 and 2011. A Long-Term Water Resource Assessment (LTWRA) for northern Victoria has not been completed, however an assessment is planned to start in 2025 to align with the Murray-Darling Basin Plan review scheduled for 2026.

Each year the Victorian Environmental Water Holder (VEWH) sets seasonal watering objectives that seek to achieve the best environmental outcomes with its available environmental water holdings. Monitoring and reporting of environmental watering by the Victorian Government is intended to contribute to advancing localised management of environmental water for better environmental outcomes. However, there is currently a gap in the monitoring of environmental watering outcomes at a statewide scale that needs addressing to improve future reporting as required by Action 3.6 of Victoria's water plan, Water for Victoria.

The VEWH's annual reports show that between 63% and 70% of its planned watering actions have been fully achieved, and 87% to 92% have been fully or partially achieved for each of the past three years (2019–20 to 2021–22). In comparison, an analysis of river flow data for each of the five years from 2017–18 to 2021–22 determined that between 19% to 35% of environmental flow study recommendations were fully achieved across Victoria. A further 43% to 51% of flow study recommendations were partially achieved each year, with 22% to 33% of recommendations not achieved.

The data show that the VEWH is generally fully achieving what it has planned with its potential watering actions each year. However, there remains a shortfall to fully achieve the scientifically recommended flow regimes. This highlights a gap between what Victorian river systems need from a hydrological perspective and what the VEWH can currently achieve from its environmental watering program.

For many catchments in Victoria, the run-off response to rainfall has declined this century, particularly during the Millennium Drought (WR:08). This means that many Victorian catchments have been getting less streamflow for a given amount of rainfall compared with past decades. Since streamflow has been below the long-term average most years this century, the status assessment for the condition of flow regimes indicator is poor, consistent with the status assessment for this indicator in the SoE 2018 Report.

Water for the environment is having a greater impact on fully achieving wetland watering requirements than it is on fully achieving optimum river flows. These results only include assessments for rivers and wetlands where environmental water is being delivered, which incorporates most of the regulated rivers in Victoria but only a small percentage of regulated wetlands. Higher achievement of recommended water regimes is likely occurring in wetlands because environmental watering targets many of Victoria's highest value wetlands. In some instances, dedicated environmental infrastructure (e.g. pumps) is deployed to deliver environmental water entitlements to priority and icons sites. In contrast, environmental watering of river systems is more heavily impacted by available volumes of held environmental entitlements, the natural seasonal conditions in any given water year, physical constraints within delivery systems (e.g. outlet valve capacities) and policy constraints (e.g. the obligation to avoid flooding towns and private land).

As per the *Water Act 1989*, water for the environment is delivered for the purpose of preserving the environmental values and health of water ecosystems, including:

- their biodiversity
- ecological functioning
- the quality of water
- the other uses that depend on environmental condition.

Current monitoring and reporting of environmental watering by the Victorian Government is intended to improve the use of environmental water at a given time in a particular location. This contributes to better localised management of environmental water. However, there is a knowledge gap, with no quantitative analysis of environmental watering outcomes available (both environmental and community outcomes) to be produced on a statewide scale.

Energy

Measured globally, the energy sector is responsible for almost three-quarters of all GHG emissions. The proportionate role of energy in emissions is even greater in Australia, and greater still in Victoria. This is due to the dominance of coal in Australia's electricity generation and the use of emission-intensive brown coal in Victoria. In 2022 the Victorian Government committed to bringing forward its net zero-emissions target by five years to 2045, meaning that Victoria will need to track slightly ahead of the International Energy Agency's (IEA) progress indicators.

Only one energy indicator received a status assessment of good in 2023, with three indicators rated as fair and two as poor. However, the 2023 assessments are a significant improvement compared with the SoE 2018 Report. In 2018, eight out of the nine energy indicators were rated as poor. The indicator trends in 2018 were generally assessed as improving, which is consistent with the upgrade in status assessments reported in 2023.

Indicator 'E:01 Primary energy consumption' highlights that Victoria performs well relative to Australia by consuming less energy per-capita and producing fewer GHG emissions from the energy sector per capita. While this is positive, per-capita energy consumption remains high relative to most G20 countries.

Critically, even though the energy sector in Victoria achieved a significant reduction (36%) of GHG emissions per capita during the past decade (2010–20) – a larger percentage reduction than any other Australian state or territory during that period – a much greater reduction (68%) is required during the next decade to meet the IEA's 2030 progress target for the objective of net zero emissions by 2050.[45]

An increase in the use of renewables in electricity production is driving the environmental improvements in the energy sector. Indicator 'E:04 Electricity generation by fuel' shows that renewable sources of Victorian electricity have increased from 6% in 2008–09 to 30% in 2020–21, while coal has dropped from 92% in 2008-09 to 66% in 2020–21.

45. In 2022 the Victorian Government committed to bring forward its net zero emissions target by five years to 2045, which means that Victoria will need to track ahead of the IEA progress indicators.

The Victorian Government's legislated renewable energy target – 25% of electricity in Victoria produced from renewable sources by 2020 – has been met. However, further improvements are now needed to reach the next target of 40% by 2025. Furthermore, the Victorian Government has committed to increase its 2030 target from 50% renewable electricity generation to 65%, and to legislate a new target of 95% by 2035 – highlighting that the next decade is a critical period for renewable energy transition in Victoria.[46] The power system is rapidly decentralising, and it will be valuable for the Victorian Government to establish and publish data to track the progress to/of variable renewable generation (i.e. solar and wind power).

Despite the gains by renewables for electricity production, emissions from fossil fuel fired-electricity generation accounted for 41.7 Mt CO2-e in 2020, which was about half (50.1%) of Victoria's total net emissions. Coal remains the dominant fuel source for electricity generation in Victoria, which offsets the relatively high penetration of renewable sources when benchmarked against G20 countries.

There has only been a small decline in per-capita gas consumption (E:05) in Victoria (compared to electricity) and an under-performance in Victoria relative to South Australia and New South Wales for per-capita gas distribution. With gas prices rising steadily, GHG emissions from residential fuel combustion increasing, and international events causing uncertainty in gas supply and price around the world, reducing gas consumption and associated GHG emissions is an important and immediate focus for Victoria. Over two million Victorian homes and businesses use gas – more than any other state or territory.[47] To effectively monitor the transition from natural gas in residential water heating and space heating, it will be critical to report data on the energy consumed by water heaters installed in each year, and in the total residential sector, classified by fuel type.

Victoria's performance in energy consumption (and GHG emissions) in transport (E:06) is poor by comparison to GHG emissions in stationary energy. Energy use and GHG emissions from transport are both lower than the previous state of the environment reporting period; however, this is more likely due to a reduction in travel associated with the COVID-19 restrictions rather than factors that would contribute to an enduring change.

Unlike total energy consumption per capita from all sectors, which has declined year-on-year in Victoria since 2009 (except for a minor increase in 2018), energy consumption from the transport subsector had not been distinctly decoupling from population growth – at least until the COVID-19 pandemic, when travel restrictions and substantial reductions in energy consumption from transport occurred in both 2019–20 and 2020–21. There have been no significant changes in GHG efficiency in the transport sector since data was first available in 1990.

To reduce GHG emissions from the transport subsector, fossil fuel energy use per person needs to decline at a faster rate than population growth, and technological advancements must reduce GHG emissions from transport.

Waste and resource recovery

Waste persists as a significant issue in Victoria. The waste and resource recovery indicators in this SoE 2023 Report showed few demonstrable improvements since the SoE 2018 Report, with most indicators (four out of six) either declining in status and/or trend or maintaining an assessment of poor.

Contributing to the deterioration or lack of progress were external factors that severely impacted Victoria's waste and resource recovery sector between 2018 and 2021 (i.e. during the SoE 2023 reporting period), particularly within the municipal solid waste (MSW) sector.

In January 2018, China began to stringently enforce restrictions on the importation of recycled materials under its National Sword policy. This impacted the global market for recyclable material as it effectively removed a key international market, which Victoria and Australia had relied upon heavily for trading sorted recyclables. This has created volatility in global and domestic pricing for recovered materials.

With limited export destinations available, the vulnerabilities within Victoria's waste and resource recovery sector were exposed. Local reprocessing capacity and capability were shown to be inadequate

46. Department of Energy, Environment and Climate Action (DEECA), 'Victorian renewable energy and storage targets', https://www.energy.vic.gov.au/renewable-energy/victorian-renewable-energy-and-storage-targets Accessed 15 February 2023.
47. Department of Environment, Land, Water and Planning (DELWP) 2022, 'Victoria's gas substitution roadmap', https://www.energy.vic.gov.au/renewable-energy/victorias-gas-substitution-roadmap Accessed 9 June 2023.

to manage the state's volume of recyclable material or the rapid concentration of waste generated by the MSW sector. The situation was exacerbated by the impact of the COVID-19 stay-at-home restrictions and the lack of local demand for recovered materials. Sharp increases in contamination levels among household recyclable materials have also lowered their value and potential for recovery.[48]

With market influences being considered a major driver for legitimate stockpiling practices, excessive stockpiling of combustible waste materials ensued as waste recycling and recovery operators sought to redirect collected recyclables to alternative destinations and take advantage of economies of scale.[49] What eventuated were a number of illegal incidents among resource recovery facilities, and their ultimate closure.[50] With the loss of these facilities, significant quantities of household recyclables were landfilled during 2019 and 2020 and costs to local governments for managing waste rose.

Total waste generation (W:01) has been on an upward trajectory from 2014–15 to 2019–20, following a short period of decline from 2012–13 to 2013–14. By 2019–20, Victoria had discarded more waste than in any other financial year. The pattern of waste generation since 2014–15 followed a linear model, in that growth in waste levels trended in line with increases in the state's population and gross state product (GSP), with the rate of increase in waste generation surpassing that of population growth.[51, 52] During the SoE 2023 reporting period the amount of waste produced rose at a more rapid rate (10%) and peaked at a higher level (15.9 Mt) than during the SoE 2018 reporting period – 7% and 12.9 Mt, respectively.[53] The escalating levels of waste generation in recent years is likely a reflection of higher levels of infrastructure development and improvements occurring within the state (e.g. the Big Build program of works).[54]

Even after removing the effects of population growth, the pattern of rising waste generation in the state persists. There has been a gradual, but continued, upward trend in per-capita waste generation (W:02) There has been a gradual, but continued, upward trend in per-capita waste generation (W:02 — up from 1,188 kg in 2017-18 to 1,225 kg in 2019-20 — while resource recovery declined modestly overall (1%) across the three years that data were available, despite recyclables maintaining a larger proportion of per-capita waste totals. These findings suggest that factors other than population size are driving Victorians to dispose of progressively more waste and recycle less overall. This pattern was underpinned by such factors as per-capita behaviour, the availability of adequate recycling collection services, particularly among the commercial and industrial (C&I) waste sector, as well as the clearance of stockpiled recyclables.

Importantly, as the definition of per-capita behaviour in this report has been broadened to include waste generated from both the MSW and C&I sectors — not just the MSW as in previous SoE reports — direct comparisons across SoE reports are not possible.[55]

The rate at which Victoria was diverting waste from landfill (W:04) had remained relatively stable since 2010–11, ranging from 63% to 70%, with the rate of increase slowing in more recent years (2017–18 to 2019–20). A modest increase of 5% was also observed across state of the environment reporting periods which is in contrast to the growth seen in both waste generation (32%) and disposal (20%) since 2012–13, meaning that Victorians are disposing of more waste every year.

During the SoE 2023 reporting period, the construction and demolition (C&D) sector had the highest diversion rate among all source sectors, recovering between 84% and 87% of generated

48. Envisage Works, IndustryEdge and Sustainable Resource Use (SRU) 2021, 'Victorian Market Intelligence Project', *Recovered Resources Market Bulletin*, e18, https://assets.sustainability.vic.gov.au/susvic/Recovered-Resources-Market-Bulletin-July-2021.pdf Accessed 12 August 2022.
49. Infrastructure Victoria (IV) 2020, 'Advice on recycling and resource recovery infrastructure', Melbourne, Victoria https://www.infrastructurevictoria.com.au/wp-content/uploads/2020/03/Advice-on-recycling-and-resource-recovery-FINAL-REPORT.pdf Accessed on 29 July 2022.
50. Environment Protection Authority (EPA) Victoria 2021, 'Management and storage of combustible recyclable and waste material', https://www.epa.vic.gov.au/about-epa/publications/1667-3 Accessed 8 June 2023.
51. Van Fan Y, Klemeš JJ, Lee CT, Tan RR 2021, 'Demographic and socio-economic factors including sustainability related indexes in waste generation and recovery', *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, https://www.tandfonline.com/doi/full/10.1080/15567036.2021.1974610 Accessed 9 June 2023.
52. Sustainability Victoria (SV) 2021, 'Waste and recycling in Victoria – recycling industry workbook 2019-20', https://assets.sustainability.vic.gov.au/susvic/Workbook-Waste-Recycling-Industry-Workbook-2019%E2%80%9320.xlsx Accessed 5 July 2022.
53. Data for the indicator assessments of this chapter do not cover the full SoE 2023 reporting period. Limitations in data availability have resulted in only a subset of years within the reporting cycle to be considered in the assessments. The range of years varies across the waste and resource recovery indicators.
54. Blue Environment 2020, 'National waste report 2020', report prepared for the (now) Department of Climate Change, Energy, the Environment and Water (DCCEEW), https://www.dcceew.gov.au/sites/default/files/env/pages/5a160ae2-d3a9-480e-9344-4eac42ef9001/files/national-waste-report-2020.pdf Accessed 4 July 2022.
55. This measurement change was made by CES, in consultation with data custodians, to align with the circular economy policy target, thereby improving future monitoring of progress towards the 15% reduction in per capita waste target.

waste. Increasing reliance on recycled materials for infrastructure projects contributed to much of the growth in material recovery by the C&D sector. This construction practice was standardised in 2020 under the Recycled First Policy, which mandates organisations delivering major transport projects to prioritise the use of recycled and reused materials over virgin materials.[56] By contrast, the C&I and MSW sectors had considerably lower rates of waste diversion, and present the greatest opportunity for improving resource recovery.

Food waste generation (W:03) has fluctuated across the state of the environment reporting periods. Following an overall decline from 2013–14 (1.2 Mt) to 2018–19 (1.1 Mt) and a 5% decrease in food waste generation in the SoE 2018 reporting period, food waste has begun to increase in recent years, with households being by far the greatest contributor to the state's food waste totals (70%). Given the declining rates of recovery, coupled with increasing levels of disposal during the SoE 2023 reporting period, food waste continued to represent a dominant waste stream entering landfill. This was particularly evident during 2018–19, when 16% of the state's total disposed waste was made up of food material, which equates to 711 Kt of food entering landfill.

The amount of litter (W:05) has been declining overall since the SoE 2018 Report, but there has been a small increase in recent years. Despite continued reductions in total annual litter items, the proportion of litter streams has remained relatively unchanged.[57] Cigarette butts were consistently the largest litter type across years, while illegal dumping, plastic bags and other glass litter types contributed the least. Illegal dumping rates have been on the rise since the SoE 2018 Report, with peak dumping volumes occurring in 2018–19.[58]

Hazardous waste (W:06) has been increasing, with Victoria reaching its highest levels of hazardous waste arisings by 2019–20, the second highest level in Australian jurisdictions.[59, 60] The level of growth was 24% in the SoE 2023 reporting period compared with 5% during the previous reporting cycle. Much of this recent growth has been driven by more asbestos, waste oil/water and contaminated soils being generated and managed. As of 2019–20, large-scale development projects resulted in the unprecedented growth of contaminated soils, to become the largest single contributor (59%) of hazardous waste arisings in Victoria. During this same year there was a sharp rise in clinical waste arisings – personal protective equipment from the healthcare and aged care sectors, and to a smaller degree from communities – due to the COVID-19 pandemic. More interstate movement of hazardous waste was required to cope with the influx of personal protective equipment.

Issues in the accuracy, breadth and methodology of annual waste data collection and reporting have prevented a full understanding of waste generation and recovery patterns in Victoria, and they impede on the evaluation of progress towards the state's circular economy targets. These issues were highlighted by several inquiries and audits of Victoria's waste and resource recovery sector and led to mandated changes under the new legislative framework to modernise the state's waste data collection systems.[61, 62, 63, 64] The intended long-term gains arising from these actions have not yet been fully realised, and information gaps still remain in annual waste reporting. Therefore, data confidence for several waste and resource recovery indicators reported has been reduced.

56. Ecologiq 2020, 'Recycled first policy', https://bigbuild.vic.gov.au/about/ecologiq/recycled-first-policy Accessed 9 June 2023.
57. Keep Australia Beautiful (KAB) 2019, 'National litter index 2018-2019: Victoria results', Newtown, New South Wales https://assets.sustainability.vic.gov.au/susvic/Report-National-Litter-Index-2018-19-Victoria-results.pdf Accessed 14 July 2022.
58. Sustainability Victoria (SV) 2020, 'Victorian local government annual waste services report 2018-19', Melbourne, Victoria https://assets.sustainability.vic.gov.au/susvic/Report-Victorian-Local-Government-Annual-Waste-Services-Report-2018-19.pdf Accessed 30 June 2022.
59. The term 'arisings' is used in relation to hazardous waste data derived from tracking systems. Waste arises when it is delivered to hazardous waste processing, storage, treatment or disposal infrastructure. This is distinguished from 'generation', a term commonly used in waste reporting. If hazardous waste is transported to more than one site, it may 'arise' more than once in the tracking system data.
60. Blue Environment, Ascend Waste and Environment 2021, 'Australian hazardous waste data compilation (data up to and including financial year 2019–20)', report prepared for the (now) Department of Climate Change, Energy, the Environment and Water (DCCEEW), https://www.dcceew.gov.au/sites/default/files/documents/national-hazwaste-data-collation-2019-20.xlsx Accessed on 5 July 2022.
61. Parliament of Victoria Legislative Council Environment and Planning Committee, 2019, 'Inquiry into recycling and waste management', https://www.parliament.vic.gov.au/file_uploads/LCEPC_59-02_Inquiry_into_recycling_and_waste_management__6hNrvBj7.pdf Accessed 28 July 2022.
62. Victorian Auditor-General's Office (VAGO) 2019, 'Recovering and reprocessing resources from waste: Independent assurance report to Parliament', Melbourne, Victoria, https://search.informit.org/doi/10.3316/agispt.20200107022396 Accessed 9 June 2023.
63. Infrastructure Victoria (IV) 2020, 'Advice on recycling and resource recovery infrastructure in Victoria', https://www.infrastructurevictoria.com.au/project/advice-on-waste-infrastructure-in-victoria Accessed 29 July 2022.
64. Victorian Auditor-General's Office (VAGO) 2021, 'Council waste management services', https://www.audit.vic.gov.au/report/council-waste-management-services?section= Accessed 28 July 2022.

Recommendations

The following recommendations are informed by the science and analyses presented in Parts 2 and 3 of this report. They are intended to support environmental improvement over the next decade and beyond. Although most of the recommendations do not specify delivery timelines, except where noted, it is anticipated that they would be fully implemented by 2033, with clear progress evident within five years, recognising that the next SoE Report is due in 2028.

The recommendations:

- prioritise actions that improve multiple environmental outcomes
- focus on improving the evidence base to deliver key policy and legislative actions and targets
- are informed by the findings of other respected reports[65]
- identify actions to achieve ecologically sustainable development and United Nations (UN) Sustainable Development Goals (SDG) targets by 2030
- support the development of a system for environmental-economic accounting for Victoria.

The CES Act requires the Victorian Government to respond to all the SoE recommendations within 12 months of the report being tabled in the Parliament of Victoria.

Table 4 provides a summary of the recommendations, the challenges they propose to overcome, their status in relation to the SoE 2018 recommendations, and their alignment with the UN SDG targets and goals.

Major Event Review of Victoria's Regional Forest Agreements

The Major Event Review was introduced in the modernised Regional Forest Agreements (RFAs) in March 2020. A Major Event Review assesses the impacts of major events such as bushfire, flood and disease outbreaks in relation to the objectives and operation of the RFAs. The 2019–20 bushfires was the first event to trigger a Major Event Review.

The Commissioner for Environmental Sustainability was one of a three-member independent panel for the Major Event Review of the 2019–20 bushfires. The panel report dated March 2022 made 37 recommendations, many of which focus on the environmental values of Victorian forests.[66] The Victorian and Australian governments are required to respond to these recommendations.

65. The CES acknowledges the significant research undertaken by others, including VEAC, Victorian Auditor-General's Office (VAGO) and the Independent Panel of the Major Event Review of Victoria's Regional Forest Agreements.
66. Major Event Review Independent Panel 2022, 'Victorian regional forest agreements: Major event review of the 2019-20 bushfires', https://www.agriculture.gov.au/sites/default/files/documents/vic-rfa-mer-bushfires-report-2022.pdf Accessed 21 November 2022.

Cultural landscape health and management

Recommendation 1: That the Victorian Government resources and supports Victoria's Traditional Owners to implement a program of on-ground assessment and develop contemporary bio-cultural indicators to restore the knowledge system of Traditional Owners in Victoria consistent with policy and legislative requirements. Initially, the Victorian Government would resource and support the Eastern Maar and Wadawurrung Traditional Owners to deliver the legislative obligations of the *Great Ocean Road and Environs Protection Act 2020* and inform future consultation on bio-cultural indicators with other Traditional Owners in Victoria.

Challenges this recommendation addresses

Aboriginal existence and identity are underpinned by healthy cultural landscapes. Along with water and other natural resources, the land that is now the State of Victoria was managed for thousands of years according to traditional laws, customs and practices. Shaped by a sustainable-use regime and managed with a deep understanding of natural systems and an embedded lore and culture, Country (land, water, animals, plants, people, spirits and customs) has provided for the material, cultural and spiritual needs of thousands of generations of Aboriginal people.[67]

Reporting on Victoria's diverse and valuable ecosystems must acknowledge, and learn from, the long history of Traditional Owner knowledge that has underpinned care for these cultural landscapes.

It must reflect the aspirations that Victoria's Traditional Owners have shared with the Victorian Government:

> 'Restoring the knowledge system must reflect the fundamental principle that traditional knowledge is owned by Traditional Owners. Traditional Owners as custodians of knowledge and practice continue to decide how consent to share knowledge is given.'
>
> 'We need resources for data collection, then will give the state the management objectives. The State and other [land management organisations] need to support our projects, not us supplementing theirs.'[68]

Context

The CES acknowledges that sharing data, knowledge and stories to inform reporting on cultural landscape health and management is always at the discretion of Traditional Owner groups. Aboriginal people own their knowledge and will determine when to inform others on how to use it to manage Country.

Recommendation 1 of the SoE 2018 Report recommended:

> *'That the Victorian Government, in consultation with Traditional Owners and relevant agencies, develop contemporary cultural indicators to inform future environmental reporting. These indicators must reflect the priorities of Traditional Owners, have practical and cost-effective data-collection methods, be meaningful, and demonstrate change within a five-year reporting period.'*

The Victorian Government supported this recommendation in principle.

67. Parks Victoria (PV) 2018, 'Managing Country Together', Melbourne, Victoria, https://www.parks.vic.gov.au/managing-country-together Accessed 9 June 2023.
68. Federation of Victorian Traditional Owner Corporations 2021, 'The Victorian Traditional Owner Cultural Landscapes Strategy', Melbourne, Victoria, https://fvtoc.com.au/wp-content/uploads/2023/03/1258_FVTOC_CulturalStrategy_web.pdf Accessed 9 June 2023.

The CES supports the aspirations of Traditional Owners and the restoration of traditional knowledge systems. Increased connection, participation and self-determination in managing and looking after Country will improve the condition of cultural landscapes. In the future, SoE assessments must adopt an approach that allows adaptation and modification of bio-cultural indicators to support self-determination by Traditional Owner and Registered Aboriginal Parties.

The Victorian Government should resource and support Traditional Owners to implement a program of on-ground assessment to develop these indicators consistent with policy and legislative requirements including:

- the *Yarra River Protection (Wilip-gin Birrarung murron) Act 2017*
- the *Great Ocean Road and Environs Protection Act 2020*
- Victorian Regional Forest Agreements
- Water is Life: Traditional Owner Access to Water Roadmap.

The indicators must:

- reflect the priorities of the Eastern Maar and Wadawurrung Traditional Owners
- have practical and cost-effective data-collection methods
- be meaningful
- demonstrate change within a five-year reporting period
- inform future consultations on bio-cultural indicators with other Traditional Owners in Victoria to protect, conserve, manage, and prevent future harm to, Country.

With appropriate support from the Victorian Government this work could begin for the State of the Great Ocean Road Coast and Parks 2024 Report, which would inform legislative requirements including the report on the environmental condition of the Great Ocean Road coast and parks and implementation of the Great Ocean Road strategic framework plan. The bio-cultural indicators would also be used to update environmental-economic accounting for the Great Ocean Road, which DEECA is preparing consistent with the UN System of Environmental-Economic Accounting guidelines.

Climate change

Recommendation 2: That the Victorian Government downscales and applies the latest climate change modelling and scenarios for Victoria, consistent with the Intergovernmental Panel on Climate Change Sixth Assessment Report. The updated modelling and scenarios will provide a critical foundation to develop a climate hazards decision support tool for Victoria to improve decision-making in adapting to the impacts of climate change.

Challenges this recommendation addresses

The assessments for the 'Climate projections' indicators in this report are generally based on results from the Victorian Climate Projections project (VCP19) – a collaboration between DELWP and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) that produced new local-scale climate projections for the entire state of Victoria for medium- and high-emissions pathways. Since then, a new generation of global climate models have been developed as part of CMIP6, and were featured in the IPCC Sixth Assessment Report, which included a new set of emission scenarios. The new modelling and scenarios are yet to be downscaled and applied for Victoria.

Context

Recommendation 2 of the SoE 2018 Report recommended:

'That DELWP, in coordination with research partners, conduct further analysis to improve localised climate projections (particularly in agricultural regions). These projections would aim to reduce the uncertainties associated with rainfall projections as a minimum.'

The Victorian Government supported this recommendation and collaborated with CSIRO to undertake localised projections in Victoria.

We do not know what social, economic and technological pathways will be followed over time and how they will determine GHG emissions, so climate scientists use emissions scenarios to project a reasonable range of possible future climates.

The Australian Government Department of Climate Change, Energy, the Environment and Water (DCCEEW) is working with state and territory governments, CSIRO, BOM, universities, and other Australian Government funded initiatives such as the National Environmental Science Program (NESP) Climate Systems Hub and the Australian Climate Service (ACS) to develop an updated set of national downscaled climate projections.[69]

In 2023 DCCEEW developed a Climate Projections Roadmap for Australia in collaboration with the Australian climate projections community. The roadmap includes a shared vision statement for the newly established National Partnership for Climate Projections. It will guide delivery of a nationally aligned, sustainable and integrated approach to Australian projection science and projections information.[70]

Applying the latest climate change modelling and scenarios to Victoria is critical for creating the next generation of technology to inform decision-making. This includes a decision support tool to improve the management of service delivery in Victoria (e.g. health, education, housing, transport and justice) and ensure data are publicly available for all end users on the impacts of climate hazards: heat, water scarcity, fire and flood. The new models and the decision support tool will inform the delivery and evaluation of Victoria's seven climate change adaptation plans, providing valuable insights and assisting in developing more targeted reporting in Victoria's state of the environment and climate science reports.

69. Department of Climate Change, Energy, the Environment and Water (DCCEEW), 'Future climate change', https://www.dcceew.gov.au/climate-change/policy/climate-science/climate-science/climate-change-future Accessed on 5 June 2023.
70. National Partnership for Climate Projections 2023, 'Climate projections roadmap for Australia', https://www.dcceew.gov.au/climate-change/publications/climate-projections-roadmap-for-australia Accessed on 9 June 2023.

Air

Recommendation 3: That EPA Victoria develops IT infrastructure and data analytics capacity to interface air-quality sensor monitoring data – including citizen science monitoring data – with EPA Victoria's existing network of standard air monitoring sites. The complete suite of air monitoring data would interface with a regularly updated air pollution inventory, to be provided as an input for air-quality modelling.

Challenges this recommendation addresses

Data from EPA Victoria's regional network of sensor monitoring sites are lower quality than the standard monitoring sensors. Data from these lower quality sensors are therefore, not included in this SoE 2023 Report.

EPA Victoria's air pollution inventory has proven to be a very useful tool; however, it has not been updated since the base year of 2016.

Context

Recommendation 3 of the SoE 2018 Report recommended:

'That EPA Victoria prioritise the implementation of the EPA Inquiry [2016 Independent Inquiry into the Environment Protection Authority] recommendations 6.3 and 7.2 to develop a publicly accessible, real-time assessment of air quality across Victoria that incorporates air-quality monitoring data, citizen science observations, air-quality modelling and an up-to-date air-pollution inventory. Future monitoring and assessments would also be expanded to include ultrafine particles and data on indoor air quality.'

The Victorian Government supported this recommendation in principle.

Air-quality management requires a systems response. Elements such as air-quality monitoring, air-quality modelling, air pollution inventories, meteorological data and chemical transport models can be integrated to provide a statewide map of air quality in Victoria that is available for all Victorians.

The map and underpinning data would be a tool to calculate population exposure to air pollution and associated health burden. Population exposure metrics could be calculated and tracked to guide policy and intervention efforts for air pollution management strategies and emission reduction initiatives.

Since the SoE 2018 Report, EPA Victoria has made improvements that support the type of comprehensive air pollution tool described above. These improvements include expanding the air-quality monitoring network, releasing an air pollution inventory with a base year of 2016, and estimating the percentage of the Victorian population exposed to annual $PM_{2.5}$ concentrations exceeding the air-quality standard ('A:06 Population exposure to air pollution'). However, more can be done; for example, improving the quality of monitoring sensors and data currency of the air pollution inventory.

To enable development of a real-time statewide map of air quality that blends air-quality modelling and monitoring, EPA Victoria will benefit from enhancing its IT infrastructure and data analytics capacity so that it can interface air-quality sensor monitoring data – including citizen science monitoring data – with EPA Victoria's existing network of standard air monitoring sites. This would be complemented by EPA Victoria regularly updating its air pollution inventory, incorporating real-time activity data such as live traffic data and data on active bushfires and prescribed burns. The air monitoring and air pollution inventory datasets must be formatted so they can be readily used as inputs for air-quality modelling.

Air pollution mitigation strategies require considered analyses to understand the underlying characteristics contributing to air pollution. The air pollution tool described above would allow for accurate sensitivity analyses (for example, determining how much effect reducing truck movements by various amounts would have on local air quality). This would allow appropriate thresholds to be developed and tracked (for example, determining an acceptable number of trucks travelling along a road with sensitive receptors within a given period).

The air pollution tool would be the foundation upon which evidence-based air pollution mitigation strategies are developed in Victoria. The tool could also include GHG emissions, which would allow ambient air pollutants and GHGs to be assessed simultaneously, providing even greater utility for cost–benefit analyses on topics like low-emission vehicles, where there are likely to be impacts for ambient air pollutants and GHGs.

Recommendation 4: That the Victorian Government leads the establishment of a contemporary pollen-monitoring network that incorporates forecasting and publishes monitoring information and pollen forecasts in real time, to provide the community with timely and accessible information on pollen levels.

Challenges this recommendation addresses

Victorians are currently unable to access information about real-time pollen levels, except for people in inner Melbourne who can pay for a subscription to the Melbourne Pollen app developed and maintained by the University of Melbourne. Pollen forecasts are currently provided for each day, but details such as what time during the day that peak pollen levels will occur are not provided.

Context

Recommendation 4 of the SoE 2018 Report recommended:

> *'That Victoria's Chief Environmental Scientist, supported by relevant government agencies and research partners, lead the establishment of a contemporary pollen-monitoring network to enable community access to information on pollen levels in the air in a timely manner, through actions including increasing the number of locations monitored, the frequency of the monitoring, and automating the monitoring process.'*

The Victorian Government did not support this recommendation.

While the government response acknowledged the important role of pollen monitoring to take preventive action during the grass pollen season, the government indicated that the intent had been met by its work to establish the pollen-monitoring and community awareness program following the epidemic thunderstorm asthma event in November 2016.

Recognising the need for a contemporary pollen-monitoring network, the University of Melbourne purchased and installed Australia's first automated pollen counter in 2021. Initially operating as a trial and funded by subscribers to the Melbourne Pollen app, the automated monitor is now a permanent fixture operated by the University of Melbourne. Automated monitoring has the potential to supersede the existing network of eight pollen-monitoring sites overseen by the University of Melbourne and funded by the Victorian Government.

Further support for a contemporary pollen-monitoring network in Victoria is found in the Parliament of Victoria Inquiry into the Health Impacts of Air Pollution in Victoria final report, published in November 2021. The Inquiry made 35 recommendations to improve monitoring of air pollution and mitigate its impacts on the community, including Recommendation 31, 'That the Victorian Government reconsider its response to Recommendation 4 of the Victorian State of the Environment 2018 Report and implement a contemporary pollen monitoring network.'

Publicly accessible real-time monitoring information for several places within Victoria, combined with pollen forecasts for different parts of the day (rather than one forecast per day), would greatly help Victorians to minimise exposure to the worst pollen concentrations.

Given the significance of pollen impacts on health, wellbeing and the economy ('A:07 Pollen' and 'A:14 Health impacts from pollen') it is recommended that the Victorian Government contributes to the development of a contemporary pollen-monitoring network in Victoria, consistent with its commitment following the 2016 EPA Inquiry to explore the links between environmental and human health (recommendations 6.2 and 6.3) and expand EPA Victoria's capabilities.[71]

71. Victorian Government 2016, 'Independent inquiry into the environment protection authority', Melbourne, Victoria.

Biodiversity

Recommendation 5: That the Victorian Government (i) establishes independent biennial reporting to the Parliament of Victoria on Biodiversity 2037 targets, (ii) oversees an integrated and comprehensive biodiversity monitoring program for the state with an emphasis on arresting threatened species decline, and (iii) evaluates the implementation and outcomes of Biodiversity 2037 and the efficiency of investment in threatened species.

Challenges this recommendation addresses

In its 2020 submission to the Parliament of Victoria Inquiry into Ecosystem Decline in Victoria, DELWP reported that one-quarter to one-third of 'Victoria's terrestrial plants, birds, reptiles, amphibians and mammals, along with numerous invertebrates and ecological communities, are considered threatened with extinction.'[72] This fate has already occurred for 18 mammal, two bird, one snake, three freshwater fish, six invertebrate[73] and 51 plant species in Victoria since European settlement.[74]

The DELWP submission states, 'The longer-term outlook for many threatened species and habitats that rely on Victoria's approximately eight million hectare public land estate for their conservation is poor;'[75] and that protecting the state's biodiversity, habitats and public lands estate will 'require biodiversity conservation being given greater consideration in decisions involving competing public land uses as well as increased, better targeted and coordinated investment to manage key threats within a tenure-blind ecosystem-based framework.'[76]

Context

The main drivers of biodiversity decline in Victoria have been population growth, urban development, bushfires, invasive species, land clearing and climate change. The result is highly fragmented native vegetation, habitat loss, habitat degradation, reduced connectivity, loss of ecological processes and functions, and the spread of invasive species.

To date, the implementation of Biodiversity 2037 is not meeting the Victorian Government's targets.[77] This is confirmed by the assessments in this report. Although evaluation and reporting on the progress of Biodiversity 2037 are limited; important targets including invasive species management, the establishment of new, permanently protected areas on private land, and revegetation are not being met.

Recommendation 5 of the SoE 2018 Report recommended:

> *'That DELWP streamline the governance and coordination of investment in the science and data capability of all government biodiversity programs and improve the coherence and impact of the publicly funded, scientific endeavour. Further, that DELWP establish the position of the Chief Biodiversity Scientist to oversee this coordinated effort and provide esteemed counsel to the DELWP Secretary and the Minister for Environment to improve the impact of investment in biodiversity research across the Victorian environment portfolio. That DELWP improve biodiversity outcomes on public land by streamlining and coordinating governance arrangements.'*

The Victorian Government supported this recommendation in part.

Victoria's first Chief Biodiversity Officer was appointed in July 2022. The role provides technical leadership and oversight of research and information systems within DEECA and liaises with key portfolio partners and community groups to enable evidence-based decision-making within the sector.

72. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Protecting Victoria's environment – Biodiversity 2037', Melbourne, Victoria.
73. Monitoring of invertebrate biodiversity is limited. It is likely that many more than six species of invertebrates have become extinct.
74. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Submission to the Legislative Council Environment and Planning Committee Inquiry into ecosystem decline in Victoria', Parliament of Victoria, Melbourne.
75. Ibid
76. Ibid
77. Victorian Auditor-General's Office (VAGO) 2021, 'Protecting Victoria's biodiversity', Melbourne, Victoria.

The role as it has been implemented is constrained in how it can address the systemic causes of biodiversity and threatened species decline in the state. This role would be a critical liaison for the author of the independent biennial report.

Since the SoE 2018 Report, data on ecosystem condition and species abundance and distribution continues to be limited (including for invasive species). Monitoring is neither comprehensive nor integrated. Resourcing of habitat and species research, recovery and restoration programs is inadequate, although efforts in response to the 2019–20 bushfires were well managed and coordinated. The number of threatened species have increased and the tools available in the FFG Act to conserve threatened species, such as action statements and critical habitat determinations, are underutilised.

Biodiversity 2037 committed the Victorian Government to targets for biodiversity and threatened species management in Victoria. These targets were established through strong engagement with the community and scientists. The CES and VAGO have reported on the lack of data for many of these targets and, where data are available, a lack of progress in meeting the commitments. VAGO's 2021 report Protecting Victoria's Biodiversity made nine recommendations to improve the evidence base and biodiversity and threatened species management in Victoria. All recommendations were accepted by DEECA. Furthermore, while five-yearly reporting through the SoE reports will track performance over the long term, it is inadequate to achieving systemic uplift in performance, conservation outcomes and halting biodiversity decline. The introduction of an independent biennial report on Biodiversity 2037 targets tabled in the Parliament of Victoria that reports on the science curated by the established monitoring program can help to address this gap in the system.

Transparency and accountability are central to improving biodiversity and threatened species management and outcomes. To that end, the accountability, urgency and scrutiny of the biodiversity system in Victoria needs to be refreshed. A biennial report would allow for regular, public interrogation of the science and review of management tools and options.

This proposal is sensitive to other initiatives and technologies as they mature. For example, over time, the incorporation of the data integration strategy (Recommendation 14) and the eDTV (Recommendation 15) is envisaged. It is consistent with the Victorian Government's shift in the past decade to more independent environmental reporting. Experience from environmental reporting reforms of the past decade is that this approach is likely to raise awareness and collective action across government, business and the community, and help foster co-creation and partnerships to improve biodiversity outcomes.

The independent reporting would extend to assessing listings (threatened species, ecological communities, key threatening processes) and whether they are updated in a timely manner appropriate to current trends in biodiversity loss.

The biennial report and associated monitoring program should incorporate the recommendations of VAGO's 2021 report Protecting Victoria's Biodiversity, and be designed to achieve the following:

- assess species status, trend and data availability to more meaningfully report on species (Biodiversity 2037 Section 2.2; VAGO Recommendation 2)
- develop, implement and report on targeted monitoring programs for each threatened species to assess and evaluate species' responses to management interventions (Biodiversity 2037 Section 2.2; VAGO Recommendation 3)
- prioritise species for development of action statements, develop these and oversee their timely implementation, evaluation, monitoring and reporting (Biodiversity 2037 Section 3.1; VAGO Recommendation 5)
- prioritise and fund critical knowledge and data gaps (Biodiversity 2037 Section 3.2; VAGO Recommendation 7)
- provide updated, comprehensive, scientific and evidence-based advice to the Victorian Government on the ongoing resources needed to improve the net outlook for all threatened species listed under the FFG Act and the investment needed to protect and recover prioritised critically endangered species at extreme risk of extinction (Biodiversity 2037 Section 3.4; VAGO Recommendation 8 and 9).

The Victorian Government has committed to implementing the VAGO recommendations.

Recommendation 6: That the Victorian Government establishes multiple safe havens in Victoria to protect and restore critical habitats for nature and wildlife. These will be world-class refuges, free from feral predators and herbivores. They will be conservation flagships for threatened species that will demonstrate the best in network governance, where the government's environmental and emergency management bodies, Traditional Owners, scientists and all Victorians valuing nature can work together to protect habitats and species.

Challenges this recommendation addresses

Ecosystems are transforming under climate change, with substantial shifts in ecological processes (e.g. fire, landscape connectivity) and important ecosystem services (e.g. pollination, water filtration) occurring at unprecedented rates.[78] The evidence in this report demonstrates that biodiversity decline is continuing in Victoria despite the ongoing commitment and effort from the Victorian Government, community groups, scientists and environmental managers.

Context

There is great scientific uncertainty and conflicting values across major conservation management issues and approaches, and returning ecosystems to historical states is no longer universally appropriate. There is, however, acknowledgement that natural systems are not divorced from human activity, and examination of the role of Traditional Owner practices (such as cultural burning) in creating and maintaining ecosystems is required.

By establishing world-class safe havens in Victoria with restored habitats free from feral predators and herbivores, the Victorian Government can trial and apply tested management practices to create and maintain refuges for Victoria's nature and wildlife, and the community can experience these refuges and contribute to their ongoing conservation.

A clear objective of the safe havens is to prevent species extinctions by adopting best-practice conservation and emergency management and supporting strong engagement with local Traditional Owners and the community to best protect diverse habitats and wildlife species from the impacts of climate change.

The proposed safe havens would demonstrate a new way of working together for government, scientists, Traditional Owners and the community to adapting to climate change. New approaches would move away from the academic and theoretical to transformative, multidisciplinary frameworks for action.[79] Traditional Owner knowledge, the social sciences, and socio-political research become important considerations in these new frameworks.

Ongoing governance of the safe havens will need to ensure that core activities – including design, management, monitoring, reporting and community engagement – are driven primarily by policy and the goal of conserving and restoring threatened species. Given the scale, ambition and urgency of these refuges – and the importance of what they are established to protect – design and monitoring should be directed to provide 'good enough' answers, with less precision and detail than research scientists might find ideal.[80]

78. Jackson ST 2021, 'Transformational ecology and climate change: Management of imminent ecosystem shifts demands adaptive, translational approaches', *Science*, 373(6559), pp. 1085–1086, https://www.science.org/doi/pdf/10.1126/science.abj6777 Accessed on 9 June 2023.
79. Crausbay SD, Sofaer HR, Cravens AE, Chaffin BC, Clifford KR, Gross JE, Knapp CN, Lawrence DJ, Magness DR, Miller-Rushing AJ, Schuurman GW, Stevens-Rumann CS 2021, 'A science agenda to inform natural resource management decisions in an era of ecological transformation', *BioScience*, 72(1), pp. 71-90, https://doi.org/10.1093/biosci/biab102 Accessed on January 2022.
80. Jackson ST 2021, 'Transformational ecology and climate change: Management of imminent ecosystem shifts demands adaptive, translational approaches', *Science*, 373(6559), pp. 1085–1086, https://www.science.org/doi/pdf/10.1126/science.abj6777 Accessed on 9 June 2023.

Recommendation 7: That the Victorian Government commissions the Victorian Environmental Assessment Council to investigate and recommend additions to the protected area network to support the achievement of Priority 18 in Biodiversity 2037, which is to maintain and enhance a world-class system of protected areas. This will involve accelerating the establishment of new, permanently protected areas on private land, especially in high-priority ecosystems and landscapes.

Challenges this recommendation addresses

In 2017 VEAC identified a gap of 2.1 million hectares between the coverage of the existing protected area network and what is needed for a world-class system that is comprehensive, adequate and representative. This was acknowledged in Biodiversity 2037. Increasing the conservation of native vegetation on private land can assist in filling that gap; however, most of the expansion will need to occur on public land. Before that can occur, VEAC will need to investigate, identify and recommend sites for inclusion in the protected areas network.

The Parliament of Victoria Inquiry into Ecosystem Decline in Victoria final report, published in 2021, found that the major threats to biodiversity were invasive plant and animal species, habitat loss and fragmentation, and climate change. This assessment came four years after the Victorian Government released Biodiversity 2037. To date, the implementation of Biodiversity 2037 is not meeting its targets, and data on its progress are limited.[81]

Context

Biodiversity 2037 reported that, 'The estimated gap in additional protected areas required to meet Australia's criteria for a comprehensive, adequate and representative reserve system is 2.1 million hectares.' The report concluded that one of the key components for maintenance and improvement of the system would be a 'comprehensive, adequate and representative system across public land, private land and Indigenous protected areas, that continues to be the cornerstone of conserving biodiversity'.

Priority 18 of Biodiversity 2037 is to 'maintain and enhance a world-class system of protected areas'. However, protection levels for Victoria's ecosystems have been largely stable since then, with only small additions to the protected areas network.

Victoria's protected areas network is critical to the conservation and recovery of biodiversity and the protection of cultural heritage, along with providing opportunities for co-management of Country with Traditional Owners. The state's national parks and other conservation areas currently provide protection for thousands of native species, including 90% of Victoria's threatened plant and animal species.

Recommendation 6 of the SoE 2018 Report recommended:

> *'That DELWP improve biodiversity outcomes on private land by accelerating private land conservation. This will require resourcing permanent protection measures that focus on high-priority ecosystems and landscapes and investing in local government capability to enforce the existing Guidelines for the Removal, Destruction or Lopping of Native Vegetation and the Invasive Plants and Animals Policy Framework.'*

The Victorian Government supported this recommendation in principle.

Almost 90% of the ecological vegetation classes that are poorly represented in parks and reserves are found on private land. However, only 1% to 2% of private agricultural land is managed for conservation (e.g. native vegetation protection, revegetation and livestock exclusion). Just 0.5% is managed under a conservation agreement. The way in which private land is used and managed in the future will be critical in Victoria's efforts to secure, restore and conserve biodiversity.

81. Victorian Auditor-General's Office (VAGO) 2021, 'Protecting Victoria's biodiversity', Melbourne, Victoria.

Vegetation clearance continues on private land, an issue that was the focus of the VAGO report Offsetting Native Vegetation Loss on Private Land, which found that DELWP had not achieved the 'no net loss' objective in the management of offsets associated with vegetation clearance regulations.[82] Although Trust for Nature and DEECA have been working to significantly increase the area of native vegetation that is conserved on private land, the outcomes are currently well below the annual target of 10,000 hectares needed to meet the Biodiversity 2037 target of 200,000 hectares.

Although VEAC is only legislated to make recommendations for public land, there is precedent for its investigations and assessments to include private land, to ensure a systems approach and to provide appropriate context (e.g. Remnant Native Vegetation Investigation).[83] The scope of the proposed protected area network investigation would be terrestrial; however, a future assessment could be expanded to include marine and coastal areas.

82. Victorian Auditor-General's Office (VAGO) 2022, 'Offsetting native vegetation loss on private land', Melbourne, Victoria.
83. Victorian Environmental Assessment Council (VEAC) 2011, 'Remnant native vegetation investigation: Final report', East Melbourne, Victoria, https://www.veac.vic.gov.au/investigations-assessments/previous-investigations/document/getDownload?fid=Mjcy Accessed on 5 June 2023.

Land

Recommendation 8: That DEECA leads the design and delivery of a state soil and land condition monitoring and mapping program.

Challenges this recommendation addresses

The growth of urban areas, the spread of invasive plants and animals, and the expansion of agriculture have led to the loss of native vegetation and have significantly degraded Victoria's land health due to soil erosion, dryland salinity, soil acidification and reduction of soil organic carbon.

Few long-term datasets exist to inform our knowledge of Victoria's land health and to assist decision-making and land management practices.

Context

Recommendation 7 of the SoE 2018 Report recommended:

'That Agriculture Victoria lead the design and delivery of a state soil and land condition monitoring program, that includes analysis of the threats and impacts of land use and land-use change, to improve decision-making across a variety of sectors including agriculture, planning and water management.'

The Victorian Government supported this recommendation in principle.

There has been no progress on the implementation of the SoE 2018 recommendation.

The changing mix of non-natural and natural land-cover types is most apparent in and around Melbourne and in regional growth areas. Population growth from migration and tree-change and sea-change demographic shifts are driving development that is replacing agricultural land and biodiversity with residential and small-acre allotments.

Urban expansion impacts land health through land clearance, generation of stormwater, spread of invasive species, habitat loss and fragmentation, increased wastewater and hard waste, pollution of local waterways and land, and exacerbation of the impacts of a warming climate (e.g. heat islands). Biodiversity-sensitive urban design is an innovative response to this.

Maintenance and expansion of vegetation cover is critical to improving land health, especially with climate change projected to increase the frequency of drought and bushfires and create the conditions for more intense storm events, with soil erosion and reduced soil health as potential consequences.

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.

DEECA's time series data on land-cover classes across Victoria have shown a long-term and ongoing decline in natural environments since the 1980s, with reductions in grasslands, wetlands, shrublands and other biodiversity. However, data are limited on the overall impacts and long-term outcomes of these changes on land health, biodiversity and agricultural productivity. This is due to the absence of comprehensive monitoring of such matters as soil erosion and acidification, the storage of soil organic carbon and dryland salinity. The agriculture sector is increasingly investing in best practice for sustainability outcomes; however, publicly available data on the outcomes are limited.

A better understanding of the capability of land to support various uses would provide land users and land managers the best available evidence to consider environmental implications in their decision-making and stewardship.

It is essential that a long-term plan is developed for the collection, consolidation, reporting and assessment of land data across the state. Remote-sensing technology will be an important tool in this research. Further analyses of the threats and impacts of land use and land-use change would improve policy development and decision-making across a variety of sectors, including agriculture, planning and water management.

Inland waters

Recommendation 9: That DEECA works with its portfolio agencies to ensure consistent statewide methodologies in monitoring, data analysis and timely public reporting of water quality.

Challenges this recommendation addresses

Urban development, population growth, agricultural land management, irrigation and climate change are impacting on water quality and aquatic biodiversity in Victoria.

A disaggregated water-quality monitoring regime undermines evidence-based decision-making.

Context

Recommendation 12 of the SoE 2018 Report recommended:

'That DELWP, working with its portfolio agencies, implement an agile water-quality monitoring framework that (i) clarifies the roles and responsibilities of all agencies and the community, (ii) improves monitoring of pollution hotspots, and (iii) builds on EPA Victoria's implementation of EPA Inquiry recommendations 6.3 and 7.2.'

The Victorian Government supported this recommendation.

There has been limited progress made in the development of legislation, policies and strategies that could support the implementation of the SoE 2018 recommendation.

Although the assessments for the individual water quality indicators in this SoE 2023 Report vary across the state and catchment management regions, water quality in general is poor, with water quality at its lowest in the Melbourne region. Recent wet years have seen some improvements in water quality; however, this is likely to be reversed during future dry years.

A disaggregated water-quality monitoring regime undermines the ability to improve management responses. Water quality is typically reported every five years by catchment management authorities. A more regular and coordinated regime is required, ideally with information being presented in a transparent and accessible way such as an interactive map. The response to the Victorian floods in October 2022 demonstrated the value of good quality, timely information; that is now the benchmark for the provision of all future water quality information.

Although considerable water data exist, there is little reporting on the impact of poor to good water quality on the aquatic environment or human health.

A key step in addressing poor water quality is establishing consistent methods of water-quality monitoring, interpretation and reporting. Improvements could be made through the monitoring, analysis and timely public reporting of:

- the spatial extent, number and trends in water pollution incidents, fish deaths and EPA field responses
- the distribution, number, volumes and impacts of licensed discharges to Victoria's inland waterways, and the level and trends in compliance
- outcomes for aquatic and human health generated by poor or deteriorating water quality and water pollution incidents
- the number, extent, duration and impact of blue–green algal blooms in Victoria's waterways.

Recommendation 10: That DEECA, in consultation with the Victorian Commissioner for Environmental Sustainability (i) delivers a framework for future reporting on environmental watering outcomes consistent with Action 3.6 of Water for Victoria, (ii) develops metrics and thresholds for the agreed indicators to enhance reporting on environmental watering outcomes, and (iii) integrates the framework into an improved and integrated system of inland waters health reporting, including updating the Index of Stream Condition by 2025.

Challenges this recommendation addresses

Recognising the importance of reporting progress towards expected environmental outcomes from environmental watering, Action 3.6 from Water for Victoria contains a requirement that the CES 'report on the outcomes of environmental watering in Victoria, as part of the five-yearly State of the Environment Report' and 'recommend ways to improve future public reporting'.

As per the *Water Act 1989*, water for the environment is delivered for the purpose of preserving the environmental values and health of water ecosystems, including:

- their biodiversity
- ecological functioning
- the quality of water
- the other uses that depend on environmental condition.

Current monitoring and reporting of environmental watering by the Victorian Government is intended to improve the use of environmental water at a given time in a particular location. This contributes to better localised management of environmental water. However, there is a knowledge gap, with no quantitative analysis of environmental watering outcomes available (both environmental and community outcomes) to be produced on a statewide scale.

Context

In this SoE 2023 Report, indicator assessments look at how delivery of water for the environment impacts on rivers and wetlands where water is delivered, as well the condition of flow regimes more broadly. A synthesis of environmental and community outcomes from water for the environment is also included.

An aim of the proposed framework is to share a vision for how the current understanding of environmental watering can be re-framed to better report on the cross-cutting and interconnected nature of environmental watering across the broader Victorian community. This approach would consider not only biophysical outcomes but also shared benefits and social, cultural, economic and recreational outcomes. The framework will consider current constraints in delivering environmental water and flexible arrangements to improve environmental outcomes.

As part of the framework development, DEECA will develop a provisional list of indicators with input from stakeholders which encompass delivery and hydrology, environmental outcomes and community outcomes.

The ISC and LTWRAs are important resources for managing the health of Victoria's inland waters. The ISC was last released in 2013, based on data from 2010. As a requirement of the Water Act 1989, the Victorian Government must complete a LTWRA every 15 years. A LTWRA for southern Victoria was published in 2020. An assessment for northern Victoria has not been completed, however an assessment is planned to start in 2025 to align with the Murray-Darling Basin Plan review scheduled for 2026. These assessments are valuable because they are designed to identify whether there has been: (i) any decline in the long-term availability of surface water or groundwater and whether the decline has fallen disproportionately on the environmental water reserve or on the allocation of water for consumptive purposes; and (ii) there has been any deterioration in waterway health for reasons related to flow.

The framework must be developed in the broader context of inland waters health and be part of an integrated approach to river and wetland management. To that end, it is critical that the ISC be updated no later than 2025, and the LTWRA for northern Victoria is completed during the next SoE cycle (i.e. before 2028), to ensure the new framework reflects contemporary data and analysis and aligns with the Victorian Government's prioritisations, informed by the ISC and LTWRA evidence bases.

Energy

Recommendation 11: That DEECA collects and publishes data annually to monitor progress on the development of variable renewable electricity and to report on the biodiversity impacts of this transition.

Challenges this recommendation addresses

In its 2022 election, the Victorian Government committed to legislating 65% variable renewable generation in Victoria by 2030 and 95% by 2035.

The quality and completeness of data on wholesale electricity production and consumption provided by the Australian Energy Market Operator is excellent. These data are publicly available and can be compiled and reported (as this report has done).

However, data on distributed (behind-the-meter) electricity generation and storage are neither complete nor high quality. In most cases behind-the-meter generation data are estimated rather than measured, and it is not centrally reported. Reliable data on behind-the-meter storage capacity and its operation do not exist.

Furthermore, the allocation of land for new infrastructure to support the transition to renewable electricity (e.g. solar and wind farms and transmission installations) will impact on biodiversity, and this impact should be understood.

Context

The Victorian Government's renewable electricity targets must be met in order to achieve annual per-capita CO_2 emissions of four tonnes by 2030 (this is about one-third of the current emissions level and is broadly in line with the Victorian Government's policy).

The power system is rapidly decentralising, and it will be valuable for the Victorian Government to establish and publish data that track progress on variable renewable generation, preferably by establishing statistically robust surveys.

Reporting on the development of variable renewable electricity will need to include the following metrics:

- volume (GWh) of behind-the-meter and grid-connected renewable electricity spilled due to congestion in the transmission and distribution system and power system constraints, per year
- renewable electricity generator transmission and distribution system connection lead time (the time between connection application and connection approval), per year
- number and volume (MW) of behind-the-meter and distribution system renewable electricity and storage connections partially or fully refused, per year
- capacity (kW) and production (MWh) from behind-the-meter renewable generation, per year
- capacity (kW), annual charge volume (MWh) and discharge volume (MWh) from behind-the-meter and front-of-meter electricity storage.

While data dashboards will be useful to analysts and policy–makers, suitably presented information can be useful in informing consumers' choices. This is already done on energy bills and in energy ratings for new products. Information on the share of renewable energy (not just emissions) in grid-supplied electricity is likely to be helpful in informing consumers' choices on electricity consumption and production/storage.

The transition to renewable generation will impact on biodiversity by using land for solar and wind farms and electricity transmission. Aggregate biodiversity impacts are difficult to measure, but one option is to report the volume (km^2) and value ($m) of biodiversity offsets resulting from new generator entry and transmission system expansion.

Recommendation 12: That DEECA collects and publishes data annually on the electrification of water heating and transport.

Challenges this recommendation addresses

To enable monitoring of the transition away from the use of natural gas in residential water heating and space heating, it will be critical to report data on the energy consumed by water heaters installed in each year, and in the total residential sector, classified by fuel type.

Decarbonising private transport is likely to require electrification. To monitor progress it will be valuable for the Victorian Government to annually publish data on vehicle type, GHG intensity and fuel consumption of passenger vehicle stock and new passenger vehicles sold.

Context

To monitor the transition away from the use of gas in residential water heating and space heating, the Victorian Government will need to compile data on:

- the energy consumption (TWh) in residential water heating and space heating of new water heaters installed
- total stock by type (gas/electricity-resistance/electricity-heat pump/gas-boosted solar/electricity-heat pump boosted solar).

To better understand the electrification challenge in transport it will be valuable for Victoria to publish data on the existing stock of passenger vehicles and on new passenger vehicle sales. This data would be available from VicRoads through its role in vehicle licensing. Objective measures of progress in decarbonising transport in Victoria are likely to include:

- the number of new passenger vehicles sold and total registered, categorised by fuel (petrol, diesel, battery-electric, hydrogen-electric, plug-in hybrid, hybrid) and complemented by data for vehicle kilometres travelled for each vehicle/fuel type
- GHG emission intensity (g CO2-e/km) and fuel consumption (litres/100 km) of new passenger vehicles sold and total registered, categorised by fuel (petrol, diesel, electric, plug-in hybrid, hybrid).

Waste and resource recovery

Recommendation 13: That the Victorian Government fulfils Key Commitment 11 of Recycling Victoria: A New Economy by developing and implementing a circular economy monitoring and evaluation framework to track the state's progress in transitioning to a circular economy. Biennial reporting would support tracking progress and enable strategic adaptive management, with the first report to be delivered by the end of 2025.

Challenges this recommendation addresses

To evaluate the effectiveness of policy initiatives in meeting Victoria's targets and track progress towards a circular economy, a monitoring and evaluation framework will be developed in fulfilment of Key Commitment 11 of Recycling Victoria: A New Economy as well in response to part of Recommendation 13 of the SoE 2018 Report.

Without such a framework, underpinned by appropriate data collection and analysis, the level of circularity within the state cannot be effectively assessed, nor can policy adjustments be made to address lags within sectors or societal needs.

Context

Recommendation 13 of the SoE 2018 Report recommended:

> *'That Sustainability Victoria (SV), in 2019, develop indicators and implement a comprehensive monitoring and reporting framework to measure delivery of the current Victorian Statewide Waste and Resource Recovery Infrastructure Plan (SWRRIP) and the regional plans against the circular-economy design principles. From July 2020, that SV expand that monitoring and reporting framework to track the progress of the implementation of the strategy and publicly report, at least annually, on Victoria's transition to a circular economy.'*

The Victorian Government supported this recommendation in principle.

The circular economy monitoring and evaluation framework will be coordinated by Recycling Victoria and serve to track Victoria's transition to a circular economy. The proposed framework must:

- include metrics that serve as a diagnostic tool to identify sectors and societal needs that may be lagging in the transition process
- provide insight into the level of influence that different government, business and community initiatives have on strategic outcomes and impacts of the circular economy
- clarify roles and responsibilities in implementation and reporting.

Data and information

Recommendation 14: That DEECA (i) delivers a data integration strategy for state of the environment reporting, and (ii) coordinates collection, validation and calculation of critical data from Victorian Government departments and agencies to improve outcomes in evidence-based environmental management in Victoria.

Challenges this recommendation addresses

There is a lack of comprehensive and reliable data across the Victorian Government to report on the state's natural assets. This is mainly due to inconsistent data collection, validation and calculations as well as lack of timely interpretations.

The volume of data is growing exponentially through improved technology and the contributions of citizen scientists. Unfortunately, the capacity of researchers and scientists to conduct comprehensive analyses of the data, to support evidence-based environmental policy and management, is not keeping up with this growth. Investment is needed to interpret and analyse the output data in a timely manner. The number of publicly available databases is increasing; however, many of these databases are not analysed and interpreted, or combined and integrated with other cultural, social or economic datasets.

Context

Since it was established under the CES Act, the CES has produced four SoE reports (2008, 2013, 2018 and 2023). A recurring issue has been the limitations of data and evidence to fulfil the legislative obligations of the CES Act. This is especially challenging for the 'Biodiversity' chapter and measuring impacts on biodiversity in the 'Climate change', 'Forests', 'Land' and 'Inland waters' chapters.

These data limitations have become even more pronounced now that CES reporting obligations have been expanded since 2014 to include the following:

- state of the marine and coastal environment reports
- precinct reports (reports on the state of the Yarra and its parklands and the state of the Great Ocean Road coast and parks)
- reporting in Victorian Government flagship policy documents (Water for Victoria and Biodiversity 2037)
- interim arrangements to deliver legislative obligations from additional acts (state of the forests and state of the parks reports).

The CES's expanded responsibilities and the Victorian Government's commitment to accountability and transparency – which this broader role demonstrates – need to be supported by a commensurate and complementary monitoring and reporting regime.

Good data, interrogated for understanding, is the foundation for evidence-based environmental policy and management. The Victorian Government has been increasing its investment in data collection through field survey, remote sensing and sensor data-acquisition systems. Traditional Owners and Registered Aboriginal Parties also need resources for data collection, to assist in understanding the current state of cultural heritage values and bio-cultural condition assessment (see Recommendation 1).

Integration and systemisation of datasets across Victorian Government departments and agencies is critical to identifying insights into complex data at landscape scales. It requires comprehensive analysis and integration of current and accurate environmental, social, cultural and economic information, to help decision makers determine strategies for emerging issues and sustainable management. A data integration strategy for state of the environment reporting will create a foundation for this system and enable more targeted reporting to support decision-making in improving environmental outcomes.

Space and spatial analysis

Recommendation 15: That the Victorian Government develops an environmental Digital Twin for Victoria building on the existing Digital Twin Victoria program.

Challenges this recommendation addresses

The Victorian Government has no centralised spatial system to store, manage and analyse environmental data, and there is limited in-house expertise to generate actionable insights from data. These gaps result in a convoluted process for indicator assessment that relies on external groups for interpretation of data. There is also a critical shortage of high-quality, up-to-date data for the assessment of biodiversity targets and indicators, and Victoria is not leveraging existing biodiversity-related spatial tools and datasets to their full potential.

Context

Digital Twin Victoria (DTV) is helping to set the digital foundations for Victoria, using data to answer new questions and make better data-led decisions. DTV is bringing Victoria's built assets together into a single, information-rich, 3D platform. It aims to enable better understanding, communication, visualisation and decision-making in relation to Victoria's built environment.

A digital twin is a dynamic digital representation of a real-world object or system on which services can be performed that provide value to an organisation. Digital twins offer a transformative approach to developing integrated, interoperable, scalable technology to address the challenges within complex natural environments. The technology provides data management, analysis, visualisation and the ability to effect and reflect change in the real world, as well as to support regional planning, strategic management and evidence-based reporting and investment.

Digital twins exist for the built environment but, to our knowledge, have not yet been applied to the natural environment. Establishing an eDTV would put Victoria at the forefront in this area, and the technology could be rolled out to other jurisdictions.

The capability to implement an eDTV already exists within the system of DTV tools in development by Land Use Victoria within the Department of Transport and Planning.

Digital twins require significant data to produce value, but data alone do not provide understanding. Actionable insights come from the analysis, interpretation and visualisation of data. A formalised collaboration would be required between DTV (Land Use Victoria in the Department of Transport and Planning) and DEECA to produce an eDTV that is a central, spatial decision support system, and to manage the datasets and models required for analysis and indicator assessment. This would be supported by:

- new methods for data creation to fill critical gaps and populate the eDTV
- strategic collaborations to leverage existing tools and datasets through interoperability (e.g. EcoCommons, Digital Earth Australia)
- in-house experts to provide interpretations for actionable insights.

The first steps are to establish the foundation infrastructure, based on DTV, and integrate existing Victorian Government datasets (e.g. habitat distribution models and Land Cover Time Series). As the eDTV matures it would be continually improved by updating analysis models and filling critical data gaps with new data sources, such as Earth observation combined with machine learning and Internet of Things networked smart sensors.

Aerial shot of the Royal Botanic Gardens, Melbourne.
Credit: Ain Raadik.
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Recommendations in summary

Table 4 provides a summary of the 15 recommendations made in this report. The summary describes each recommendation in full, as well as:

- the theme to which the recommendation relates to
- the challenges the recommendation aims to overcome
- its relationship to the SoE 2018 Report recommendations, whereby:
  - 'expansion' refers to recommendations that build upon SoE 2018 Report recommendations that have been addressed by the Victorian Government
  - 'reiteration' refers to recommendations from the SoE 2018 Report that have not been fully addressed by the Victorian Government and therefore have been repeated in this report
  - 'new' refers to recommendations that have been put forward for the first time in this report
- how the recommendations align with the UN SDG targets and goals.

Table 4: SoE 2023 recommendations, challenges and UN SDG targets for future reporting, by theme.[84]

Lead theme:	**Cultural landscape health and management**
Recommendation 1	**That the Victorian Government resources and supports Victoria's Traditional Owners to implement a program of on-ground assessment and develop contemporary bio-cultural indicators to restore the knowledge system of Traditional Owners in Victoria consistent with policy and legislative requirements. Initially, the Victorian Government would resource and support the Eastern Maar and Wadawurrung Traditional Owners to deliver the legislative obligations of the *Great Ocean Road and Environs Protection Act 2020* and inform future consultations on bio-cultural indicators with other Traditional Owners in Victoria.**
Recommendation category	Expansion
Challenges this recommendation addresses Aboriginal existence and identity are underpinned by healthy cultural landscapes. Along with water and other natural resources, the land that is now the State of Victoria was managed for thousands of years according to traditional laws, customs and practices. Shaped by a sustainable-use regime and managed with a deep understanding of natural systems and an embedded lore and culture, Country (land, water, animals, plants, people, spirits and customs) has provided for the material, cultural and spiritual needs of thousands of generations of Aboriginal people.[85] Reporting on Victoria's diverse and valuable ecosystems must acknowledge, and learn from, the long history of Traditional Owner knowledge that has underpinned care for these cultural landscapes. It must reflect the aspirations that Victoria's Traditional Owners have shared with the Victorian Government: Restoring the knowledge system must reflect the fundamental principle that traditional knowledge is owned by Traditional Owners. Traditional Owners as custodians of knowledge and practice continue to decide how consent to share knowledge is given. We need resources for data collection, then will give the state the management objectives. The State and other [land management organisations] need to support our projects, not us supplementing theirs.[86]	
UN SDG targets alignment	1.5, 4.7, 11.4

84. More detail regarding the alignment of the SoE 2023 recommendations with the UN SDG targets can be found within Appendix B of this report.
85. Parks Victoria (PV) 2018, 'Managing Country Together', Melbourne, Victoria, https://www.parks.vic.gov.au/managing-country-together Accessed on 9 June 2023.
86. Federation of Victorian Traditional Owner Corporations 2021, 'The Victorian Traditional Owner Cultural Landscapes Strategy', Melbourne, Victoria, https://fvtoc.com.au/wp-content/uploads/2023/03/1258_FVTOC_CulturalStrategy._web.pdf Accessed on 9 June 2023.

Lead theme:	Climate change - Impacts
Recommendation 2	That the Victorian Government downscales and applies the latest climate change modelling and scenarios for Victoria, consistent with the Intergovernmental Panel on Climate Change Sixth Assessment Report. The updated modelling and scenarios will provide a critical foundation to develop a climate hazards decision support tool for Victoria to improve decision-making in adapting to the impacts of climate change.
Recommendation category	Expansion

Challenges this recommendation addresses

The assessments for the 'Climate projections' indicators in this report are generally based on results from the Victorian Climate Projections project (VCP19) – a collaboration between DELWP and CSIRO that produced new local-scale climate projections for the entire state of Victoria for medium and high-emissions pathways. Since then, a new generation of global climate models have been developed as part of CMIP6, and were featured in the IPCC Sixth Assessment Report, which included a new set of emission scenarios. The new modelling and scenarios are yet to be downscaled and applied for Victoria.

UN SDG targets alignment	2.4, 6.5, 9.5, 13.2, 13.3

Lead theme:	Air
Recommendation 3	That EPA Victoria develops the IT infrastructure and data analytics capacity to interface air-quality sensor monitoring data – including citizen science monitoring data – with EPA Victoria's existing network of standard air monitoring sites. The complete suite of air monitoring data would interface with a regularly updated air pollution inventory, to be provided as an input for air-quality modelling.
Recommendation category	Reiteration

Challenges this recommendation addresses

Data from EPA Victoria's regional network of sensor monitoring sites are lower quality than the standard monitoring sensors. Data from these lower quality sensors are therefore, not included in this SoE 2023 Report.

EPA Victoria's air pollution inventory has proven to be a very useful tool; however, it has not been updated since the base year of 2016.

Align with UN SDG targets	3.9, 9.5, 11.6

Recommendation 4	That the Victorian Government leads the establishment of a contemporary pollen-monitoring network that incorporates forecasting and publishes monitoring information and pollen forecasts in real time, to provide the community with timely and accessible information on pollen levels.
Recommendation category	Reiteration

Challenges this recommendation addresses

Victorians are currently unable to access information about real-time pollen levels, except for people in inner Melbourne who can pay for a subscription to the Melbourne Pollen app developed and maintained by the University of Melbourne. Pollen forecasts are currently provided for each day, but details such as what time during the day that peak pollen levels will occur are not provided.

UN SDG targets alignment	3.9, 9.5, 11.6

Lead theme:	Biodiversity
Recommendation 5	That the Victorian Government (i) establishes independent biennial reporting to the Parliament of Victoria on the Biodiversity 2037 targets, (ii) oversees an integrated and comprehensive biodiversity monitoring program for the state with an emphasis on arresting threatened species decline, and (iii) evaluates the implementation and outcomes of Biodiversity 2037 and the efficiency of investment in threatened species.
Recommendation category	Expansion

Challenges this recommendation addresses

In its 2020 submission to the Parliament of Victoria Inquiry into Ecosystem Decline in Victoria, DELWP reported that one-quarter to one-third of 'Victoria's terrestrial plants, birds, reptiles, amphibians and mammals, along with numerous invertebrates and ecological communities, are considered threatened with extinction.' This fate has already occurred for 18 mammal, two bird, one snake, three freshwater fish, six invertebrate and 51 plant species since European settlement.

The DELWP submission states, 'The longer-term outlook for many threatened species and habitats that rely on Victoria's approximately eight million hectare public land estate for their conservation is poor,' and that protecting the state's biodiversity, habitats and public lands estate will 'require biodiversity conservation being given greater consideration in decisions involving competing public land uses as well as increased, better targeted and coordinated investment to manage key threats within a tenure-blind ecosystem-based framework.'

UN SDG targets alignment	2.5, 4.7, 6.3, 6.4, 6.5, 6.6, 6.b, 11.4, 11.7, 12.2, 12.8, 13.1, 13.3, 14.4, 15.1, 15.3, 15.4, 15.5, 15.6, 15.7, 15.8, 15.9, 16.6, 17.14, 17.17

Recommendation 6	That the Victorian Government establishes multiple safe havens in Victoria to protect and restore critical habitats for nature and wildlife. These will be world-class refuges, free from feral predators and herbivores. They will be conservation flagships for threatened species that will demonstrate the best in network governance, where the government's environmental and emergency management bodies, Traditional Owners, scientists and all Victorians valuing nature can work together to protect habitats and species.
Recommendation category	New

Challenges this recommendation addresses

Ecosystems are transforming under climate change, with substantial shifts in ecological processes (e.g fire, landscape connectivity) and important ecosystem services (e.g. pollination, water filtration) occurring at unprecedented rates.[87] The evidence in this report demonstrates that biodiversity decline is continuing in Victoria despite the ongoing commitment and effort from the Victorian Government, community groups, scientists and environmental managers.

UN SDG targets alignment	15.5, 15.8

Recommendation 7	That the Victorian Government commissions the Victorian Environmental Assessment Council to investigate and recommend additions to the protected area network to support the achievement of Priority 18 in Biodiversity 2037, which is to maintain and enhance a world-class system of protected areas. This will involve accelerating the establishment of new, permanently protected areas on private land, especially in high-priority ecosystems and landscapes.
Recommendation category	New

Challenges this recommendation addresses

In 2017 VEAC identified a gap of 2.1 million hectares between the coverage of the existing protected area network and what is needed for a world-class system that is comprehensive, adequate and representative. This was acknowledged in Biodiversity 2037. Increasing the conservation of native vegetation on private land can assist in filling that gap; however, most of the expansion will need to occur on public land. Before that can occur, VEAC will need to investigate, identify and recommend sites for inclusion in the protected areas network. The Parliament of Victoria Inquiry into Ecosystem Decline in Victoria final report, published in 2021, found that the major threats to biodiversity were invasive plant and animal species, habitat loss and fragmentation, and climate change. This assessment came four years after the Victorian Government released Biodiversity 2037. To date, the implementation of Biodiversity 2037 is not meeting its targets and data on its progress are limited.[88]

UN SDG targets alignment	4.7, 6.6, 12.2, 12.8, 15.1, 15.3, 15.4, 15.5, 15.8

87. Jackson ST 2021, 'Transformational ecology and climate change: Management of imminent ecosystem shifts demands adaptive, translational approaches', *Science*, 373(6559), pp. 1085–1086, https://www.science.org/doi/pdf/10.1126/science.abj6777 Accessed on 9 June 2023.
88. Victorian Auditor-General's Office (VAGO) 2021, 'Protecting Victoria's biodiversity', Melbourne, Victoria.

Lead theme:	Land
Recommendation 8	**That DEECA leads the design and delivery of a state soil and land condition monitoring and mapping program.**
Recommendation category	Reiteration

Challenges this recommendation addresses

The growth of urban areas, the spread of invasive plants and animals, and the expansion of agriculture have led to the loss of native vegetation and have significantly degraded Victoria's land health due to soil erosion, dryland salinity, soil acidification and reduction of soil organic carbon.
Few long-term datasets exist to inform our knowledge of Victoria's land health and to assist decision-making and land management practices.

UN SDG targets alignment	2.4, 6.5, 9.5, 12.2, 15.3

Lead theme:	Inland waters – Water quality
Recommendation 9	That DEECA works with its portfolio agencies to ensure consistent statewide methodologies in monitoring, data analysis and timely public reporting of water quality.
Recommendation category	Reiteration

Challenges this recommendation addresses

Urban development, population growth, agricultural land management, irrigation and climate change are impacting on water quality and aquatic biodiversity in Victoria.

A disaggregated water-quality monitoring regime undermines evidence-based decision-making.

UN SDG targets alignment	6.3, 6.6, 9.5

Lead theme:	Inland waters – Water resources
Recommendation 10	That DEECA, in consultation with the Victorian Commissioner for Environmental Sustainability, (i) delivers a framework for future reporting on environmental watering outcomes consistent with Action 3.6 of Water for Victoria, (ii) develops metrics and thresholds for the agreed indicators to enhance reporting on environmental watering outcomes, and (iii) integrates the framework into an improved and integrated system of inland waters health reporting, including updating of the Index of Stream Condition by 2025.
Recommendation category	New

Challenges this recommendation addresses

Recognising the importance of reporting progress towards expected environmental outcomes from environmental watering, Action 3.6 from Water for Victoria contains a requirement that the CES 'report on the outcomes of environmental watering in Victoria, as part of the five-yearly State of the Environment Report' and 'recommend ways to improve future public reporting'.

As per the *Water Act 1989*, water for the environment is delivered for the purpose of preserving the environmental values and health of water ecosystems, including:

- their biodiversity
- ecological functioning
- the quality of water
- the other uses that depend on environmental condition.

Current monitoring and reporting of environmental watering by the Victorian Government is intended to improve the use of environmental water at a given time in a particular location. This contributes to better localised management of environmental water. However, there is a knowledge gap, with no quantitative analysis of environmental watering outcomes available (both environmental and community outcomes) to be produced on a statewide scale.

UN SDG targets alignment	6.4, 6.5, 9.5, 13.2, 15.1

Lead theme:	Energy
Recommendation 11	That DEECA collects and publishes data annually to monitor progress on the development of variable renewable electricity and to report on the biodiversity impacts of this transition.
Recommendation category	New

Challenges this recommendation addresses

In its 2022 election, the Victorian Government committed to legislating 65% variable renewable generation in Victoria by 2030 and 95% by 2035.

The quality and completeness of data on wholesale electricity production and consumption provided by the Australian Energy Market Operator is excellent. These data are publicly available and can be compiled and reported (as report has done).

However, data on distributed (behind-the-meter) electricity generation and storage are neither complete nor high quality. In most cases behind-the-meter electricity generation data are estimated rather than measured, and it is not centrally reported. Reliable data on behind-the-meter storage capacity and its operation does not exist.

Furthermore, the allocation of land for new infrastructure to support the transition to renewable electricity (e.g. solar and wind farms and transmission installations) will impact on biodiversity, and this impact should be understood.

UN SDG targets alignment	7.1, 7.2, 7.3, 7.a, 15.9

Recommendation 12	That DEECA collects and publishes data annually on the electrification of water heating and transport.
Recommendation category	New

Challenges this recommendation addresses

To enable monitoring of the transition away from the use of natural gas in residential water heating and space heating, it will be critical to report data on the energy consumed by water heaters installed in each year, and in the total residential sector, classified by fuel type. Decarbonising private transport is likely to require electrification. To monitor progress it will be valuable for the Victorian Government to annually publish data on vehicle type, GHG intensity and fuel consumption of the passenger vehicle stock and new passenger vehicles sold.

UN SDG targets alignment	7.2, 13.2, 13.3

Lead theme:	Waste and resource recovery
Recommendation 13	That the Victorian Government fulfils Key Commitment 11 of Recycling Victoria: a New Economy by developing and implementing a circular economy monitoring and evaluation framework to track the state's progress in transitioning to a circular economy. Biennial reporting would support tracking progress and enable strategic adaptive management, with the first report to be delivered by the end of 2025.
Recommendation category	Reiteration

Challenges this recommendation addresses

To evaluate the effectiveness of policy initiatives in meeting Victoria's targets and track progress towards a circular economy, a monitoring and evaluation framework will be developed in fulfilment of a key commitment under the circular economy policy as well in response to part of Recommendation 13 of the SoE 2018 report.

Without such a framework, underpinned by appropriate data collection and analysis, the level of circularity within the state cannot be effectively assessed, nor can policy adjustments be made to address lags within sectors or societal needs.

UN SDG targets alignment	12.3, 12.4, 12.5

Lead theme:	Data and information
Recommendation 14	That DEECA (i) delivers a data integration strategy for state of the environment reporting, and (ii) coordinates collection, validation and calculation of critical data from Victorian Government departments and agencies to improve outcomes in evidence-based environmental management in Victoria.
Recommendation category	New

Challenges this recommendation addresses

There is a lack of comprehensive and reliable data across the Victorian Government to report on the state's natural assets. This is mainly due to inconsistent data collection, validation and calculations as well as lack of timely interpretations.
The volume of data is growing exponentially through improved technology and the contributions of citizen scientists. Unfortunately, the capacity of researchers and scientists to conduct comprehensive analyses of the data, to support evidence-based environmental policy and management, is not keeping up with this growth. Investment is needed to interpret and analyse the output data in a timely manner. The number of publicly available databases is increasing; however, many of these databases are not analysed and interpreted, or combined and integrated with other cultural, social or economic datasets.

UN SDG targets alignment	Underpins improvement on reporting on all selected SDG targets

Lead theme:	Space and spatial analysis
Recommendation 15	That the Victorian Government develops an environmental Digital Twin for Victoria building on the existing Digital Twin Victoria program.
Recommendation category	Expansion

Challenges this recommendation addresses

The Victorian Government has no centralised spatial system to store, manage and analyse environmental data, and there is limited in-house expertise to generate actionable insights from data. These gaps result in a convoluted process for indicator assessment that relies on external groups for interpretation of data, which limits reliability of analysis for reporting. There is also a critical shortage of high-quality, up-to-date data for the assessment of biodiversity targets and indicators, and Victoria is not leveraging existing biodiversity-related spatial tools and datasets to their full potential.

UN SDG targets alignment	Underpins improvement on reporting on all selected SDG targets

Female King Parrot and Koala, Victoria.
Credit: Darren Donlen.

Part 2A
Space and spatial analysis

Victorian State of the Environment 2023 Report

Mitta Mitta River is a perennial alpine river and a direct tributary of the Murray River within the Murray–Darling Basin, located in the Alpine district of Victoria. It partly carries overflow from the Murray River and then opens out at Lake Dartmouth. The name Mitta Mitta is derived from the Aboriginal word *mida-modoenga*, meaning reeds called modunga.

Space and spatial analysis: An integrated approach to biodiversity data management, analysis and visualisation

Purpose and context

This part of the report evidences the need for future investment in space and spatial analysis to address biodiversity information limitations and support an integrated biodiversity monitoring solution for Victoria. It proposes that the first step along that path is an environmental Digital Twin Victoria (eDTV).

It builds on previous work by the Commissioner for Environmental Sustainability (CES) published in the Victorian State of the Marine and Coastal Environment (SMCE) 2021 Report and supports delivery of Victoria's biodiversity policy, Protecting Victoria's Environment – Biodiversity 2037, which aims to stop the decline of biodiversity and improve overall biodiversity in Victoria over the next 20 years.

Appendix A provides important complementary information, including:

- an updated space and spatial technology maturity assessment for nine categories of spatial data-collection technologies and data processing technologies
- major space and spatial analysis updates since the SMCE 2021 Report
- a detailed analysis on the application of space and spatial technologies to biodiversity conservation.[89]

Challenges and opportunities

A goal of Biodiversity 2037 is that Victoria's natural environment is healthy, with a target of net improvement in the outlook for all native species by 2037. As this report and other recent reports (the CES State of the Environment Biodiversity Update 2021 Report and VAGO's Protecting Victoria's Biodiversity report) have shown, the crucial problem is how to measure and report on progress against Biodiversity 2037 targets, and corresponding Victorian State of the Environment (SoE) biodiversity indicators, at scale and in a timely, cost-effective, reliable and ongoing manner.

There are short-, medium- and long-term opportunities to leverage space and spatial technologies to improve Biodiversity 2037 and state of the environment reporting, providing the capability to improve measurement of the progress of Biodiversity 2037 goals and targets.

Victoria currently has several biodiversity-related spatial decision support systems, including the Strategic Management Prospects tool, specific needs analysis and habitat distribution models (HDMs). Strategic Management Prospects is a fine-scale, statewide spatial modelling tool with inputs including HDMs, threat models, expert elicited response models for thousands of species, management actions and cost estimates for management actions. Specific needs analysis is a structured decision support process relying on expert elicitation. HDMs are spatial models combining confirmed species locations and sets of environmental predictors that provide detailed information on factors such as climate, terrain, local productivity and vegetation structure.

The Victorian Government currently has no centralised spatial system for environmental data storage, management and analysis, and limited in-house expertise to generate actionable insights from data. Also, it has a critical shortage of high-quality, up-to-date data for the assessment of biodiversity targets and indicators, and Victoria is not currently leveraging existing biodiversity-related spatial tools and datasets to their full potential.

Evidence is growing that space and spatial information technology can integrate currently disparate biodiversity and environment data from many sources. In October 2021, a paper entitled 'A comprehensive overview of technologies for species and habitat monitoring and conservation' was published in the journal BioScience.[90] The research identified artificial intelligence (AI) and machine learning (ML) as the most promising technologies for biodiversity conservation. Other areas with potential identified by the research include increased integration of different technologies and associated data, Internet of Things (IoT), open-source innovation enabling new technology specifically for conservation, and genetic or molecular technology.

The paper Overview of Remote Monitoring Methods in Biodiversity Conservation – published in the journal Environmental Science and Pollution Research in October 2022 – similarly concluded that the best technology for biodiversity conservation includes 'a combination of sophisticated monitoring methods including system-based smart techniques, transformative smart technologies, remote sensing, geographical information system, and artificial intelligence in combination with molecular approaches'.[91]

89. Updated from the State of the Marine and Coastal Environment 2021 Report, which only considered technologies in terms of marine and coastal ecosystems.
90. Lahoz-Monfort JJ, Magrath MJL 2021 'A comprehensive overview of technologies for species and habitat monitoring and conservation', BioScience, 71(10), pp. 1038-1062, https://academic.oup.com/bioscience/article/71/10/1038/6322306 Accessed 28 May 2023.

The most promising space and spatial technologies for addressing biodiversity decline include:

- analytics, simulation and modelling in digital twins and decision support systems
- remote sensing (RS) or Earth observation (EO) combined with AI or machine learning for automating the generation of data and enabling ongoing reproduction of data to assess change
- IoT sensor networks for automated collection of field data
- increased integration of technologies to produce landscape-scale systems
- collaboration to leverage existing datasets, portals, digital tools and platforms.

Major Australian space and spatial developments since 2021

Since the release of the State of the Marine and Coastal Environment 2021 Report, progress has been made in space and spatial initiatives at both the state and federal levels. Major new developments providing important context for space and spatial in biodiversity are outlined here:

- **May 2021**: Geoscience Australia's interactive Digital Atlas of Australia was announced as a key investment in the Commonwealth Budget 2021–22. The Digital Atlas of Australia will include near real-time and historical location-based environmental data. The beta prototype will be available in mid-2023.
- **May 2021**: The Australian Government agency Australian Climate Service was established in July 2021. The Australia Climate Service is a partnership between the Bureau of Meteorology, Geoscience Australia, the CSIRO and the Australian Bureau of Statistics. Its roles are to connect and leverage the Commonwealth's extensive climate and hazard information into a single national view, and to support natural disaster prevention, preparedness, response, recovery, relief and resilience.
- **March 2022**: The $1.2 billion National Space Mission for Earth Observation program is led by the Australian Space Agency and CSIRO in partnership with Geoscience Australia, the Bureau of Meteorology and the Department of Defence. The mission aims to design, construct, launch and operate new EO satellites and strengthen Australia's space capability.
- **August 2022**: The Digital Twin Victoria (DTV) program is a $37.4 million investment in digital twin technology by the Victorian Government. This program will facilitate digital modelling of 2D, 3D, real-time and historical data for Victoria. Digital twins are key to predicting the effects of and building resilience to climate change.
- **February 2023**: The Victorian Government, FrontierSI and RMIT University have successfully applied to the SmartSat Vic Node to begin a project investigation into space-based data streams for updating and enriching Foundation Spatial Data for Victoria. The project will explore combining space-based data with advanced spatial data fusion and ML techniques to increase the quality and speed of maintaining and enriching the spatial dataset for Victoria while reducing ongoing costs. The project will also provide a framework and guidance for how Victoria can leverage and plan for the rapidly growing range and evolution of space-based EO sensors, data and algorithms. Vicmap Hydro datasets will be used as a pilot test case, developing enriched information about Victoria's freshwater rivers and lakes, dams, wetlands and estuaries.
- **November 2022**: Planet Research Data Commons is an Australian Research Data Commons project for which proposal development for pilot initiatives ran from November 2022 to April 2023. This program aims to develop and deliver digital research infrastructure for earth and environmental research on a national scale to support improved evidence-based environmental and earth science decision-making by policymakers and managers.

91. Kerry RG, Montalbo FJP, Das R, Patra S 2022, 'An overview of remote monitoring methods in biodiversity', Environmental Science and Pollution Research, 2022(3), pp. 1-43, https://link.springer.com/article/10.1007/s11356-022-23242-y Accessed 28 May 2023.

An integrated biodiversity monitoring solution for Victoria

Figure 4 presents a proposed future integrated biodiversity monitoring solution for Victoria, combining technologies from every category investigated in this analysis.

Development of this solution would need to be integrated into a landscape-scale strategic framework with testing at local scale to extrapolate to landscape-scale. The system would automatically collect data, provide real-time and post-processed data analysis, enable rapid dissemination of intelligence, and inform timely reporting, investment and decision-making around biodiversity response actions (Figure 5).

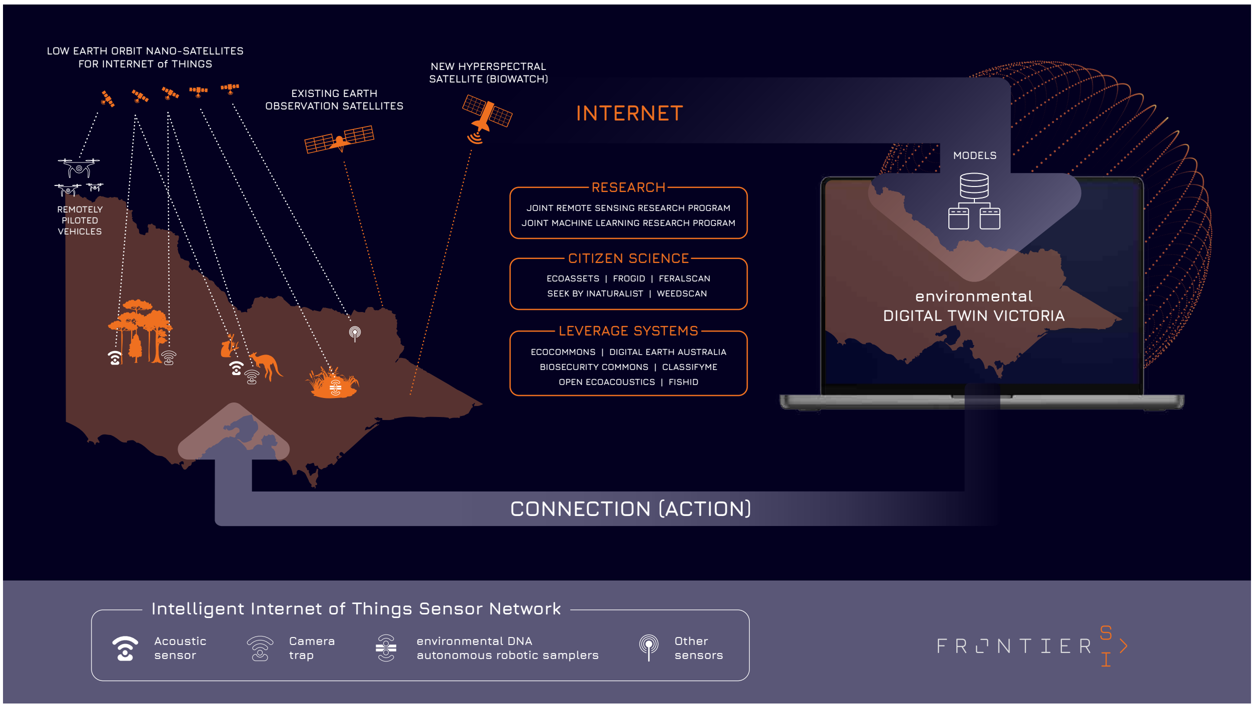


Figure 4: Proposed future integrated biodiversity monitoring solution for Victoria.

Central to this proposed solution, and a significant first step, is an eDTV, which would be part of the existing DTV platform. Digital twins exist for the built environment but are not known to have been applied to the natural environment.

A digital twin is a dynamic digital representation of a real-world object or system on which services can be performed that provide value to an organisation. This emerging technology can provide a centralised spatial environment to enable the tracking of progress towards achieving the Biodiversity 2037 targets. Digital twins offer a transformative opportunity to develop integrated, interoperable, scalable technology to address the challenges within complex natural environments. They provide data management, analysis, visualisation and the ability to effect and reflect change in the real world, as well as enable strategic management and evidence-based reporting and budgeting:

- The eDTV would integrate currently disparate biodiversity and environment data from many sources (including existing data, EO/RS and IoT) and act as a decision support system to generate actionable insights from data. It would be open, accessible and centralise all information required for Biodiversity 2037 and state of the environment reporting to streamline these processes. Also, it would ensure ongoing, reliable access to the required information, providing a user-friendly way to search, interrogate and visualise data across Victoria.

- The eDTV would be developed to be compatible and interoperable with other space and spatial analysis tools. It would also leverage and integrate the results of citizen science data collection by being interoperable with technology such as EcoAssets, FeralScan, FrogID, Seek by iNaturalist and WeedScan.[92, 93, 94, 95, 96]
- Existing satellite and other EO data and/or derived products will create rich, accurate and current data for the eDTV. Greater leveraging of existing EO data and the potential of new biodiversity-specific EO data (through a new Australian Government satellite or high-altitude pseudo-satellite with hyperspectral sensor) would help to fill data gaps and increase the reliability and availability of data for managing biodiversity.
- An intelligent IoT network of field sensors could be established to automate and increase biodiversity data collection and availability in the eDTV. It could utilise a low earth orbit nano-satellite constellation like Myriota (or the planned AquaWatch IoT satellites) and potentially be powered by solar energy or bio-batteries.[97]
- The use of remotely piloted vehicles (RPVs) for aerial and underwater RS data collection can further increase data availability for the eDTV, especially where higher resolution imagery (compared to that of a satellite) is required, surveying inaccessible areas or reducing human field-survey time.
- A mini-Global Positioning System (GPS) or ear-tag tracking program for larger terrestrial animals could be implemented, potentially IoT-enabled for automatic data upload to the eDTV. This could complement the IoT-enabled smart sensor network and provide a further source of biodiversity data.

RECOMMENDATION 15: That the Victorian Government develops an environmental Digital Twin for Victoria, building on the existing Digital Twin Victoria program.

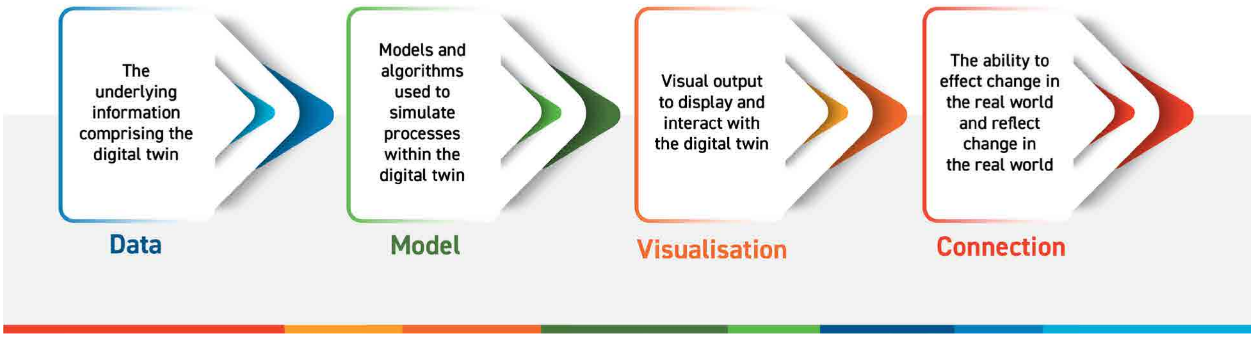


Figure 5: Components and capabilities of a digital twin.

92. EcoAssets, 'EcoAssets: Building data linkages for environmental reporting', https://ecoassets.org.au Accessed on 30 May 2023.
93. Centre for Invasive Species Solutions (CISS), 'FeralScan: Record pest animal activity in your local area to protect farms, biodiversity and communities', https://feralscan.org.au Accessed 31 May 2023.
94. FrogID, 'Australia's frogs need your help', https://www.frogid.net.au Accessed 29 May 2023.
95. iNaturalist, 'Seek by iNaturalist', https://www.inaturalist.org/pages/seek_app Accessed 29 May 2023.
96. Centre for Invasive Species Solutions (CISS), 'WeedScan: Record priority weeds in your local area to protect the environment, farms and communities', https://test.weedscan.org.au/ Accessed 8 June 2023.
97. Myriota, 'Myriota, everywhere' https://myriota.com Accessed 5 June 2023.

The proposed eDTV builds on the space and spatial analysis recommendation from the SoE 2018 Report: 'Recommendation 18: That DELWP develop its spatial information capability and database, and ensure it is regularly and routinely updated, to inform decision-making across the environment portfolio.'

The eDTV would provide data management, analysis, visualisation and the ability to effect and reflect changes in the real world. The data component of a digital twin comprises the data itself plus a method to store and access it (e.g. a database). Digital twins are not static; their data and models, and even visualisation and connection components, can be updated. As the eDTV matures, it would be regularly and routinely improved by updating analysis models and filling critical data gaps from new sources, such as EO combined with ML (and IoT-networked smart sensors). Digital twins are ultimately decision support systems and the eDTV would enable strategic management, investments, and evidence-based reporting and insights for environment management.

Digital twins require significant amounts of data to produce value, but data alone does not provide understanding. Actionable insights only come from interpretation of the results of data analysis. In-house specialists for expert interpretations would be needed to create knowledge and wisdom from the data and information within the eDTV. A formalised collaboration would be required across Victorian Government departments and agencies to produce an eDTV decision support system and manage all the datasets and models required for analysis and assessment. This would need to be supported by new methods for data creation to fill critical gaps and populate the eDTV, and strategic collaborations to leverage existing tools and datasets through interoperability (e.g. EcoCommons, Digital Earth Australia).

Victorian Government progress on State of the Environment 2018 Report recommendations

The SoE 2018 Report included recommendations to the Victorian Government to improve environmental sustainability outcomes.

Presented below is the recommendation, as well as:

- the full Victorian Government response to the recommendation, including the level of support, as published in the Victorian Government Response to the State of the Environment 2018 Report
- a description of progress made on the implementation of the recommendation over the past five years. The content of this section is derived from written material supplied directly to the CES by relevant government entities and/or it synthesises information that is publicly available in referenced reports, legislation and websites. Importantly, this section summarises the progress made since 2018 in relation to the recommendation; it is not an audit of the extent and quality of the completed work.

Recommendation 18 of the SoE 2018 Report recommended:

That DELWP develop its spatial information capability and database, and ensure it is regularly and routinely updated, to inform decision-making across the environment portfolio.

Government response in 2020:
SUPPORT IN PRINCIPLE

'The Victorian Government supports the intent of this recommendation and acknowledges the important role of spatial data to inform decision-making across the environment portfolio.'[98]

'Spatial data and services are fundamental to the delivery of many of the Department of Environment, Land, Water and Planning's (DELWP) core service obligations. The Department is uniquely placed to take a leadership role in spatial data service design and delivery, given DELWP's expertise, custodianship of essential data sets and the role these services provide for so many public and private sector activities.'[99]

98. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Government response: State of the Environment 2018 Report', https://www.ces.vic.gov.au/state-of-reports/government-response-state-environment-Ibid.2018-report Accessed on 8 June 2023.
99. Ibid.

'DELWP maintains a wide range of spatial information – including topographic, public land, forestry, biodiversity and marine data – and has several systems already in place to store, update and share it. The Department's spatial data are stored in the Victorian Spatial Data Library, which contains over 2,000 datasets that are made available externally through both the Spatial Datamart Victoria and the DataVic websites.' [100]

'Released in 2018, the DELWP Core Spatial Data Services Strategy sets the direction for the core spatial data services that underpin the State's spatial offerings. The strategy emphasises the need for efficient foundation data infrastructure and the development of spatial products and services that are informed by customer insights and envisages a three-year implementation plan which is well progressed.' [101]

'In delivering the strategy DELWP has been investing significantly in modernising its spatial infrastructure, establishing cloud-based storage for its spatial data, exploring the potential for foundational spatial datasets to take on a 3D form and trialling new technologies, including digital twins, machine learning and artificial intelligence. To ensure clearer governance and coordination the Department is also establishing the DELWP Spatial Steering Committee that will set the vision and strategy for future spatial service modernisation.' [102]

'DELWP will explore the following options to improve its spatial information capability and database:

- Ensuring that the Victorian Spatial Data Library contains a comprehensive list of spatial data collected by DELWP.
- Promoting awareness and supporting greater access to DELWP spatial data.
- Developing a roadmap to deliver improved spatial infrastructure and building the case for 'One-VPS Shared Services'. [103]

'While the Government acknowledges the risk associated with not actively curating datasets, there are significant costs associated with the collection and management of spatial data to achieve this outcome. In line with existing Government commitments and portfolio priorities, DELWP will consider a review of its information asset register to identify core spatial datasets as a platform to support effective decision-making.' [104]

Progress made since 2018

Update on recent Machinery of Government changes

Following the 2022 state elections, a number of Machinery of Government changes were announced in December 2022. As a result of these changes, functions performed by the former DELWP have been reassigned to two new departments. The Department of Energy, Environment and Climate Action (DEECA) maintains responsibility for the Environment portfolio. Land management and planning functions have transitioned to the Victorian Department of Transport and Planning (DTP). Land Use Victoria, the Office of the Surveyor-General of Victoria, Digital Twin Victoria and Vicmap Spatial Services are now part of DTP.

Update on progress

The Victorian Government, through the former DELWP, has made substantial investments since 2018 to develop its spatial information capabilities and related systems to better inform a range of critical portfolios, including the environment. Some of these improvements are highlighted in the following sections.

Positioning improvements

Accurate positioning is the basis of all spatial information and analysis. Since 2018, DELWP has supported significant improvements in the accuracy of Victoria's base spatial information and positioning systems, including:

- leading the adoption of Australia's new geocentric datum, GDA2020
- extending the state's Survey Control Network with a significant number of new survey marks contributed by the Office of the Surveyor-General of Victoria
- collaborating with Geoscience Australia and the Geologic Survey Victoria to capture consistent airborne gravity data across 100,000 km^2, including the Victorian coast from Cape Otway

100. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Government response: State of the Environment 2018 Report', https://www.ces.vic.gov.au/state-of-reports/government-response-state-environment-2018-report Accessed on 8 June 2023.
101. Ibid.
102. Ibid.
103. Ibid.
104. Ibid.

to Cape Howe, metropolitan Melbourne and the Australian Alps. This new gravity survey, to be completed by the end of 2023, will significantly improve the accuracy of real-world heights from GPS positioning in Victoria to within a few centimetres. Furthermore, it will be used by geoscientists to understand south-eastern Australia's geological 'architecture' and how it has evolved over time

- investing $45 million through the Digital Cadastre Modernisation project to bring the authoritative map of Victoria's property boundaries into the digital age, improving the accuracy of Vicmap Property from 25 m to 50 m in some places to within centimetres of its true cadastral position. These changes have been cascaded throughout the Vicmap suite of foundational spatial products, bringing improvements to Vicmap Property, Vicmap Address, Vicmap Admin, Vicmap Crown Land Tenure, Vicmap Index and Vicmap Planning.

Investments in core spatial data

DELWP has continued to coordinate investments and work with data custodians to keep Victoria's core spatial data up to date and has adopted more modern approaches since 2018 to the creation and maintenance of foundation spatial data.

Elevation data

DELWP has coordinated investments from across government of more than $10 million in high-resolution elevation data across large areas of the state since 2018, including:

- the Regional Forest Agreement LiDAR project in 2019–20, which mapped the forests across eastern Gippsland to create high-resolution 3D models of Victoria's forest structure – from the top of the forest canopy through to the understorey. This enabled researchers to create models and detailed, accurate forest maps across this region to improve fuel load modelling for fire management purposes, and to understand the interaction of critical species and their forest environments
- mapping of the entire Great Ocean Road in 2019–20 with high-resolution imagery and LiDAR to support the establishment of the Great Ocean Road Coast and Parks Authority to protect and manage coastal Crown land along the Great Ocean Road
- over $4 million in new Light Detection and Ranging (LiDAR) surveys as part of the DTV platform to support a range of land management activities including flood mapping, vegetation mapping, surface modelling, cultural heritage mapping and land surface change detection. This LiDAR project will contribute detailed forest models, support ecological analysis, guide bushfire preparation and recovery, and inform climate change responses over the coming decades. Vegetation models will extend to urban forests, contributing valuable information about street trees and providing information for urban greening projects.

These and other high-resolution elevation surveys are being combined to publish a new digital elevation model (DEM) — the Vicmap 1M DEM — due for launch at the end of 2023. It will cover over 60% of Victoria's land area and 98% of its population, a 100-fold improvement on the existing Vicmap 10M DEM.

Satellite imaging data

Through the DTV program, DELWP established the Victorian Government's first commercial satellite tasking panel in 2022, enabling immediate access by government and emergency services to more than 50 satellites from across six constellations covering both optical and radar capabilities, with resolutions as low as 30 cm. This tasking capability enables delivery of data to users within 12 hours of the completion of a satellite survey and has significantly improved the Victorian Government's ability to monitor and respond to emerging risks in critical environments.

New approaches to creating and maintaining spatial information

DELWP has also innovated on ways to make data from data using machine learning, enabling the creation of new datasets and creating opportunities for automation of regular data maintenance workflows:

- In 2021, DELWP used machine-learning for the first time to update and create a Vicmap product, Vicmap Vegetation, a dataset that had not been updated for over a decade. This work contributed to building internal capabilities in this area and will lead to a future redesign of the product management workflows, aiming to ensure that Vicmap products can be updated using machine learning and other automatic detection techniques as new imagery is acquired by the Victorian Government.

- The expertise in machine learning being built by the Vicmap Spatial Services team creates opportunities for updating statewide datasets using cloud-based technologies and parallel processing. In some cases, product updates using traditional methods would be so time-consuming they may not be viable. In the case of the Vicmap Vegetation work, such an update could take up to 100 full-time employees more than two years to deliver the results that the network obtained within a week. This approach opens new opportunities, as it can enable Vicmap products to evolve to allow comparisons of changes in the data over time.
- In 2023, the Victorian Government launched Vicmap Buildings: a new machine-learning-supported 3D Vicmap product of the built environment. This dataset has been collected together with more than four million of the best available building models from across the state into the Vicmap 3D Buildings datasets, available to visualise for free in the DTV web-based 3D platform. Knowledge of the built environment and how it is changing is vital to understanding the impact on our critical ecosystems from urbanisation and semi-urban expansion.

Vicmap Spatial Services continues to proactively partner with public sector organisations and research institutions to ensure sustainable funding is available to support continuous research, development and innovation in Vicmap data management processes.

Improvements to systems and development of new platforms

DELWP has also worked to improve its spatial information systems, through major uplifts that have modernised the architecture of spatial systems to take advantage of cloud-based storage and computing. It has also developed new platforms to leverage modern data publishing and visualisation approaches. These developments include:

- the launch of Datashare in 2021, replacing Spatial Datamart and giving users easier access to find and download information from the most comprehensive catalogue of Victorian spatial data, including data in Vicmap, and in relation to fire mapping, planning, biodiversity, water and climate change
- modernisation of the Victorian Spatial Data Library through redesigning the databases that store and manage spatial information from across the Victorian Government to work with reliable, tolerant, cloud-based services, and relaunching the system as the Vector Data Platform
- delivery of the new Vicmap-as-a-Service (VaaS), which enables users to access Victorian foundational spatial data in the cloud via web services and application programming interfaces as an alternative to traditional methods such as downloads and file transfer. VaaS enables customers to seamlessly integrate their spatial infrastructure with Vicmap and access near real-time data
- the Victorian Government's 2019 launch of the 5-year, $45-million Digital Cadastre Modernisation (DCM) project to enhance the locational accuracy of Vicmap. The positional accuracy of features within multiple Vicmap products will be improved based on topology rules. These products include Vicmap Address, Vicmap Admin, Vicmap Crown Land Tenure, Vicmap Features of Interest, Vicmap Hydro, Vicmap Index and Vicmap Transport. The DCM project is now in the integration phase, having delivered better locational accuracy to Vicmap data to over 23 local government authorities, and counting
- investment in 2021 by the Victorian Government of a record $37.4 million in digital twin technology, spatial data and spatial innovation under the DTV program. DTV is helping to foster and connect a range of innovations, including launching the DTV platform in 2022. Partnering with CSIRO's Data61, this platform has created a digital twin of Victoria with more than 4,000 spatial datasets online, free and available to visualise in a user-friendly web browser platform. DTV is unlocking the value of our spatial digital data, improving collaboration and communication, and developing future-ready skills and capability by providing access to an extensive catalogue of open data from across local, state and federal governments, enabling integrated visualisation services capable of displaying 2D, 3D, time-dynamic and real-time data in a web browser.

Abbreviations for Part 2a

AI .... artificial intellligence
Biodiversity 2037 .... Protecting Victoria's Environment: Biodiversity 2037
CES .... Commissioner for Environmental Sustainability
DEECA .... Department of Energy, Environment and Climate Action
DCM .... Digital Cadastre Modernisation
DEM .... digital elevation model
DTP .... Victorian Department of Transport and Planning
DTV .... Digital Twin Victoria
eDTV .... environmental Digital Twin Victoria
EO .... earth observation
GPS .... Global Positioning System
IoT .... Internet of Things
HDM .... habitat distribution model
LiDAR .... Light Detection and Ranging
ML .... machine learning
RPV .... remotely piloted vehicle
RS .... remote sensing
SMCE .... State of the Marine and Coastal Environment
SoE .... State of the Environment
VaaS .... Vicmap-as-a-Service

Part 2B
Applying international frameworks

Victorian State of the Environment 2023 Report

Cape Otway Lightstation, Great Otway National Park 2018.
Credit: Matt Donovan.

The United Nations Sustainable Development Goals and state of the environment reporting in Victoria

Key findings

This report provides a comprehensive scientific analysis of Victoria's environmental condition. For the first time in modern Victorian state of the environment reporting, the State of the Environment (SoE) 2023 Report returns to the scientific baseline of the previous report (SoE 2018) to measure the same indicators, report on trends, assess progress on previous recommendations and propose, or reiterate, new recommendations informed by the latest evidence.

The SoE 2018 reporting process ushered in new ways of working with our stakeholders to enhance the value of independent science reporting by the Commissioner. Central to this endeavour was the embedding of international frameworks and advocacy for the adoption of the United Nations (UN) Sustainable Development Goals (SDGs) and the UN System of Environmental-Economic Accounting (SEEA) into local reporting.

> 'Putting the United Nations Sustainable Development Goals under the microscope to determine which are the most relevant to environmental reporting in Victoria is a crucial step in achieving meaningful, high-quality and transparent reporting.' [105]
>
> *Hon. Lily D'Ambrosio MP, Minister for Energy, Environment and Climate Change, 2018*

Similar to the efforts of building on the 2018 scientific baseline, the important analysis of the utility of international frameworks being applied to the science to draw out important stories and interlinkages between reporting themes has also been further developed in this report. This section outlines a method for applying the UN SDGs as an operating framework for reporting on the state of the environment.

It reiterates and builds on the six-phase approach to operationalise the SDGs that was published in the Victorian State of the Marine and Coastal (SMCE) 2021 Report.

The six phases combined deliver on the commitments of the Science for Sustainable Development Framework for the Victorian State of the Environment 2023 Report and adopt the SDGs to broaden the focus of environmental reporting and to better address economic, social and environmental considerations.[106]

Phases 1 to 4 were discussed in the SMCE 2021 Report. For this report, the findings and outputs developed in partnership with the Centre for Spatial Data Infrastructures and Land Administration (CSDILA) at the University of Melbourne are added to explore Phases 5 and 6 of the proposed method and develop:

- a process to assess the interlinkages between SDG targets (and the corresponding indicators)
- a prototype digital platform that will be made available for further research and development to enable others to further explore interlinkages, and ultimately predictive analysis, for different scenarios.

The digital platform is preliminary in its design, but predictive analysis as a decision-making support tool will be possible once the platform is further developed.[107]

Framing state of the environment reporting with the SDGs provides a depth and breadth to the science on, and storytelling about, the natural environment to better reflect the views, and respond to the needs, of Victoria's diverse community.

> The 139 state of the environment indicators in this report have contributed to a comprehensiveness and progress assessment of 76 SDG targets (Phase 2 and Phase 4, respectively). This analysis is provided in Appendix B.

This method developed by the Commissioner of codifying a system based on a repeatable baseline of indicators at scale is a critical value-add for future development of the platform — and can be repeated for future reports. However, doing this effectively would require a commensurate improvement in the evidence base (Recommendation 14 and 15 in this report).

105. Commissioner for Environmental Sustainability 2020, 'Framework for the Victorian State of the Environment 2023 Report: Science for Sustainable Development', Victorian Government, Melbourne.
106. Ibid.
107. The platform will be made available on the CSDILA webpage: https://eng.unimelb.edu.au/csdila

In identifying the practical implications of applying different data and models (Phase 5) and developing the platform for the interpretation of results and improving decision-making (Phase 6), the method revealed that Phases 1 to 4, informed by the SoE evidence base, are an indispensable foundation for the platform.

Phases 1 to 4 were verified in this work as necessary to refine SDG target (and corresponding indicator) selection and weighting, as well as providing the focus on local priorities and low-performing targets that may require enhanced management intervention, before analysis by the platform and its predictive analysis capability.

> In simpler terms, the earlier phases are critical for selecting the most appropriate inputs (SDG targets and data sets), and therefore, generating the most appropriate outputs through the digital platform to inform local decision-making.

Purpose and context

The Science for Sustainable Development framework, released in 2020, informs the current approach of the Commissioner for Environmental Sustainability (CES) to state of the environment reporting in Victoria.[108] A key assumption of the framework is that the UN SDGs can animate the objectives of the *Commissioner for Environmental Sustainability Act 2003* (CES Act). Hence the framework pushes the aspiration for the SoE 2023 Report beyond the limitations of previous state of the environment reporting cycles.

This part of the current report outlines a method for applying the SDGs as an operating framework for state of the environment reporting and builds on the findings published in the SMCE 2021 Report.[109] Specifically, it proposes a six-phase method to incorporate the SDGs into state of the environment reporting, with an emphasis on Phases 5 and 6 in this report.

The six phases are summarised on the following page.

Lake Tyrrell Wildlife Reserve 2018.
Credit: Anne Morley.

108. Commissioner for Environmental Sustainability 2020, 'Framework for the Victorian State of the Environment 2023 report: Science for Sustainable Development', Victorian Government, Melbourne.
109. Commissioner for Environmental Sustainability 2021, 'State of the Marine and Coastal Environment 2021 Report', Victorian Government, Melbourne.

Operationalising the Sustainable Development Goals for state of the environment reporting: A six-phase approach

Phases 1 and 2 were undertaken for both the SMCE 2021 and the SoE 2023 reports. Refer to Appendix B for the analysis undertaken for this report.

Phase 1: Selection of relevant SDG targets proposes a list of SDG targets that are relevant to state of the environment reporting in Victoria and describes the selection process.

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

Phases 3 and 4 were undertaken for the SMCE 2021; refer to that report for additional detail. The reporting component of Phase 4 was also undertaken for this report (Appendix B); however, the storytelling component was replaced by Phases 5 and 6 in this report.

Phase 3: Localisation of the SDGs describes the steps undertaken to understand local priorities through an engagement process with local environmental 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 state of the environment 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 of the report, but with a focus on the system and the telling of interconnected stories to inform holistic policy interventions and management.

The focus in this report is on the method's final two phases, to operationalise the SDGs for state of the environment reporting and identify the interlinkages among the SDG targets. This prototype platform detailed in this report were developed by the CSDILA for the SoE 2023 between December 2022 and May 2023.

Phase 5: Understanding interlinkages — to deepen understanding of the interlinkages between systems, pressures and processes occurring in our environment and enhance evidence-based decision-making, Phase 5 considers the analysis of interlinkages between competing priorities in complex systems.[110]

Phase 6: Predictive analysis — provides a prototype platform for end users to understand the interlinkages and undertake a comparative analysis of the impact of potential interventions on progressing specific targets.[111]

110. Unpublished research undertaken by the CSDILA.
111. Ibid.

Relevance of the UN SDGs to state of the environment reporting

The UN SDGs took effect on 1 January 2016. The 17 SDGs provide a comprehensive and integrated framework of 169 targets and 230 indicators to support planning and reporting through to 2030. They provide business, government and civil society with a compelling framework for future growth that aims to be socially fair, environmentally sustainable and economically prosperous.

Four critical aspects of the SDG framework are relevant to state of the environment reporting. The SDGs provide:

- a pre-prosecuted framework for reporting across complex and disparate areas of social, economic and environmental policy
- a framework that is internationally agreed and widely supported
- a common language for measuring progress against goals and targets
- broad support from across business, government and community.

The CES Act defines sustainable development as 'development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends'.[112] In the Act, the Objectives and Functions of the CES (ss 8, 9) clarify that state of the environment reporting is a key function assisting the CES in achieving ecologically sustainable development (ESD) objectives. The international adoption of the SDGs in 2016 enables the CES to:

- analyse the SDGs through the authorisation of the CES Act
- identify SDG goals and targets that correspond with the ESD definition in the CES Act and require reporting by the CES.

From this perspective, the SDGs are the missing link that brings the ESD objectives and guiding principles in the Act to life.

112. Parliament of Victoria 2003, *Commissioner for Environmental Sustainability Act 2003*, https://www.legislation.vic.gov.au/in-force/acts/commissioner-environmental-sustainability-act-2003/016 Accessed on 8 June 2023, Victorian Government, Melbourne.
113. Ibid

Role of the Science for Sustainable Development framework

The CES Science for Sustainable Development framework encompasses three aspects of synthesis:

- reporting on environmental condition
- assessing interlinkages across the SDG targets
- tracking progress on selected SDG targets.

A key assumption of the Science for Sustainable Development framework is that the SDGs can enable the four objectives of the CES Act in a way that was not available to the CES in relation to state of the environment reporting prior to 2015. Hence the framework pushes the aspiration for the SoE 2023 report beyond the limitations of previous state of the environment reporting cycles and more specifically enables the objectives (s 7) of the CES Act, through state of the environment reporting:

a. Report on matters relating to the condition of the natural environment of Victoria
b. Encourage decision-making that facilitates ecologically sustainable development
c. Enhance knowledge and understanding of issues relating to ecologically sustainable development and the environment
d. Encourage sound environmental practices and procedures to be adopted by the Government of Victoria and local government as a basis for ecologically sustainable development.[113]

Method for applying the SDGs to state of the environment reporting

Designing the method

A six-phase approach was adopted to apply the SDGs as an operating framework for environmental reporting in Victoria.

Phases 1 to 4 were trialled in the SMCE 2021 Report, and elements were applied in this report (Appendix B) to provide a foundation for Phases 5 and 6 (described below).

It became clear in delivering the SMCE 2021 Report that applying the SDGs to state of the environment reporting would benefit from a model of reporting that goes beyond the technical application of a measurement framework to emphasise the importance of the interlinkages between SDG targets.

A future priority was proposed in the SMCE 2021 Report, to:

> '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.' [114]

The work presented here in Phases 5 and 6 of the method was developed between December 2022 and May 2023 for a report to the CES. It was prepared by CSDILA under the leadership of Abbas Rajabifard, CSDILA's Director and Chair of the Academic Network of the UN–Global Geospatial Information Management Academic Network.[115] Phases 5 and 6 deliver on that proposed experimentation and enquiry, and present a prototype 'platform' for further research.

Method

The following logic is applied to the method:

- Deliver a reporting regime that 'operationalises' the SDG framework by anticipating the whole system – representing all 17 goals – in its findings and recommendations.
- Improve 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.

As Figure 6 explains, the proof of concept for Phases 5 and 6 is largely dependent on the evidence base established by the first four phases. Appendix B in this report provides a progress assessment (Phase 4) on the 77 selected SDG targets (Phase 1). That analysis provides useful summary diagrams that assesses the status, trend and data confidence of the 77 selected targets. Note that these assessments are indicative only, as the comprehensiveness analysis (Phase 2) determined limitations with the data and analysis that the implementation of Recommendations 14 and 15 will address. In this way, the summaries of the selected SDG targets become an essential engagement tool to work with local environmental managers and practitioners (Phase 3) to prioritise the focus of Phases 5 and 6, and, ultimately, the research platform, below.

Proof of concept

A proof of concept for each of Phases 5 and 6 of the method is presented below.

Phase 5 describes a process to analyse interlinkages across the 'indivisible whole' of the SDG framework. Phase 6 provides a link to a prototype platform for predictive analysis. Both these phases were developed in partnership with the CSDILA and fulfil the commitment of the Science for Sustainable Development framework.[116]

The predictive analysis platform[117] is preliminary in its design, but predictive analysis as a decision-making support tool will be possible after the research platform is further developed.

Phase 5: Understanding interlinkages

In the SMCE 2021 Report, the interlinkages effort was limited to the scope of the scientific assessments in Part 3; however, this report explores links beyond the boundaries of the scientific evidence base reported in Part 3 – and considers interlinkages with the system as a whole. The platform presented below as a prototype will enable decision-makers to understand the co-benefits (positive interactions) and trade-offs (negative interactions) between environmental management interventions.

114. Commissioner for Environmental Sustainability 2021, 'State of the Marine and Coastal Environment 2021 Report', Victorian Government, Melbourne.
115. Unpublished research undertaken by the CSDILA.
116. Commissioner for Environmental Sustainability 2020, 'Framework for the Victorian State of the Environment 2023 report: Science for Sustainable Development', Victorian Government, Melbourne.
117. The platform will be made available on the CSDILA webpage: https://eng.unimelb.edu.au/csdila

Quantitative model design and mathematics

This section details the methods, application and results that were developed to identify the interlinkages among the SDG targets. In addition to identifying the most critical targets (informed by the analysis in Phases 1 and 2), this phase also located their nexuses (defined as clusters of highly interconnected SDG targets and corresponding indicators).

To assess the interconnectedness and nexuses of the SDG targets for this proof of concept, UN data were used. The rationale for this is that the:

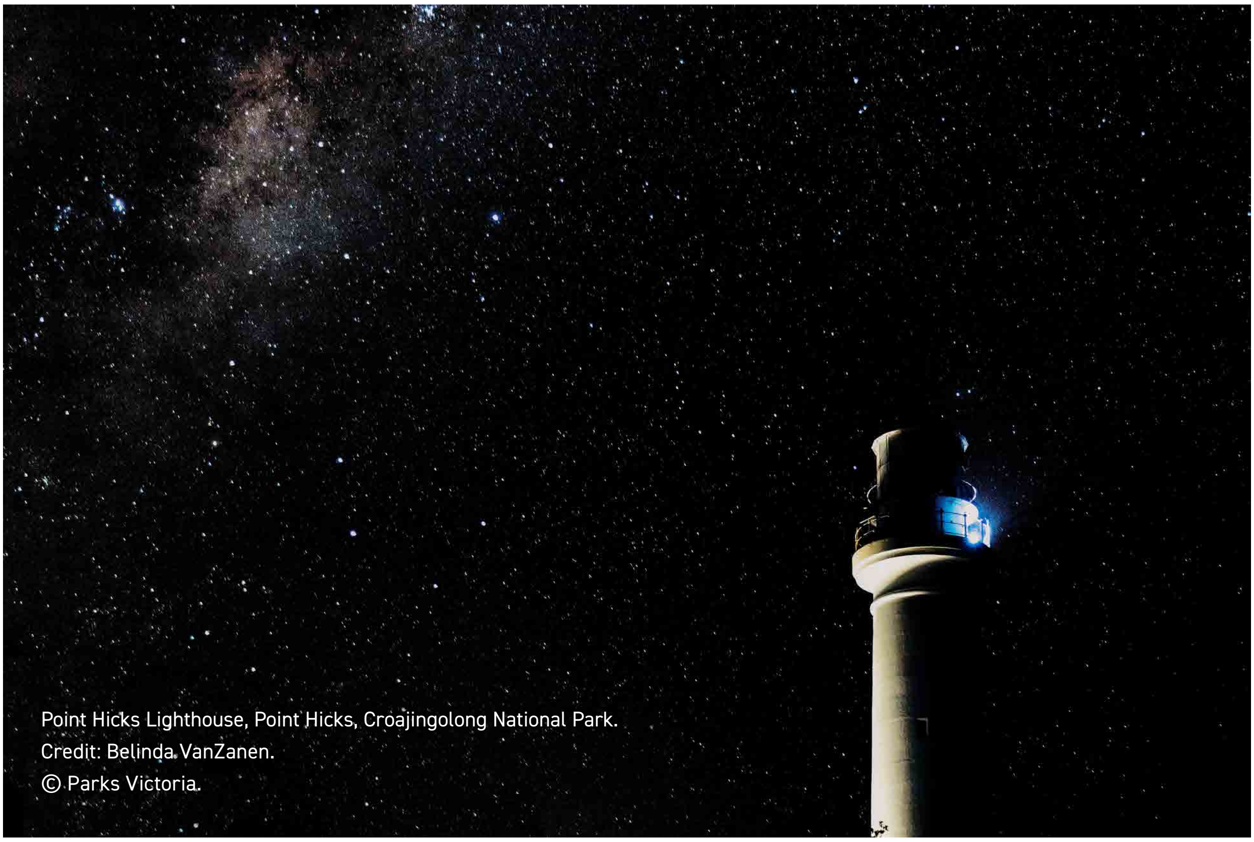
- data are of high quality and allow the user to evaluate the performance of the developed methodology
- scope of the data is considerably broader than that of the content of this SoE report and enables the potential to understand the interlinkages between environmental condition reporting and the 'indivisible whole' anticipated by the SDG framework.

It is envisaged that further development of the prototype platform (Phase 6) would enable the methodology tested here to be applied to specific interlinkages using data at a statewide or local scale, drawing on the insights of local priorities delivered in Phase 3 of the method.

Based on the UN data, the following outcomes were sought:

- understanding the relationship between different targets (e.g. the relationship between climate change and population)
- identifying a set of targets that can be used as predictors for each target
- identifying a nexus of strongly interconnected targets.

The following is a modified extract from the report to the CES by the CSDILA.[118] The research material on the prototype platform will be the subject of future University of Melbourne publications from the CSDILA.[119]



Point Hicks Lighthouse, Point Hicks, Croajingolong National Park.
Credit: Belinda VanZanen.
© Parks Victoria.

118. Research undertaken by the CSDILA.
119. Centre for Spatial Data Infrastructures and Land Administration (CSDILA), 'Centre for Spatial Data Infrastructures and Land Administration: Faculty of Engineering and Information Technology', https://eng.unimelb.edu.au/csdila Accessed 5 June 2023.

Phase 5 model development progress and challenges

Three steps were developed to measure the interlinkages between SDG targets, and to determine the performance and causality of these interlinkages.

1. Measure the performance of interlinkages between SDG targets

This step produces a measure of the strength and direction of interlinkages for SDG targets.

A simple way to measure a target's performance is to calculate the mean overall value of indicators at the target level. As such, all indicators are given equal weight in this proof of concept.

Before calculating the mean, indicator values need to be rescaled to account for different unit measures. For example, the mean of the employment rate (as a percentage, between 0 and 100) and GDP per capita (in $) will be skewed towards the latter measure. After rescaling all variables, all values are expressed relatively, and the unit of measurement ceases to matter.

In the future development of the platform, the design could account for indicators' relative weights when considering their direct impact on the progress of a specific SDG target (Phase 2). In this way, users could prioritise indicators that are most important to them and adjust the weight of each indicator for the desired target. This allows for more accurate target measurement, tailored to a user's needs.

2. Calculate the strength of interlinkages between SDG targets

The aim of this calculation is to determine the strength of the relationship between SDG targets. This strength is a variable with a value between −100 and +100. The stronger the relationship, the closer the value is to ±100. A positive value indicates that targets are directly related. In this situation, as the value of one variable increases, the value of the other also tends to do so. A negative value indicates that targets are inversely related. In this situation, as the value of one variable increases, the value of the other tends to decrease.

3. Assess the causality of interlinkages between SDG targets (and corresponding indicators)

Three methods – Granger causality, convergent cross-mapping and transfer entropy – were used to assess the causal relationships between SDG targets (and corresponding indicators). Based on the results of the trial, Granger causality analysis was chosen to be applied to the development of the prototype platform in Phase 6.

Granger causality analysis was developed by British economist Clive Granger in the 1960s. It has been widely applied in various fields, such as economics, finance, neuroscience and climatology, to analyse causal relationships between variables. As a statistical method, Granger causality analysis determines whether one time series (a sequence of observations measured over time) can predict another time series. The method is used to identify causal relationships between two variables, even in the presence of other variables that may be influencing both. It tests whether the past values of one time series provide useful information for predicting the future values of another time series, beyond what can be predicted by past values of the original time series.

Source: Extract adapted from a report submitted to the Commissioner for Environmental Sustainability by the Centre for Spatial Data Infrastructures and Land Administration.

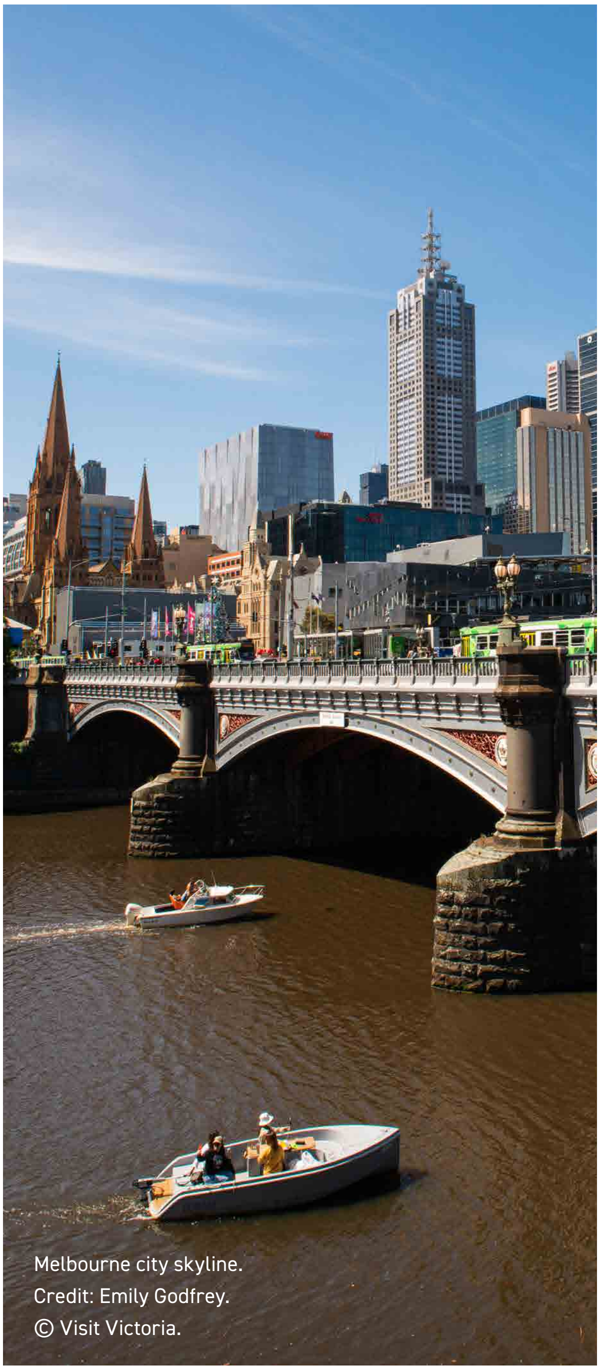
Phase 6: Predictive analysis

> '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.' [120]

This section introduces how causality analysis, introduced in Phase 5, is integrated with the prediction model to deliver a prototype platform. In Phase 5, Granger causality analysis was used to identify predictors and responses that relate to the targets and corresponding indicators of the SDGs. In Phase 6, all possible predictors of each target and indicators are identified using results of the Granger causality analysis. Fewer predictors can simplify both the model and understanding of the factors driving the predictions, but can limit the model's ability to capture significant relationships in the data and result in lower predictive accuracy. Hence, in future research, having more predictors could increase the model's ability to capture complex relationships in the data and improve its predictive accuracy.

Proposed method for prediction

Various steps in the development of the prediction model, and inputs required from other phases of the method, are explained in Figure 6.



Melbourne city skyline.
Credit: Emily Godfrey.

120. Commissioner for Environmental Sustainability 2020, 'Framework for the Victorian State of the Environment 2023 report: Science for Sustainable Development', Victorian Government, Melbourne.

The proposed method for prediction

The utility of the research platform is dependent on the five phases that precede it.

Phase 1: Selection of relevant SDG targets proposes a list of SDG targets that are relevant to state of the environment reporting in Victoria and describes the selection process; this is the first stage of limiting the scope of Phases 5 and 6 to enable a functional prediction method.

Phase 2: Evaluating comprehensiveness of indicators assigns indicators from the scientific assessments (Part 3) of the report to the SDG targets identified in Phase 1 of the method. This phase is entirely dependent on the indicator selection process that is undertaken for every report in the Commissioner's state of the environment legislative program. This independent and extensive process, not described in detail here, delivers the evidence base of the scientific assessments analysed in Part 3. The assigned indicators chosen from the indicator suite are then weighted against specific SDG targets for Phase 2, because not all of the indicators that are mapped to a specific target are equally important in assessing that target; critical indicators are given a heavier weighting. This phase is critical for delivering Phase 4 and, ultimately, influencing the inputs into the Phase 6 research platform.

Phase 3: Localisation of the SDGs is arguably the most influential input into Phases 5 and 6 as it is undertaken to understand local priorities through an engagement process with local environmental managers and practitioners. This process will prioritise the SDG targets and interlinkages, initially selected in Phase 1, into an even more refined subset — of critical importance to the end users of the research platform.

Phase 4: Reporting on SDG target assessments details the progress on the SDG targets that were identified in Phase 1 (i.e. those targets selected as being relevant to state of the environment reporting in Victoria) and assessed in Phase 2 (i.e. those targets evaluated for comprehensiveness for the current suite of state of the environment indicators to report progress in a meaningful way). Reporting on the SDG targets in Phase 4 draws on, and is limited by, the information and evidence base in Part 3 of the report so, complementing Phase 3, it is also critical for influencing which targets and interlinkages are analysed in Phases 5 and 6. For example, local environmental managers and practitioners may choose to prioritise targets that are low-performing or where data confidence is high.

Phase 5: Understanding interlinkages – to deepen understanding of the interlinkages between systems, pressures and processes occurring in our environment and to enhance evidence-based decision making, Phase 5 considers the analysis of interlinkages between competing priorities in complex systems.[121] The Phase 6 research platform is wholly dependent on the data and scope that Phase 5 contributes to it.

Phase 6 is described in detail in the subsequent passages. The detailed information explains the nine steps undertaken to develop the research platform. The first three concern the 'preparation of the platform'; the latter six describe 'developing predictive analysis'.

Phase 6: Predictive analysis[122] – provides a prototype platform for end users to understand the interlinkages and undertake a comparative analysis of the impact of potential interventions on progressing specific targets.

Figure 6: Predictive analysis - Summary of the phases developed to operationalise the SDGs for state of the environment reporting – Phases 1 to 5 are prerequisites for Phase 6 predictive analysis.

121. Research undertaken by the CSDILA.
122. Ibid.

The 'Preparing the platform' and 'Developing predictive analysis' descriptions below are extracted from the CSDILA specialist report delivered to the Commissioner for Environmental Sustainability in May 2023.[123]

Future development of the predictive analysis platform

Preparing the platform

The two-step procedure for preparing the predictive analysis platform is as follows:

1. Import the target subset (and corresponding indicators)

To avoid poor interpretability, the model needs to be constrained to a smaller set of variables. This can be done by carefully selecting the most relevant targets and indicators (based on the analysis in Phase 5), which will be used as predictors. In future iterations of the model, Phases 3 and 4 of this method will provide valuable scope for selecting this constrained smaller set of variables by localising priorities and targeting low-performing assessments, respectively.

2. Import the data set into the Grainger causality analysis

In this step, the selected data set is imported into the Grainger causality analysis. The analysis aims to test whether the past values of one time series provide information about the future values of another time series (step 3). This is beyond what can be predicted from the past values of that time series alone. This analysis helps to identify the direction and strength of causal relationships between two variables.

Developing predictive analysis

The six steps for developing the predictive analysis capability of the platform are:

1. Select lag order

In time-series analyses, lag order refers to the number of past observations used to predict or model future values of the time series. A model's accuracy in forecasting future values depends on the choice of lag order. Models with too few lags may not capture all the relevant information in the time series, while models with too many lags may perform poorly in out-of-sample predictions. The selection of an appropriate lag order is therefore an important step in the analysis of time series.

2. Create a vector autoregression model

Vector autoregression (VAR) is a statistical model used to analyse the relationship between two or more time-series variables. VAR is often used in econometrics, finance and other fields to model complex systems such as macroeconomic variables, financial markets and climate systems. The model is useful for analysing the dynamic relationships between variables over time and for making predictions about the future values of the variables. The key assumption of VAR is that each variable is affected by the past values of the other variables in the model. This allows for the modelling of complex interactions and feedback mechanisms between the variables.

3. Split data into training and test data sets

Splitting data into training and test sets is essential for building and evaluating prediction models. This approach trains the model on a subset of the data (the training set) and evaluates its performance on the remaining data (the test set) to measure how well the model can generalise to upcoming, unseen data. This helps to ensure that the model is not 'overfitted' to the training data.

123. Research undertaken by the CSDILA.

4. Check for 'stationarity'

Checking for 'stationarity' is an essential step in analysing time-series data, as many time-series models require stationary data to make accurate predictions. Initially, in this proposed model, the differencing method is used to calculate the difference between consecutive observations in a time series, with the goal of removing any trend or seasonality in the data to transform non-stationary time-series data into stationary data.

5. Predict the targets

The model assumes that the current values of a set of variables are related to the values of other variables in the same set. VAR uses a set of linear equations to estimate the future values of the variables. Each equation is a linear combination of the past values of all the variables in the set. The model is then used to forecast future values for each of the variables in the set.

6. Calibrate and evaluate the model

Finally, the model is calibrated and the results are plotted to visualise the model's performance. Calibration ensures that the probabilities predicted by a model are very close to the actual probabilities. A well-calibrated model is accurate, reliable and easier to interpret. Decision-makers can confidently use a well-calibrated model to accurately assess the risk associated with different actions, and choose the action that is most likely to have a desirable outcome.

The model evaluation aims to examine the model's performance on test sets. As part of this proposed method, the predicted results of the test set are compared with the actual values of the test set. To visualise the relationship between the predicted values and the actual data, a calibration curve is plotted for each target and/or indicator.

These visualisations will be plotted for the user when the prototype platform[122] is tested.

Source: Extract adapted from a report submitted to the Commissioner for Environmental Sustainability by the Centre for Spatial Data Infrastructures and Land Administration.

Further updates on the progress of the prototype platform, the full report and related research will be published in the future by the CSDILA. The finalisation of the report by the CSDILA for the CES marks the completion of the development of a research platform for understanding SDG interlinkages and predictive analysis committed to in the Science for Sustainable Development framework.

124. The platform will be made available on the CSDILA webpage: Centre for Spatial Data Infrastructures and Land Administration, The University of Melbourne (unimelb.edu.au).

Future research

This section has outlined a method for applying the UN SDGs as an operating framework for state of the environment reporting.

In addition to Phases 1 to 4, developed in 2020–21 for the SMCE 2021 Report, Phases 5 and 6 of this report delivered two major additional outputs:

- a process to assess the interlinkages between SDG targets (and the corresponding indicators)
- a prototype platform for further development to enable stakeholders and decision-makers to apply predictive analysis under different scenarios.

In identifying the practical implications of applying different data and models (Phase 5) and developing the platform for the interpretation of results and improving decision-making (Phase 6), the method revealed that Phases 1 to 4 are critical in informing the platform and its utility and accessibility.

Phases 1 to 4 refine target (and corresponding indicator) selection and weighting, as well as focusing on local priorities and low-performing targets that require management intervention, before applying the platform and its predictive analysis capability.

In Appendix B, the 139 state of the environment indicators in this report have contributed to a comprehensiveness and progress assessment of 76 SDG targets (Phases 2 and 4 respectively). This method, developed by the CES, of codifying a system based on a repeatable baseline of indicators at scale, is a critical improvement for future development of the platform, and it can be repeated for all the reports in the suite of Victorian state of the environment reporting.

Phase 5 includes some discussion by the CSDILA on how future development of the platform would need to include data at the state and local scales. This demonstrates the importance of improving the evidence base (Recommendations 14 and 15 of this report).

The data integration strategy (Recommendation 14) to be developed for Victorian Government data custodians could also consider the needs of the proposed method. This strategy would improve the decision-making potential of the method and would provide a pathway to data enrichment, ensuring standards for data collection that address data gaps and enable time-series data for better trend analysis and predictive capability.

Spatial data will add value to the accuracy and insights generated from the analytics. If further developed, the predictive analysis tool can be improved by the spatial data and analysis to highlight the impact of location factors on the performances of SDG targets and indicators. Moreover, it is believed that the pattern of targets and indicators' interlinkages will differ depending on the geographical contexts. Therefore, spatial data and analysis are important in producing evidence-based outcomes.

Not only should the model acquire more accurate data at the state and local scale, but metadata need to be created to communicate the level of reliability of the data and analytics. This will ensure the confidence level necessary for interpreting results and making decisions in the future. Ecological sustainability is a complex system, and the simplified approach of the proposed model might not represent the entire system. Therefore, having more predictors (and the data that underpin them) will increase the model's ability to capture complex relationships in the data and improve its predictive accuracy.

Victorian Government progress on State of the Environment 2018 Report recommendations

The SoE 2018 Report included recommendations to the Victorian Government to improve environmental sustainability outcomes. Presented below is the recommendation as well as:

- the full Victorian Government response to the recommendation, including the level of support, as published in the Victorian Government Response to the State of the Environment 2018 Report
- a description of progress made on the implementation of the recommendation over the past five years. The content of this section is derived from written material supplied directly to the CES by relevant government entities and/or synthesises information that is publicly available in referenced reports, legislation and websites. Importantly, this section summarises the progress made since 2018 in relation to the recommendation; it is not an audit of the extent and quality of the completed work.

Recommendation 20 of the SoE 2018 Report recommended:

That the Minister for Environment include in the Statement of Expectations to the Commissioner for Environmental Sustainability a requirement to adopt the SDGs as an operating framework for state of the environment reporting in Victoria from 2023. This will require that DELWP support the Commissioner by leading a portfolio review of the data requirements to assess Victoria's progress against the selected SDG targets, which will include a complementary analysis of current legislation, policy and programs against the SDG targets, and the development of a plan to improve data-acquisition processes for socio-economic indicators by 2021.

Government response in 2020:
SUPPORT IN PRINCIPLE

'The Victorian Government supports the objectives of the United Nations Sustainable Development Goals (SDGs) and supports the Commissioner for Environmental Sustainability utilising the SDG framework to enhance Victoria's environmental reporting. This will be reflected by the Minister for Environment in the Statement of Expectations to the Commissioner for Environmental Sustainability.'[125]

'The SDGs and their objectives feature in important government initiatives including Plan Melbourne 2017–2050, Water for Victoria, and Biodiversity 2037. As the Government's leader of sustainability policy and programs, the Department of Environment, Land, Water and Planning (DELWP) embarked on a whole-of-department approach to the SDGs in 2019. Key activities included releasing a statement of support for the SDGs in the Department's Corporate Plan and aligning the Department's Outcomes Framework to the SDG framework. As part of DELWP's ongoing support of the SDG framework, DELWP will take a portfolio-wide approach to engaging with the SDGs in the future. This will involve engaging with portfolio agencies to understand where they are on their SDG journey and providing tailored advice.' [126]

'To ensure government policies and programs are outcome-focussed each department adheres to an outcomes framework, which includes outcomes, indicators and measures. Work occurs at the whole-of-department level, and at the business unit level, to refine outcomes, indicators and measures as required. There is awareness across Government and DELWP that both socio-economic and biophysical indicators are important to provide an easy-to-understand and meaningful narrative for the Victorian community.' [127]

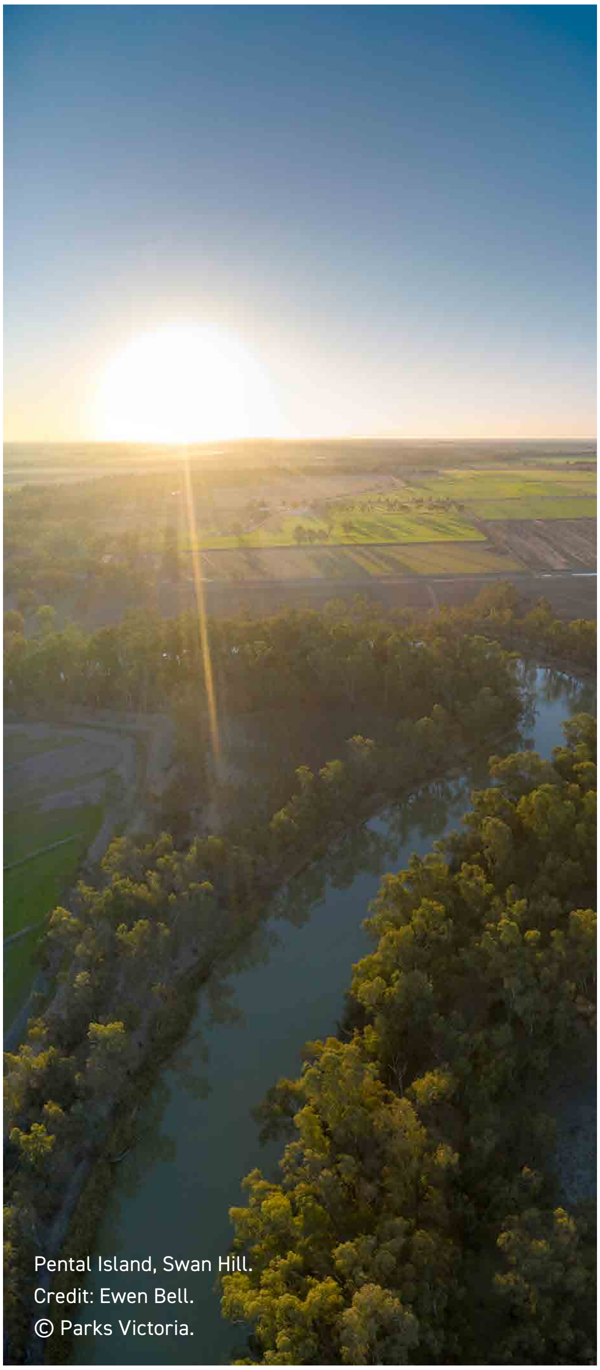
'DELWP's ongoing process of refining indicators will include both socio-economic and biophysical indicators as appropriate. DELWP is willing to work with the Commissioner for Environmental Sustainability to ensure alignment of indicators to enhance environmental reporting. Consistent with the Government's focus on outcomes, DELWP's focus is on identifying and settling indicators that will demonstrate outcomes and impact. The refined set of indicators supported by data will inform DELWP's ongoing engagement with the SDG Framework.' [128]

Progress made since 2018

Reflecting the Victorian Government's support of the objectives of the UN SDGs and support of the Commissioner for Environmental Sustainability utilising the SDG framework to enhance Victoria's environmental reporting, the Commissioner for Environmental Sustainability's Statement of Expectations was amended by the then Minister for Energy, Environment and Climate Change in 2018. The Statement of Expectations requires the Commissioner to provide international relevance and national leadership by aligning measurement and reporting work with international frameworks such as the SDGs.

The Department of Energy, Environment and Climate Action (DEECA) continues to lead the Victorian Government's sustainability agenda and implement work within its portfolios that directly contributes to the global community's progress to achieve the SDGs. This includes work that delivers affordable, clean energy, clean water and sustainable cities and communities for Victoria, as well as policy and programs focused on climate action and biodiversity conservation.

Information on how DEECA's work contributes to the SDGs is in its corporate plan and annual reports, which can be found on the department's website.[129]



Pental Island, Swan Hill.
Credit: Ewen Bell.
© Parks Victoria.

125. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Government response: State of the Environment 2018 Report', https://www.ces.vic.gov.au/state-of-reports/government-response-state-environment-2018-report Accessed on 8 June 2023.
126. Ibid.
127. Ibid
128. Ibid.
129. Department of Energy, Environment and Climate Action (DEECA), 'Department of Energy, Environment and Climate Action: Supporting thriving, productive and sustainable communities, environments and industries', https://www.deeca.vic.gov.au Accessed on 5 June 2023.

The United Nations System of Environmental-Economic Accounting: Urban environmental-economic account for Melbourne

Purpose and context

The value of green and blue infrastructure in urban environments is well established and widely acknowledged. Urban parks, market gardens, street trees, rivers and lakes provide food and recreational opportunities, as well as regulate noise, air quality, and local and global climates. These environmental goods and services lead to a range of health and wellbeing benefits, as well as financial benefits, that can be quantified and valued using economic analysis.

This section is a baseline environmental-economic account (EEA) for urban Melbourne that has been prepared by DEECA and aligns with the UN System of Environmental-Economic Accounting – Ecosystem Accounts guidance.[130] The UN SEEA is a framework for reporting on links between the environment and the economy using internationally agreed accounting concepts.

An ecosystem account is an EEA that takes 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 of them. Figure 7 sets out the ecosystem accounting framework.

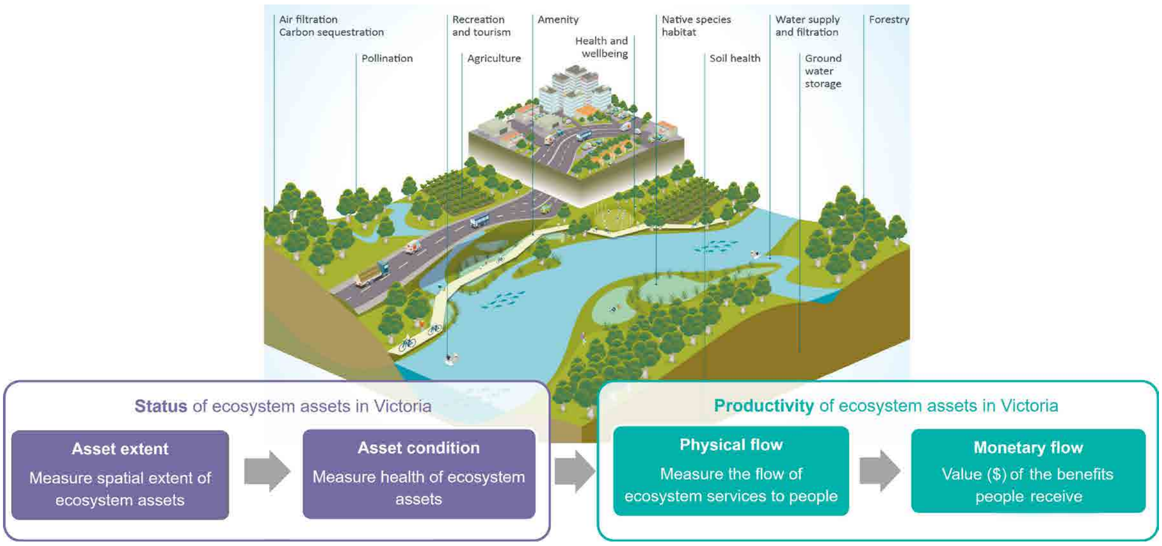


Figure 7: Environmental-economic accounting – an ecosystem accounting framework.

There is a significant amount of data and analysis on the socio-economic value of green and blue infrastructure in Victoria and Melbourne. However, it is not currently consolidated or articulated in a way that is useful for decision-makers. The urban Melbourne EEA integrates the best available data using the EEA framework, and identifies evidence gaps to understand and communicate the economic benefits of urban Melbourne ecosystems to society. It will allow for higher quality and more consistent information to be used more widely in communities.

Approach to the urban Melbourne EEA

The methodological approach to the urban Melbourne EEA was based on a review of economic assessments of urban ecosystem assets globally, international guidance on EEAs and existing information on ecosystem status and productivity within Melbourne.

This urban Melbourne EEA has used the best available information at the time of the study. Given that no data have been collected specifically for the study region or for the purpose of developing an EEA, justifiable assumptions have been adopted based on data (where possible) or expert judgement to align readily available information with the urban

130. United Nations (UN) 2021, 'System of environm ental-economic accounting – ecosystem accounting', https://www.preventionweb.net/publication/system-environmental-economic-accounting-ecosystem-accounting Accessed on 9 June 2023.

Melbourne EEA boundary and with the principles of SEEA as best as possible. Based on this approach, and given its uncertainties, the results should be interpreted as indicative order-of-magnitude estimates that provide a proof-of-concept urban Melbourne EEA. They are also a basis for future work to refine and expand the accounting to provide useful evidence on the status and productivity of ecosystem assets in the region.

The account has been developed for 2019 because this is the most recent year for which most of the necessary information exists (including the latest ecosystem extent data in Victoria) and ensures that the account is not skewed by the impact of COVID-19. Information for 2019 was used where possible; if it was not available, data for 2015 to 2021 were used (some condition data precede this but are presented for completeness). The account could therefore be more accurately described as being representative of ecosystem status and productivity over the period 2015 to 2021.

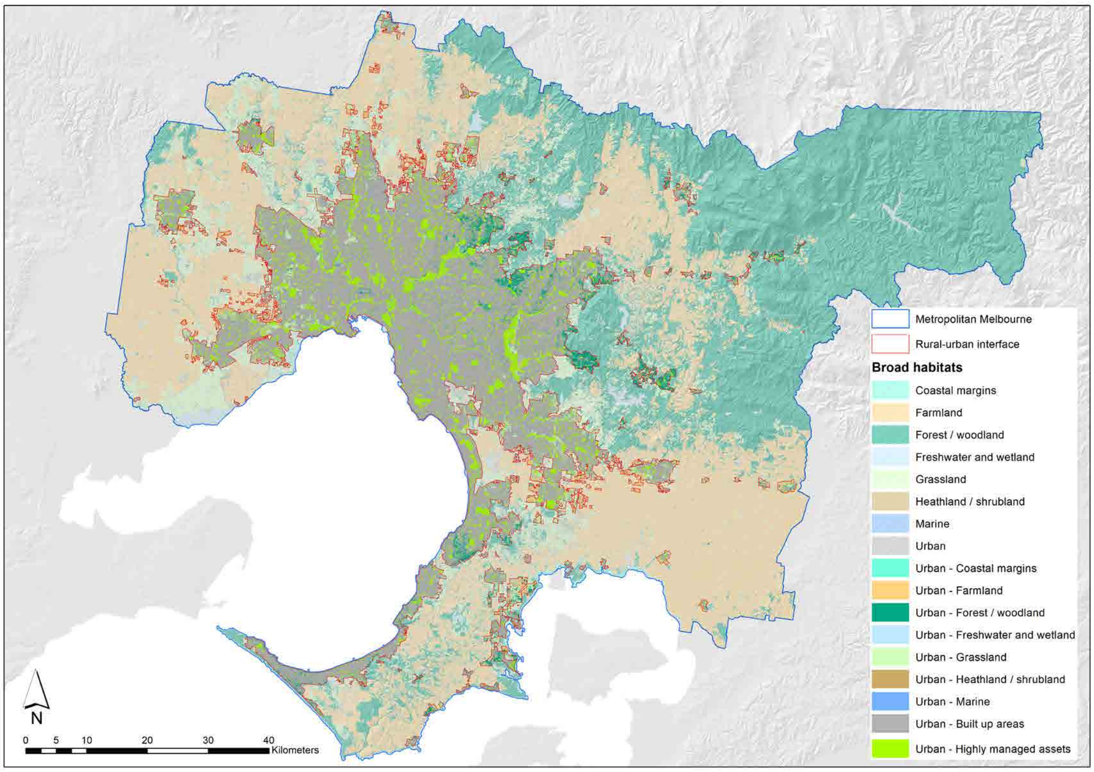


Figure 8: Spatial distribution of ecosystem assets across the urban Melbourne EEA area in 2019.

Ecosystem extent account

The spatial distribution of the asset extent within the urban Melbourne EEA area is defined by the outer perimeter of the 'Rural-urban interface'.[131] Figure 8 illustrates the spatial distribution of ecosystem assets across the urban Melbourne EEA area in 2019.

The urban Melbourne EEA region consists mostly of built-up areas and grey infrastructure (~127,000 ha or 59%). The remaining area of approximately 88,000 hectares (41%) consists of the natural ecosystem assets within the urban extent.

Highly managed assets – including parks, open spaces, reserves, and sports and recreation assets – make up the largest urban ecosystem asset type (~32,000 ha or 15%), and integrated green infrastructure (street and city tree canopy) covers approximately 16,000 hectares (7%).

131. Department of Environment, Land, Water and Planning (DELWP) 2018, 'Land use and population research', Urban Development Program, Melbourne, Victoria.

Ecosystem condition account

The urban Melbourne EEA compiles information on metrics that capture the ecological condition of ecosystem assets within the study area for 2019 (or as close to 2019 as possible). The ecosystem condition account also reports on broader socio-economic characteristics that support the co-production of ecosystem services, including ecosystem location, cultural assets, built assets and natural resource governance.

Figure 9 details the condition scores for a select group of metrics for ecosystems in the urban Melbourne EEA area.

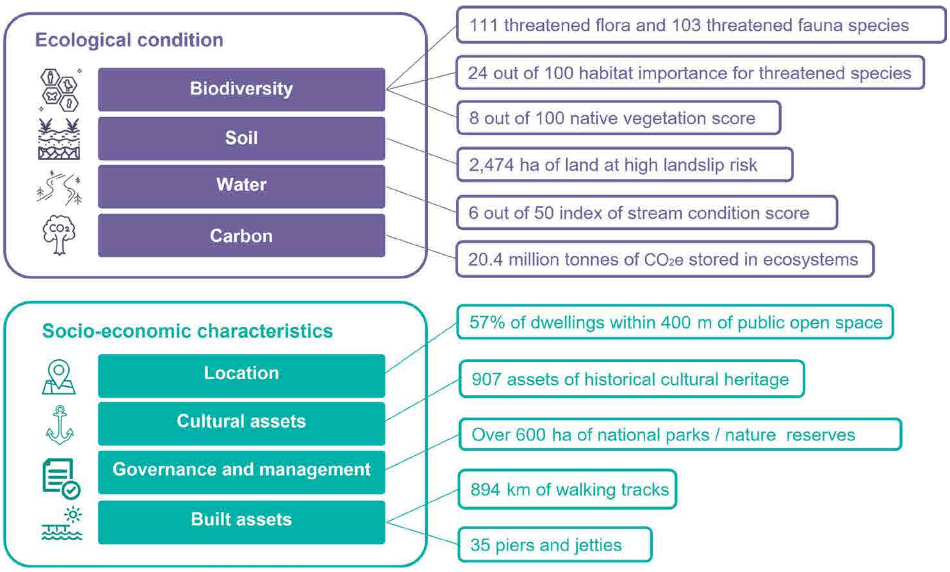


Figure 9: Summary of ecosystem condition account for the urban Melbourne EEA area.

Physical and monetary flow accounts

The physical flow account estimates the physical quantity of six ecosystem services produced by ecosystems in the urban Melbourne EEA region in 2019 (Figure 10).

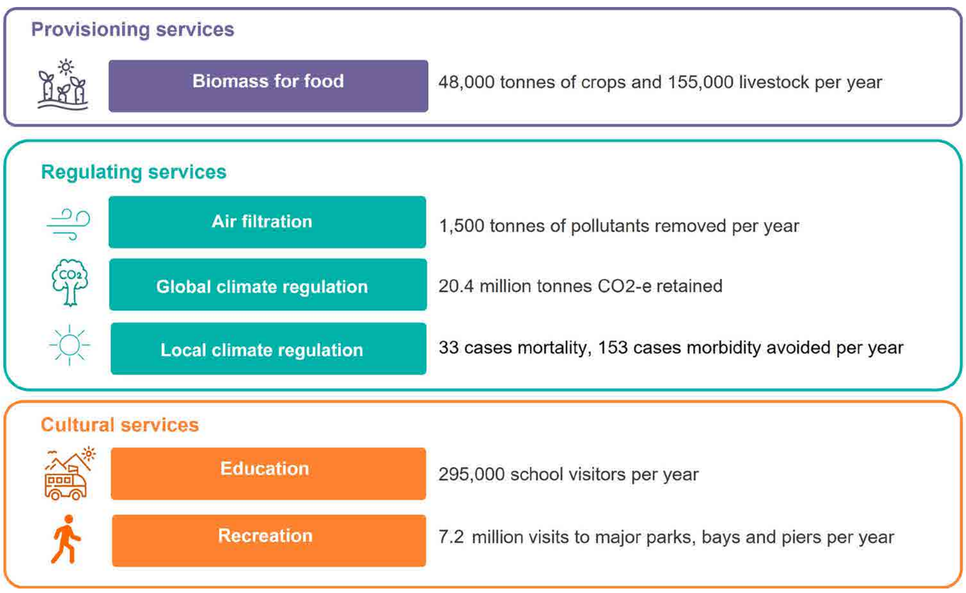


Figure 10: Summary of physical flow account for the urban Melbourne EEA.

The urban Melbourne EEA is only a partial assessment of the full range of ecosystem services that are provided by ecosystems in the region. The ecosystem services that were selected for inclusion were largely determined by data availability.

Several ecosystem services were not assessed within this initial urban Melbourne EEA because of a lack of current data and analysis. This included ecosystem services such as noise attenuation, flood risk regulation, water provision and water purification.

The monetary flow accounts estimate the societal value ($) of the physical ecosystem service flows, as well as the value for amenity, which reflects the value of a bundle of ecosystem services (Figure 11).

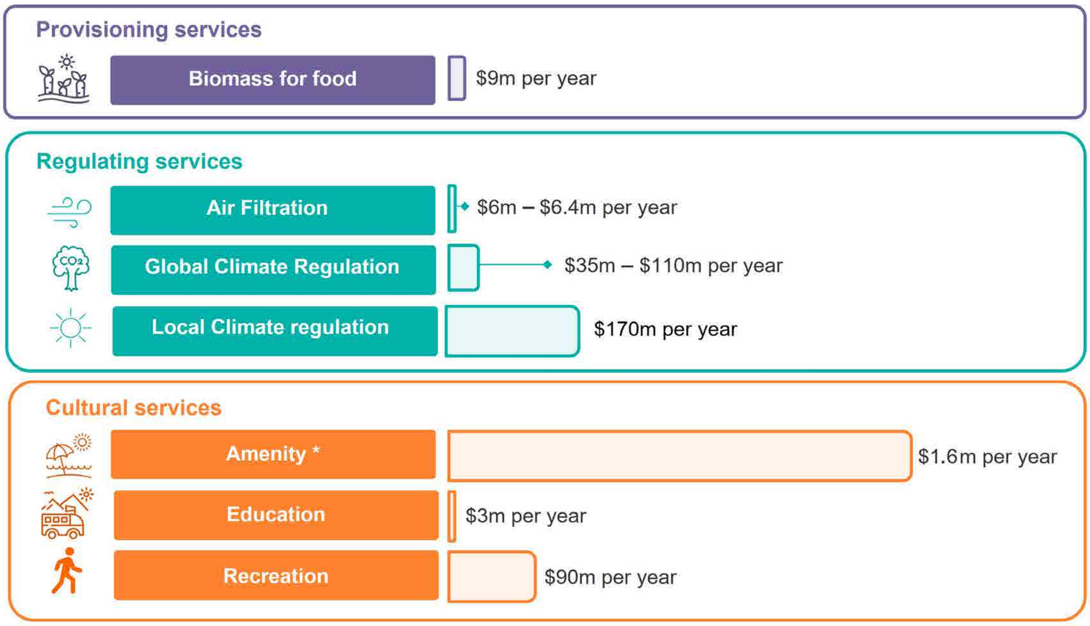
Key insights of the monetary flow account are:

- The analysis undertaken for the urban Melbourne EEA suggests that the ecosystems of the region deliver ecosystem services worth at least $300 million per year. An alternative estimate suggests that the ecosystem services could be worth at least $1.6 billion per year. The estimate of at least $300 million excludes the amenity valuation, as this estimate potentially captures values from other ecosystem services, including those assessed as part of this account. The alternative estimate of (at least) $1.6 billion combines the valuations of amenity and global climate regulation, because the global climate-regulation service is the only assessed ecosystem service that does not specifically provide benefits on a localised scale. Thus, the benefits of the global climate regulating services of ecosystem assets would not factor in the value that local residents place on green space – a value captured in the estimated house price premiums associated with proximity to green space.
- The amenity value of green infrastructure is estimated to be the most highly valued ecosystem service. However, the nature of the bundle of ecosystem services captured within this approach is unclear. This amenity value should be used cautiously alongside other estimates of the value of ecosystem services from urban ecosystem assets in Melbourne. The estimated amenity value of metropolitan parks within the urban Melbourne EEA region is estimated to be $0.5 billion per year and $1 billion per year for sports and recreation parks. This value is a demonstration of residents' willingness to pay to live closer to these types of parks, which will in part be determined by their ability to pay. The interpretation of this value for policy decision-making needs careful consideration to avoid the conclusion that those in affluent communities value parks more highly than those in less affluent areas. It is recommended that these results are not used as the sole measure of benefits of green space, including in any prioritisation process for comparisons of the benefits of new parks in different locations.
- Global climate regulation service is estimated based on avoided release of carbon stocks, which total 20.4 million tonnes CO_2-e in the urban Melbourne EEA area. This ecosystem service is valued at between $35 million per year based on the avoided cost of greenhouse gas abatement or offset measures, and $106 million per year based on the avoided damages to society (social cost of carbon).
- The local climate-regulating service of ecosystem assets in the urban Melbourne EEA region is estimated through the reduction in number of days with temperatures above 30°C and valued based on the avoided adverse health impacts and productivity losses. The aggregated effect of ecosystem assets (urban rivers, lakes, ponds and wetlands, as well as parks and gardens, street trees and green roofs) on temperatures across urban Melbourne in 2019 is estimated at −0.23°C. Compared to adverse health outcomes due to extreme heat under a 'without ecosystem' scenario, the aggregated effect is estimated to avoid 33 additional deaths, 37 additional ambulance attendances and 116 additional emergency department presentations in those aged 64 years or older. The estimated value of adverse health outcomes associated with these events is $168 million. The gain in productivity due to the presence of green and blue infrastructure and its cooling effect is estimated to be worth $5 million per year.
- The partial estimate of recreational visits that can be attributed to the existence of ecosystems within the urban Melbourne EEA region is 7.4 million per year in 2018–19. Approximately a third of these visits (2.1 million) are estimated

parks, one pier and the botanic gardens and is therefore an underestimate of the total number of recreational visits to urban ecosystems in Melbourne. Approximately 770,000 of total visits are estimated to be 'active visits' that meet certain physical activity guidelines (and therefore provide a health benefit). These 'active visits' are undertaken by around 65,000 visitors, who visit the urban ecosystems for physical exercise several times each year.

The economic value of recreation in the urban Melbourne EEA region is approximately $91 million per year, based on the following estimates for 2018–19:

- $86 million in welfare value of recreation within the urban Melbourne EEA region
- $1 million due to improved productivity of the Australian labour force from 'active visits'
- $4 million in avoided medical costs to Australian households and government from 'active visits'.



** Amenity captures a bundle of ecosystem services and is not additive to other ecosystem services.*

Figure 11: Summary of monetary flow account for the urban Melbourne EEA.

Use of the initial urban Melbourne EEA

This initial proof-of-concept urban account for Melbourne will be a useful contribution to the potential development of Victoria-wide EEA for urban areas (Figure 12). The information compiled in the urban Melbourne EEA can be used:

- as evidence of the total value of urban Melbourne's ecosystem assets to the Victorian, Australian and global economy and community, and the distribution of this value across the region. The analysis undertaken for the urban Melbourne EEA suggests that the ecosystems of the region deliver ecosystem services that are worth at least $300 million per year, with an alternative estimate suggesting that the ecosystem services could be worth at least $1.6 billion per year
- to build the business case for investment and/or alternative policies and management to maintain current ecosystem status and productivity. The sustained delivery of the estimated annual benefits from urban ecosystems depends on current ecosystem status to be maintained (at a minimum). The distribution of socio-economic value is mapped (for most ecosystem services)

across the region, enabling the identification of hotspots delivering significant value to society that could provide some prioritisation of ecosystem maintenance

- to assess the effectiveness of existing policy and environmental management and identify opportunities to enhance ecosystem status and productivity through future policy, management and investment. Information on the status and productivity of ecosystems in the urban Melbourne region can be judged against policy or management targets to identify areas for improvement. For example, the urban Melbourne EEA ecosystem condition account suggests that the status of native vegetation (8 out of 100), fresh water (6 out of 50) and estuaries (23 out of 50) are areas for improvement, which could deliver enhancements in ecosystem service delivery (e.g. improved recreational experience and greater carbon sequestration)
- to improve understanding of the trade-offs in the use of contested assets (e.g. between the use of ecosystem assets for recreation or biodiversity) and land-use change (e.g. loss of ecosystems for built development). The information in the urban Melbourne EEA can be used to estimate what will be lost if the current ecosystems in the region are degraded
- as a basis for collaboration with land or water management organisations by using the accounts to explore synergies across ecosystems and geographic areas. This includes impacts and dependencies of assets under an organisation's management with other ecosystems and geographic areas. For example, the reliance of water-body quality within urban Melbourne on land use outside of the urban Melbourne area (and vice-versa)
- as an underpinning evidence base to explore other policy and/or management issues, including links to other reporting frameworks such as the SDGs, making the case for investing to expand ecosystem assets and estimating the magnitude and value of the loss of ecosystem service associated with pressures and risks
- as a useful contribution to the potential development of Victoria-wide EEAs for urban areas.

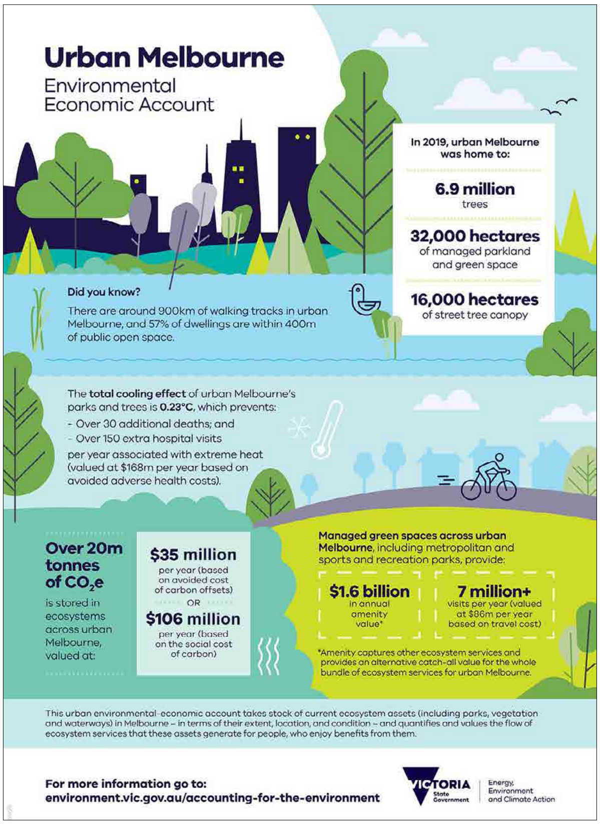


Figure 12: The urban Melbourne environmental-economic account.[132]

132. Department of Energy, Environment and Climate Action (DEECA), 'Accounting for the environment', https://www.environment.vic.gov.au/accounting-for-the-environment Accessed on 26 May 2023.

Victorian Government progress on State of the Environment 2018 Report recommendations

The SoE 2018 Report included recommendations to the Victorian Government to improve environmental sustainability outcomes. Presented below is the recommendation as well as:

- the full government response to the recommendation, including the level of support, as published in the Victorian Government Response to the State of the Environment 2018 Report
- a description of progress made on the implementation of the recommendation over the past five years. The content of this section is derived from written material supplied directly to the CES by relevant government entities and/or it synthesises information that is publicly available in referenced reports, legislation and websites. Importantly, this section summarises the progress made since 2018 in relation to the recommendation; it is not an audit of the extent and quality of the completed work.

Recommendation 19 of the SoE 2018 Report recommended:

That DELWP establishes environmental economic accounting as a core capability and delivers a set of environmental economic accounts for Victoria by 2022, consistent with the System for Environmental-Economic Accounting (SEEA) guidelines, the DELWP Valuing Accounting for Victoria's Environment strategy and aligned with the agreed common national approach. Further, that the Minister for Environment include in the Statement of Expectations to the Commissioner for Environment Sustainability a requirement to incorporate reporting against Victoria's environmental-economic accounts in state of the environment reporting for Victoria from 2023.

Government response in 2020:
SUPPORT IN PART

'The Victorian Government supports the overall intent of this recommendation. The recommendation to deliver a set of environmental-economic accounts for Victoria by 2022 is not supported at this time. The production of comprehensive state-wide environmental-economic accounts by the Department of Environment, Land, Water and Planning (DELWP) is not currently feasible.' [133]

'DELWP will continue to build on its capabilities in environmental-economic accounting and produce accounts to improve the evidence base available for future policy development, planning and decision-making in Victoria. This work will be consistent with the current experimental United Nations System of Environmental Economic Accounting (UN SEEA) guidance and the revision process due to be completed by December 2020, DELWP's Valuing and Accounting for Victoria's Environment Strategic Plan 2015–2020 and the common national approach. The scope and depth of DELWP's program on environmental-economic accounting will be driven by policy needs, focusing on areas where there is greatest need for building the evidence base on connections between the environment and economy to tackle future challenges facing Victoria.' [134]

'The recommendation for a requirement for environmental-economic accounts in the Ministerial Statement of Expectations to the Commissioner for Environment Sustainability is also not supported at this time. DELWP will continue to provide the Commissioner with products from its environmental-economic accounting program to support future reporting and contribute to the development of a comprehensive statewide environmental-economic accounting framework in the future.' [135]

133. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Government response: State of the Environment 2018 Report', https://www.ces.vic.gov.au/state-of-reports/government-response-state-environment-2018-report Accessed 8 June 2023.
134. Ibid
135. Ibid
136. McCormick F, Showers C 2019, 'Ecosystem services from forest in Victoria: Assessment of regional forest agreement regions', Department of Land, Water and Planning (DELWP), https://nla.gov.au/nla.obj-2602553152/view Accessed on 5 June 2023.
137. McCormick F, Showers C 2020, 'Ecosystem services from forests in Victoria: Impact of the 2019-20 bushfires', Department of Land, Water and Planning (DELWP), https://www.environment.vic.gov.au/__data/assets/pdf_file/0023/555116/Ecosystem-services-from-forests-in-Victoria-Impact-of-the-2019-20-bushfires.pdf Accessed on 5 June 2023.
138. Department of Climate Change, Energy, the Environment and Water (DCCEEW), 'National strategy and action plan', https://eea.environment.gov.au/about/national-strategy-and-action-plan Accessed on June 2023.
139. Department of Climate Change, Energy, the Environment and Water (DCCEEW), 'Practical guidance notes for urban ecosystem accounting (June 2021)', https://eea.environment.gov.au/accounts/ecosystem-accounts/practical-guidance-notes Accessed on June 2023.

Progress made since 2018

DEECA and its predecessor DELWP produced a series of accounts over the past five years to improve the evidence base available for future policy development, planning and decision-making in Victoria. This work has been consistent with the relevant UN SEEA guidance available at the time and has supported the development of a common national approach to environmental-economic accounting. Environmental-economic accounts produced since the 2018 report include:

- Economic Assessment of Victoria's Forests: Ecosystem Services and Benefits 2019
- Ecosystem Services from Forests in Victoria: Impact of the 2019–20 Bushfires 2020
- Urban Melbourne Environmental-Economic Account 2023 (being finalised)
- Great Ocean Road Coast and Parks Environmenta-Economic Account (being finalised).[136, 137]

Mount Buffalo National Park.
© Parks Victoria.

Commissioner *for* Environmental Sustainability Victoria

Appendix A
Spatial technologies for biodiversity conservation

Victorian State of the Environment 2023 Report

Appendix A. Spatial technologies for biodiversity conservation

The work presented in Appendix A was developed in 2022 for a report to the Commissioner for Environmental Sustainability. It was prepared by FrontierSI. The content has been modified for brevity and style.

Space and spatial technologies maturity assessment

Space and spatial technologies are divided into nine categories for this analysis. Five categories represent data collection technologies and four are defined as data processing technologies (Figure 13 and 14). There is overlap between categories because collection technologies must be paired with a processing technology to analyse acquired data, and due to the rise of integrated technologies. For example, citizen scientists using remotely piloted vehicles (RPVs) to capture Earth observation (EO) data, which are then processed by machine learning (ML) algorithms to extract useful information. Because SoE data are primarily obtained through information used to assess indicators from external sources, the category 'Datasets, portals, digital tools and platforms' is included to capture sources currently used by the State of the Environment (SoE) reports, existing with potential to be used, and known to be in production.

Table 5: Spatial technologies applicable to biodiversity related indicator themes.

Indicator themes	EO and ERS	Smart sensors and IoT	RPV	GPS and tracking	Citizen science	AI and ML	Big data and analytics	Simulation and monitoring	Datasets, portals, digital tools and platforms
Wetlands and rivers	✓	✓	✓	✓	✓	✓	✓	✓	✓
Threatened species and communities	✓	✓	✓	✓	✓	✓	✓	✓	✓
Invasive species	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ecosystem health	✓	✓	✓	-	✓	✓	✓	✓	✓
Threats and responses	✓	✓	✓	✓	✓	✓	✓	✓	✓
Forests	✓	✓	✓	✓	✓	✓	✓	✓	✓
Climate change	✓	✓	✓	-	✓	✓	✓	✓	✓
Air	✓	✓	✓	-	✓	✓	✓	✓	✓
Overall impact	**Very high**	**Moderate**	**Moderate**	**Low**	**Moderate**	**High**	**Moderate**	**Moderate**	**High**

Table 5 shows that nearly every spatial technology included in this review is applicable to biodiversity indicators for state of the environment reporting. Although most technologies could apply, those that will provide the highest impact and value for money for biodiversity conservation are discussed under the relevant subheadings following the table. The potential overall impact of each technology on biodiversity indicators across themes is also estimated in the final row of the table.

	Earth observation and remote sensing	Smart sensors and Internet of Things	Remotely piloted vehicle systems	GPS and tracking	Citizen science
Current	• Satellite passive & active sensors • Aerial imagery • Airborne LiDAR • Mobile LiDAR • Ship sonar • Video • Camera trapping • Joint Remote Sensing Research Program	• QR codes, barcodes, RFID • Smartphones • Telemetry systems • Sensors/meters/probes • Data loggers • Smart meters • Acoustic sensors	• Fixed-wing, single-rotor, multi-rotor • Blimps, balloons & kites • Boats, submersibles, underwater gliders • Optical camera & video payloads • Thermal camera payloads • Multi/hyper spectral camera payloads	• Data loggers/passive tracking • Data pushers/active tracking • Data pullers/transponders • Free, open centimetre accurate positioning • Dead-reckoning techniques • Geofencing	• Traditional citizen science projects • Citizen science platforms • Crowdsourcing • Real-time data streams for planning/ mapping e.g. Google traffic
Emerging	• SmallSats & CubeSats • 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 • Integrated multisensory platforms • Aquawatch Australia • Enviro/bio specific instruments e.g. NASA SBG & CHIME • High-resolution thermal satellite imagery	• Real-time 5G mobile IoT • Edge computing • Explosion of IoT devices/things • Intelligent sensor networks • IoT analytics • Smart cities • Mobile phone LiDAR • Low earth communication e.g. Starlink • Mobile phones as connected multisensor platforms • Chemical nano-sensors e.g. e-nose devices	• Hybrid platforms • LiDAR payloads • Specialised payloads • Obstacle detection & collision avoidance • Open RTK & SBAS for aviation • Automated RPV for sonar seafloor capture • Autonomous robotic eDNA samplers • Underwater robots e.g. QUT COTSbot • Weeding robots e.g. Uni Sydney RIPPA	• Integrating IoT connectivity • Device miniatirisation • Precise indoor positioning • Release timers • SBAS/RTK accurate positioning • GNSS+IMU sensor fusion • Precise smartphone GNSS	• New technologies for data collection • Citizen science in policymaking • Gamification • Virtual peers (bots) • ML for citizen science data
Future	• Real-time EO • Persistent EO • High-definition video from space • Sensor miniaturisation and integration • New sensors e.g. ultraspectral, conservation targeted • Space-based edge computing • Satellite on-board processing • Real-time multispectral video (MiDAR) • National Space Mission for EO	• Smart cars • Smart houses • Intelligent mobility • The Internet of Animals • IoT networked eDNA sensors • Bio-batteries • Kinetic batteries	• Solar RPV • Self-driving autonomous RPV • Smart RPV (capture, analyse and act) • Smart sensor payloads • On-board optimisation of big-data processing • Robots for envionmental weeding • Micro/nano RPV cyborgs e.g. DragonFlEye • Swarm theory	• Improved battery life for multi-year lifespan tracking • The Internet of Animals • Ubiquitous, low-cost, high accuracy devices	• Citizen sensing

Figure 13: Space and spatial technology maturity assessment – data collection technologies.

	Artificial intelligence and machine learning	Big data and analytics (incl. GIS)	Simulation and modelling	Datasets, portals, digital tools and platforms	
Current	• Predictive analysis • Decision support systems • Optimisation • Machine learning (ML)	• Local storage & computing • Distributed processing • Data mining • Predictive analysis • Visualisation • GIS analysis for experts • Scripting, visual modelling • Cloud storage & computing	• Environmental modelling • Species predictive modelling (ARI) • Atmospheric modelling	• GBIF • TERN ÆKOS • NatureKit 2.0 • DataShare • FeralScan • FeralFishScan • Land Cover Time series • Vicmap Vegetation • Victorian Biodiversity Atlas • Atlas of Living Australia	• EPA Victoria water quality monitoring • Water measurement information system • Melbourne water river health monitoring • Index of estuary condition • Ecological vegetation class biodiversity conservation status data • lightpollutionmap.info & radiance light trends • DEECA knowledge portal • DCCEEW environment data
Emerging	• Artificial intelligence (AI) • Deep learning • Automated feature extraction • Real-time predictions • Natural language processing	• Hybrid storage (local & cloud) • Multi-cloud environments e.g. BigQuery • Open Data Cube (ODC) • Cloud-based supercomputer capability	• Thematic digital twins • Environmental modelling and simulation & warning • Simulated populations	• FrogID • Australian Acoustic Observatory • Wild Dog Alert • ClassifyMe • Digital Earth Australia (DEA) products • Groundwater Dependent Ecosystems Atlas • HCAS v2.1 • MODIS snow cover • Restor • CMiP6 Visualisation Tool & World Bank Group CMiP6	• Digital Twin Victoria • MARXAN, ARIES, Costing Nature DSS • Global Coastal Wetlands Index App • Blue Forest Data Explorer • Waterbird Population Estimates • Freshwater Ecosystems Explorer • Movebank • EcoCommons & EcoAssets • Living Planet Database • National Land Cover Interactive SA2 map • FishID • Animal Tracking Database
Future	• Generative adversarial networks • AI robotics & Artificial Intelligence of Things • Event detection from ML • Space-based ML and AI	• Space-based edge computing • Quantum computing • Fast data • Actionable data • Intelligent modelling (eGIS for non-experts) • Self-organising big-data optimisation	• Real-time monitoring integration • Aquatic environment modelling/simulation • Environmental digital twins	• Digital Atlas of Australia • Australian Climate Service • Planet Research Data Commons • DEA Wetlands Insight Tool • Open Ecoacoustics • Biosecurity Commons	• Global Wetlands Observing System (GWOS) • WeedScan project • eBioAtlas • AusEnHealth

Figure 14: Space and spatial technology maturity assessment – data processing technologies.

Victoria has several biodiversity-related spatial decision support systems, including Strategic Management Prospects, specific needs analysis and habitat distribution models (HDMs). Strategic Management Prospects is a fine-scale, statewide spatial modelling tool with inputs including HDMs, threat models, expert elicited response models for thousands of species, management actions and cost estimates for management actions. Specific needs analysis is a structured decision support process relying on expert elicitation. HDMs are spatial models combining confirmed species locations and sets of environmental predictors that provide detailed information on variables such as climate, terrain, local productivity and vegetation structure.

The following sections provide an overview of spatial technologies applicable to biodiversity, forests, climate change and air indicators.

Wetlands and rivers

Existing datasets, portals, digital tools and platforms may help address the wetlands and Ramsar wetlands indicators. The Global Wetlands Project (GLOW), established at Griffith University, Queensland, has produced the Global Coastal Wetlands Index app, analysing a range of global datasets to derive 34 indicators that provide a full picture of the health of coastal wetlands.[140, 141] Data resolution is 100 km^2 and can be explored using 5 or 18 typologies. They also have a Blue Forest Data Explorer (and other apps) to help identify opportunities for conserving blue forests (i.e. mangroves, seagrass, saltmarsh and kelp forests) using the parameters of extent, threat, carbon, biodiversity, coastal communities and coastal protection.[142] Waterbird Population Estimates is a Wetlands International database that may support the waterbird indicator.[143]

Another existing digital tool related to the wetlands, Ramsar wetlands and river health indicators is the Freshwater Ecosystems Explorer. This was developed by the United Nations Environmental Programme to enable countries to track progress towards SDG indicator 6.6.1, which requires measurement of changes in water ecosystems in terms of size, water quality and water quantity.[144] These measurements can be tracked over time and by country using the app. This free global data platform has accurate, annually updated, high-resolution geospatial data from EO and in-situ sources depicting the extent of freshwater ecosystem change over time. Data can be visualised and downloaded at national, subnational and basin levels for permanent and seasonal surface waters, reservoirs, wetlands, mangroves and water quality.

A future remote sensing (RS)-based digital tool that may help address the wetlands and Ramsar wetlands indicators is Digital Earth Australia's (DEA's) beta Wetlands Insight Tool based on Landsat data, developed with the Queensland Government. The tool summarises how the amount of open water, wet green vegetation, dry vegetation and bare soil varies over time (since 1987) within each wetland.[145] The Queensland Joint Remote Sensing Research Program (with which DEECA is a collaborative partner) developed the Fractional Cover algorithm, which is one of the inputs into the Wetlands Insight Tool.[146] There is also the Global Wetlands Observing System (GWOS) that is being developed under the global Group on Earth Observations (GEO)–Wetlands initiative, coordinated by the University of Bonn, Wetlands International and the Ramsar Convention Secretariat.[147] Work began on the GWOS in 2007 and is progressing with another three-year work plan.[148] The group identified more than 30 programs delivering national, regional or global information for wetlands inventories from EO and aims to better coordinate and integrate these.

EO and modelling or ML also have potential for the wetlands and Ramsar wetlands indicators. Sentinel-2 data have been used to map freshwater wetland vegetation and saltmarsh across the Gippsland Lakes Ramsar site by Brooks Ecology and Technology using supervised maximum

140. GLOW, 'Global index: global status of coastal wetlands to inform conservation', Griffith University, https://globalwetlandsproject.org/globalmap Accessed 30 May 2023.
141. GLOW, 'Global Coastal Wetlands Index Web App' Griffith University https://glowdex.wetlands.app Accessed 30 May 2023.
142. Blue Forests, 'Welcome to the Blue Forest Data Explorer', Griffith University, https://global-wetlands.shinyapps.io/blue-forests-app Accessed 30 May 2023.
143. Wetlands International, 'Waterbirds population portal', http://wpe.wetlands.org Accessed 30 May 2023.
144. United Nations Environmental Programme (UNEP), 'Welcome to the Freshwater Ecosystems Explorer', https://map.sdg661.app Accessed 30 May 2023.
145. Australian Government Geoscience Australia, Digital Earth Australia (DEA), 'DEA wetlands insight tool (QLD)', https://www.dea.ga.gov.au/products/dea-wetlands Accessed 30 May 2023.
146. Joint Remote Sensing Research Program (JRSRP) 'Home', https://www.jrsrp.org.au Accessed 29 May 2023.
147. GEO BON Secretariat, 'Towards a GEO-Wetlands Initiative and a Global Wetlands Observing System (GWOS)', https://geobon.org/global-wetlands-observing-system-gwos Accessed 30 May 2023.
148. Group on Earth Observations (GEO), 'Renewed GEO Wetlands Initiative aims to meet data needs for accelerated conservation and restoration', https://www.earthobservations.org/geo_blog_obs.php?id=562 Accessed 30 May 2023.

likelihood classification models.[149] Internationally, the Satellite-based Wetland Observation Service is a commercial service generating mapping products and indicators for global wetlands from free satellite data and in-situ data.[150] Recent studies in Chile and the United States (US) have used ML with satellite imagery to identify wetlands.[151, 152]

The RS-based DEECA Index of Stream Condition (ISC), which directly addresses river health, was intended to be conducted eight yearly and could be repeated to acquire updated data on river health.[153] The Queensland Government references the Victorian ISC as part of its Wetland*Info* Assessment Toolbox, indicating it is still good practice.[154] If the ISC is not repeated, the AquaWatch national water quality (and environmental factors) monitoring system (hyperspectral satellite, and Internet of Things sensors and satellites), scheduled to be available as a prototype from 2026, will contribute to the measurement of the water quality component of river health and potentially wetlands, Ramsar wetlands and riparian vegetation, using vegetation measurement.[155] Until then, several systems – such as Environment Protection Authority water quality monitoring, the DEECA Water Measurement Information System, Melbourne Water river health monitoring (and that done by catchment management authorities) and the Index of Estuary Condition – continue to address the water quality component.[156, 157, 158, 159]

The International Water Management Institute, Consultative Group on International Agricultural Research Program on Water, Land and Ecosystems and the World Wide Fund for Nature, put forward the New Zealand Freshwater Biophysical Ecosystem Health Framework in 2018 as a good blueprint for a global river health framework.[160] The framework incorporates nearly all key biophysical attributes of river health, including components of water quantity, habitat, water quality, aquatic life and ecological processes. Each is measured and quantified through in-situ and EO data. Regional councils are required to publish data on each component annually, providing reliable information to decision-makers. For biological data collection, environmental DNA (eDNA) provides a rapid and cost-effective method for identifying species that exist in vast areas.

An alternative to the ISC — which uses aerial imagery, and light detection and ranging (LiDAR) — for measurement of riparian vegetation quality may be a new RS method using freely available Google Earth satellite high-resolution images and Sentinel-2 imagery combined with in-situ measurement.[161] Another example is the Copernicus Riparian Zones product, which provides detailed information on the state and characteristics of riparian zones across Europe and the United Kingdom (UK) to support biodiversity monitoring, and to map and assess ecosystems services.[162] It provides status maps for the two reference years and one change product.

EO and modelling or ML are relevant to the floodplains indicator. An RS method has been developed to predict annual stand condition of floodplain forests along the Murray River for the Murray–Darling Basin Authority.[163] The method was built into a software package and stand-condition maps were produced for the Murray River floodplain from 2009 to 2014 using RapidEye reflectance and Landsat

149. Brooks Ecology and Technology, 'Mapping wetland vegetation from Sentinel-2 satellite imagery', https://brooks.eco/projects/mapping-wetland-vegetation-from-sentinel-2-satellite-imagery_117s38 Accessed 30 May 2023.
150. Remote Sensing Solutions, 'SWOS: Satellite-based Wetland Observation Service', https://www.remote-sensing-solutions.com/satellite-based_wetland_observation Accessed 30 May 2023.
151. Munizaga J, García M, Ureta F, Novoa V, Rojas O, Rojas C 2022, 'Mapping coastal wetlands using satellite imagery and machine learning in a highly urbanized landscape', *Sustainability*, 14(9), p. 5700, https://doi.org/10.3390/su14095700 Accessed 30 May 2023.
152. Halabisky M, Miller D, Stewart AJ, Lorigan D, Brasel T, Moskal LM 2022, 'The Wetland Intrinsic Potential tool: Mapping wetland intrinsic potential through machine learning of multi-scale remote sensing proxies of wetland indicators' *EGUsphere*, https://egusphere.copernicus.org/preprints/2022/egusphere-2022-665 Accessed 30 May 2023.
153. Department of Energy, Environment and Climate Action (DEECA), 'Third index of stream condition report', https://www.water.vic.gov.au/water-reporting/third-index-of-stream-condition-report Accessed 30 May 2023.
154. Queensland Government Department of Environment and Science 2013, 'Wetland*Info*', https://wetlandinfo.des.qld.gov.au/wetlands/resources/tools/assessment-search-tool/index-of-stream-condition-isc Accessed 30 May 2023.
155. Commonwealth Scientific and Industrial Research Organisation (CSIRO), 'AquaWatch Australia', https://www.csiro.au/en/about/challenges-missions/aquawatch Accessed 30 May 2023.
156. Environment Protection Authority (EPA) Victoria, 'How EPA monitors water quality', https://www.epa.vic.gov.au/for-community/monitoring-your-environment/monitoring-victorias-water-quality Accessed 30 May 2023.
157. Department of Environment, Land, Water and Planning (DELWP), 'Water monitoring', https://data.water.vic.gov.au Accessed 30 May 2023.
158. Melbourne Water, 'River health and monitoring', https://www.melbournewater.com.au/water-and-environment/water-management/rivers-and-creeks/river-health-and-monitoring Accessed 30 May 2023.
159. Department of Energy, Environment and Climate Action (DEECA), 'Index of estuary condition', https://www.ari.vic.gov.au/research/rivers-and-estuaries/index-of-estuary-condition Accessed 30 May 2023.
160. Clapcott J, Young R, Sinner J, Wilcox M, Storey R, Quinn J, Daughney C, Canning A 2018, 'Report no. 3194: Freshwater biophysical ecosystem health framework', Cawthron Institute, https://environment.govt.nz/assets/Publications/Files/freshwater-ecosystem-health-framework.pdf Accessed 30 May 2023.
161. Pace G, Gutierrez-Canovas C, Henriques R, Carvalho-Santos C, Cassio F, Pascoal C 2022, 'Remote sensing indicators to assess riparian vegetation and river ecosystem health', *Ecological Indicators*, 144, article no. 109519, https://www.sciencedirect.com/science/article/pii/S1470160X2200992X Accessed 9 June 2023.
162. Copernicus, 'Riparian zones', https://land.copernicus.eu/local/riparian-zones Accessed 30 May 2023.
163. Cunningham SC, Griffioen P, White MD, Nally RM 2017, 'Assessment of ecosystems: A system for rigorous and rapid mapping of floodplain forest condition for Australia's most important river', *Land Degradation and Development* 19(1), pp. 127-137, https://onlinelibrary.wiley.com/doi/abs/10.1002/ldr.2845 Accessed 8 June 2023.

5 data. The outcomes were useful to Murray–Darling Basin Authority land managers, so the approach was extended to the floodplain forests of the whole Murray–Darling Basin. The predictions were generally poorer than for the Murray River floodplains, as the input data did not cover other systems. The authority stated that 'Forest condition can be mapped accurately and annually at medium resolution (25 × 25 m) for large areas (100,000s ha) if quantitative ground surveys, satellite imagery, ML and future validation are combined'. The Advanced Land Observing Satellite (ALOS) and WorldView-2 RS data and modelling have been used for floodplain vegetation monitoring in Kakadu National Park.[164]

Greater tracking of animal movement may be possible using smaller and cheaper Global Positioning System (GPS) tracking devices along with advances in satellite receiver technology, which enable greater coverage and more frequent position estimates.[165] The ICARUS (International Cooperation for Animal Research Using Space) initiative is an example of this.[166] They have a receiver on the International Space Station, which began operation in March 2021, as well as mini-transmitters weighing only 5 grams. The transmitters have a GPS function and can withstand cold, heat, moisture and dust. They can transmit their data by radio for months or years to the receiver in space. The program is initially targeted at birds, so it is relevant to the waterbird indicator. Ultimately, the aim is to produce the Internet of Animals, which merges tracking with the Internet of Things (IOT).[167] The data are contributed to MOVEBANK, a free online database of animal tracking data.[168]

RS (aerial, RPV or ground imagery) and ML can also be used to inform the waterbird (and threatened terrestrial bird species) indicators. In Botswana and Australia, researchers collected RPV images of breeding waterbirds at colonies and developed a semi-automated ML counting method that efficiently provided accurate (>90%) estimates of nesting species of waterbirds, even within complex backgrounds.[169] This method was 500% quicker (not including development time) than manual counting. RPV imagery and deep convolutional neural networks have been used to detect and count seabirds (piscivorous terns and gulls) in West Africa.[170] The researchers showed that limitations of traditional survey methods, which are tedious, imprecise and cause disturbance, are all overcome by this technology.

A study in Turkey used a deep learning model with geotagged, ground-based digital photos to detect migratory birds.[171] The model outputs were also used in a proof-of-concept geographical information system (GIS) application to map countrywide bird distribution and assist bird population trend analysis. More recent studies using ML methods for waterbird counting include both RPV and ML, use of aerial imagery and ML, and use of ML through Google's Teachable Machine for species recognition and counting from iPhone images.[172, 173, 174]

The European Network for the Radar Surveillance of Animal Movement is a research network looking at terrestrial radar for animal migration at a continental scale.[175] Small, purpose-built, vertical-looking radar, like BirdScan, can detect individual birds, bats and insects flying over it.[176]

164. Antsee J, Botha EJ, Byrne GT, Dyce P, Schroeder T 2015, 'Remote sensing methods to map and monitor the condition of coastal habitats and other surrogates for biodiversity, Part A: Floodplain vegetation mapping of the Kakadu National Park', CSIRO Oceans and Atmosphere Flagship, Australia, https://www.researchgate.net/publication/305984193_Remote_sensing_methods_to_map_and_monitor_the_condition_of_coastal_habitats_and_other_surrogates_for_biodiversity_Part_A_Floodplain_vegetation_mapping_of_the_Kakadu_National_Park Accessed 30 May 2023.
165. Sequeira AMM, Hays GC, Sims DW, Eguíluz VM, Rodríguez JP, Heupel MR, Harcourt R, Calich H, Queiroz N, Costa DP, Fernández-Gracia J, et al. 2019, 'Overhauling ocean spatial planning to improve marine megafauna conservation', *Frontiers in Marine Science*, 6, p. 639, https://www.frontiersin.org/articles/10.3389/fmars.2019.00639/full Accessed 30 May 2023.
166. International Cooperation for Animal Research Using Space (ICARUS), 'ICARUS: Global monitoring with animals', https://www.icarus.mpg.de/en Accessed 30 May 2023.
167. International Cooperation for Animal Research Using Space (ICARUS), 'The internet of animals', https://www.icarus.mpg.de/28546/icarus-internet-of-animals Accessed 30 May 2023.
168. Max Planck Institute of Animal Behaviour, 'MOVEBANK for animal tracking data', https://www.movebank.org/cms/movebank-main Accessed 30 May 2023.
169. Francis RJ, Lyons MB, Kingsford RT, Brandis KJ 2020, 'Counting mixed breeding aggregations of animal species using drones: Lessons from waterbirds on semi-automation', *Remote Sensing,* 12(7) p. 1185, https://www.mdpi.com/2072-4292/12/7/1185 Accessed 30 May 2023.
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171. Akcay HG, Kabasakal B, Aksu D, Demir N, Oz M, Erdogan A 2020, 'Automated bird counting with deep learning for regional bird distribution mapping', *Animals*, 10(7), p. 1207, https://www.mdpi.com/2076-2615/10/7/1207 Accessed 30 May 2023.
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175. European Network for the Radar Surveillance of Animal Movement (ENRAM), 'Home', http://www.enram.eu Accessed 30 May 2023.
176. Swiss Birdradar Solution AG, 'Radar systems to track aerial biomass; Bio-monitoring in real time', https://swiss-birdradar.com Accessed 30 May 2023.

Threatened species and communities

Citizen science can apply across all threatened species. The Atlas of Living Australia (ALA), a database providing open access to Australia's biodiversity data, could contribute to flora and fauna indicators.[177] Users can search for data, download records, perform spatial analysis, upload data, discover citizen science projects and more. Data can be collected and contributed using iNaturalist Australia, enabling users to record sightings that can then be identified by community expertise and image recognition, and by BioCollect, an advanced but simple-to-use data collection tool for biodiversity science.[178, 179] iNaturalist data are also submitted to the Global Biodiversity Information Facility (GBIF), which provides free access to global biodiversity data.[180] Seek by iNaturalist is an app using artificial intelligence (AI) for real-time species identification via augmented reality from smartphone cameras.[181] Before taking the picture, the on-screen identification guides users to take a better photo by prompting angle changes and other adjustments until the species is identified. SWIFFT (State Wide Integrated Flora and Fauna Teams), a Victoria-specific network for threatened species and biodiversity conservation, provides detailed information on threatened species, projects, nature observations and more, and may also contribute to flora and fauna indicators.[182]

EcoCommons is a new digital platform giving Australian researchers and decision-makers access to world-leading ecological and environmental modelling tools.[183] It contains species occurrence records from the ALA, GBIF, Terrestrial Ecosystem Research Network (TERN), Australian Ecological Knowledge and Observation System (ÆKOS) and Ocean Biodiversity Information System, as well as environmental and climate projection data.[184, 185] These enable models such as species distribution, climate change species distribution projection and habitat condition assessments, which could inform all threatened species indicators. The new portal EcoAssets brings together environmental data from the ALA, the Integrated Marine Observing System (IMOS) and TERN, standardises formats, integrates the data and openly shares the resources to support environmental reporting at federal, state and territory levels.[186]

All threatened vertebrate species indicators may be assisted by the global existing data portal Living Planet Index, which is a measure of the state of global biological diversity based on population trends of vertebrate species.[187] The associated Living Planet Database currently holds time-series data for over 31,821 populations of more than 5,230 mammal, bird, fish, reptile and amphibian species from around the world, from which subsets can be downloaded.[188] The Living Planet Report 2022 affords a comprehensive study of trends in global biodiversity.[189]

RS and ML are the proven solutions for the land-cover classes indicator. The ARI Land Cover Time Series maps (19 land-cover classes with 25 m resolution) were produced using RS, big-data analytics and ML. They can be viewed on DEECA's NatureKit 2.0 under the Landcover heading.[190] The polygon data can also be downloaded from DataShare and analysis tools used in GIS to compute differences between land-cover classes over time.[191] The Australian Bureau of Statistics (ABS) National Land Cover Account interactive Statistical Area 2 (SA2) map for 2020 includes 10 land-cover categories for SA2 regions.[192] ABS produced the

177. Atlas of Living Australia, 'Open access to Australia's biodiversity data', https://www.ala.org.au Accessed 30 May 2023.
178. iNaturalistAU, 'iNaturalist Australia: How it works', https://inaturalist.ala.org.au Accessed 30 May 2023.
179. Atlas of Living Australia, 'BioCollect', https://www.ala.org.au/biocollect Accessed 30 May 2023.
180. Global Biodiversity Information Facility (GBIF), 'Free and open access to biodiversity data', https://www.gbif.org Accessed 30 May 2023.
181. iNaturalist, 'Seek by iNaturalist', https://www.inaturalist.org/pages/seek_app Accessed 29 May 2023.
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183. EcoCommons, 'Your platform of choice', https://www.ecocommons.org.au Accessed 30 May 2023.
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185. Ocean Biodiversity Information System (OBIS), 'OBIS is a global open-access data and information clearing-house on marine biodiversity for science, conservation and sustainable development', https://obis.org/ Accessed 30 May 2023.
186. EcoAssets, 'EcoAssets: Building data linkages for environmental reporting', https://ecoassets.org.au Accessed 30 May 2023.
187. 'Living Planet Index', https://www.livingplanetindex.org/search Accessed 30 May 2023.
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189. World Wildlife Fund (WWF), 'Living planet report 2022', https://livingplanet.panda.org/en-US/ Accessed 30 May 2023.
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191. Department of Energy, Environment and Climate Action (DEECA), 'DataShare – Search', https://datashare.maps.vic.gov.au/search?md=81726131-7c8d-52b9-a243-d6a8429966e2 Accessed 30 May 2023.
192. Australian Bureau of Statistics (ABS), 'National land cover interactive SA2 map – 2020', https://absstats.maps.arcgis.com/apps/MapSeries/index.html?appid=0e6b6d8525a64998ad6a9d12f9cc7c39 Accessed 30 May 2023.

statistics from Geoscience Austalia DEA Landcover data which is a 25 m resolution product generated from Landsat satellite imagery.[193, 194] Radiant Earth has released ML training datasets for land cover for each continent, including Australia.[195] LandCoverNet is a global annual land-cover classification training dataset with labels for the multi-spectral satellite imagery from Sentinel-1 (10 m resolution), Sentinel-2 (10 m resolution) and Landsat 8 missions in 2018, which could be used to generate new land-cover maps. The data have higher resolution than the ARI Land Cover Time Series, but only has seven land-cover classes: water, natural bare ground, artificial bare ground, woody vegetation, cultivated vegetation, (semi) natural vegetation and permanent snow/ice.

A global dataset has been produced by Esri using Sentinel-2 imagery, Impact Observatory's deep learning AI land classification model, a massive training dataset of billions of human-labelled image pixels developed by the National Geographic Society and Microsoft's Planetary Computer.[196, 197, 198, 199] Dynamic World is another free global land-cover dataset based on Sentinel-2 imagery and produced daily using deep learning with nine land-cover classes.[200]

It allows a before-and-after swipe view on the map between a chosen start and end date.

ML and RPV underwater imagery or video could be used for underwater indicators, including threatened freshwater mammals, threatened wetland-dependent species, threatened large-bodied fish and threatened small-bodied fish. For example, Curtin University and the Australian Institute of Marine Science (AIMS) used deep learning for automated analysis of fish data from baited remote underwater video stations, which provides a scalable way to analyse video.[201]

In the UK, AI is being used to analyse underwater RPV images of deep-sea animals. Much has been published on ML for fish detection, including a 2020 automatic fish detection and species classification technique by Australian researchers.[202] FishID, an Australian platform developed by GLOW, uses AI to automate the analysis of videos and images of animals such as fish, crabs and sea cucumbers, even in challenging environments including turbid waters and at night.[203] Monitoring can use unbaited cameras, remotely operated vehicles (ROVs) and baited remote underwater video stations to measure things such as abundance and species – which, combined with location, could produce distribution maps.

ML with camera trapping and IoT could be used for threatened terrestrial mammal indicators. Advanced camera traps can have wireless connectivity, networked cameras and remote camera status checking. The Instant Detect platform expands the traditional camera trap to include other sensors (e.g. acoustic), with real-time data communication via satellite.[204] New intelligent camera traps (e.g. BuckEye Cam) use AI for in-device image processing and recognition.[205] AI can help with automated sorting of imagery (e.g. discarding images with no animals) and automated species identification, which can also be done online by crowdsourced, human-based species identification. ML has been used to detect animals (rather than background) in camera-trap images and video (during both day and night) with complex, dynamic backgrounds to an accuracy of 91.4%.[206]

The IMOS Animal Tracking Database and web interface is a central repository for the acoustic tag detections (over 130 million) and metadata from Australia's 1,213 active tracking and IoT receivers.[207] However, IMOS acoustic telemetry has

193. Australian Bureau of Statistics (ABS), 'National land cover account: Experimental statistics on detailed land cover stock positions and changes in land cover from 1988 to 2020', https://www.abs.gov.au/statistics/environment/environmental-management/national-land-cover-account/latest-release#interactive-map-showing-land-cover-by-statistical-area-level-2 Accessed 30 May 2023.
194. Australian Government Geoscience Australia, 'Digital Earth Australia, DEA land cover (Landsat)', https://cmi.ga.gov.au/data-products/dea/607/dea-land-cover-landsat#basics Accessed 30 May 2023.
195. Radiant MLHub, 'LandCoverNet Australia', https://mlhub.earth/data/ref_landcovernet_au_v1 Accessed 30 May 2023.
196. Esri, 'Sentinel-2 10m land use/land cover time series of the world', https://www.arcgis.com/home/item.html?id=cfcb7609de5f478eb7666240902d4d3d Accessed 30 May 2023.
197. Impact Observatory, 'AI-powered geospatial monitoring to understand risks and anticipate change at unprecedented speed and scale', https://www.impactobservatory.com Accessed 30 May 2023.
198. Tait AM, Brumby SP, Hyde SB, Mazzariello J, Corcoran M 2021, 'Dynamic world training dataset for global land use and land cover categorization of satellite imagery', *PANGEA*, https://doi.pangaea.de/10.1594/PANGAEA.933475 Accessed 30 May 2023.
199. Microsoft, 'A planetary computer for a sustainable future', https://planetarycomputer.microsoft.com Accessed 30 May 2023.
200. Dynamic World, 'Explore Dynamic World', https://dynamicworld.app/explore Accessed 30 May 2023.
201. Australian Institute of Marine Science (AIMS), 'OzFish dataset – Machine learning dataset for baited remote underwater video stations', https://apps.aims.gov.au/metadata/view/38c829d4-6b6d-44a1-9476-f9b0955ce0b8 Accessed 8 June 2023.
202. Jalal A, Salman A, Mian A, Shortis M, Shafait F 2020, 'Fish detection and species classification in underwater environments using deep learning with temporal information', Ecological Informatics, 57, pp. 101088 https://www.sciencedirect.com/science/article/abs/pii/S1574954120300388?via%3Dihub Accessed 30 May 2023.
203. GLOW, 'FISHID: The future of environmental monitoring at your fingertips', https://globalwetlandsproject.org/fishid Accessed 29 May 2023.
204. Zoological Society of London (ZSL), 'Wildlife monitoring: Instant Detect 2.0', https://www.zsl.org/what-we-do/projects/instant-detect-2 Accessed 30 May 2023.
205. Buckeye Cam, 'Now with AI with image recognition', https://www.buckeyecameras.com Accessed 30 May 2023.
206. Verma GK, Gupta P 2018, 'Wild animal detection using deep convolutional neural network', *Proceedings of 2nd International Conference on Computer Vision and Image Processing*, 2, pp. 327-338, Springer Singapore, https://www.researchgate.net/publication/324960511_Wild_Animal_Detection_Using_Deep_Convolutional_Neural_Network Accessed 30 May 2023.
207. Integrated Marine Observing System (IMOS), 'Australian animal acoustic telemetry database', https://animaltracking.aodn.org.au Accessed 30 May 2023.

only one permanent receiver array in Victoria (in Portland).[208] IMOS will lend acoustic receivers for up to 12 months to 'help establish studies in new regions and allow researchers to collect preliminary data that can be used to form the basis of funding applications to establish more permanent acoustic receiver arrays'. Acoustic Telemetry Arrays, funded by the Queensland Government Department of Environment and Science, provide the infrastructure to understand the distribution and movement of important marine species along the east coast of Queensland.[209] Future investment in this technology could include the loan of a receiver for a trial study, with the aim of establishing more permanent receivers. This could be complemented by a tagging program, potentially including threatened large-bodied fish, threatened small-bodied fish, threatened freshwater mammals and larger threatened freshwater invertebrates, to contribute to the assessment of these indicators and the IMOS database.

There is very little evidence of spatial technology being used for (threatened) freshwater invertebrates; however, eDNA (which can be combined with spatial technology) is increasingly being used. A study looking at improving freshwater macroinvertebrate detection from eDNA concluded that detection from stream water was greatly increased with a new specific method, but that generally methods are still in the development stage.[210] A systematic literature review confirmed the ongoing rapid growth of eDNA-focused literature in freshwater systems, but found that standardisation is needed and methodologies for all taxa need to be developed (fish are currently the main focus group).[211] Traditional macroorganism monitoring approaches rely on human observers and combinations of direct sampling and tagging; similarly, most eDNA analytical procedures require a person to collect and process samples. Researchers have studied the use of underwater RPV with an autonomous sampling instrument to collect water samples, analyse them in situ and preserve them for return to a laboratory.[212] Autonomous robotic eDNA samplers have been used at US Geological Survey stream gauge sites and satellite communication for automatic upload of data.[213] Aerial RPVs specifically designed for water sampling, such as Nero RPV, are already used by Melbourne Water to sample treatment plants and reservoirs.[214, 215]

The 'Threatened frog species' indicator could also be informed by emerging eDNA and RPV methods, which are now common for monitoring fish but not as common for frogs. Work is being done to help standardise an eDNA analysis method for amphibians that will enable anyone to easily monitor them in their habitats. This would be done by collecting water samples – which, as already discussed, could be done using RPV.[216] A comparison of two eDNA methods to conventional field sampling of amphibians found both methods to be competitive or improving upon conventional methods.[217] eDNA has great potential to apply across all threatened and invasive fauna species (discussed further in the 'Invasive species' section below). The eDNA method can also be used for threatened terrestrial invertebrates (although in relation to invasive species) to 'potentially revolutionise monitoring of invertebrates by providing the ability to characterise entire communities from a single, easily collected environmental sample'.[218]

208. Integrated Marine Observing System (IMOS), 'Acoustic telemetry', https://imos.org.au/facilities/animaltracking/acoustictelemetry Accessed 30 May 2023.
209. Integrated Marine Observing System (IMOS), 'Acoustic telemetry arrays – Queensland', https://imos.org.au/facilities/animaltracking/acoustic-telemetry-qld Accessed 30 May 2023.
210. Leese F, Sander M, Buchner D, Elbrecht V, Haase P, Zizka VMA 2020, 'Improved freshwater macroinvertebrate detection from environmental DNA through minimized nontarget amplification', *Environmental DNA*, 3(1), pp. 261–276, https://onlinelibrary.wiley.com/doi/full/10.1002/edn3.177 Accessed 30 May 2023.
211. Schenekar T, 2022 'The current state of eDNA research in freshwater ecosystems: are we shifting from the developmental phase to standard application in biomonitoring?', Hydrobiologia, 850, pp. 1263–1282, https://link.springer.com/article/10.1007/s10750-022-04891-z Accessed 30 May 2023.
212. Yamahara KM, Preston CM, Birch J, Walz K, Marin III R, Jensen S, Pargett D, Roman B, Ussler III W, Zhang Y, Ryan J, Hobson B, Kieft B, Raanan B, Goodwin KD, Chavez FP, Scholin C 2019, 'In situ autonomous acquisition and preservation of marine environmental DNA using an autonomous underwater vehicle', *Frontier Marine Science*, 6, https://www.frontiersin.org/articles/10.3389/fmars.2019.00373/full Accessed 30 May 2023.
213. Sepulveda AJ, Hoegh A, Gage JA, Caldwell Eldridge SL, Birch JM, Stratton C, Hutchins PR, Barnhart EP 2021, 'Integrating environmental DNA results with diverse data sets to improve biosurveillance of river health', *Frontiers in Ecology and Evolution*, 9, https://www.frontiersin.org/articles/10.3389/fevo.2021.620715/full Accessed 30 May 2023.
214. Nero, 'Aerial sampling at its best', https://spheredrones.com.au/pages/nero Accessed 30 May 2023.
215. Nero, 'Melbourne Water', https://nerosampler.com/blogs/case-studies/melbourne-water Accessed 30 May 2023.
216. Sakata MK, Kawata MU, Kurabayashi A, Kurita T, Nakamura M, Shirako T, Kakehashi R, Nishikawa K, Hossman MY, Nishijima T, Kabamoto J, Miya M, Minamoto T 2022, 'Development and evaluation of PCR primers for environmental DNA (eDNA) metabarcoding of Amphibia', *Metabarcoding and Metagenomics*, 6, e76534, https://mbmg.pensoft.net/article/76534/list/9 Accessed 30 May 2023.
217. Moss WE, Harper LR, Davis MA, Goldberg CS, Smith MM, Johnson PTJ 2022, 'Navigating the trade-offs between environmental DNA and conventional field surveys for improved amphibian monitoring', *Ecosphere*, 13(2), e3941, https://esajournals.onlinelibrary.wiley.com/doi/full/10.1002/ecs2.3941 Accessed 30 May 2023.
218. Begley C, Rainbow R, Younus F 2020, 'Invasive species solutions 2030: Overview of technology opportunities', Centre for Invasive Species Solutions (CISS), Canberra, Australia, https://invasives.com.au/wp-content/uploads/2021/02/CISS-Overview-of-Technology-Opportunities_web-final.pdf Accessed 30 May 2023.

FrogID combines citizen science, ML and acoustics for frog identification in Australia.[219] Citizens use an app on their smartphone to record frog calls. Each audio recording is unique, time-stamped and georeferenced, and scientists can use the recordings to understand and conserve threatened frogs. It now uses ML to automate recognition of frog calls.[220] A map is provided to explore FrogID records, and the data can be downloaded (data are also on ALA).[221]

Acoustic monitoring (in combination with IoT, AI and platforms) is a strategy that complements other forms of ecological surveying. It can be used to answer questions on species occupancy, abundance, behaviour and species richness, and show trends over time and space. It can be used to monitor many threatened terrestrial bird species, threatened frogs, threatened terrestrial invertebrates and threatened terrestrial mammals. Because sound propagates underwater, this strategy can also be applied to threatened freshwater mammals, threatened freshwater invertebrates, threatened large-bodied fish and threatened small-bodied fish. For example, AudioMoth is a low-cost, full-spectrum, open-source acoustic monitoring device that has been used in several applications, including automating the search for an elusive insect species and listening for ultrasonic bat calls.[222] HydroMoth is a variant specifically designed to be deployed underwater. AI can then be used for automatic species recognition, and modern electronics could even allow in-device detection of species or events in real time.

Acoustic monitoring produces huge amounts of data, so automating the data pipeline (handling, storing, processing) is essential to operationalise the method at scale. Some end-to-end solutions (e.g. the Automated Remote Biodiversity Monitoring Network, which includes acoustic stations wirelessly connected to a data repository) and back-end support (e.g. Queensland University of Technology's Ecosounds online data repository) exist.[223, 224] The network is a novel combination of hardware and software for automating data acquisition, data management and species identification based on audio-recordings.[225]

Open Ecoacoustics (an Australian Research Data Commons project) is an emerging digital platform in open acoustics monitoring that will enable aggregation and sharing of data and analysis, including ML.[226] It will extend and generalise the existing ecoacoustics platform, Ecosounds, which uses Acoustic Workbench software, to make it openly available.[227] The Australian Acoustic Observatory is a continental-scale acoustic sensor network that provides data for hundreds of continuously operating acoustic sensors (~360) across seven Australian ecoregions.[228] The data are freely available to researchers, citizen scientists and the general public. In this project, data from the Australian Acoustic Observatory were used to predict masked owl distribution using ML, generated on the EcoCommons platform.[229] Citizen scientists can use smartphones equipped with microphones and adequate computational power for acoustic monitoring of birds, which is facilitating rapid growth in the population of acoustic detectors.

RS and modelling are being used to monitor threatened reptiles. The European Space Agency used Sentinel-1 and Sentinel-2 data in Samaria National Park in Greece to monitor an endemic lizard.[230] This area is mountainous, with diverse terrain and microclimates, and Sentinel-1 provides terrain data such as elevation, aspect, slope and openness to the sky, while Sentinel-2 provides landscape dynamics such as vegetation growth and changes in land cover. NASA scientists successfully used EO data to predict the geographic distribution of 11 known chameleon species in Madagascar.

219. FrogID, 'Australia's frogs need your help', https://www.frogid.net.au Accessed 29 May 2023.
220. Australian Museum 2022, 'FrogID, Atlassian foundation and Engage4Good', https://australian.museum/blog/amri-news/frogid-atlassian Accessed 30 May 2023.
221. FrogID, 'Explore FrogID records', https://www.frogid.net.au/explore Accessed 30 May 2023.
222. Open Acoustic Devices, 'AudioMoth', https://www.openacousticdevices.info/audiomoth Accessed 30 May 2023.
223. Rainforest Connection, 'Arbimon', https://arbimon.rfcx.org Accessed 30 May 2023.
224. Ecosounds, 'Who are we?', https://www.ecosounds.org Accessed 30 May 2023.
225. Aide TM, Corrada-Bravo C, Campos-Cerqueira M, Carlos M, Vega G, Alvarez R, 2013, 'Real-time bioacoustics monitoring and automated species identification', *PeerJ* 1, e103, https://peerj.com/articles/103 Accessed 30 May 2023.
226. Open Ecoacoustics, 'What is Open Ecoacoustics?', https://openecoacoustics.org Accessed 30 May 2023.
227. Ecosounds, 'QUT Ecoacoustics Research Group', https://research.ecosounds.org Accessed 30 May 2023.
228. Australian Acoustic Observatory, 'About A20', https://acousticobservatory.org/home_1 Accessed 30 May 2023.
229. EcoCommons, 'Ecoacoustics SDM use case', https://www.ecocommons.org.au/acoustic-sdm-use-case Accessed 30 May 2023.
230. Foundation for Research and Technology Hellas (FORTH) and the Samaria National Park 2019, 'Copernicus Sentinels become powerful tool in biodiversity conservation', https://sentinels.copernicus.eu/web/sentinel/-/copernicus-sentinels-become-powerful-tool-in-biodiversity-conservation Accessed 30 May 2023.

Researchers from the International Society for Photogrammetry and Remote Sensing used SPOT-4 satellite data and modelling techniques to map the distribution and abundance (probability of occurrence) of reptile and amphibian species.[231] RPV had been employed to collect high-resolution imagery, which was then visually examined to manually identify freshwater turtles. ML could potentially also be used to automate identification.[232]

In relation to indicators for threatened terrestrial plants (vascular and non-vascular), researchers point out that non-vascular vegetation is a different RS challenge to vascular vegetation. This is because the spectral signal of non-vascular plants is highly influenced by their moisture content, and physiologically they behave differently.[233] In areas like the tundra, which have a mix of vascular and non-vascular plants, it can be difficult to interpret spectral observations, but an understanding of geographic patterns of vegetation species distribution (e.g. climate and soil properties) can help interpretation. One literature review concluded that RS has great potential for the detection and prediction of rare plants in both terrestrial and aquatic environments in terms of both species distribution models (SDMs) and species abundance models (SAMs). It reported on the use of high-resolution (<30 m) and medium-resolution (30–300 m) RS to detect and predict rare vascular and non-vascular plants with distinctive traits.[234] Another study highlighted that SDMs have been researched and developed more than SAMs.[235]

Researchers compared SAMs based on climatic, topographic and landscape variables (air temperature, precipitation, land cover, Digital Elevation Model) to SAMs based on satellite-derived attributes (MODIS Enhanced Vegetation Index) for a rare European lily and found that the latter were more robust predictions of species abundance. They concluded that RS can be used to predict local abundance for rare plant species and that their proposed framework is flexible enough to be applicable to other species and socio-environmental contexts globally.

For threatened terrestrial vascular plants, RS has been used to produce a 30-metre spatial resolution map of Australian forest and woodland structure (height and cover) by integrating Landsat Thematic Mapper and Enhanced Thematic Mapper, ALOS, Phased Arrayed L-band Synthetic Aperture Radar (PALSAR), Ice, Cloud, and Land Elevation Satellite (ICESat) and Geoscience Laser Altimeter System data.[236] It can be used for carbon budgeting and science, biodiversity assessment and conservation, and better forest management. RS variables of the Normalized Difference Vegetation Index (NDVI) and land surface temperatures have been combined with topographic and geological variables to produce detailed species distribution models for alpine plant species in Austria.[237] The combination of all variables was found to outperform models using fewer of the same variables, and results correlated highly with actual species distribution ranges.

For threatened terrestrial non-vascular plants bryophytes (non-vascular) have been acknowledged as an essential component of biodiversity and play a significant role in ecosystem functioning, yet they are often overlooked due to lack of knowledge about their distribution.[238] This research used an Ensemble of Small Models (ESM) with six RS (and modelling)-derived predictors, including topographic position index and enhanced vegetation index, to predict rare bryophyte (non-vascular) distribution and abundance in Canadian boreal forests. ESMs are ensembles of bivariate (two-variable) models generated from all pairwise predictor combinations from a larger set of predictors. They can produce more accurate

231. Skidmore AK, Toxopeus AG, de Bie CAJM, Corsi F, Venus V, Omolo DP, Marquez J, Giménez RR 2006, 'Herpetological species mapping for the Mediterranean', ISPRS 2006: mid-term symposium remote sensing: from pixels to processes, https://research.utwente.nl/en/publications/herpetological-species-mapping-for-the-medditeranean Accessed 9 June 2023.
232. Bogolin AP, Davis DR, Kline RJ, Rahman AF 2021, 'A drone-based survey for large, basking freshwater turtle species', *PLOS* ONE 16(10), e0257720, https://doi.org/10.1371/journal.pone.0257720 Accessed 31 May 2023.
233. Nelson PR, Maguire AJ, Pierrat Z, Orcutt EL, Yang D, Serbin S, Frost GV, Macander MJ, Magney TS, Thompson DR, Wang JA, et al. 2022, 'Remote sensing of tundra ecosystems using high spectral resolution reflectance: Opportunities and challenges', *Journal of Geophysical Research*: *Biogeosciences*, 127(2), e2021JG006697, https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2021JG006697 Accessed 31 May 2023.
234. Cerrejón C, Valeria O, Marchand P, Caners RT, Fenton NJ 2021. 'No place to hide: Rare plant detection through remote sensing', *Diversity and Distributions*, 27(6), pp. 948-961, https://onlinelibrary.wiley.com/doi/full/10.1111/ddi.13244 Accessed 31 May 2023.
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236. Scarth P, Armston J, Lucas R, Bunting P 2019, 'A structural classification of Australian vegetation using ICESat/GLAS, ALOS PALSAR, and Landsat sensor data', *Remote Sensing*, 11(2), pp. 147, https://www.mdpi.com/2072-4292/11/2/147 Accessed 31 May 2023.
237. Schwager P, Berg C 2021, 'Remote sensing variables improve species distribution models for alpine plant species', *Basic and Applied Ecology*, 54, pp. 1-13, https://www.sciencedirect.com/science/article/pii/S1439179121000694 Accessed 31 May 2023.
238. Schwager P, Berg C 2021, 'Remote sensing variables improve species distribution models for alpine plant species', Basic and Applied Ecology, 54, pp. 1-13, https://www.sciencedirect.com/science/article/pii/S1439179121000694 Accessed 31 May 2023.

predictions than traditional SDMs and reduce model overfitting for rare species. The researchers propose that the combined use of ESMs and RS would work for other threatened non-vascular species lacking distribution data.

Note that threatened wetland-dependent species are included in individual species (e.g. frogs, birds) discussed in the sections above.

Invasive species

A lot of the technologies discussed for threatened species are also highly applicable to invasive species. The Australian Centre for Invasive Species Solutions (CISS) published a comprehensive 2020 report providing a landscape analysis of biosecurity and invasive species technology opportunities.[239] The report discusses (and references many journal articles about) the use of aerial imagery, LiDAR, free and commercial satellite imagery, RPV data collection, miniature sensors, acoustic sensors, eDNA, IoT, citizen science, big data and ML to identify and map animal and plant invaders, as well as predict current and potential distributions. For example, it discusses the use of chemical nano-sensors such as an e-nose device. If networked and scaled appropriately using IoT, the device can detect the presence of invasive species (e.g. through detecting volatile organic compounds emitted by plants when vegetative tissues are damaged by invasive species).[240] Two areas highlighted for improvement are the involvement and cooperation of individuals and groups from industry, communities and government in detecting and reporting pests, and innovative, low-cost technological improvements to assist in pest reporting and identification.

Citizen science data can help collect data at scale for invasive species, and data-quality issues can be addressed with methods such as the big-data approach used by eBird to curate and analyse data.[241] MyPestGuide Reporter, the Western Australian Government Department of Primary Industries and Regional Development app for citizen science reporting of pests, is targeted at invasive invertebrates and weeds.[242] FeralScan provides a free, citizen science pest-animal recording and management digital tool for a range of terrestrial and other vertebrates, including the invasive terrestrial herbivores deer, pig and rabbit.[243] It can be used to record sightings and evidence, damage and control activities, and data can be requested. FeralFishScan is part of FeralScan and has information on carp.[244] The EcoCommons platform and its associated databases could also apply to invasive species, as could the in-development Biosecurity Commons decision support system for modelling and analysing biosecurity risk and response.[245] Acoustic monitoring (in combination with IoT, AI and platforms), discussed in the 'Threatened species and communities' section, is also applicable to invasive species: researchers have investigated wireless acoustic sensor networks for monitoring cane toads in northern Australia, and another research group used a large-scale acoustic monitoring pipeline to investigate spatial distribution of 16 invasive species (including birds, mammals and frogs) in Puerto Rico.[246, 247]

RS is the technology most applicable to invasive freshwater plant species. US researchers mapped invasive floating aquatic vegetation using Sentinel-2 imagery and ML to overcome the temporal gaps in the current RS method of airborne imaging spectroscopy.[248] A Canadian study reviewed RS of submerged aquatic vegetation and determined that RS had not been used as extensively in

239. Cerrejón C, Valeria O, Muñoz J, Fenton NJ 2022, 'Small but visible: Predicting rare bryophyte distribution and richness patterns using remote sensing-based ensembles of small models', *PLOS ONE*, 17(1), e0260543 https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0260543 Accessed 31 May 2023.
240. Begley C, Rainbow R, Younus F 2020, 'Invasive species solutions 2030: Overview of technology opportunities', Centre for Invasive Species Solutions (CISS), Canberra, Australia, Sensigent Intelligent Sensing Solutions, 'Solutions for QC testing and inspection', https://www.sensigent.com Accessed 31 May 2023.
241. Kelling S, Fink D, La Sorte FA, Johnston A, Bruns NE, Hochachka WM 2015, 'Taking a "Big Data" approach to data quality in a citizen science project', *Ambio*, 44, pp. 601-611, https://link.springer.com/article/10.1007/s13280-015-0710-4 Accessed 31 May 2023.
242. Department of Primary Industries and Regional Development, 'MyPestGuide reporter', https://www.agric.wa.gov.au/apps/mypestguide-reporter Accessed 31 May 2023.
243. Centre for Invasive Species Solutions (CISS), 'FeralScan: Record pest animal activity in your local area to protect farms, biodiversity and communities', https://feralscan.org.au Accessed 31 May 2023.
244. Centre for Invasive Species Solutions (CISS), 'Record feral fish activity in FeralFishScan', https://feralscan.org.au/feralfishscan/default.aspx Accessed 31 May 2023.
245. Biosecurity Commons, 'Powerful biosecurity analytics at your fingertips', https://www.biosecuritycommons.org.au Accessed 31 May 2023.
246. Hu W, Bulusu N, Chou CT, Jha S, Taylor A, Tran VN 2009, 'Design and evaluation of a hybrid sensor network for cane toad monitoring', *ACM Transactions on Sensor Networks*, 5(1), pp. 1-28, https://dl.acm.org/doi/10.1145/1464420.1464424 Accessed 31 May 2023.
247. Ribeiro Jr JW, Harmon K, Leite GA, de Melo TN, LeBien J, Campos-Cerqueira M 2022, 'Passive acoustic monitoring as a tool to investigate the spatial distribution of invasive alien species', *Remote Sensing*, 14(18), p. 4565, https://www.mdpi.com/2072-4292/14/18/4565 Accessed 31 May 2023.
248. Ade C, Khanna S, Lay M, Ustin SL, Hestir EL 2022, 'Genus-level mapping of invasive floating aquatic vegetation using Sentinel-2 satellite remote sensing', *Remote Sensing*, 14(13), p. 3013, https://www.mdpi.com/2072-4292/14/13/3013 Accessed 8 June 2023.

aquatic studies as in terrestrial investigations, but can provide efficient, accurate and large-scale monitoring.[249] It is complicated by the water column, but this can be largely addressed using modelling. Visible and (sometimes) near-infrared (IR) spectra are most suitable because water absorbs most IR energy, and ultraviolet (UV) signals are often weak. Depth and turbidity obscure the measured reflectance of underwater plants and reduce the accuracy. High spatial, spectral, radiometric (i.e. elements used to encode pixels) and temporal resolutions are critical for accurate results. Using RS to map extent can produce results with overall classification accuracy of up to 99%, but technologies for more complex questions (such as those relating to species identification) are still emerging. Technological innovations like Portable Remote Imaging Spectrometer (PRISM; an airborne sensor specifically designed to address the challenges of coastal ocean RS), Canadian WaterSat Imaging Spectrometer Experiment (WISE; for a near-UV-visible–near-IR hyperspectral microsatellite mission) and MiDAR (NASA real-time multispectral video sensor for aquatic observation) are producing raw data that are more appropriate to aquatic applications than traditional sensors.[250, 251, 252] The planned AquaWatch hyperspectral imagery is in this category and will assist this indicator.

RS in invasive species research is becoming more prevalent every year and is often used in combination with ground surveys to map distribution for invasive terrestrial plant species. Mapping the presence of plants and animals using RS can be done with optical imagery when a species has distinguishing physical characteristics. NASA used RS NDVI to map the presence of a riverbank tree species with unique needle-like leaves and pink flowers.[253] Environmental parameters such as slope, proximity to water, temperature, and precipitation data can then be used to predict its potential spread. A general workflow for detecting invasive plant species across terrestrial, riparian, aquatic, and human-modified ecosystems using RS has been published, which separates detection methods by biome, and splits them into more specific ecosystems and case studies.[254] Promising developments for invasive plant species mapping and monitoring by RS include the upcoming NASA Surface Biology and Geology global mapping hyperspectral satellite, the European Space Agency's Copernicus Hyperspectral Imaging Mission for the Environment and the increased use of RPV hyperspectral imagery.[255, 256]

ML can also be used for invasive terrestrial plant species. A CISS WeedScan project (of which DEECA is a partner) is underway to develop, trial and implement Australia's first real-time, AI-based, automated identification of national, state and regional priority weeds from smartphone photos.[257] A prototype website has been developed by New South Wales Department of Primary Industries, with a full version of the WeedScan website and smartphone app to be launched in 2023.[258] The app can be used by both professionals and citizen scientists. The Western Australian Government Department of Primary Industries and Regional Development is using RPV and AI to detect and map individual skeleton weed plants in a paddock (these are agricultural weeds, but the technology could be transferrable).[259]

Australian company Ninox Robotics produces distribution maps of animals (invasive terrestrial herbivores and invasive terrestrial predators such as wild dogs, pigs and rabbits) and invasive terrestrial plant species using RPVs. These have

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249. Rowan GSL, Kalacska M 2021, 'A review of remote sensing of submerged aquatic vegetation for non-specialists', *Remote Sensing*, 13(4), p. 623, https://www.mdpi.com/2072-4292/13/4/623 Accessed 31 May 2023.
250. Mouroulis P, Van Gorp B, Green RO, Dierssen H, Wilson DW, Eastwood M, Boardman J, Gao BC, Cohen D, Franklin B, Loya F et al. 2014, 'Portable Remote Imaging Spectrometer coastal ocean sensor: design, characteristics, and first flight results', *Applied Optics*, 53(7), pp. 1363-1380, https://opg.optica.org/viewmedia.cfm?r=1&rwjcode=ao&uri=ao-53-7-1363&seq=0&html=true Accessed 31 May 2023.
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252. National Aeronautics and Space Administration (NASA), 'MiDAR – Active multispectral imaging', https://www.nasa.gov/ames/las/midar Accessed 31 May 2023.
253. Cassidy M 2020. 'Sensing invasive species from space', https://www.earthdata.nasa.gov/learn/articles/sensing-invasive-species Accessed 3 July 2023.
254. Bolch EA, Santos MJ, Ade C, Khanna S, Basinger NT, Reader MO, Hestir EL 2020, 'Remote detection of invasive alien species', *Remote Sensing of Plant Biodiversity*, pp. 267-307, https://link.springer.com/chapter/10.1007/978-3-030-33157-3_12#citeas Accessed 31 May 2023.
255. National Aeronautics and Space Administration (NASA), 'Surface biology and geology (SBG)', https://science.nasa.gov/earth-science/decadal-sbg Accessed 31 May 2023.
256. European Space Agency (ESA), 'Chime (Copernicus Hyperspectral Imaging Mission for the Environment)', https://www.eoportal.org/satellite-missions/chime-copernicus#mission-capabilities Accessed 31 May 2023.
257. Centre for Invasive Species Solutions (CISS), 'Computer Vision Weeds ID App and WeedScan community management and communication system', https://invasives.com.au/research/computer-vision-weeds-id-app-and-weedscan-community-management-and-communication-system Accessed 31 May 2023.
258. Centre for Invasive Species Solutions (CISS), 'WeedScan: Record priority weeds in your local area to protect the environment, farms and communities', https://test.weedscan.org.au Accessed 8 June 2023.
259. Department of Primary Industries and Regional Development 2019, 'Skeleton weed under drone spotlight', https://www.agric.wa.gov.au/news/media-releases/skeleton-weed-under-drone-spotlight Accessed 31 May 2023.

advanced real-time optical and thermal imaging capabilities and can be used over large areas and difficult terrain.[260] As well as helping to detect invasive terrestrial plant species, RPV can be used to eliminate them. Although more common in agriculture, this is starting to be applied to the areas of infrastructure and in biodiversity. Taz Drones is Tasmania's first licensed RPV weed sprayer.[261] It assesses problem areas using RPV photography survey, develops tailored action plans and uses targeted RPV spot-spraying to eliminate weeds. Taz Drones services weed management projects including those of local city councils, landholders, agriculture industries and land-care organisations. In 2023, the New South Wales Government will be deploying RPV to detect and spray weeds across councils in the Central West.

Queensland University of Technology uses COTSbot and RangerBot underwater RPV robots (with AI/ML) to help control marine pests such as the crown-of-thorns starfish (COTS). COTSbot integrates robotic vision and ML classification algorithms for real-time and on-board automated image-based detection of COTS, autonomous injection of bile salts into detected COTS, and autonomous navigation within shallow coral reefs.[262] RangerBot is the next generation of COTSbot. This type of underwater RPV robot could be used to monitor invasive freshwater predator species, trends in carp or potentially even invasive freshwater plant species.

From 2016 to 2019, the University of Sydney built the Robot for Intelligent Perception and Precision Application (RIPPA), an autonomous terrestrial robot, for vegetable farming. It has demonstrated RIPPA's capability for real-time detection of weeds among crops and real-time weeding using mechanical prongs, as well as directed spraying technologies that minimise chemicals.[263] Although this and other examples have been used in agriculture, there is potential for environmental weeding in relation to the invasive terrestrial plant species indicator. Taking RPV robots a step further, Charles Stark Draper Laboratory's DragonflEye project in the US has developed an insect backpack, with integrated energy, guidance and navigation systems, which effectively turns dragonflies into 'cyborg drones'.[264] Micro/nano-RPV technology has been developed for defence but could play an important role in invasive species monitoring over a longer duration.

eDNA methods combined with citizen scientist or RPV collection could be applied to invasive freshwater predator species and trends in carp. An eDNA method has been developed to monitor the simultaneous presence of invasive brown trout and two endangered galaxiids in 19 rivers and ponds across the Falkland Islands.[265] A National Environmental Science Program project in northern Australia developed eDNA methods for selected key exotic species (cane toads, cabomba, spotted tilapia, Mozambique tilapia, snakehead fish, yellow crazy ants) and threatened species (largetooth sawfish, three turtle species, three rainforest frog species) and trialled simplified field methods for eDNA sampling in remote locations so samples can be collected by Indigenous rangers and citizen scientists.[266] Species-specific eDNA testing has been used to detect invasive European carp in two lakes in Tasmania.[267] CISS was involved in the Tasmanian carp project and stated, 'eDNA surveys can be a useful tool for detecting remnant individuals following eradication programmes and a cost-efficient means of monitoring where positive detections are likely to be a rare occurrence'. CISS is now developing rapid eDNA detection tools using real-time technology for in-situ application for red-eared slider turtles and Asian black-spined toads.[268] The Great Barrier Reef Foundation is using eDNA and AI for biosecurity surveillance of invasive ants and rats on reef islands.[269] eBioAtlas is collecting species data and creating a global database for eDNA-

260. Ninox Robotics, 'Map animal and weed populations over vast areas', https://ninox-robotics.com/services/biosecurity-conservation Accessed 31 May 2021.
261. Taz Drone Solutions, 'Drone weed-management', https://www.tazdronesolutions.com/weed-management Accessed 31 May 2023.
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263. AUSVEG, 'Advancing robotics in the Australian vegetable industry', https://ausveg.com.au/articles/advancing-robotics-in-the-australian-vegetable-industry Accessed 31 May 2023.
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269. Great Barrier Reef Foundation (GBRF) 2022, 'Drones, AI and e-DNA keeping tabs on Great Barrier Reef and animal health', https://www.barrierreef.org/news/news/drones-ai-and-edna-keeping-tabs-on-great-barrier-reef-and-animal-health Accessed 31 May 2023.

based biodiversity data. The database will be freely available to non-commercial users.[270]

The Australian Wild Dog Alert system uses AI and IoT with camera-trap images for automated species recognition with real-time messaging for invasive terrestrial predator management.[271] In work funded by the Wild Dog Alert research initiative and delivered through CISS, the University of New England and New South Wales Department of Primary Industries developed an ML software tool called ClassifyMe, which filters camera-trap images for those containing animals, removes images with none, and then uses ML automation to identify species in images, with a particular focus on Australasian species.[272] It is designed for field researchers without programming skills, allowing them to check through camera-trap images using field computers instead of office-based, high-speed-processor computers. Model coverage is currently supported for northern New South Wales, New Zealand and Tanzania (Serengeti), with models under development for North America and Bhutan; a model would need to be developed for Victoria. Model performance has been evaluated and accuracy is 90% to 95% across all models.

CISS has a number of AI/ML projects underway for invasive terrestrial herbivores and invasive terrestrial predators, including developing automated AI/ML models to help analyse thermal imagery for pest-animal species such as pigs, rabbits and deer, and developing and demonstrating a cost-effective remote acoustic surveillance, detection and reporting solution integrated with Western Australia's starling control program, as well as for other high-priority invasive pest animals.

RS for invasive terrestrial herbivores and invasive terrestrial predators generally requires indirect approaches to estimate abundance, by identifying an animal's influence on the reflective properties of the dominant plants in an area. For example, in 2013, invasive spotted deer and elephants in the Andaman Islands were detected via MODIS NDVI identification of vegetation degradation as the animals moved across the regions.[273] Direct RS from satellite, aircraft and RPV has been the subject of a review.[274] It has only been used to detect very large animals (>0.6 m), for example using very-high-resolution (31-124 cm) satellite imagery and ML to detect and count African elephants.[275] Aerial RS can acquire higher resolution imagery but it is more costly, and noise can disturb animals. RPV, as discussed earlier in this section for Ninox Robotics, can produce distribution maps of animals using optical and thermal imagery. Thermal imaging from space has been too coarse to detect animals, with resolutions greater than 100 m. In 2023, the UK's Satellite Vu plans to launch a constellation of thermal imaging satellites, with a resolution of 3.5 m, in collaboration with SpaceX. However, this is likely to be too coarse for animal detection from space, except for perhaps a single large animal or herd of animals.[276] Fusion of fine-spatial-resolution RPV data, broad spatial coverage, very-high-resolution satellite imagery and high-temporal-resolution animal GPS tracking data may provide critical data in monitoring wild animals over large areas.

Indirect approaches, such as generating species habitat data, are also required to predict species distribution. DEECA already produces HDMs. Development of terrestrial species habitat data could leverage recent datasets and tools like NASA's Soil Moisture Active Passive high-resolution (3 km and 9 km) soil moisture data and DEA products for land cover, fractional cover, water and coastal environments.[277, 278]

CSIRO Vertebrate Pest Detect-and-Deter virtual fencing technology (smart sensors) has been trialled in Australia to help primary industries facing problems with a range of animals, including ducks, cockatoos, rabbits, feral pigs, wallabies, foxes and dingoes (invasive terrestrial herbivores and invasive

270. eBioAtlas, 'In the midst of mass extinction, we still don't know what lives where', https://ebioatlas.org Accessed 31 May 2023.
271. Centre for Invasive Species Solutions (CISS), 'Wild dog alert', https://invasives.com.au/research/wild-dog-alert Accessed 31 May 2023.
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275. Duporge I, Isupova O, Reece S, Macdonald DW, Wang T 2020, 'Using very-high-resolution satellite imagery and deep learning to detect and count African elephants in heterogeneous landscapes', *Remote Sensing in Ecology and Conservation*, 7(3), pp. 369-381, https://zslpublications.onlinelibrary.wiley.com/doi/10.1002/rse2.195 Accessed 31 May 2023.
276. Satellite Vu, 'The world's thermometer', https://www.satellitevu.com Accessed 31 May 2023.
277. Jet Propulsion Laboratory, California Institute of Technology, 'SMAP: Soil moisture active passive', https://smap.jpl.nasa.gov Accessed 31 May 2023.
278. Australian Government Geoscience Australia, Digital Earth Australia, 'Land and vegetation', https://www.dea.ga.gov.au/land-and-vegetation Accessed 31 May 2023.

terrestrial predators).[279] It consists of two systems: a motion sensor and a group of cameras that can detect images and heat signatures of an animal, with lights and sounds functioning as deterrents for pests. CSIRO is part of a consortium developing GPS tracking ear tags combined with ML and analytics software to help Traditional Owners manage buffalo and cattle (invasive terrestrial herbivores) across the Northern Territory.[280] Better management will reduce grazing pressure and improve water quality to help biodiversity. CSIRO is also working with commercial agtech partner Ceres Tag to develop smart ear tags for livestock.[281]

Ecosystem health

EO data can be used in monitoring groundwater-dependent ecosystems (GDEs) and vegetation, and then combined with models to determine vegetation health and decline over time. In 2020, FrontierSI and Curtin University developed EO-based, groundwater-dependent vegetation likelihood models and a toolkit for mining companies in Western Australia to use for mine dewatering purposes.[282, 283] Opportunities exist for the increased use of ML approaches to detect and characterise GDEs from EO data, such as processes developed by the Northern Territory Government.[284] Existing datasets could also help identify and characterise GDEs for subsequent biodiversity indicator analysis. A significant data resource is the Bureau of Meteorology's (BOM's) national Groundwater Dependent Ecosystems Atlas, which enables visualisation, analyses and download of GDE information for aquatic, terrestrial and subterranean ecosystems.[285] A Department of Primary Industries Victoria project produced a series of Potential Groundwater Dependent Ecosystem Mapping datasets in 2011-12 that are accessible from DataShare.[286] A GDE species-tolerance grid based on 2012 modelling is also available.[287]

RS from Sentinel-2 satellite imagery (20 m resolution) and ML were used to determine land-use intensity of German grasslands. The key parameters determined were mowing frequency; grazing intensity of cattle, horses, sheep and goats; and fertilisation.[288, 289] These were combined to derive an index indicating management intensity of a grassland area ranging from 'extensive' to 'intensive'. An online map of the results showed the number of mowing events, grazing intensity, the use of fertiliser and the degree of land use for 2017 and 2018.[290] A comprehensive 2022 review of RS for grassland monitoring discusses several analytical techniques, identifying the advantages of ML and deep learning techniques over simple regression models.[291] While not focused on native grasslands, the review discusses monitoring for different applications, such as degradation, grazing and drought, and carbon-cycle monitoring techniques and shortcomings. Research in Ireland has further addressed the use of ML and deep learning techniques to auto-classify, map and qualify the condition of open grasslands from in-situ imagery, and multispectral and Synthetic Aperture Radar (SAR) imagery.[292] Using ML combined with RS and observational data (e.g. field surveys, camera traps), up-to-date grassland maps with bioindicator status could be produced and potentially incorporated into Vicmap Vegetation

279. Commonwealth Scientific and Industrial Research Organisation (CSIRO) 2017, 'Keeping pests at bay the hi-tech way', https://www.csiro.au/en/news/All/News/2017/August/Keeping-pests-at-bay-the-hi-tech-way Accessed 31 May 2023.
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285. Bureau of Meteorology (BOM), 'Groundwater dependent ecosystems atlas', http://www.bom.gov.au/water/groundwater/gde/map.shtml Accessed 31 May 2023.
286. Department of Energy, Environment and Climate Action (DEECA), 'DataShare – Search', https://datashare.maps.vic.gov.au/search?md=81726131-7c8d-52b9-a243-d6a8429966e2 Accessed 30 May 2023.
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as another dataset.[293] Some existing datasets such as Victoria's Land Cover Time series dataset have a category for native pasture and grassland.[294] Other fragmented Victorian grasslands data resources are available, such as the Grassy Plains Network map, Victorian National Parks Association grassland maps and the website and app Grasslands: Biodiversity of South-Eastern Australia.[295, 296, 297] The New South Wales Government incorporates grassland extent (but not bioindicator data) into its Trees Near Me app.[298]

Alpine ecosystems exist in Victoria's alpine or high-country areas. These diverse ecosystems include bog, moss and fern-populated areas, grasslands, heathlands and forests of distinct species such as snow gum.[299] This diversity, as well as remoteness and terrain, present distinct monitoring and management challenges. Traditional monitoring has been through on-the-ground vegetation surveys at long-term monitoring sites (1947–2013), with data available from the Long Term Ecological Research Network (LTERN).[300] Alpine ecosystem dataset resources beyond satellite imagery are sparse, with potential for the Vicmap Vegetation Tree Extent to identify tree lines.[301] A subset of LTERN is the Victorian Alpine Plot Network dataset (1940-2018).[302]

For grasslands and GDEs, RS-based ML analysis using vegetation indices can be used to characterise and categorise the diverse alpine ecosystems. Optical and non-optical RS (e.g. SAR and LiDAR) combined with ML have been proven to help identify the impact of feral horse grazing, monitor snowline changes over time, and determine fire hazards (i.e. fuel loads), impacts and recovery.[303, 304, 305, 306, 307]

RPVs have an increasing role in characterisation, monitoring and management for alpine areas, such as to characterise alpine peatlands, and to monitor stream bank impacts of feral horses in Kosciuszko National Park.[308, 309] As alpine ecosystems are particularly climate sensitive, predictive models have been developed to explore the impact of climate change on ecosystem characteristics, including fire regimes and species distributions.[310]

Analysis of RS satellite imagery is used to identify woody foliage, estimate understorey biomass and identify fire impacts on vegetation for mallee ecosystems.[311, 312, 313] Techniques used to monitor bioindicator species include aerial LiDAR identification of malleefowl breeding mounds, and linking vegetation productivity indices and malleefowl breeding activity.[314, 315]

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Fixed-site sensor technology such as phenocam imaging has been used to identify vegetation structure and condition in South Australia.[316] Camera traps used to monitor malleefowl sites also produce predator and other species data, which is manually sorted and classified by volunteers.[317]

There is overlap between mallee and GDEs, with the existing datasets GDE mapping of the Victorian Mallee region performed using satellite imagery, geological data and groundwater monitoring sites, and species tolerance modelling grids for GDEs are available for the Mallee region.[318] LTERN provides data for the Mallee Plot Network managed by the University of New South Wales.[319] Visualising Victoria's Biodiversity portal is a visual interface of several datasets including for mallee vegetation and habitat characterisation, and flora and fauna data derived from the Victorian Biodiversity Atlas.[320, 321] A similar visualisation portal is available from NatureKit.[322]

Fire regimes are a key factor in the ecology of heathland ecosystems, because fires add nutrients to soils and promote new growth.[323] RS-based ML analysis using vegetation indices can be used to monitor fuel loads in heathlands.[324] For biodiversity indicators beyond heathland vegetation extent (identified using RS and ML, as discussed for grasslands, alpine and mallee ecosystems), information is sparse. Some research data on heathlands biodiversity (outside of Victoria) are available at the archived LTERN data portal.[325] Aerial imagery combined with analysis and potentially ML has been shown to effectively identify plant disease impacts on heathlands, which can contribute to condition mapping.[326]

Threats and responses

DEECA already produces HDMs using modelling for many species. HDMs could be made for all threatened and invasive species in an automated way that could be repeated for each state of the environment reporting cycle. Each time the modelling is re-run, the most up-to-date data for confirmed species locations and environmental predictors should be used. To determine habitat loss, data for subsequent years could be differenced to find areas that have degraded (and improved) for each species (i.e. change in suitable habitat).

An alternative is CSIRO's recently developed Habitat Condition Assessment System (HCAS), which uses RS, spatial ecological modelling and sparse data from on-ground condition assessments.[327] It describes terrestrial habitat condition for native biodiversity for the assessment period 2001–18, with scores ranging from 0.0 (habitat completely removed) to 1.0 (habitat in reference condition). The HCAS v2.1 national dataset comprises 19 datasets, of which 17 (~250 m raster) cover continental Australia.[328] It has two approaches to assess potential change over recent years based on epochs within the 18-year time series: an estimate of condition change between 2010 and 2015, and one-year epochs to indicate trends in condition over the 18 years of the base model. It is piloting the development of a change-assessment capability for future national SoE and other reporting applications, which could be leveraged for assessment of the habitat loss indicator. The 2021 technical report for HCAS states they have a 'roadmap for future development', and that the 'next step is to clarify the value proposition of the HCAS through consultation with stakeholders', acknowledging that

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319. Long Term Ecological Research Network (LTERN), 'Mallee Plot Network', https://www.ltern.org.au/ltern-plot-networks/mallee Accessed 31 May 2023.
320. Visualising Victoria's Biodiversity (VVB), 'Visualising Victoria's biodiversity', https://www.vvb.org.au/vvb_map.php Accessed 31 May 2023.
321. Department of Environment, Land, Water and Planning (DELWP), 'Victorian biodiversity atlas', http://vba.dse.vic.gov.au/vba/# Accessed 31 May 2023.
322. Department of Energy, Environment and Climate Action (DEECA), 'NatureKit', https://maps2.biodiversity.vic.gov.au/Html5viewer/index.html?viewer=NatureKit Accessed 30 May 2023.
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325. Australian National University, 'Open research library', https://openresearch-repository.anu.edu.au/advanced-search?query=heath&location=1885%2F130861 Accessed 31 May 2023.
326. Hill RJ, Wilson BA, Rookes JE, Cahill DM 2009, 'Use of high resolution digital multi-spectral imagery to assess the distribution of disease caused by *Phytophthora cinnamomi* on heathland at Anglesea, Victoria', *Australasian Plant Pathology*, 38, pp. 110-119, https://link.springer.com/article/10.1071/AP08092 Accessed 31 May 2023.
327. Commonwealth Scientific and Industrial Research Organisation (CSIRO), 'A habitat condition assessment system for Australia', https://research.csiro.au/biodiversity-knowledge/projects/hcas Accessed 31 May 2023.
328. Harwood T, Williams K, Lehmann E, Ware C, Lyon P, Bakar S, Pinner L, Schmidt B, Mokany K, Van Niel T, Richards A, Dickson F, McVicar T, Ferrier S 2022, '9 arcsecond gridded HCAS 2.1 (2001-2018) base model estimation of habitat condition for terrestrial biodiversity, 18-year trend and 2010-2015 epoch change for continental Australia', Commonwealth Scientific and Industrial Research Organisation (CSIRO) Data access portal, https://doi.org/10.25919/nkjf-f088 Accessed 31 May 2023.

the 'first published dataset (HCAS v2.1) will not yet meet all aspirations and requirements' and that the 'follow-on step involves scoping requirements for operationalising HCAS'.[329] Two components need to be considered for operationalising: 'ongoing development of the science and technology within an operational environmental monitoring framework; and providing accessible delivery platforms that present data and visualisation tools for ready access and use by a range of stakeholders'.

The Queensland Statewide Landcover and Trees Study, done in conjunction with the Joint Remote Sensing Research Program, uses satellite imagery to monitor changes in Queensland's woody vegetation.[330] It now employs Sentinel-2 imagery (10 m resolution) for improved annual monitoring and reporting of woody vegetation change due to clearing and regrowth. Vicmap Vegetation produces woody vegetation extent (20 cm resolution) from aerial imagery RS and ML.[331] DEECA intends to produce this data regularly and look at change, which could contribute to the assessment of habitat loss.

Restor is a digital tool to analyse vegetation restoration potential for any area in the world. Users can draw a polygon around a site of interest and get information on, for example, local biodiversity, current and potential soil carbon, land-cover patterns, soil pH and annual rainfall.[332] Restor computes statistics for polygon sites from global modelled raster data. This could be replicated with Australian or Victorian open data such as DEA, the ALA for flora and fauna and CSIRO's Australian Soil Resource Information System, and could help with measurement and reporting of indicators such as habitat loss.[333]

The Australian Conservation Foundation produced a tabular habitat destruction approval dataset in 2022 by compiling 10 years of publicly available information on all Australian Government Environment Protection and Biodiversity Conservation approval decisions to destroy threatened species habitat.[334] The data can be searched, sorted and filtered, for example by species, town, state, or critically endangered species and ecosystems. Users can view key findings, species summaries, and data analysis for charts, and use an interactive case study generator. The data could be spatialised based on town information.

Forests

ML and deep learning combined with RS imagery are increasingly useful for forestry applications, for example understanding area and type of human-induced disturbance caused by grazing. A study focusing on forests and grasslands leveraged a large time series of Landsat images and BEAST (Bayesian Evolutionary Analysis Sampling Trees), an ML method that can identify fine-scale abrupt changes to classify areas where grazing is encroaching on undisturbed forests or areas of native vegetation.[335] In addition to ML and RS, the University of Melbourne's Coupled Model Intercomparison Project (CMIP6) Visualisation Tool includes a suite of 'carbon mass' variables relevant to understanding carbon dioxide emissions associated with grazing and forestry impacts, including carbon mass flux into the atmosphere due to grazing.[336]

ML is being recognised for its ability to discern the degree of disturbance to native forest caused by invasive species. A 2022 Special Issue of the journal Remote Sensing showcased several studies using algorithms to detect invasive species location compared to native vegetation, as well as their environmental impacts and relative abundance.[337]

ML for assessing forest biomass response to climate change and contributions of forest ecosystems to the global greenhouse gas balance is addressing over- and underestimation errors in previous studies. Use of

329. Williams K, Harwood T, Lehmann EA, Ware C, Lyon P, Bakar S, Pinner L, Schmidt RK, Mokany K, Van Niel T, Richards A, et al. 2021, 'Habitat condition assessment system (HCAS version 2.1) Enhanced method for mapping habitat condition and change across Australia', Commonwealth Scientific and Industrial Research Organisation (CSIRO) Research Publications Repository, https://publications.csiro.au/publications/publication/PIcsiro:EP2021-1200 Accessed 31 May 2023.
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331. Department of Energy, Environment and Climate Action (DEECA), 'Vicmap vegetation: Identify woody vegetation areas across Victoria', https://www.land.vic.gov.au/maps-and-spatial/spatial-data/vicmap-catalogue/vicmap-vegetation Accessed 31 May 2023.
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333. Commonwealth Scientific and Industrial Research Organisation (CSIRO), 'Australian Soil Resource Information System (Asris)', http://www.asris.csiro.au/mapping/viewer.htm Accessed 31 May 2023.
334. Australian Conservation Foundation (ACF), 'Habitat destruction approval data', https://www.acf.org.au/habitat-destruction-data-intro Accessed 31 May 2023.
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336. University of Melbourne, 'The world's new climate projections CMIP6 visualisation tool', https://cmip6.science.unimelb.edu.au Accessed 31 May 2023.
337. MDPI, 'Special issue "*Remote sensing of invasive species*"', https://www.mdpi.com/journal/remotesensing/special_issues/invasive_species_rs Accessed 31 May 2023.

ML algorithms on higher-resolution satellite imagery has been shown to overcome errors caused by pixel saturation in lower-resolution imagery, especially when combined with radiometric imagery.[338]

Climate change

Data.vic daily snow depth data for Victorian alpine resorts can be used to validate the results of snow-cover RS. Satellite RS is well suited to the measurement of snow cover because snow's high albedo (ratio of reflected to incoming solar radiation) gives it good contrast with most other natural surfaces, except clouds. Snow has been observed from space optically since 1960, and the US National Oceanic and Atmospheric Administration (NOAA) currently produces daily snow-cover data with the Moderate Resolution Imaging Spectroradiometer (MODIS), accessible through the US National Snow and Ice Data Center.[339, 340] Optical imagery is limited by cloud cover and polar darkness, whereas SAR can sense day and night, in any cloud and weather conditions. A review of SAR for snow cover identified three main SAR-based approaches to map snow cover: detecting wet snow based on SAR backscattering behaviour, a polarimetric SAR (PolSAR) technique, and interferometric SAR (InSAR) techniques.[341] The researchers drew several conclusions, including that ancillary data such as a digital elevation model, land cover and meteorological data are important as additional inputs, and that SAR approaches can complement conventional optical approaches. An Australian study used MODIS to look at the spatial and temporal trends in snow cover, and another used object-based image analysis to determine snow cover in the Snowy Mountains using Landsat imagery.[342, 343] The latter concluded that continuous processing of satellite images using object-based image analysis is effective in obtaining accurate spatio–temporal snow-cover data and that a hybrid ML and object-oriented method could be applied.

US researchers have investigated the use of RS and ML for snow cover to improve mountain snow-cover mapping using very-high-resolution optical satellite images and Random Forest ML models.[344] They used WorldView-2 and WorldView-3 images and concluded that these can complement the existing operational snow data products from Landsat and MODIS to map the evolution of seasonal snow cover.

The University of Melbourne's CMIP6 Visualisation Tool includes temperature (near-surface air and surface) and precipitation variables.[345] The tool allows users to search on several other parameters including CMIP era (5 or 6) and experiment (scenario) (the relevant region encompassing Victoria is AR6 – south Australia). It then produces a graph showing the chosen variable (e.g. temperature) over time from 1850 to 2300. Data can also be downloaded. The World Bank Group presents Australia's projected climate based on CMIP6, including the variables temperature, precipitation and extreme weather (such as number of days with maximum temperature exceeding 40°C).[346] Data can be filtered by variable, time period, scenario and model. A map interface can be used to display seasonal cycle, time series and heat-plot graphs specific to Victoria. Tabulated data for Australia and data can be downloaded. Long-term weather and climate forecasts are available from BOM.[347]

A 2020 article examining CMIP6 for Australia states: 'Projections of Australian temperature and rainfall from the available CMIP6 ensemble broadly agree with those from CMIP5, except for a group of CMIP6 models with higher climate sensitivity and greater warming and increase in some extremes after 2050. CMIP6 rainfall projections are similar to CMIP5, but the ensemble examined has a narrower range of rainfall change in austral summer in Northern Australia and austral winter in Southern Australia.

338. Li Y, Li M, Wang Y 2022, 'Forest aboveground biomass estimation and response to climate change based on remote sensing data', *Sustainability*, 14(21), article no. 14222, https://www.mdpi.com/2071-1050/14/21/14222 Accessed 31 May 2023.
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345. University of Melbourne, 'The world's new climate projections CMIP6 visualisation tool', https://cmip6.science.unimelb.edu.au Accessed 31 May 2023.
346. World Bank Group, 'Climate change knowledge portal: For development practitioners and policy makers', https://climateknowledgeportal.worldbank.org/country/australia/climate-data-projections Accessed 31 May 2023.
347. Bureau of Meteorology (BOM), 'Long range weather and climate', http://www.bom.gov.au/climate/ Accessed 31 May 2023.

Overall, future national projections are likely to be similar to previous versions but perhaps with some areas of improved confidence and clarity'.[348]

AusEnHealth is Australia's first national digital environmental health decision support platform and is currently in the proof-of-concept stage.[349] This open-source resource, designed to enable decisions related to human health and plans for a changing climate, may be applicable to health impacts indicators within the Air theme. It uses a range of spatial and RS datasets and models to produce environment-based health indicators. The Heat Risk Assessment at SA3 and SA2 levels to 2020 includes a Heat Vulnerability Index derived by averaging the spatial rankings of relevant exposure (climate, air quality), sensitivity (demographics, chronic disease) and adaptive capacity (demographics, waterbodies, hospitals, NDVI) subindices. The state or local government area (LGA) level Heat Climate Change Assessment to 2100 shows the forecasted number of 'at risk' heat days during the period.[350] There is potential to integrate data for the occurrence and impacts of extreme weather indicator into this system or spin off a similar decision support system for this and other climate change indicators. It could include development of a new heat-stress impact metric by LGA combining vulnerability, demographics, Socio-Economic Indexes for Areas, age of housing stock, air conditioner presence and heatwave frequency.

Air

The lightpollutionmap.info digital tool uses several EO sources including the Visible Infrared Imaging Radiometer Suite (VIIRS) from NOAA. The global light pollution spatial data are of good quality; however, no one in Victoria or Australia is known to be analysing this data to determine light pollution indicator trends.[351] Summed radiance, radiance per 1000 head of population and mean radiance statistics for Australia from 2012 to 2021 can be obtained from the VIIRS Country statistics page.[352] The Radiance Light Trends page allows users to analyse radiance (VIIRS/Defense Meteorological Satellite Program) changes over time.[353] The Lights layer option includes annual data for 2014 to 2021 and monthly data for 2012 to 2022. Analysis can be performed by selecting a pixel or a polygon area up to 10,000 km^2 for annual or monthly periods for average or summed radiance.

EPA AirWatch is an IoT air-quality monitoring network but it does not measure light pollution.[354] Other than using RS, night-time light pollution can be measured by photometer and digital camera. An automatic network of purpose-built mobile devices, covering the entire city of Toruń, Poland, measured light intensity at night, using Long Range Wide Area Network technologies for IoT data transmission.[355] If a light pollution network of sensors was established in Victoria, such data could feed into an environmental digital twin for Victoria and be analysed with population and development data and linked to metrics on species health.

348. Grose MR, Narsey S, Delage FP, Dowdy AJ, Bador M, Boschat G, Chung C, Kajtar JB, Rauniyar S, Freund MB, Lyu K, et al, 2020, 'Earth's future: Insights from CMIP6 for Australia's future climate', *Advancing Earth and Space Science*, 8(5), e2019EF001469, https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019EF001469 Accessed 31 May 2023.
349. 'AusEnHealth', https://www.ausenhealth.com/home Accessed 31 May 2023.
350. AusEnHealth, 'Heat Climate Change Assessment metadata', https://ausenhealth.s3-ap-southeast-2.amazonaws.com/public/%5bAEHP%5d%20Metadata.pdf Accessed 31 May 2023.
351. 'Lightpollutionmap', https://www.lightpollutionmap.info/#zoom=4.00&lat=45.8720&lon=14.5470&state=eyJiYXNlbWFwIjoiTGF5ZXJCaW5nUm9hZCIsIm92ZXJsYXkiOiJ3YV8yMDE1Iiwib3ZlcmxheWNvbG9yIjpmYWxzZSwib3ZlcmxheW9wYWNpdHkiOjYwLCJmZWF0dXJlc29wYWNpdHkiOjg1fQ== Accessed 31 Map 2023.
352. VIIRS country statistics 'Australia', https://www.lightpollutionmap.info/LP_Stats/country.html?country=Australia&type= Accessed 31 May 2023.
353. 'Radiance light trends', https://lighttrends.lightpollutionmap.info/#zoom=0&lon=0.00000&lat=33.78523 Accessed 31 May 2023.
354. Environment Protection Authority (EPA) Victoria, 'EPA AirWatch', https://www.epa.vic.gov.au/for-community/airwatch?siteId=3a5e1716-5612-4f3e-a3d6-a924c0899804 Accessed 31 May 2023.
355. Karpińska D, Kunz M 2022, 'Device for automatic measurement of light pollution of the night sky', *Scientific Reports*, 12, article no. 16476, https://www.nature.com/articles/s41598-022-20624-7#:~:text=The%20most%20commonly%20used%20methods,world14%2C20%2C22 Accessed 31 May 2023.

There is opportunity to set up a network similar to the US National Ecological Observatory Network (NEON).[356] This continental-scale observation facility is designed to collect long-term, open-access freshwater and terrestrial ecological data to better understand how US ecosystems are changing. NEON collects data and samples using an extensive network of thousands of automated instruments and hundreds of field technicians, as well as through airborne RS. At all field sites, data are collected to characterise the weather and climate, land cover and organisms of the surrounding ecosystem. The automated instruments collect meteorological, soil, phenological, surface water and groundwater data, with a huge number of parameters measured.[357, 358, 359, 360, 361]

TERN has a similar, although less comprehensive, network consisting of Landscape Monitoring sites (three in Victoria), Ecosystem Surveillance sites (about 12 in Victoria) and Ecosystem Processes sites (two in Victoria).[362, 363, 364] Landscape monitoring is done using RS to obtain data on vegetation structure and composition, land cover, bushfire and soil. Ecosystem surveillance is done using field surveys at plots to sample soil and vegetation. Ecosystem processes are more intensive field stations using sensors, field survey and RS for micro-meteorological observations of atmospheric-ecosystem energy, carbon and water exchanges, as well as biological and environmental observations of flora, fauna, microbial biodiversity, soils and hydrology. This could be expanded and IoT enabled for Victoria, and extended to many of the non-biodiversity Air theme indicators.

356. National Ecological Observatory Network (NEON), 'Good science is built on good data', https://www.neonscience.org Accessed 31 May 2023.
357. National Ecological Observatory Network (NEON), 'Meteorology', https://www.neonscience.org/data-collection/meteorology Accessed 31 May 2023.
358. National Ecological Observatory Network (NEON), 'Soil sensors', https://www.neonscience.org/data-collection/soil-sensors Accessed 31 May 2023.
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Abbreviations for Appendix A

ABS .... Australian Bureau of Statistics
ÆKOS .... Australian Ecological Knowledge and Observation System
AI .... artificial intelligence
ALA .... Atlas of Living Australia
ALOS .... Advanced Land Observing Satellite
ARD .... analysis ready data
ARIES .... Artificial Intelligence for Ecosystem Services
BEAST .... Bayesian Evolutionary Analysis Sampling Trees
BOM .... Australian Bureau of Meteorology
CES .... Commissioner for Environmental Sustainability
CHIME .... Copernicus Hyperspectral Imaging Mission for the Environment
CISS .... Centre for Invasive Species Solutions
CMIP6 .... Coupled Model Intercomparison Project Phase 6
COTS .... crown-of-thorns starfish
CSIRO .... Commonwealth Scientific and Industrial Research Organisation
DEA .... Digital Earth Australia
DEECA .... Victorian Department of Energy, Environment and Climate Action
DTP .... Victorian Department of Transport and Planning
DTV .... Digital Twin Victoria
eDNA .... environmental DNA
eDTV .... Environmental Digital Twin Victoria
EO .... Earth observation
ESM .... Ensemble of Small Models
GBIF .... Global Biodiversity Information Facility
GDE .... groundwater-dependant ecosystem
GEO .... Group on Earth Observations
GIS .... geographical information system
GLOW .... Global Wetlands Project (Griffith University QLD)
GNSS .... Global Navigation Satellite System
GPS / GNSS .... Global Positioning System / Global Navigation Satellite System
GWOS .... Global Wetland Observing System
HAPS .... High Altitude Pseudo Satellites
HDM .... habitat distribution model

ICARUS........International Cooperation for Animal Research Using Space

ICESat........Ice, Cloud, and Land Elevation Satellite

IMOS........Integrated Marine Observing System

IMU........inertial measurement unit

InSAR........Interferometric Synthetic aperture Radar

IoT........Internet of Things

IR........infrared

ISC........Index of Stream Condition

JMLRP........Joint Machine Learning Research Program

JRSRP........Joint Remote Sensing Research Program

LGA........local government area

LiDAR........Light Detection and Ranging

LTERN........Long Term Ecological Research Network

LUV........Land Use Victoria

MiDAR........real-time multi-spectral video

ML........machine learning

NASA........United States National Aeronautics and Space Administration

NDVI........Normalized Difference Vegetation Index

NEON........National Ecological Observatory Network

NOAA........United States National Oceanic and Atmospheric Administration

NSMEO........National Space Mission for Earth Observation

ODC........Open Data Cube

PALSAR........Phased Arrayed L-band Synthetic Aperture Radar

PolSAR........Polarimetric Synthetic Aperture Radar

PRISM........Portable Remote Imaging Spectrometer

RFID........United States National Aeronautics and Space Administration

RIPPA........Robot for Intelligent Perception and Precision Application

ROV........remotely operated vehicle

RPV........remotely piloted vehicle

RS........remote sensing

RTK........real-time kinematic positioning

SA2........Statistical Area 2

SAM........species abundance model

SAR........Synthetic Aperture Radar

SBAS........Satellite Based Augmentation System

SDM	species distribution model
SBG	surface biology and technology
SMCE	State of the Marine and Coastal Environment
SNA	specific needs analysis
SoE	State of the Environment
TERN	Terrestrial Ecosystem Research Network
UK	United Kingdom
US	United States
VIIRS	Visible Infrared Imaging Radiometer Suite
WISE	Canadian WaterSat Imaging Spectrometer Experiment

Royal spoonbills and cormorants, Sale Common Nature Conservation Reserve.
Credit: Start Rodney.

Commissioner for Environmental Sustainability Victoria

Appendix B
Progress assessment of selected SDG targets

Victorian State of the Environment 2023 Report

Appendix B. Progress assessment of selected SDG targets

This appendix provides a progress assessment on 76 selected SDG targets.

As explained in the SDG section of Part 2B of this This appendix provides a progress assessment on 76 selected SDG targets.

As explained in the SDG section of Part 2B of this report, the assessments contained here are based on the 139 state of the environment indicators in this report and, where necessary, the 82 indicators in the SCME 2021 Report.

A comprehensiveness assessment has been undertaken for the 76 SDG targets presented here (Phase 2 of the method described in the SDG section), assigning indicators to each target and weighting their influence on assessing the target.

The assessments presented for each target in this appendix are indicative only. The method developed by the Commissioner of codifying a system based on a repeatable baseline of indicators at scale is a critical value-add for understanding Victoria's progress on selected SDG targets; however, doing this effectively would require a commensurate improvement in the evidence base (Recommendation 14 and 15 in this report).

There are also other significant limitations to the analysis presented in this appendix. For instance, investment in supporting Traditional Owners to develop bio-cultural indicators for cultural landscape health and management (Recommendation 1 in this report) would help address the critical gap in traditional knowledge that would improve our understanding of Victoria's progress against many SDG targets that reflect the importance of supporting Traditional Owners' self-determination.

Furthermore, to remain consistent with the international consensus that created the UN SDG framework, the original titles of all the targets have been maintained. Some licence has been used to interpret the scope of these targets in a Victorian context and to emphasise those clauses of the targets' titles that explore Victorian priorities.

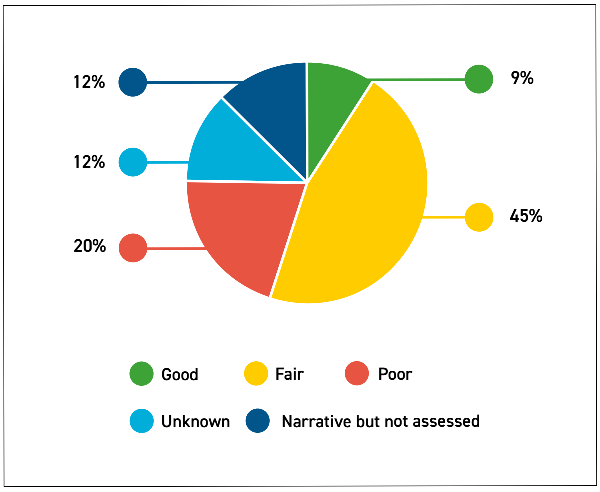

Figure 15: Proportional distribution of status assessments for 76 SDG targets.

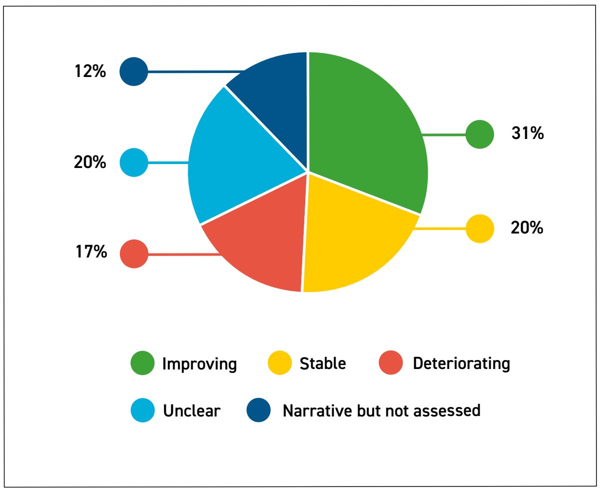

Figure 16: Proportional distribution of trend assessments for 76 SDG targets.

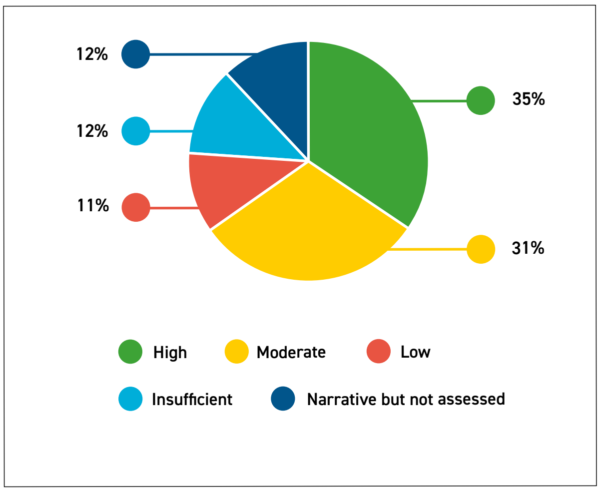

Figure 17: Proportional distribution of data confidence assessments for 76 SDG targets.

Table 6: Overall summary of selected SDG targets assessments.

SDG	SDG target number	Target description	Indicator theme	Aligned SoE/SMCE indicator number	Aligned SoE/SMCE indicator title	Status	Trend	Confidence	Weighting	SDG target status	SDG target trend	SDG target confidence
1 NO POVERTY	1.5	By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters	Climate change impacts	CCIm:10	Occurrence and impacts of extreme weather	Red	↙	Green	40	Red	↙	Green
			Fire	Fi:02	Impacts of bushfires	Red	↙	Green	20			
			Fire	Fi:04	Bushfire risk	Yellow	↙	Green	40			
2 ZERO HUNGER	2.3	By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment	Land	L:01	Land-cover classes in Victoria	N/A	N/A	Grey	10	N/A	?	Grey
			Land	L:02	Changes in Victoria's land-cover classes	Red	?	Green	40			
			Land	L:03	Changes in land tenure	N/A	→	Grey	40			
			Land	L:04	Greenfield and infill development in Melbourne	Yellow	↙	Yellow	10			
	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	Water quality	WQ:08	Proportion of water bodies with good ambient water quality	Yellow	↗	Green	10	Grey	↗	Grey
			Water quality	WQ:09	Groundwater quality	Grey	?	Grey	5			
			Climate change impacts	CCIm:10	Occurrence and impacts of extreme weather	Red	↙	Green	20			
			Land	L:11	Use of best practice for sustainability outcomes on agricultural lands	Grey	↗	Grey	65			
	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 the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed	Biodiversity	B:36	New, permanently protected areas on private land	Grey	?	Grey	20	Grey	?	Grey
			Biodiversity	B:30	Priority pest herbivore control	Grey	?	Grey	20			
			Biodiversity	B:32	Priority pest predator control	Grey	?	Grey	20			
			Biodiversity	B:38	Priority revegetation	Grey	?	Grey	20			
			Biodiversity	B:28	Priority weed control	Grey	?	Grey	20			

SDG	SDG target number	Target description	Indicator theme	Aligned SoE/SMCE indicator number	Aligned SoE/SMCE indicator title	Status	Trend	Confidence	Weighting	SDG target status	SDG target trend	SDG target confidence
2 ZERO HUNGER	2.a	Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity in developing countries, in particular least developed countries	Water resources	WR:03	Surface water harvested for consumptive use	🟡	↙	🟢	10	⚪	↗	⚪
			Water resources	WR:06	Percentage of agricultural land with improved irrigation	⚪	↗	⚪	20			
			Land	L:07	Soil acidification	⚪	?	⚪	10			
			Biodiversity	B:36	New, permanently protected areas on private land	⚪	?	⚪	30			
			Land	L:11	Use of best practice for sustainability outcomes on agricultural lands	⚪	↗	⚪	30			
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	Air	A:11	Health impacts of air pollution	🔴	?	🟢	25	🔴	?	⚪
			Land	L:09	Contaminated sites	🟡	?	🔴	10			
			Fire	Fi:02	Impacts of bushfires	🔴	↙	🟢	25			
			Water quality	WQ:11	Percentage of inland water pollution reports requiring a field response by EPA Victoria	⚪	?	⚪	40			
	3.d	Strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks	Climate change impacts	CCIm:10	Occurrence and impacts of extreme weather	🔴	↙	🟢	100	🔴	↙	🟢
4 QUALITY EDUCATION	4.5	By 2030, eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities, indigenous peoples and children in vulnerable situations	Land	L:10	Participation in natural resource management activities	🟢	↗	🟢	100	🟢	↗	🟢

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4 QUALITY EDUCATION	4.7	By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development	Biodiversity	B:34	Change in suitable habitat for threatened native species	🔴	?	🔴	10	🟡	→	🟢
			Biodiversity	B:36	New, permanently protected areas on private land	⚪	?	⚪	22			
			Biodiversity	B:39	Victorians value nature — Target 1	🟡	→	🟢	30			
			Biodiversity	B:39	Victorians value nature — Target 2	🟢	→	🟢	30			
			Biodiversity	B:28	Priority weed control	⚪	?	⚪	2			
			Biodiversity	B:30	Priority pest herbivore control	⚪	?	⚪	2			
			Biodiversity	B:32	Priority pest predator control	⚪	?	⚪	2			
			Biodiversity	B:38	Priority revegetation	⚪	?	⚪	2			
5 GENDER EQUALITY	5.1	End all forms of discrimination against all women and girls everywhere	Land	L:10	Participation in natural resource management activities	🟢	↗	🟢	100	🟢	↗	🟢
6 CLEAN WATER AND SANITATION	6.1	By 2030, achieve universal and equitable access to safe and affordable drinking water for all	Water quality	WQ:08	Proportion of bodies of water with good ambient water quality — 2 CMAs	🟢	↗	🟢	22	🟡	↗	🟢
			Water quality	WQ:08	Proportion of bodies of water with good ambient water quality — 3 CMAs	🟡	↗	🟢	22			
			Water quality	WQ:08	Proportion of bodies of water with good ambient water quality — 4 CMAs	🔴	↗	🟢	22			
			Water quality	WQ:08	Proportion of bodies of water with good ambient water quality — 1 CMA	⚪	↗	🟢	22			
			Water quality	WQ:09	Groundwater quality	⚪	?	⚪	12			

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6 CLEAN WATER AND SANITATION	6.2	By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations	Water quality	WQ:10	Volume of treated and poorly treated discharges to surface waters and compliance with licence requirements		?		100		?	
	6.3	By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	Water quality	WQ:11	Percentage of inland water pollution reports requiring a field response by EPA Victoria		?		25		↗	
			Water resources	WR:05	Water recycling		↙		50			
			Water quality	WQ:08	Proportion of water bodies with good ambient water quality		↗		20			
			Water quality	WQ:09	Groundwater quality		?		5			
	6.4	By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	Water resources	WR:01	Water resources and storage trends – long-term		↙		15		↙	
			Water resources	WR:01	Water resources and storage trends – short-term		↗		15			
			Water resources	WR:03	Surface water harvested for consumptive use		↙		15			
			Water resources	WR:04	Percentage of compliance with entitlements for the take of surface water		→		15			
			Water resources	WR:05	Water recycling		↙		15			
			Water resources	WR:06	Percentage of agricultural land with improved irrigation		↗		5			
			Water resources	WR:07	Groundwater levels, consumption and use – most shallow aquifers		→		5			
			Water resources	WR:07	Groundwater levels, consumption and use – shallow aquifers in northern region		↙		5			

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6 CLEAN WATER AND SANITATION	6.4	By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	Water resources	WR:07	Groundwater levels, consumption and use — lower aquifers in Gippsland region	🟡	↙	🟢	5	🟡	↙	🟢
			Water resources	WR:07	Groundwater levels, consumption and use — lower aquifers in northern region	🟡	↙	🟢	5			
	6.5	By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate	Water resources	WR:09	Delivering water for the environment	🟡	→	🟡	20	🟡	→	🟢
			Water resources	WR:08	Condition of flow regimes	🔴	→	🟢	10			
			Water resources	WR:01	Water resources and storage trends — long-term	🟡	↙	🟢	15			
			Water resources	WR:01	Water resources and storage trends — short-term	🟡	↗	🟢	15			
			Water resources	WR:03	Surface water harvested for consumptive use	🟡	↙	🟢	10			
			Water resources	WR:04	Percentage of compliance with entitlements for the take of surface water	🟢	→	🟢	10			
			Water resources	WR:07	Groundwater levels, consumption and use — most shallow aquifers	🟡	→	🟢	5			
			Water resources	WR:07	Groundwater levels, consumption and use — shallow aquifers in northern region	🟡	↙	🟢	5			
			Water resources	WR:07	Groundwater levels, consumption and use — lower aquifers in Gippsland region	🟡	↙	🟢	5			
			Water resources	WR:07	Groundwater levels, consumption and use — lower aquifers in northern region	🟡	↙	🟢	5			

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6 CLEAN WATER AND SANITATION	6.6	By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes	Biodiversity	B:02	Wetlands	🔴	↙	🟡	10	🔴	→	🟡
			Biodiversity	B:03	Health and status of Victoria's inland Ramsar wetlands	🟡	↗	🟢	25			
			Biodiversity	B:04	Groundwater-dependent ecosystems	⚪	?	⚪	15			
			Biodiversity	B:05	Rivers	🔴	→	🟡	30			
			Biodiversity	B:06	Riparian vegetation	🔴	→	🟡	20			
	6.a	By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies	Water resources	WR:04	Percentage of compliance with entitlements for the take of surface water	🟢	→	🟢	15	🟡	↙	🟢
			Water resources	WR:05	Water recycling	🟡	↙	🟢	25			
			Water resources	WR:03	Surface water harvested for consumptive use	🟡	↙	🟢	12			
			Water quality	WQ:08	Proportion of bodies of water with good ambient water quality – 2 CMAs	🟢	↗	🟢	12			
			Water quality	WQ:08	Proportion of bodies of water with good ambient water quality – 3 CMAs	🟡	↗	🟢	12			
			Water quality	WQ:08	Proportion of bodies of water with good ambient water quality – 4 CMAs	🔴	↗	🟢	12			
			Water quality	WQ:08	Proportion of bodies of water with good ambient water quality – 1 CMA	⚪	↗	🟢	12			

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6 CLEAN WATER AND SANITATION	6.b	Support and strengthen the participation of local communities in improving water and sanitation management	Biodiversity	B:05	Rivers		→		40		↙	
			Water resources	WR:05	Water recycling		↙		40			
			Water resources	WR:07	Groundwater levels, consumption and use – most shallow aquifers		→		5			
			Water resources	WR:07	Groundwater levels, consumption and use – shallow aquifers in northern region		↙		5			
			Water resources	WR:07	Groundwater levels, consumption and use – lower aquifers in Gippsland region		↙		5			
			Water resources	WR:07	Groundwater levels, consumption and use – lower aquifers in northern region		↙		5			
7 AFFORDABLE AND CLEAN ENERGY	7.1	By 2030, ensure universal access to affordable, reliable and modern energy services	Air	A:06	Population exposure to air pollution – years with significant bushfires		?		15		↗	
			Air	A:06	Population exposure to air pollution – other years		?		15			
			Energy	E:03	Electricity consumption		↗		70			
	7.2	By 2030, increase substantially the share of renewable energy in the global energy mix	Energy	E:02	Primary energy consumption by source		↗		100		↗	
	7.3	By 2030, double the global rate of improvement in energy efficiency	Energy	E:01	Primary energy consumption		↗		100		↗	
	7.a	By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology	Energy	E:01	Primary energy consumption		↗		20		↗	
			Energy	E:02	Primary energy consumption by source		↗		80			

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8 DECENT WORK AND ECONOMIC GROWTH	8.4	Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-Year Framework of Programmes on Sustainable Consumption and Production, with developed countries taking the lead	Climate change impacts	CCM:11	Annual greenhouse gas emissions	🟡	↗	🟢	40	🟡	↗	🟢
			Energy	E:01	Primary energy consumption	🟡	↗	🟢	15			
			Energy	E:02	Primary energy consumption by source	🟡	↗	🟢	15			
			Water resources	WR:03	Surface water harvested for consumptive use	🟡	↙	🟢	30			
	8.9	By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products	Communities	SMCE:64	Recreational boating	🟡	→	🟢	10	🟡	→	🟡
			Communities	SMCE:63	Recreational boating and fishing contribution to the Victorian economy	🟢	↙	🟡	20			
			Communities	SMCE:65	Recreational fishing	🟡	?	🟡	10			
			Communities	SMCE:62	Tourism	🟡	→	🟡	60			
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 well-being, with a focus on affordable and equitable access for all	Climate and climate change impacts	SMCE:51	Climate change impact on marine and coastal infrastructure	🔴	↙	🔴	45	🔴	↙	🔴
			Climate and climate change impacts	SMCE:48	Coastal erosion	🟡	?	🟡	15			
			Stewardship and collaborative management	SMCE:80	Institutional knowledge and capacity	⚪	?	🔴	25			
			Communities	SMCE:66	Shipping and ports	🟢	→	🟡	15			
	9.4	By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities	Climate change impacts	CCM:11	Annual greenhouse gas emissions	🟡	↗	🟢	75	🟡	↗	🟢
			Water resources	WR:05	Water recycling	🟡	↙	🟢	25			

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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 or economic or other status	Communities	SMCE:71	Built and public benefit infrastructure	🟡	→	🟡	10	N	N	N
			Stewardship and collaborative management	SMCE:81	Engagement and inclusiveness	N	N	N	60			
			Stewardship and collaborative management	SMCE:80	Institutional knowledge and capacity	⚪	?	🔴	20			
			Communities	SMCE:62	Tourism	🟡	→	🟡	10			
	10.3	Ensure equal opportunity and reduce inequalities of outcome, including by eliminating discriminatory laws, policies and practices and promoting appropriate legislation, policies and action in this regard	Land	L:10	Participation in natural resource management activities	🟢	↗	🟢	100	🟢	↗	🟢
11 SUSTAINABLE CITIES AND COMMUNITIES	11.3	By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries	Communities	SMCE:59	Coastal settlements	N	N	🟡	10	N	N	N
			Managing coastal hazard risks	SMCE:52	Considering climate change risks in land-use planning	🟡	?	🟡	10			
			Stewardship and collaborative management	SMCE:81	Engagement and inclusiveness	N	N	N	35			
			Communities	SMCE:58	Significant landscape	🟡	→	🟡	10			
			Stewardship and collaborative management	SMCE:78	Planning and implementation	N	N	N	35			

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11 SUSTAINABLE CITIES AND COMMUNITIES	11.4	Strengthen efforts to protect and safeguard the world's cultural and natural heritage	Biodiversity	B:03	Health and status of Victorian inland Ramsar wetlands	Yellow	↗	Green	15	Green	→	Green
			Biodiversity	B:33	Net gain in extent and condition of native vegetation	Red	↙	Green	15			
			Biodiversity	B:36	New, permanently protected areas on private land	Grey	?	Grey	15			
			Biodiversity	B:37	The conservation of Victorian ecosystems on public land	Yellow	→	Green	15			
			Communities	SMCE:60	Cultural heritage	Green	→	Green	40			
	11.5	By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations	Climate change impacts	CCIm:10	Occurrence and impacts of extreme weather	Red	↙	Green	50	Red	↙	Green
			Fire	Fi:02	Impacts of bushfires	Red	↙	Green	50			
	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	Air	A:01	Particle pollution ($PM_{2.5}$ and PM_{10})	Grey	→	Red	25	Yellow	→	Red
			Climate change impacts	CCM:11	Annual greenhouse gas emissions	Yellow	↗	Green	50			
			Waste and resource recovery	W:05	Litter and illegal dumping	Yellow	→	Red	25			

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11 SUSTAINABLE CITIES AND COMMUNITIES	11.7	By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities	Stewardship and collaborative management	SMCE:75	Community connection to the coast	🟢	→	🟢	25	N	N	N
			Stewardship and collaborative management	SMCE:81	Engagement and inclusiveness	N	N	N	40			
			Stewardship and collaborative management	SMCE:78	Planning and implementation	N	N	N	20			
			Communities	SMCE:61	Use of marine and coastal areas	🟢	?	🟡	15			
	11.a	Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning	Climate and climate change impacts	SMCE:45	Areas of coastal vulnerability	N	N	N	20	N	N	N
			Communities	SMCE:59	Coastal settlements	N	N	🟡	20			
			Communities	SMCE:58	Significant landscape	🟡	→	🟡	20			
			Stewardship and collaborative management	SMCE:78	Planning and implementation	N	N	N	40			
	11.b	By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015–2030, holistic disaster risk management at all levels	Climate change impacts	CCIm:10	Occurrence and impacts of extreme weather	🔴	↙	🟢	35	🔴	↙	🟢
			Managing coastal hazard risks	SMCE:52	Considering climate change risks in land-use planning	🟡	?	🟡	35			
			Fire	Fi:02	Impacts of bushfires	🔴	↙	🟢	30			

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12 RESPONSIBLE CONSUMPTION AND PRODUCTION	12.1	Implement the 10-Year Framework of Programmes on Sustainable Consumption and Production Patterns, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries	Waste and resource recovery	W:01	Total waste generation	🔴	↙	🟡	20	🔴	?	🔴
			Waste and resource recovery	W:02	Generation of waste per capita	🟡	?	🔴	20			
			Waste and resource recovery	W:03	Total food waste generation	🔴	?	🔴	20			
			Waste and resource recovery	W:04	Diversion rate	🔴	→	🔴	40			
	12.2	By 2030, achieve the sustainable management and efficient use of natural resources	Biodiversity	B:36	New, permanently protected areas on private land	⚪	?	⚪	20	⚪	↗	🟡
			Land	L:11	Use of best practice for sustainability outcomes on agricultural lands	⚪	↗	⚪	40			
			Forests	Fo:17	Use of best practice for sustainability outcomes on agricultural lands	🟡	↙	🟢	40			
	12.3	By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses	Waste and resource recovery	W:03	Total food waste generation	🔴	?	🔴	100	🔴	?	🔴
	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 minimize their adverse impacts on human health and the environment	Air	A:11	Health impacts of air pollution	🔴	?	🟢	35	⚪	?	⚪
			Land	L:09	Contaminated sites	🟡	?	🔴	15			
			Water quality	WQ:11	Percentage of inland water pollution reports requiring a field response by EPA Victoria	⚪	?	⚪	50			
	12.5	By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse	Waste and resource recovery	W:03	Total food waste generation	🔴	?	🔴	50	🔴	→	🔴
			Waste and resource recovery	W:04	Diversion rate	🔴	→	🔴	50			

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12 RESPONSIBLE CONSUMPTION AND PRODUCTION	12.6	Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle	Climate change impacts	CCM:11	Annual greenhouse gas emissions	🟡	↗	🟢	30	🟡	↗	🟢
			Energy	E:01	Primary energy consumption	🟡	↗	🟢	30			
			Forests	Fo:15	Proportion of timber harvest area successfully regenerated by forest type	🔴	↙	🟡	20			
			Forests	Fo:20	Investment and expenditure in forest management	⚪	?	🔴	20			
	12.7	Promote public procurement practices that are sustainable, in accordance with national policies and priorities	Biodiversity	B:36	New, permanently protected areas on private land	⚪	?	⚪	80	⚪	?	⚪
			Land	L:10	Participation in natural resource management activities	🟢	↗	🟢	20			
	12.8	By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature	Stewardship and collaborative management	SMCE:75	Community connection to the coast	🟢	→	🟢	20	🟢	→	🟡
			Stewardship and collaborative management	SMCE:82	Delivery and accountability	🟢	↗	🟡	40			
			Stewardship and collaborative management	SMCE:80	Institutional capacity and knowledge	⚪	?	🔴	40			
	12.b	Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products	Communities	SMCE:62	Tourism	🟡	→	🟡	70	🟡	→	🟡
			Communities	SMCE:60	Cultural heritage	🟢	→	🟢	30			
	12.c	Rationalize inefficient fossil-fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts, taking fully into account the specific needs and conditions of developing countries and minimizing the possible adverse impacts on their development in a manner that protects the poor and the affected communities	Energy	E:02	Primary energy consumption by source	🟡	↗	🟢	100	🟡	↗	🟢

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13 CLIMATE ACTION	13.1	Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	Climate and climate change impacts	SMCE:45	Areas of coastal vulnerability	N	N	N	40	N	N	N
			Managing coastal hazard risks	SMCE:54	Nature-based adaptation	🔴	?	🟡	20			
			Communities	SMCE:56	Coastal population – resident	N	N	🟢	10			
			Managing coastal hazard risks	SMCE:55	Emergency planning and preparedness	🟢	↗	🟡	20			
			Climate and climate change impacts	SMCE:46	Sea level and coastal inundation	🟡	↙	🟢				
	13.2	Integrate climate change measures into national policies, strategies and planning	Managing coastal hazard risks	SMCE:53	Climate change adaptation plans	🟡	↗	🔴	15	🟡	?	🟡
			Managing coastal hazard risks	SMCE:54	Nature-based adaptation	🔴	?	🟡	30			
			Managing coastal hazard risks	SMCE:52	Considering climate change risks in land-use planning	🟡	?	🟡	30			
			Managing coastal hazard risks	SMCE:55	Emergency planning and preparedness	🟢	↗	🟡	15			
			Stewardship and collaborative management	SMCE:80	Institutional knowledge and capacity	⚪	?	🔴	10			
	13.3	Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning	Managing coastal hazard risks	SMCE:53	Climate change adaptation plans	🟡	↗	🔴	35	🟡	↗	🔴
			Managing coastal hazard risks	SMCE:52	Considering climate change risks in land-use planning	🟡	?	🟡	15			
			Managing coastal hazard risks	SMCE:55	Emergency planning and preparedness	🟢	↗	🟡	15			
			Stewardship and collaborative management	SMCE:80	Institutional knowledge and capacity	⚪	?	🔴	35			
	13.b	Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities	Climate change impacts	CCIm:10	Occurrence and impacts of extreme weather	🔴	↙	🟢	30	🟡	?	🟡
			Managing coastal hazard risks	SMCE:52	Considering climate change risks in land-use planning	🟡	?	🟡	70			

SDG	SDG target number	Target description	Indicator theme	Aligned SoE/SMCE indicator number	Aligned SoE/SMCE indicator title	Status	Trend	Confidence	Weighting	SDG target status	SDG target trend	SDG target confidence
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	Water quality and catchment inputs	SMCE:10	Coastal acid sulfate soils	● (grey)	?	● (grey)	5	● (yellow)	→	● (yellow)
			Litter and pollution	SMCE:13	Coastal contaminated land	● (green)	?	● (red)	5			
			Climate and climate change impacts	SMCE:50	Frequency and impact of fire on marine and coastal ecosystems	● (yellow)	?	● (yellow)	15			
			Water quality and catchment inputs	SMCE:6	Regulated point source discharges to marine waters	● (grey)	?	● (grey)	25			
			Water quality and catchment inputs	SMCE:5	Enterococci bacteria	● (yellow)	→	● (green)	25			
			Water quality and catchment inputs	SMCE:8	Total nutrient loads	● (yellow)	→	● (yellow)	25			
	14.2	By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans	Communities	SMCE:68	Aquaculture	● (yellow)	↗	● (yellow)	10	● (yellow)	?	● (yellow)
			Biodiversity	SMCE:15	Conservation of coastal ecosystems in protected areas	● (yellow)	?	● (red)	30			
			Seafloor integrity and health	SMCE:32	Conservation of marine ecosystems in protected areas	● (yellow)	→	● (yellow)	30			
			Managing coastal hazard risks	SMCE:52	Considering climate change risks in land-use planning	● (yellow)	?	● (yellow)	15			
			Managing coastal hazard risks	SMCE:55	Emergency planning and preparedness	● (green)	↗	● (yellow)	15			

SDG	SDG target number	Target description	Indicator theme	Aligned SoE/SMCE indicator number	Aligned SoE/SMCE indicator title	Status	Trend	Confidence	Weighting	SDG target status	SDG target trend	SDG target confidence
14 LIFE BELOW WATER	14.3	Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels	Climate and climate change impacts	SMCE:44	Ocean acidification	🟡	↙	🟢 (Status) 🔴 (Trend)	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, in order 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	Communities	SMCE:68	Aquaculture	🟡	↗	🟡	20			
			Communities	SMCE:67	Commercial fishing	🟡	→	🟡	40	🟡	→	🟡
			Communities	SMCE:65	Recreational fishing	🟡	?	🟡	40			
	14.5	By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information	Stewardship and collaborative management	SMCE:78	Planning and implementation	N	N	N	100	N	N	N
	14.6	By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation	Communities	SMCE:67	Commercial fishing	🟡	→	🟡	30			
			Stewardship and collaborative management	SMCE:80	Institutional knowledge and capacity	⚪	?	🔴	40	🟡	?	🟡
			Communities	SMCE:65	Recreational fishing	🟡	?	🟡	30			

SDG	SDG target number	Target description	Indicator theme	Aligned SoE/SMCE indicator number	Aligned SoE/SMCE indicator title	Status	Trend	Confidence	Weighting	SDG target status	SDG target trend	SDG target confidence
14 LIFE BELOW WATER	14.7	By 2030, increase the economic benefits to small island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism	Biodiversity	SMCE:24	Commercially and recreationally important fish	🟢	→	🟡	20	🟡	→	🟡
			Communities	SMCE:62	Tourism	🟡	→	🟡	30			
			Communities	SMCE:65	Recreational fishing	🟡	?	🟡	20			
			Communities	SMCE:67	Commercial fishing	🟡	→	🟡	10			
			Communities	SMCE:68	Aquaculture	🟡	↗	🟡	20			
	14.a	Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries	Stewardship and collaborative management	SMCE:74	Stewardship	⚪	?	🟡	10	⚪	?	🔴
			Stewardship and collaborative management	SMCE:77	Citizen science	🟡	↗	🟡	15			
			Stewardship and collaborative management	SMCE:80	Institutional knowledge and capacity	⚪	?	🔴	75			
	14.b	Provide access for small-scale artisanal fishers to marine resources and markets	Cultural landscape health and management	To be developed*	To be developed*	N/A	N/A	N/A	N/A	N/A	N/A	N/A

** 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 targets in this table need to be considered in terms of Victorian Traditional Owner aspirations and recognition (see 'Cultural landscape health and management' in Part 3).*

SDG	SDG target number	Target description	Indicator theme	Aligned SoE/SMCE indicator number	Aligned SoE/SMCE indicator title	Status	Trend	Confidence	Weighting	SDG target status	SDG target trend	SDG target confidence
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	Water resources	WR:08	Condition of flow regimes	●	→	●	10	●	→	●
			Water resources	WR:09	Delivering water for the environment	●	→	●	20			
			Forests	Fo:04	Fragmentation of native forest cover	●	↙	●	15			
			Land	L:06	Area affected by dryland salinity	●	?	●	15			
			Biodiversity	B:02	Wetlands	●	↙	●	10			
			Biodiversity	B:05	Rivers	●	→	●	30			
	15.2	By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally	Climate change impacts	CCM:12	Victorian ecosystem carbon stocks	●	?	●	15	●	↗	●
			Forests	Fo:01B	Area of forest by type and tenure – forest type	●	?	●	10			
			Forests	Fo:08B	Scale and impact of agents and processes affecting forest health and vitality – bushfire affected area and climate	●	↙	●	15			
			Forests	Fo:13	Area of native forest harvested	●	→	●	15			
			Forests	Fo:16	Extent to which the legal framework (laws, regulations, guidelines) supports the conservation and sustainable management of forests	●	↗	●	10			
			Forests	Fo:17	Extent to which the institutional framework supports the conservation and sustainable management of forests	●	↙	●	10			
			Forests	Fo:18	Extent to which the economic framework supports the conservation and sustainable management of forests	●	?	●	10			

SDG	SDG target number	Target description	Indicator theme	Aligned SoE/SMCE indicator number	Aligned SoE/SMCE indicator title	Status	Trend	Confidence	Weighting	SDG target status	SDG target trend	SDG target confidence
15 LIFE ON LAND	15.2	By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally	Forests	Fo:19	Capacity to conduct and apply research and development aimed at improving forest management, including development of scientific understanding of forest ecosystem characteristics and functions	🟢	↗	🟢	15	🟡	↗	🟡
	15.3	By 2020, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world	Biodiversity	B:36	New, permanently protected areas on private land	⚪	?	⚪	5	⚪	?	⚪
			Biodiversity	B:37	The conservation of Victorian ecosystems on public land	🟡	→	🟢	10			
			Fire	Fi:04	Bushfire risk	🟡	↙	🟢	5			
			Land	L:01	Land-cover classes in Victoria	N/A	N/A	⚪	10			
			Land	L:05	Soil organic carbon storage	⚪	?	⚪	10			
			Land	L:06	Area affected by dryland Salinity – Murray River	🟡	↗	🟡	10			
			Land	L:06	Area affected by dryland Salinity – elsewhere	⚪	?	⚪	10			
			Land	L:07	Soil acidification	⚪	?	⚪	20			
			Land	L:08	Soil erosion – wind	🟢	?	🔴	10			
			Land	L:08	Soil erosion – water	🟡	?	🔴	10			

SDG	SDG target number	Target description	Indicator theme	Aligned SoE/SMCE indicator number	Aligned SoE/SMCE indicator title	Status	Trend	Confidence	Weighting	SDG target status	SDG target trend	SDG target confidence
15 LIFE ON LAND	15.4	By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development	Biodiversity	B:36	New, permanently protected areas on private land	⚪	?	⚪	20	🔴	↙	🟢
			Biodiversity	B:37	The conservation of Victorian ecosystems on public land	🟡	→	🟢	20			
			Biodiversity	B:33	Net gain in extent and condition of native vegetati	🔴	↙	🟢	20			
			Biodiversity	B:39	Victorians value nature — Target 1	🟡	→	🟢	10			
			Biodiversity	B:39	Victorians value nature — Target 2	🟢	→	🟢	10			
			Fire	Fi:03	Actual fire regimes compared to optimal fire regimes	🔴	↙	🟡	20			
	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	Biodiversity	B:12	Threatened terrestrial and freshwater mammals	🔴	↙	🟢	10	🔴	↙	🟡
			Biodiversity	B:13	Threatened wetland-dependent species	🔴	↙	🟡	9			
			Biodiversity	B:14	Threatened terrestrial bird species	🔴	↙	🟢	9			
			Biodiversity	B:16	Threatened terrestrial and wetland reptile species	🔴	↙	🟡	9			
			Biodiversity	B:17	Threatened large-bodied freshwater fish species	🔴	↙	🟡	9			
			Biodiversity	B:18	Threatened small-bodied freshwater fish species	🔴	↙	🟡	9			
			Biodiversity	B:19	Threatened frog species	🔴	↙	🟡	9			
			Biodiversity	B:20	Threatened freshwater invertebrate species	🔴	↙	🔴	9			
			Biodiversity	B:21	Threatened terrestrial invertebrate species	🔴	↙	🔴	9			
			Biodiversity	B:22	Threatened terrestrial vascular plant species	🔴	↙	🟡	9			
			Biodiversity	B:23	Threatened terrestrial fungi, lichen, moss and liverwort species	🔴	?	🔴	9			

SDG	SDG target number	Target description	Indicator theme	Aligned SoE/SMCE indicator number	Aligned SoE/SMCE indicator title	Status	Trend	Confidence	Weighting	SDG target status	SDG target trend	SDG target confidence
15 LIFE ON LAND	15.6	Promote fair and equitable sharing of the benefits arising from the utilization of genetic resources and promote appropriate access to such resources, as internationally agreed	Biodiversity	B:36	New, permanently protected areas on private land	⚪	?	⚪	10	🔴	?	🔴
			Forests	Fo:05	Number of in-situ and ex-situ conservation efforts for forest-dependent species	🔴	?	🟡	50			
			Biodiversity	B:30	Priority pest herbivore control	⚪	?	⚪	20			
			Biodiversity	B:38	Priority revegetation	⚪	?	⚪	10			
			Biodiversity	B:28	Priority weed control	⚪	?	⚪	10			
	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	SMCE: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	Forests	Fo:07	Degree of disturbance to native forest species caused by invasive species	🟡	?	🟡	10	🔴	↙	🟡
			Biodiversity	B:24	Invasive freshwater plant species	⚪	?	⚪	10			
			Biodiversity	B:25	Invasive freshwater animal species	🔴	↙	🟡	10			
			Biodiversity	B:26	Trend in carp	🔴	↙	🟢	10			
			Biodiversity	B:27	Invasive terrestrial plant species	🔴	↙	🟡	10			
			Biodiversity	B:28	Priority weed control	⚪	?	⚪	10			
			Biodiversity	B:29	Invasive terrestrial herbivore species	🔴	↙	🟡	10			
			Biodiversity	B:30	Priority pest herbivore control	⚪	?	⚪	10			
			Biodiversity	B:31	Invasive terrestrial predator species	🔴	↙	🟡	10			
			Biodiversity	B:32	Priority pest predator control	⚪	?	⚪	10			

SDG	SDG target number	Target description	Indicator theme	Aligned SoE/SMCE indicator number	Aligned SoE/SMCE indicator title	Status	Trend	Confidence	Weighting	SDG target status	SDG target trend	SDG target confidence
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	Communities	SMCE:59	Coastal settlements	N	N	🟡	15	N	N	N
			Managing coastal hazard risks	SMCE:52	Considering climate change risks in land-use planning	🟡	?	🟡	15			
			Communities	SMCE:58	Significant landscapes	🟡	→	🟡	15			
			Stewardship and collaborative management	SMCE:78	Planning and implementation	N	N	N	55			
	15.a	Mobilize and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems	Stewardship and collaborative management	SMCE:80	Institutional knowledge and capacity	⚪	?	🔴	40	🟡	↙	🟡
			Stewardship and collaborative management	SMCE:82	Delivery and accountability	🟢	↗	🟡	30			
			Forests	Fo:20	Investment and expenditure in forest management	🟡	↙	🟢	30			
	15.b	Mobilize significant resources from all sources and at all levels to finance sustainable forest management and provide adequate incentives to developing countries to advance such management, including for conservation and reforestation	Forests	Fo:11	Contribution of forest ecosystems to the global greenhouse gas balance	🟢	↗	🟢	20	🟡	↗	🟢
			Forests	Fo:16	Extent to which the legal framework (laws, regulations, guidelines) supports the conservation and sustainable management of forests	🟡	↗	🟡	50			
			Forests	Fo:19	Capacity to conduct and apply research and development aimed at improving forest management, including development of scientific understanding of forest ecosystem characteristics and functions	🟢	↗	🟢	30			
	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	Communities	SMCE:73	Illegal activities	🟡	→	🟡	100	🟡	→	🟡

SDG	SDG target number	Target description	Indicator theme	Aligned SoE/SMCE indicator number	Aligned SoE/SMCE indicator title	Status	Trend	Confidence	Weighting	SDG target status	SDG target trend	SDG target confidence
16 PEACE, JUSTICE AND STRONG INSTITUTIONS	16.6	Develop effective, accountable and transparent institutions at all levels	Stewardship and collaborative management	SMCE:82	Delivery and accountability		↗		40		↗	
			Stewardship and collaborative management	SMCE:81	Engagement and inclusiveness	N	N	N	30			
			Stewardship and collaborative management	SMCE:80	Institutional knowledge and capacity		?		30			
	16.7	Ensure responsive, inclusive, participatory and representative decision-making at all levels	Stewardship and collaborative management	SMCE:82	Delivery and accountability		↗		40		↗	
			Stewardship and collaborative management	SMCE:81	Engagement and inclusiveness	N	N	N	30			
			Stewardship and collaborative management	SMCE:80	Institutional knowledge and capacity		?		30			
	16.b	Promote and enforce non-discriminatory laws and policies for sustainable development	Managing coastal hazard risks	SMCE:54	Nature-based adaptation		?		15	N	N	N
			Stewardship and collaborative management	SMCE:82	Delivery and accountability		↗		15			
			Stewardship and collaborative management	SMCE:81	Engagement and inclusiveness	N	N	N	55			
			Communities	SMCE:58	Significant landscapes		→		15			

SDG	SDG target number	Target description	Indicator theme	Aligned SoE/SMCE indicator number	Aligned SoE/SMCE indicator title	Status	Trend	Confidence	Weighting	SDG target status	SDG target trend	SDG target confidence
17 PARTNERSHIPS FOR THE GOALS	17.13	Enhance global macroeconomic stability, including through policy coordination and policy coherence	Climate change impacts	CCM:11	Annual greenhouse gas emissions	●	↗	●	45	●	↗	●
			Biodiversity	B:01	Changes in land cover	●	?	●	40			
			Forests	Fo:19	Capacity to conduct and apply research and development aimed at improving forest management, including development of scientific understanding of forest ecosystem characteristics and functions	●	↗	●	15			
	17.14	Enhance policy coherence for sustainable development	Managing coastal hazard risks	SMCE:54	Nature-based adaptation	●	?	●	20	●	↗	●
			Stewardship and collaborative management	SMCE:82	Delivery and accountability	●	↗	●	20			
			Managing coastal hazard risks	SMCE:55	Emergency planning and preparedness	●	↗	●	20			
			Stewardship and collaborative management	SMCE:80	Institutional knowledge and capacity	●	?	●	20			
			Stewardship and collaborative management	SMCE:78	Planning and implementation	N	N	N	20			

SDG	SDG target number	Target description	Indicator theme	Aligned SoE/SMCE indicator number	Aligned SoE/SMCE indicator title	Status	Trend	Confidence	Weighting	SDG target status	SDG target trend	SDG target confidence
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	Stewardship and collaborative management	SMCE:77	Citizen science		↗		10	N	N	N
			Stewardship and collaborative management	SMCE:75	Community connection to the coast		→		20			
			Stewardship and collaborative management	SMCE:82	Delivery and accountability		↗		10			
			Stewardship and collaborative management	SMCE:81	Engagement and inclusiveness	N	N	N	10			
			Stewardship and collaborative management	SMCE:78	Planning and implementation	N	N	N	40			
			Stewardship and collaborative management	SMCE:80	Institutional knowledge and capacity		?		10			

Commissioner *for* Environmental Sustainability Victoria

Appendix C
Comparison of State of the Environment 2018 and 2023 indicator suites

Victorian State of the Environment 2023 Report

Appendix C.
Comparison of State of the Environment 2018 and 2023 indicator suites

The aim of the SoE 2018 indicator suite was to establish a baseline for future reporting of the health of Victoria's environment. The SoE 2018 baseline enables quantitative comparisons on the condition of natural values as well as the efficacy of government- and community-led programs, initiatives and policy. To reflect the emergence and/or strengthening of environmental pressures and challenges, availability of new data, and to align with policy targets, the state of the environment indicator suite has evolved.

The indicator suite assessed in the SoE 2023 Report includes 139 indicators compared to 170 indicators assessed in the SoE 2018 Report (Table 6). There is no Marine and Coastal Environments chapter in this report due to the establishing of a standalone State of the Marine and Coastal Environment Report in the *Marine and Coastal Act 2018*; this accounts for a reduction of 24 indicators from the SoE 2018 indicator suite.

Of the 139 SoE 2023 indicators, 99 have remained unchanged since the SoE 2018 Report, 15 are newly introduced and 25 have been derived from modifications made to SoE 2018 indicator measures. A total of 53 SoE 2018 indicators are not represented in the summary tables in Part 3 of this report. This is because either their measures are no longer directly comparable with SoE 2023 indicators, or they have been superseded by new indicators that enable more targeted assessments to be made. However, they have been largely considered within the indicator narratives (Table 7).

Some indicators have multiple assessments for status, trend and data confidence because assessments were made for several regions in Victoria, or for different environmental conditions (e.g. years with bushfires as distinct from years without bushfires). Thus, the total number of assessments exceeds the number of SoE 2023 indicators.

Table 7: Comparison of indicator assessments between the SoE 2023 and SoE 2018 reports.

Climate change — Impacts

2023 Indicator	Indicator category	2023 status	2023 trend	2023 confidence	2018 Indicator	2018 status	2018 trend	2018 data quality
CCIm:01 Observed surface temperature	Existing[a]	Red	↙	Green	CC:03 Observed surface temperature	Yellow	↙	Green
CCIm:02 Observed average rainfall	Existing	Red	↙	Green	CC:01 Observed average rainfall	Red	↙	Green
CCIm:03 Snow cover	Existing	Yellow (Falls Creek, Mount Buller, Mount Hotham) Red (Mount Baw Baw, Lake Mountain)	→ (Falls Creek, Mount Buller, Mount Hotham) ↙ (Mount Baw Baw, Lake Mountain)	Yellow	CC:02 Snow cover	Yellow	↙	Green
CCIm:04 Sea level and coastal inundation	Existing	Yellow	↙	Green	CC:07 Observed sea level	Yellow	↙	Yellow (at Victorian sites until 1993, because data until 1993 has not been formally standardised) Green (at Victorian sites since 1993)
CCIm:05 Sea-surface temperature	Existing	Red	→	Green	CC:09 Sea-surface temperature	Red	↙	Green
CCIm:06 Projected changes in temperature	Existing	N/A	↙	Green	CC:04 Projected changes in temperature	N/A	↙	Green
CCIm:07 Projected changes to average rainfall	Existing	N/A	↙	Green	CC:05 Projected changes to average rainfall	N/A	↙	Yellow
CCIm:08 Regional climate projections	Existing	N/A	↙	Green	CC:06 Regional climate projections	N/A	↙	Green
CCIm:09 Projected sea level	Existing	N/A	↙	Green	CC:08 Projected sea level	N/A	↙	Green
CCIm:10 Occurrence and impacts of extreme weather	Existing	Red	↙	Green	CC:12 Occurrence and impacts of extreme weather	Red	↙	Green

[a] *The 'existing' indicator category represents indicators whose measures have not been modified since the SoE 2018 Report.*

2023 Indicator	Indicator category	2023 status	2023 trend	2023 confidence	2018 Indicator	2018 status	2018 trend	2018 data quality
Climate change — Mitigation								
CCM:11 Annual greenhouse gas emissions	Existing	🟡	↗	🟢	CC:10 Annual greenhouse gas emissions	🔴	↗	🟢
CCM:12 Victorian ecosystem carbon stocks	Existing	🟡 (land sector) 🔴 (marine and coastal sector)	?	🔴 (land sector) 🟡 (marine and coastal sector)	CC:11 Victorian ecosystem carbon stocks	🟡 (land sector) ⚪ (marine and coastal sector)	→ (land sector) ? (marine and coastal sector)	🟡
CCM:13 Stratospheric ozone	Existing	🟡	→	🟢	A:05 Stratospheric ozone	🟡	→	🟢
Air								
A:01 Particle pollution ($PM_{2.5}$ and PM_{10})	Existing	🟡 (Geelong) 🔴 (Latrobe Valley and Melbourne) ⚪ (elsewhere)	→	🟢 (Geelong, Latrobe Valley and Melbourne) 🔴 (elsewhere)	A:03 Particle pollution ($PM_{2.5}$ and PM_{10})	🟡 (Geelong, Latrobe Valley and Melbourne) 🔴 (Brooklyn) ⚪ (elsewhere)	→	🟡
A:02 Ambient ozone levels	Existing	🟢 (Latrobe Valley) 🟡 (Geelong and Melbourne)	→	🟢	A:01 Ambient ozone levels (summer smog)	🟢	→	🟢
A:03 Carbon monoxide	Modified[b]	🟢	→	🟢	A:02 Carbon monoxide and nitrogen dioxide	🟢	↗	🟢

[b] *The 'modified' indicator category represents indicators whose measures have been modified since the SoE 2018 Report, through the disaggregation of a SoE 2018 indicator to create separate SoE 2023 indicators, the merging of multiple SoE 2018 indicators into a single SoE 2023 indicator, and/or the broadening of the measure of an SoE 2018 indicator.*

Air

2023 Indicator	Indicator category	2023 status	2023 trend	2023 confidence	2018 Indicator	2018 status	2018 trend	2018 data quality
A:04 Nitrogen dioxide	Modified	🟢	↗ (Melbourne) → (Geelong and Latrobe Valley)	🟢	A:02 Carbon monoxide and nitrogen dioxide	🟢	↗	🟢
A:05 Sulfur dioxide	Existing	🟢	→	🟢	A:04 Sulfur dioxide	🟢	→	🟢
A:06 Population exposure to air pollution	New[c]	🔴 (years with significant bushfires) 🟡 (other years)	?	🟢	Not reported on in 2018	Not reported on in 2018	Not reported on in 2018	Not reported on in 2018
A:07 Pollen	New	🔴	↙	🟡	Not reported on in 2018	Not reported on in 2018	Not reported on in 2018	Not reported on in 2018
A:08 Odour	Modified	🟡	→	🟡	A:06 Odour and noise	⚪	↙	🟡
A:09 Noise	Modified	🟡	↙	🟡	A:06 Odour and noise	⚪	↙	🟡
A:10 Light pollution	Existing	⚪	↙	🟡	A:07 Light pollution	⚪	?	🔴
A:11 Health impacts of air pollution	Existing	🔴	?	🟢	A:09 Health impacts of air pollution	🟡	?	🔴
A:12 Health impacts of noise pollution	Existing	🟡 (Melbourne) ⚪ (rest of Victoria)	?	🔴	A:10 Health impacts of noise pollution	🟡 (Melbourne) ⚪ (rest of Victoria)	?	🔴

[c] *The 'new' indicator category represents SoE 2023 indicators which have not been previously assessed in the SoE 2018 Report or have been modified extensively, making comparisons between state of the environment reporting periods inappropriate.*

2023 Indicator	Indicator category	2023 status	2023 trend	2023 confidence	2018 Indicator	2018 status	2018 trend	2018 data quality
Air								
A:13 Indoor air quality	Existing	🟡 (schools and aged care facilities) 🔴 (residential buildings during periods of bushfire smoke) ⚪ (all other scenarios)	?	🟡 (schools and aged care facilities) 🔴 (residential buildings during periods of bushfire smoke and all other scenarios)	A:11 Indoor air quality	⚪	?	🔴
A:14 Health impacts from pollen	New	🟡	?	🟡	Not reported on in 2018	Not reported on in 2018	Not reported on in 2018	Not reported on in 2018
Biodiversity								
B:01 Changes in land cover	Existing	🔴	?	🟢	B:19 Landscape-scale change	🔴	↙	🟡
B:02 Wetlands	Existing	🔴	↙	🟡	B:16 Wetlands extent and condition	⚪	?	🔴
B:03 Health and status of Victorian inland Ramsar wetlands	Modified	🟡	↗	🟢	B:17 Health and status of Ramsar wetlands in Victoria	⚪	?	🔴
B:04 Groundwater -dependent ecosystems	Existing	⚪	?	⚪	WR:10 Groundwater ecosystems	⚪	?	🔴
B:05 Rivers	Existing	🔴	→	🟡	B:09 River health	🔴	→	🟢

Biodiversity

2023 Indicator	Indicator category	2023 status	2023 trend	2023 confidence	2018 Indicator	2018 status	2018 trend	2018 data quality
B:06: Riparian vegetation	Existing		→ (statewide) ↗ (CMA and local reaches level)		B:10 Riparian vegetation habitat extent		?	
B:07 Floodplains	Modified		→		B:11 Area of functional floodplain		?	
B:08 Grasslands	New		↙		Not reported on in 2018	Not reported on in 2018	Not reported on in 2018	Not reported on in 2018
B:09 Alpine	New		↙		Not reported on in 2018	Not reported on in 2018	Not reported on in 2018	Not reported on in 2018
B:10 Mallee	New		→		Not reported on in 2018	Not reported on in 2018	Not reported on in 2018	Not reported on in 2018
B:11 Heathlands	New		→		Not reported on in 2018	Not reported on in 2018	Not reported on in 2018	Not reported on in 2018
B:12 Threatened terrestrial and freshwater mammals	Modified		↙		B:06B: Vertebrates		↙	NC[d]
B:13 Threatened wetland-dependent species	Existing		↙		B:05 Threatened species that are wetland dependent		?	
B:14 Threatened terrestrial bird species	Modified		↙		B:06B: Vertebrates		↙	NC
B:15 Waterbird species in the Murray–Darling Basin	Existing		↙		B:14 Distribution and abundance of waterbirds in the Murray–Darling Basin		↙	
B:16 Threatened terrestrial and wetland reptile species	Modified		↙		B:06B: Vertebrates		↙	NC

[d] *NC indicates that no comparisons between the SoE 2018 and SoE 2023 assessments for the modified SoE 2023 indicator were made as they were considered inappropriate due to the extensive level of variability in the measures and/or data used in the assessments between SoE reports.*

Biodiversity

2023 Indicator	Indicator category	2023 status	2023 trend	2023 confidence	2018 Indicator	2018 status	2018 trend	2018 data quality
B:17 Threatened large-bodied freshwater fish species	Modified		↙		B:13 Distribution and abundance of fish		↙	NC
B:18 Threatened small-bodied freshwater fish species	Modified		↙		B:13 Distribution and abundance of fish		↙	NC
B:19 Threatened frog species	Modified		↙		B:12 Distribution and abundance of frogs		↙	
B:20 Threatened freshwater invertebrate species	New		↙		Not reported on in 2018	Not reported on in 2018	Not reported on in 2018	Not reported on in 2018
B:21 Threatened terrestrial invertebrate species	Existing		↙		B:06C Invertebrates		↙	
B:22 Threatened terrestrial vascular plant species	Existing		↙		B:06A Vascular plants		↙	
B:23 Threatened terrestrial fungi, lichen, moss and liverwort species	New		?		Not reported on in 2018	Not reported on in 2018	Not reported on in 2018	Not reported on in 2018
B:24 Invasive freshwater plant species	Modified		?		B:01 Invasive freshwater plants and animals		?	
B:25 Invasive freshwater animal species	Modified		↙		B:01 Invasive freshwater plants and animals		?	
B:26 Trend in carp	Existing		↙		B:01A Trend in carp (*Cyprinus carpio*) distribution		↙	
B:27 Invasive terrestrial plant species	Existing		↙		B:02 Invasive terrestrial plants		↙	
B:28 Priority weed control	New		?		Not reported on in 2018	Not reported on in 2018	Not reported on in 2018	Not reported on in 2018
B:29 Invasive terrestrial herbivore species	Modified		↙		B:03 Invasive terrestrial animal species		↙	NC

Biodiversity

2023 Indicator	Indicator category	2023 status	2023 trend	2023 confidence	2018 Indicator	2018 status	2018 trend	2018 data quality
B:30 Priority pest herbivore control	New	⚪	?	⚪	Not reported on in 2018	Not reported on in 2018	Not reported on in 2018	Not reported on in 2018
B:31 Invasive terrestrial predator species	Modified	🔴	↙	🟡	B:03 Invasive terrestrial animal species	🔴	↙	NC
B:32 Priority pest predator control	New	⚪	?	⚪	Not reported on in 2018	Not reported on in 2018	Not reported on in 2018	Not reported on in 2018
B:33 Net gain in extent and condition of native vegetation	Existing	🔴	↙	🟢	B:18 Net gain in extent and condition of native vegetation	🔴	↙	🟢
B:34 Change in suitable habitat for threatened native species	Existing	🔴	?	🔴	B:20 Change in suitable habitat	🟡	→	🟢
B:35 Climate-sensitive ecosystems	Existing	⚪	?	⚪	CC13: Extent and condition of key climate-sensitive ecosystems	⚪	?	🟡
B:36 New, permanently protected areas on private land	New	⚪	?	⚪	Not reported on in 2018	Not reported on in 2018	Not reported on in 2018	Not reported on in 2018
B:37 The conservation of Victorian ecosystems on public land	Existing	🟡	→	🟢	B:08 Conservation of Victorian ecosystems	🟡	→	🟢
B:38 Priority revegetation	New	⚪	?	⚪	Not reported on in 2018	Not reported on in 2018	Not reported on in 2018	Not reported on in 2018
B:39 Victorians value nature	Existing	🟡 (Target 1: All Victorians are connected to nature) 🟢 (Target 2: More than five million Victorians acting for nature)	→	🟢	B:22 Victorians value nature	⚪	?	🔴
B:40 Number of Victorian Government organisations that manage environmental assets that contribute to DELWP Standard Output Data	Existing	⚪	?	⚪	B:23 Number of Victorian Government organisations that manage environmental assets that contribute to DELWP Standard Output Data	🔴	?	🔴

Land

2023 Indicator	Indicator category	2023 status	2023 trend	2023 confidence
L:01 Land-cover classes in Victoria	Existing	N/A	N/A	Grey
L:02 Changes in Victoria's land-cover classes	Existing	Red	?	Green
L:03 Changes in land tenure	Existing	N/A	→	Grey
L:04 Greenfield and infill development in Melbourne	Existing	Yellow	↙	Yellow
L:05 Soil organic carbon storage	Existing	Grey	?	Grey
L:06 Area affected by dryland salinity	Existing	Yellow (Murray River catchment) Grey (elsewhere)	↗ (Murray River catchment) ? (elsewhere)	Yellow (Murray River catchment) Grey (elsewhere)
L:07 Soil acidification	Existing	Grey	?	Grey
L:08 Soil erosion	Existing	Green (wind) Yellow (water)	?	Red
L:09 Contaminated sites	Existing	Yellow	?	Red
L:10 Participation in natural resource management activities	Modified	Green	↗	Green
L:11 Use of best practice for sustainability outcomes on agricultural lands	Modified	Grey	↗	Grey

2018 Indicator	2018 status	2018 trend	2018 data quality
L:01 Land-use types in Victoria	Yellow	N/A	Green
L:02 Changes in major land uses in Victoria	N/A	→	Green
L:03 Changes in land tenure	Yellow	→	Green
L:04 Greenfield versus infield development	Yellow	→	Green
L:05 Soil carbon content	Grey	?	Yellow
L:06 Area affected by salinity	Yellow (Murray River catchment) Grey (elsewhere)	↗ (river catchments that drain to the Murray River) ? (elsewhere)	Yellow (Murray River catchment) Red (elsewhere)
L:07 Soil acidification	Grey	?	Yellow
L:08 Soil erosion	Yellow	↙	Red
L:09 Contaminated sites	Grey	?	Yellow
L:11 Participation in natural resource management activities	Green	↗	Green
L:12 Use of best practice on agricultural lands	Grey	?	Red

Forests

2023 Indicator	Indicator category	2023 status	2023 trend	2023 confidence
Fo:01A Area of forest by type and tenure – forest canopy cover	Existing	⚪	?	🔴
Fo:01B Area of forest by type and tenure – forest type	Existing	⚪	?	🔴
Fo:01C Area of forest by type and tenure – plantation forest	Existing	🔴	↙	🟡
Fo:02 Area of forest type by growth stage	Existing	⚪	?	🔴
Fo:03 Area of forest type by growth stage distribution in protected zones	Existing	🟡	↗	🟡
Fo:04 Fragmentation of native forest cover	Existing	🔴	↙	🟡
Fo:05 Number of in-situ and ex-situ conservation efforts for forest-dependent species	Existing	🔴	?	🟡
Fo:06 Status of forest-dependent species at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment	Existing	🔴	↙	🟢
Fo:07 Degree of disturbance to native forest species caused by invasive species	Existing	🟡	?	🟡
Fo:08A Scale and impact of agents and processes affecting forest health and vitality – mortality, dieback, canopy health	Existing	⚪	?	🟡

2018 Indicator	2018 status	2018 trend	2018 data quality
Fo:01A Area of forest by type and tenure – forest canopy cover	⚪	?	🔴
Fo:01B Area of forest by type and tenure – forest type	🟡	↗	🟢
Fo:01C Area of forest by type and tenure – plantation forest	🟡	→	🟢
Fo:02 Area of forest type by growth stage	🟡	↗	🟢
Fo:03 Area of forest type by growth stage distribution in protected zones	🟡	↗	🟡
Fo:04 Fragmentation of native forest cover	🔴	?	🟡
Fo:05 Number of in-situ and ex-situ conservation efforts for forest-dependent species	⚪	?	🔴
Fo6: Status of forest-dependent species at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment	🟡	↙	🟢
Fo:07 Degree of disturbance to native forest species caused by invasive species	🟡	↙	🟢
Fo:08A Scale and impact of agents and processes affecting forest health and vitality – mortality, dieback, canopy health	🟡	?	🟡

Forests

2023 Indicator	Indicator category	2023 status	2023 trend	2023 confidence	2018 Indicator	2018 status	2018 trend	2018 data quality
Fo:08B Scale and impact of agents and processes affecting forest health and vitality – bushfire-affected area and climate	Existing	🔴	↙	🟢	Fo:08B Scale and impact of agents and processes affecting forest health and vitality – bushfire-affected area and climate	🟡	↙	🟢
Fo:09A Area and type of human-induced disturbance – planned burns	Existing	🟡	↙	🟢	Fo:09A Area and type of human-induced disturbance – planned burns	🟡	?	🟢
Fo:09B Area and type of human-induced disturbance – grazing	Existing	⚪	↗	🔴	Fo:09B Area and type of human-induced disturbance – grazing	⚪	→	🔴
Fo:10 Total forest ecosystem biomass and carbon pool by forest type, age class and successional stages	Existing	⚪	?	🔴	Fo:10 Total forest ecosystem biomass and carbon pool by forest type, age class and successional stages	🟡	?	🟡
Fo:11 Contribution of forest ecosystems to the global greenhouse gas balance	Existing	🟢	↗	🟢	Fo:11 Contribution of forest ecosystems to the global greenhouse gas balance	🔴	↗	🟢
Fo:12 Area and percentage of forest and net area of forest available and suitable for wood production	Existing	🟡	↙	🟢	Fo:12 Area and percentage of forest and net area of forest available and suitable for wood production	🔴	↙	🟢
Fo:13 Area of native forest harvested	Existing	🟡	→	🟢	Fo:13 Area of native forest harvested	🟡	→	🟢
Fo:14 Annual production of wood products from state forests compared to sustainable harvest levels	Existing	🟢 (wood products) ⚪ (firewood)	↙ (wood products) ↙ (firewood)	🟢 (wood products) 🟡 (firewood)	Fo:14 Annual production of wood products from state forests compared to sustainable harvest levels	🟡	↙	🟢
Fo:15 Proportion of timber harvest area successfully regenerated by forest type	Existing	🔴	↙	🟡	Fo:15 Proportion of timber harvest area successfully regenerated by forest type	🟡	→	🟢

Forests

2023 Indicator	Indicator category	2023 status	2023 trend	2023 confidence	2018 Indicator	2018 status	2018 trend	2018 data quality
Fo:16 Extent to which the legal framework (laws, regulations, guidelines) supports the conservation and sustainable management of forests	Existing		↗		Fo:16 Extent to which the legal framework (laws, regulations, guidelines) supports the conservation and sustainable management of forests		↗	
Fo:17 Extent to which the institutional framework supports the conservation and sustainable management of forests	Existing		↙		Fo:17 Extent to which the institutional framework supports the conservation and sustainable management of forests		↙	
Fo:18 Extent to which the economic framework supports the conservation and sustainable management of forests	Existing		?		Fo:18 Extent to which the economic framework supports the conservation and sustainable management of forests		?	
Fo:19 Capacity to conduct and apply research and development aimed at improving forest management, including development of scientific understanding of forest ecosystem characteristics and functions	Existing		↗		Fo:19 Capacity to conduct and apply research and development aimed at improving forest management, including development of scientific understanding of forest ecosystem characteristics and functions		→	
Fo:20 Investment and expenditure in forest management	Existing		↙		Fo:20 Investment and expenditure in forest management		→	
Fo:21 Value ($) of forest-derived ecosystem services	Existing		?		Fo:21 Value ($) of forest-derived ecosystem services		?	

2023 Indicator	Indicator category	2023 status	2023 trend	2023 confidence	2018 Indicator	2018 status	2018 trend	2018 data quality
Fire								
Fi:01 Area of native vegetation burnt in planned fires and bushfires	Existing	🔴 (bushfire) 🟡 (planned burn)	↙ (bushfire) → (planned burn)	🟢 (bushfire) 🟢 (planned burn)	Fi:01 Area of native vegetation burnt in planned fires and bushfires	🔴	↙	🟢
Fi:02 Impacts of bushfires	Existing	🔴	↙	🟢	Fi:02 Impacts of bushfires	🔴	?	🔴
Fi:03 Actual fire regimes compared to optimal fire regimes in public forests	Existing	🔴	↙	🟡	Fi:03 Actual fire regimes compared to optimal fire regimes	🟡	↙	🟢
Fi:04 Bushfire risk	Existing	🟡	↙	🟢	Fi:04 Bushfire risk	🟡	↙	🔴
Inland waters — Water quality								
WQ:01 Occurrence of algal blooms	Existing	🟡	↙	🟡	WQ:01 Occurrence of algal blooms	🟡	?	🟡
WQ:02 Dissolved oxygen concentrations in rivers	Existing	🟢	→	🟢	WQ:02 Dissolved oxygen concentration in rivers	🟢	→	🟢
WQ:03 Salinity concentrations in rivers	Existing	🟢 (7 CMAs) 🟡 (2 CMAs) 🔴 (1 CMA)	→	🟢	WQ:03 Salinity concentrations in rivers	🟢 (7 CMAs) 🟡 (2 CMAs) 🔴 (1 CMA)	→	🟢

Inland waters — Water quality

2023 Indicator	Indicator category	2023 status	2023 trend	2023 confidence		2018 Indicator	2018 status	2018 trend	2018 data quality
WQ:04 Total nitrogen concentrations in rivers	Existing	(3-4 CMAs)[e] (3 CMAs) (3-2 CMAs)[e] (Mallee CMA)	↗			WQ:04 Total nitrogen concentrations in rivers	(2 CMAs) (2 CMAs) (5 CMAs) (Mallee CMA)	→	
WQ:05 Total phosphorus concentrations in rivers	Existing	(2-4 CMAs)[e] (4 CMAs) (3-1 CMAs)[e] (Mallee CMA)	↗			WQ:05 Total phosphorus concentration in rivers	(1 CMA) (2 CMAs) (6 CMAs) (Mallee CMA)	→	
WQ:06 Turbidity levels in rivers	Existing	(5-10 CMAs)[e] (5-0 CMAs)[e]	↗			WQ:06 Turbidity levels in rivers	(3 CMAs) (7 CMAs)	↙	
WQ:07 pH levels in rivers	Existing	(10-7 CMAs)[e] (0-2 CMAs)[e] (1 CMA)	↙			WQ:07 pH		→	

[e] *The first figure presented in brackets refers to the number of CMAs whose status was based on 2010–17 data and the second figure presented in brackets refers to the number of CMAs based on 2018-21 data.*

Inland waters — Water quality

2023 Indicator	Indicator category	2023 status	2023 trend	2023 confidence	2018 Indicator	2018 status	2018 trend	2018 data quality
WQ:08 Proportion of water bodies with good ambient water quality	Existing	(2-1 CMAs)[e] (3-8 CMAs)[e] (4-0 CMAs)[e] (Mallee CMA)	↗		WQ:08 Proportion of bodies of water with good ambient water quality		↙	
WQ:09 Groundwater quality	Existing		?		WR:11 Groundwater quality	(eastern Victoria) (north-western Victoria) (elsewhere)	→	
WQ:10 Volume of treated and poorly treated discharges to surface waters and compliance with licence requirements	Modified		?		WQ:09 Volume of sewage discharge to surface waters		?	
WQ:11 Percentage of inland water pollution reports requiring a field response by EPA Victoria	Modified		?		WQ:10 Reported inland water pollution incidents	NC	NC	NC

[e] *The first figure presented in brackets refers to the number of CMAs whose status was based on 2010–17 data and the second figure presented in brackets refers to the number of CMAs based on 2018-21 data.*

Inland waters — Water resources

2023 Indicator	Indicator category	2023 status	2023 trend	2023 confidence	2018 Indicator	2018 status	2018 trend	2018 data quality
WR:01 Water resources and storage trends	Modified	🟡	↙ (long term) ↗ (short term)	🟢	WR:01 Water resources and storage trends	🟡	→	🟢
WR:02 Interception of surface water by small farm dams	Modified	🟡 (southern rivers) ⚪ (northern rivers)	↙	🟡	WR:05 Number of dams, weirs and levees	🟡	?	🟡
WR:03 Surface water harvested for consumptive use	Existing	🟡	↙	🟢	WR:06 Surface water harvested for consumptive use	🔴	→	🟢
WR:04 Percentage of compliance with entitlements for the take of surface water	Modified	🟢	→	🟢	WR:07 Percentage of waterways and groundwater areas subject to extraction, with a limit on extraction	🟢	→	🟢
WR:05 Water recycling	Existing	🟡	↙	🟢	WR:08 Water recycling	🟡	↗	🟢
WR:06 Percentage of agricultural land with improved irrigation	Existing	⚪	↗	⚪	WR:09 Percentage of agricultural land with improved irrigation	⚪	?	🔴

Inland waters — Water resources

2023 Indicator	Indicator category	2023 status	2023 trend	2023 confidence	2018 Indicator	2018 status	2018 trend	2018 data quality
WR:07 Groundwater levels, consumption and use	Modified	🟡	→ (most shallow aquifers) ↙ (shallow aquifers in northern Region; lower aquifers in Gippsland and northern Region)	🟢	WR:13 Groundwater harvested for consumptive use	🟡	→	🟢
WR:08 Condition of flow regimes	Existing	🔴	→	🟢	WR:03 Condition of flow regimes	🔴	↙	🟢
WR:09 Delivering water for the environment	Existing	🟡	→	🟡	WR:04 Delivering water for the environment	🟡	→	🟢

Energy

2023 Indicator	Indicator category	2023 status	2023 trend	2023 confidence	2018 Indicator	2018 status	2018 trend	2018 data quality
E:01 Primary energy consumption	Existing	🟡	↗	🟢	E:02 Total energy consumption by fuel	🔴	→	🟢
E:02 Primary energy consumption by source	Existing	🟡	↗	🟢	E:02 Total energy consumption by fuel	🔴	→	🟢
E:03 Electricity consumption	Existing	🟢	↗	🟢	E:05 Total electricity consumption	🟡	↗	🟢
E:04 Electricity generation by fuel	Existing	🟡	↗	🟢	E:06 Total electricity generation by fuel	🔴	↗	🟢
E:05 Gas consumption	New	🔴	→	🟢	Not reported on in 2018	Not reported on in 2018	Not reported on in 2018	Not reported on in 2018
E:06 Energy in transport	Existing	🔴	↗	🟢	E:08 Energy used in the transport sector	🔴	↙	🟢

Waste and resource recovery

2023 Indicator	Indicator category	2023 status	2023 trend	2023 confidence	2018 Indicator	2018 status	2018 trend	2018 data quality
W:01 Total waste generation	Existing	🔴	↙	🟡	W:01 Total waste generation	🟡	→	🟢
W:02 Generation of waste per capita	Modified	🟡	?	🔴	W:02 Generation of waste per capita	🟡	→	🟢
W:03 Total food waste generation	Existing	🔴	?	🔴	W:03 Total food waste generated	🔴	→	🟢
W:04 Diversion rate	Existing	🔴	→	🔴	W:04 Diversion rate	🟡	→	🟢
W:05 Litter and illegal dumping	Existing	🟡	→	🔴	W:05 Litter and illegal dumping	🟢	↗	🔴
W:06 Total hazardous waste managed	Existing	🔴	↙	🟡	W:06 Total hazardous waste managed	🟡	→	🟡

Table 8: SoE 2018 indicators not represented in the SoE 2023 indicator assessment report cards.

2018 theme	SoE 2018 indicator	Description
Climate change	CC:14 Community awareness of climate risks and associated responsibilities	Superseded by the indicator suite proposed within the new Climate Change Adaptation Framework introduced within this report
	CC:15 Councils (or other organisations) with urban forestry plans or urban greening or cooling-related strategies	Superseded by the indicator suite proposed within the new Climate Change Adaptation Framework introduced within this report
	CC:16 Considering climate change risks in land-use planning (including the coastal zone)	Superseded by the indicator suite proposed within the new Climate Change Adaptation Framework introduced within this report
	CC:17 Percentage of agri-businesses using long-term weather and climate change projections	Superseded by the indicator suite proposed within the new Climate Change Adaptation Framework introduced within this report
Air	A:08 Emissions of major air pollutants by sector	Considered within the overall assessment of individual pollutants within the SoE 2023 indicators A:01 to A:05; however, direct comparisons of the 2018 assessment for A:08 were not made against the 2023 indicator assessments within the summary table
Biodiversity	B:03A Trend in deer populations and their distributions	Merged with the SoE 2018 indicators 'B:03 Invasive terrestrial animal species' and 'B:03B Trend in horse populations and their distributions' to form the modified SoE 2023 indicator 'B:29 Invasive terrestrial herbivore species' Considered within the overall assessment of the modified SoE 2023 indicator 'B:29 Invasive terrestrial herbivore species'; however, direct comparisons of the 2018 assessment for B:03A were not made against the 2023 indicator assessments within the summary table
	B:03B Trend in horse populations and their distributions	Merged with the SoE 2018 indicators 'B:03 Invasive terrestrial animal species' and 'B:03A Trend in deer populations and their distributions' to form the modified SoE indicator 'B:29 Invasive terrestrial herbivore species' Considered within the overall assessment of the modified SoE 2023 indicator 'B:29 Invasive terrestrial herbivore species'; however, direct comparisons of the 2018 assessment for B:03B were not made against the 2023 indicator assessments within the summary table

2018 theme	SoE 2018 indicator	Description
Biodiversity	B:04 Trend in populations and distributions of threatened freshwater species in the wild	Considered within the overall assessment of the SoE 2023 indicators 'B:12 Threatened terrestrial and freshwater mammals', 'B:13 Threatened wetland-dependent species', 'B:16 Threatened terrestrial and wetland reptile species', 'B:17 Threatened large-bodied freshwater fish species', 'B:18 Threatened small-bodied freshwater fish species', 'B:19 Threatened frog species' and 'B:20 Threatened freshwater invertebrate species'; however, direct comparisons of the 2018 assessment for B:04 were not made against the 2023 indicator assessments within the summary table
	B:04A Trend in population number and distribution of trout cod (*Maccullochella macquariensis*)	Merged with the SoE 2018 indicators 'B:04B Trend in population number and distribution of Macquarie perch (*Macquaria australasica*)' and 'B:13 Distribution and abundance of fish' to form the modified SoE 2023 indicator 'B:17 Threatened large-bodied freshwater fish species' Considered within the overall assessment of the modified SoE 2023 indicator 'B:17 Threatened large-bodied freshwater fish species'; however, direct comparisons of the 2018 assessment for B:04A were not made against the 2023 indicator assessments within the summary table
	B:04B Trend in population number and distribution of Macquarie perch (*Macquaria australasica*)	Merged with the SoE 2018 indicators 'B:04A Trend in population number and distribution of trout cod (*Maccullochella macquariensis*)' and 'B:13 Distribution and abundance of fish' to form the modified SoE 2023 indicator 'B:17 Threatened large-bodied freshwater fish species' Considered within the overall assessment of the modified SoE 2023 indicator 'B:17 Threatened large-bodied freshwater fish species'; however, direct comparisons of the 2018 assessment for B:04B were not made against the 2023 indicator assessments within the summary table
	B:04C Trend in population number and distribution of Murray crayfish (*Euastacus armatus*)	Superseded by the new SoE 2023 indicator 'B:20 Threatened freshwater invertebrate species' Considered within the overall assessment of the new SoE 2023 indicator 'B:20 Threatened freshwater invertebrate species'; however, direct comparisons of the 2018 assessment for B:04C were not made against the 2023 indicator assessments within the summary table
	B:04D Trend in population number and distribution of spotted tree frog (*Litoria spenceri*)	Merged with the SoE 2018 indicators 'B:04E Trend in population number and distribution of Booroolong tree frog (*Litoria booroolongensis*)', 'B:04F Trend in population number and distribution of Baw Baw frog *(Philoria frosti)'* and 'B:12 Distribution and abundance of frogs' to form the modified SoE 2023 indicator 'B:19 Threatened frog species' Considered within the overall assessment of the SoE 2023 indicator 'B:19 Threatened frog species'; however, direct comparisons of the 2018 assessment for B:04D were not made against the 2023 indicator assessments within the summary table
	B:04E Trend in population number and distribution of Booroolong tree frog (*Litoria booroolongensis*)	Merged with the SoE 2018 indicators 'B:04D Trend in population number and distribution of spotted tree frog (*Litoria spenceri*)', 'B:04F Trend in population number and distribution of Baw Baw frog (*Philoria frosti*)' and 'B:12 Distribution and abundance of frogs' to form the modified SoE 2023 indicator 'B:19 Threatened frog species' Considered within the overall assessment of the SoE 2023 indicator 'B:19 Threatened frog species'; however, direct comparisons of the 2018 assessment for B:04E were not made against the 2023 indicator assessments within the summary table

2018 theme	SoE 2018 indicator	Description
Biodiversity	B:04F Trend in population number and distribution of Baw Baw frog (*Philoria frosti*)	Merged with the SoE 2018 indicators 'B:04D Trend in population number and distribution of spotted tree frog (*Litoria spenceri*)', 'B:04E Trend in population and distribution of Booroolong tree frog (*Litoria booroolongensis*)' and and 'B:12 Distribution and abundance of frogs' to form the modified SoE 2023 indicator 'B:19 Threatened frog species' Considered within the overall assessment of the SoE 2023 indicator 'B:19 Threatened frog species'; however, direct comparisons of the 2018 assessment for B:04F were not made against the 2023 indicator assessments within the summary table
	B:06 Trends in populations and distributions of threatened terrestrial species	Merged with the SoE 2018 indicator 'B:06B Vertebrates' to form the modified SoE 2023 indicators 'B:12 Threatened terrestrial and freshwater mammals', 'B:14 Threatened terrestrial bird species' and 'B:16 Threatened terrestrial and wetland reptile species' Considered within the overall assessments of the modified SoE 2023 indicators 'B:12 Threatened terrestrial and freshwater mammals', 'B:14 Threatened terrestrial bird species' and 'B:16 Threatened terrestrial and wetland reptile species'; however, direct comparisons of the 2018 assessment for B:06 were not made against the 2023 indicator assessments within the summary table
	B:07 Private land conservation	Merged with the SoE 2018 indicator 'L:10 Land management activities' to form the new SoE 2023 indicator 'B:36 New, permanently protected areas on private land' Considered within the overall assessment of the new SoE 2023 indicator 'B:36 New, permanently protected areas on private land'; however, direct comparisons of the 2018 assessment for B:07 were not made against the 2023 indicator assessments within the summary table
	B:15 Distribution and abundance of macroinvertebrates	Superseded by the new SoE 2023 indicator 'B:20 Threatened freshwater invertebrate species' Considered within the overall assessment of the new SoE 2023 indicator 'B:20 Threatened freshwater invertebrate species'; however, direct comparisons of the 2018 assessment for B:15 were not made against the 2023 indicator assessments within the summary table
	B:21 Area of management in priority locations	Disaggregated to form the new SoE 2023 indicators 'B:28 Priority weed control', 'B:30 Priority pest herbivore control', 'B:32 Priority pest predator control' and 'B:38 Priority revegetation' Considered within the overall assessments of the new SoE 2023 indicators 'B:28 Priority weed control', 'B:30 Priority pest herbivore control', 'B:32 Priority pest predator control' and 'B:38 Priority revegetation'; however, direct comparisons of the 2018 assessment for B:21 were not made against the 2023 indicator assessments within the summary tables
Land	L:10 Land management activities	Merged with SoE 2018 indicator 'B:07 The conservation and management of Victorian ecosystems on private land' to form the new SoE 2023 indicator 'B:36 New, permanently protected areas on private land' Considered within the overall assessment of the new SoE 2023 'B:36 New, permanently protected areas on private land'; however, direct comparisons of the 2018 assessment for L:10 were not made against the 2023 indicator assessments within the summary table
	L:13 Proportion of agricultural area under productive and sustainable agriculture	Merged with the SoE 2018 indicator 'L:12 Use of best practice on agricultural lands' to form the modified SoE 2023 indicator 'L:11 Use of best practice for sustainability outcomes on agricultural land' Considered within the overall assessment of the new SoE 2023 indicator 'L:11 Use of best practice for sustainability outcomes on agricultural lands'; however, direct comparisons of the 2018 assessment for L:13 were not made against the 2023 indicator assessments within the summary table

2018 theme	SoE 2018 indicator	Description
Water resources	WR:02 Projected runoff to dams and catchments	Merged with the SoE 2018 indicator 'WR:01 Water resources and storage trends' to form the modified SoE 2023 indicator 'WR:01 Water resources and storage trends' Considered within the overall assessment of the new SoE 2023 indicator 'WR:01 Water resources and storage trends'; however, direct comparisons of the 2018 assessment for WR:02 were not made against the 2023 indicator assessments within the summary table
	WR:12 Groundwater levels	Merged with the SoE 2018 indicator 'WR:13 Groundwater harvested for consumptive use' to form the modified SoE 2023 indicator 'WR:07 Groundwater levels, consumption and use' Considered within the overall assessment of the new SoE 2023 indicator 'WR:07 Groundwater levels, consumption and use'; however, direct comparisons of the 2018 assessment for WR:12 were not made against the 2023 indicator assessments within the summary table
Energy	E:03 Consumption of renewable energy as a share of total energy consumption	Considered within the overall assessment of the SoE 2023 indicator 'E:02 Primary energy consumption by source'; however, direct comparisons of the 2018 assessment for E:03 were not made against the 2023 indicator assessments within the summary table
	E:04 Total net energy consumption by industry sector	Considered within the overall assessment of the SoE 2023 indicator 'E:02 Primary energy consumption by source'; however, direct comparisons of the 2018 assessment for E:04 were not made against the 2023 indicator assessments within the summary table
	E:07 Share of renewable energy generation of total electricity generation	Considered within the overall assessment of the SoE 2023 indicator 'E:04 Electricity generation by fuel'; however, direct comparisons of the 2018 assessment for E:07 were not made against the 2023 indicator assessments within the summary table
	E:09 Per capita transport energy use	Considered within the overall assessment of the SoE 2023 indicator 'E:05 Gas consumption'; however, direct comparisons of the 2018 assessment for E:09 were not made against the 2023 indicator assessments within the summary table
Transport	T:01 Travel demand	Superseded by the indicator suite proposed within the new Climate Change Adaptation Framework introduced within this report
	T:02 Greenhouse gas emission and emission intensities from transport	Considered within the overall assessment of the SoE 2023 indicator 'CCM:11 Annual greenhouse gas emissions'; however, direct comparisons of the 2018 assessment for T:02 were not made against the 2023 indicator assessments within the summary table
	T:03 Air pollution from transport	Considered within the overall assessment of the SoE 2023 indicators 'A:01 Particle pollution ($PM_{2.5}$ and PM_{10})', 'A:02 Ambient ozone levels', 'A:03 Carbon monoxide', 'A:04 Nitrogen dioxide' and 'A:05 Sulfur dioxide'; however, direct comparisons of the 2018 assessment for T:03 were not made against the 2023 indicator assessments within the summary table
Marine and coastal environments	MC:01–MC:24	Assessed within the State of the Marine and Coastal Environment reporting as per the statutory requirement under the *Marine and Coastal Act 2018*

Commissioner *for* Environmental Sustainability Victoria

Appendix D
Indicator assessment summaries

Victorian State of the Environment 2023 Report

Appendix D. Indicator assessment summaries

This report assesses 139 indicators across 10 chapters, noting that 'Cultural landscape health and management' and 'Climate change adaptation' in the 'Climate Change' chapter do not currently have indicators that are assessed. This appendix comprises report cards summarising the scientific assessments – one report card for each indicator. Full scientific assessments for all indicators are provided in Part 3. Each indicator report card includes the status, trend and data confidence, the source of the data and metrics used for the assessment, criteria when appropriate, the rationale for indicator assessment within the report, and an overall comment on the assessment.

The report cards for some indicators include multiple assessments for status, trend and data confidence. This is because some assessments were made in more than one region in Victoria, or for different environmental conditions (e.g. years with bushfires as distinct from years without bushfires). Thus, the total number of assessments exceeds the number of SoE 2023 indicators.

Where appropriate, the corresponding indicator assessments from the State of the Environment 2018 Report have been included in the report cards.

Cultural landscape health and management

This theme does not include indicators.

Climate change

Climate change impacts

CCIm:01 Observed surface temperature

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	🔴	↙	🟢	🟡	↙	🟢

Data source(s):	BOM
Measure(s):	Victorian annual mean temperature anomaly Victorian annual maximum temperature anomaly Victorian annual minimum temperature anomaly Change in annual mean daily maximum temperatures since the pre-industrial period (1850–1900)

Why this indicator?

The global climate has changed relative to the pre-industrial period, and there are several lines of evidence that these changes have had impacts on organisms and ecosystems, as well as on human systems and wellbeing.

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.

As a global average, human-induced warming reached approximately 1°C above pre-industrial levels in 2017. Warming greater than the global average has already been experienced in many regions and seasons, with higher average warming over land than over the ocean.

NB: This SoE 2023 indicator was 'CC:03 Observed surface temperature' in the SoE 2018 Report.

Why this assessment in 2023?

Victoria's temperature increases identified in the SoE 2018 Report have continued.

Each year since 1997 has been warmer in Victoria than the average for the 1961 to 1990 period. Furthermore, seven years during the past decade (2013–22) have been in the top 10 warmest years on record for Victoria.

Across Victoria, the mean annual temperature has increased by 1.4°C (within a range of 1.0–1.8°C) between the pre-industrial era and the most recent decade (2011–20). In Melbourne, annual average temperatures are approaching a 1.5°C increase from an indicative pre-industrial era temperature. Some years are now more than 1.5°C warmer than the indicative pre-industrial era baseline.

If the recent rate of temperature increase continues at the current trajectory of nearly 0.5°C per decade, temperatures in Melbourne will increase by approximately 2.5°C from pre-industrial levels by 2040.

CCIm:02 Observed average rainfall

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	🔴	↙	🟢	🔴	↙	🟢
Data source(s):	BOM					
Measure(s):	Victorian annual rainfall anomaly Victorian rainfall deciles for the warm and cool seasons					

Why this indicator?

Rainfall strongly influences the agriculture and water resources sectors as it is important for many crops and for replenishing reservoirs. 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.

NB: This SoE 2023 indicator was 'CC:01 Observed average rainfall' in the SoE 2018 Report.

Why this assessment in 2023?

Despite the year-to-year rainfall variability, below-average rainfall has been recorded most years since the late 1990s, which highlights an emerging drying trend. This has been influenced by declining cool-season rainfall. Above-average rainfall (relative to the period 1961–1990) has only been recorded for six of the past 25 years in Victoria.

CCIm:03 Snow cover

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Victoria's alpine region	🟡 (Falls Creek, Mount Buller, Mount Hotham) 🔴 (Mount Baw Baw, Lake Mountain)	→ (Falls Creek, Mount Buller, Mount Hotham) ↙ (Mount Baw Baw, Lake Mountain)	🟡	🟡	↙	🟢
Data source(s):	Academic researchers, DELWP					
Measure(s):	Average natural snow depths at Victorian alpine resorts					

Why this indicator?

Snow cover in alpine areas is critical to Victoria's highland ecosystem resilience, water supply and recreation. It is also an important indicator of climate change.

NB: This SoE 2023 indicator was 'CC:02 Snow cover' in the SoE 2018 Report.

Why this assessment in 2023?

Natural snow depths in July and August have been generally stable at the higher-altitude resorts of Falls Creek, Mount Buller and Mount Hotham. Results at these locations for July and August 2011 to 2020 are within 10% of the depths for 1993 to 2002, with slight increases in natural snow depth measured at Falls Creek and Mount Buller.

For the lower altitude alpine resort locations (Lake Mountain and Mount Baw Baw), the observations show a gradual, but steady, deterioration in natural snow depth.

CCIm:04 Sea level and coastal inundation

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Victoria's coastline						(Victorian sites until 1993)* (Victorian sites since 1993)
Data source(s):	BOM					
Measure(s):	Annual mean sea level Annual maximum sea levels					

Why this indicator?

Sea-level rise is one of the biggest threats associated with climate change to marine and coastal environments. 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
- coastal erosion.

NB: This SoE 2023 was 'CC:07 Observed sea level' in the SoE 2018 Report.

Why this assessment in 2023?

The status and trend assessments of fair and deteriorating, respectively, reflect the gradual but consistently increasing mean and maximum sea levels that are exerting pressure on human coastal settlements and infrastructure.

**Sea-level data up to 1993 had not been formally standardised.*

CCIm:05 Sea-surface temperature

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Victoria's marine environment						
Data source(s):	BOM, CSIRO					
Measure(s):	Australian region sea-surface temperatures Australian sea-surface temperature anomaly – southern region					

Why this indicator?

Oceans play an important role in the global climate system, absorbing more than 90% of the excess heat trapped by GHGs. Water temperature is important for all marine life, which serve environmental (e.g. biodiversity), economic (e.g. commercial fisheries) and social (e.g. recreational fishing) functions.

NB: This SoE 2023 indicator was 'CC:09 Sea-surface temperature' in the SoE 2018 Report.

Why this assessment in 2023?

The increasing frequency of marine heatwaves around Australia in recent years has caused permanent impacts on marine ecosystem health, and marine habitats and species. These impacts include depletion of kelp forests and seagrasses, a poleward shift in some marine species, and increased occurrence of disease. This information is the basis of the status assessment of poor.

The trend for this indicator has been assessed as stable rather than deteriorating (as it was rated in the SoE 2018 Report). This is because the sea-surface temperature anomaly in the southern region has not increased further during the past five years, even though each year has been at least 0.35°C warmer than the 30-year climatology of the 1961 to 1990 period.

CCIm:06 Projected changes in temperature

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	N/A	↙	●	N/A	↙	●

Data source(s):	BOM, CSIRO
Measure(s):	Annually averaged warming for various emission scenarios relative to the climate of the 1986–2005 reference period

Why this indicator?

Projecting temperature change is important to support planning and policy decisions made by the Victorian Government, local governments and communities. Projections are also used by scientific researchers to better understand the consequences of global climate change.

NB: This SoE 2023 indicator was 'CC:04 Projected changes in temperature' in the SoE 2018 Report.

Why this assessment in 2023?

There has been no change to the assessments for this indicator since the SoE 2018 Report. Physical evidence, past trends and various models all suggest Victoria will continue warming this century, so ongoing warming is projected with high confidence.

CCIm:07 Projected changes to average rainfall

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	N/A	↙	●	N/A	↙	●

Data source(s):	BOM, CSIRO
Measure(s):	Percentage change in annual rainfall for various emission scenarios relative to the climate of the 1986–2005 reference period

Why this indicator?

Projecting rainfall change is important to support planning and policy decisions made by the Victorian Government and communities. Projections are also used by scientific researchers to better understand the consequences of global climate change.

NB: This SoE 2023 indicator was 'CC:05 Projected changes to average rainfall' in the SoE 2018 Report.

Why this assessment in 2023?

The observed reduction in cool-season (April–October) rainfall since the 1990s is projected to continue.

While the impact of global warming on Victorian rainfall is expected to increase throughout the 21st century, large natural variability will also occur. In some years and decades, this natural variability will exacerbate the underlying drying. In other periods, the underlying drying will be balanced out by natural climatic events such as La Niña.

CCIm:08 Regional climate projections

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	N/A	↙	●	N/A	↙	●

Data source(s):	BOM, CSIRO, DELWP
Measure(s):	Projected number of hot and frost days for various emission scenarios in 2030 and 2070

Why this indicator?

It is important to understand how the climate is projected to change across Victoria, as it may not change in the same way in every region. Looking at projected changes regionally gives additional information that can be lost in statewide averages.

NB: This SoE 2023 indicator was 'CC:06 Regional climate projections' in the SoE 2018 Report.

Why this assessment in 2023?

Inland regions of Victoria are projected to warm by a greater amount (2.4°C) than coastal regions (1.9°C) by the 2050s (relative to 1986–2005).

The number of very hot days in Victoria is projected to double across the state by the 2050s relative to the 1986–2005 reference period and under a high-emissions pathway.

By the 2050s, Victoria is likely to experience more extreme short-duration rainfall, despite an overall decrease in rainfall.

CCIm:09 Projected sea level

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Victoria's coastline	N/A	↙	●	N/A	↙	●

Data source(s):	BOM, CSIRO
Measure(s):	Projected mean sea level in 2030, 2050, 2070 and 2090 for all emission scenarios

Why this indicator?

Projecting sea-level change is important to support planning and policy decisions made by the Victorian Government and communities. Projections are also used by scientific researchers to better understand the consequences of global climate change.

NB: This SoE 2023 indicator was 'CC:08 Projected sea level' in the SoE 2018 Report.

Why this assessment in 2023?

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. These projected rises are based on a high-emissions scenario (RCP8.5) and are relative to the levels observed for the 1986–2005 reference period. The trend assessment of deteriorating reflects the projected rise in sea levels and increasing pressure being exerted on human coastal settlements and infrastructure.

CCIm:10 Occurrence and impacts of extreme weather						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	🔴	↙	🟢	🔴	↙	🟢
Data source(s):	Australian Institute for Disaster Resilience, BOM, CSIRO, Deloitte Access Economics, DOH, Insurance Council of Australia					
Measure(s):	Frequency of extreme heat days Number of excess deaths associated with extreme heat days Number of dangerous fire weather days Financial cost associated with natural disasters					

Why this indicator?

Extreme weather affects the frequency and intensity of natural disasters in Australia. The type of natural disasters that occur in Australia are many and varied, ranging from severe thunderstorms, hailstorms and floods to heatwaves, bushfires and droughts.

NB: This SoE 2023 indicator was 'CC:12 Occurrence and impacts of extreme weather' in the SoE 2018 Report.

Why this assessment in 2023?

There has been a significant increase in the number of days per year of unusually high temperatures in Victoria. This is linked to increasing risks of heatwaves and bushfires. A drier climate with more intense rainfall events has also been experienced in recent years.

Several catastrophic natural disaster events have occurred since the SoE 2018 Report was published. These have had significant impacts on human life, wildlife, livestock and infrastructure.

The financial cost of natural disasters is increasing in Victoria and is projected to be at least $185 billion cumulatively from 2020 to 2060.

The human impacts of extreme heat can be catastrophic, particularly during multi-day heatwaves with oppressive overnight weather. In terms of fatalities in Australia, Victoria is most at risk from heatwaves, with 183 heatwave fatalities occurring across the state from 2001 to 2018. This number is more than half of all Australian heatwave fatalities during this period.

Climate change mitigation

CCM:11 Annual greenhouse gas emissions						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	🟡	↗	🟢	🔴	↗	🟢
Data source(s):	ABS, DCCEEW					
Measure(s):	Victorian annual GHG emissions (total and by sector) Victorian per capita annual GHG emissions					

Why this indicator?

Section 52 of the *Climate Change Act 2017* (CC Act) Act requires the minister administering the CC Act to prepare annual GHG emissions reports for Victoria. The CC Act requires that the reports include an overview and collation of the best practicably available information about Victoria's GHG emissions and the extent to which emissions have been reduced compared with 2005 levels (the reference year for interim emissions reduction targets under the CC Act).

NB: This SoE 2023 indicator was 'CC:10 Annual greenhouse gas emissions' in the SoE 2018 Report.

Why this assessment in 2023?

Victoria's total net GHG emissions were 30% lower in 2020 compared with 2005 levels. Most of the improvement since 2005 has occurred in the five years since 2015: emissions decreased by 27% between 2015 and 2020. These reductions have led to an upgraded status assessment of fair in this report from poor in the SoE 2018 Report.

CCM:12 Victorian ecosystem carbon stocks

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	(land sector) (marine and coastal sector)	?	(land sector) (marine and coastal sector)	(land sector) (marine and coastal sector)	→ (land sector) ? (marine and coastal sector)	
Data source(s):	Academic researchers, DELWP					
Measure(s):	Land-sector carbon stocks Blue carbon stocks					

Why this indicator?

Terrestrial-, aquatic- and marine-based carbon stocks and their trends play an important role in the global carbon cycle and GHG balance, and provide an indication of biodiversity.

NB: This SoE 2023 indicator was 'CC:11 Victorian ecosystem carbon stocks' in the SoE 2018 Report.

Why this assessment in 2023?

There was a net 1% growth in land-sector carbon stocks from 2007 to 2016, largely due to increased carbon in forests. It is unclear what effect the 2019–20 bushfires have had on Victorian land-sector carbon stocks.

The status assessment of poor for the marine and coastal sector reflects research published in 2019 that found saltmarshes, mangroves and seagrasses in Victoria are currently capturing approximately 2% of the carbon that could be captured by 2050 if coastal wetlands naturally retreat. Because this research is a 'point-in-time' assessment, the trend is unclear.

CCM:13 Stratospheric ozone

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		→			→	
Data source(s):	BOM, CSRIO					
Measure(s):	UV index Average total column ozone Emissions of ozone-depleting substances					

Why this indicator?

Stratospheric ozone impacts on ultraviolet (UV) radiation, with less stratospheric ozone meaning more UV radiation reaches the Earth's surface.

NB: This SoE 2023 indicator was 'A:05 Stratospheric ozone' in the SoE 2018 Report.

Why this assessment in 2023?

The long-term changes in stratospheric ozone due to ozone-depleting substances over a mid-latitude location, such as Victoria, are small compared to natural variations. There was a small, but clear, decreasing trend in ozone during the 1980s and 1990s. This was followed by an increase this century that provides some evidence of a gradual stratospheric ozone recovery.

Air

A:01 Particle pollution ($PM_{2.5}$ and PM_{10})

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	🟡 (Geelong) 🔴 (Latrobe Valley and Melbourne) ⚪ (elsewhere)	→	🟢 (Geelong, Latrobe Valley and Melbourne) 🔴 (elsewhere)	🟡 (Geelong, Latrobe Valley and Melbourne) 🔴 (Brooklyn) ⚪ (elsewhere)	→	🟡

Data source(s):	EPA Victoria
Measure(s):	Annual performance against indicators and objectives for PM_{10} and $PM_{2.5}$ specified in the Victorian ERS

Why this indicator?

Greater concentrations of $PM_{2.5}$ and PM_{10} particles in the air can cause wheezing, chest tightness and difficulty breathing in people with existing heart or lung conditions (including asthma).

NB: This SoE 2023 indicator was 'A:03 Particle pollution ($PM_{2.5}$ and PM_{10})' in the SoE 2018 Report.

Why this assessment in 2023?

Smoke from large bushfires has resulted in the most widespread particle pollution impacts across Victoria, with smoke from large fires capable of travelling across large parts of Victoria.

All monitoring stations in Melbourne and Latrobe Valley have recorded exceedances of the daily $PM_{2.5}$ air-quality standard in each of the past five years (2017–2021), except for Footscray in 2021. Each monitoring location has averaged more than four days exceeding the $PM_{2.5}$ standard, which is why Melbourne and Latrobe Valley have been assessed as having a poor status. Geelong is rated as fair because, in most years of monitoring, no days or only one day has exceeded the $PM_{2.5}$ standard.

PM_{10} pollution remains an issue in Brooklyn in Melbourne's inner west and is associated with dust emissions generated by industry and vehicles.

A:02 Ambient ozone levels

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	🟢 (Latrobe Valley) 🟡 (Geelong and Melbourne)	→	🟢	🟢	→	🟢

Data source(s):	EPA Victoria
Measure(s):	Annual performance against indicators and objectives for ozone specified in the Victorian ERS

Why this indicator?

Ozone can increase respiratory problems. The elderly and those with lung disease are most at risk.

NB: This SoE 2023 indicator was 'A:01 Ambient ozone levels (summer smog)' in the SoE 2018 Report.

Why this assessment in 2023?

With the new 8-hour average ozone standard replacing the previous 4-hour and 1-hour average ozone standards, more days exceed the ozone standard than were reported in the SoE 2018 Report.

The exceedances of ozone standards in recent years have generally been due to smoke from bushfires, as during the 2019–20 summer bushfire season. Exceedances of the ozone standard are slightly more likely to occur in Melbourne and Geelong (averaging between one and two ozone exceedances per year this century) compared with Traralgon (averaging less than one ozone exceedance per year this century).

A:03 Carbon monoxide

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	●	→	●	●	↗	●

Data source(s):	EPA Victoria
Measure(s):	Annual performance against indicators and objectives for carbon monoxide specified in the Victorian ERS

Why this indicator?

Breathing air with a high concentration of carbon monoxide reduces the amount of oxygen that can be transported in the bloodstream to organs such as the heart and brain. People with cardiovascular disease are particularly at risk.

NB: This is a modified SoE 2023 indicator that was formed by disaggregating the measures of the SoE 2018 indicator 'A:02 Carbon monoxide and nitrogen dioxide' to provide a greater focus on carbon monoxide concentrations and its sources.

Why this assessment in 2023?

Carbon monoxide concentrations rarely exceed the air-quality standard — the only exceedance this century was measured at Morwell South during the fire at the Hazelwood open-cut coal mine.

A:04 Nitrogen dioxide

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	●	↗ (Melbourne) → (Geelong and Latrobe Valley)	●	●	↗	●

Data source(s):	EPA Victoria
Measure(s):	Annual performance against indicators and objectives for nitrogen dioxide specified in the Victorian ERS

Why this indicator?

Increased concentrations of nitrogen dioxide can affect the throat and lungs. Those most at risk from nitrogen dioxide pollution are people with respiratory problems, particularly infants, children and the elderly.

NB: This is a modified SoE 2023 indicator that was formed by disaggregating the measures of the SoE 2018 indicator 'A:02 Carbon monoxide and nitrogen dioxide' to provide a greater focus on nitrogen dioxide concentrations and its sources.

Why this assessment in 2023?

Nitrogen dioxide concentrations have not exceeded air-quality standards in Victoria this century. Annual average concentrations have still reduced during this century, albeit at a slower rate than in the 1980s and 1990s. Reductions in nitrogen dioxide concentrations were observed in Melbourne in 2020 and 2021. It is highly likely that this was due to travel restrictions in Melbourne as part of the Victorian Government's response to limit the spread of COVID-19.

A:05 Sulfur dioxide

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide						

Data source(s):	EPA Victoria
Measure(s):	Annual performance against indicators and objectives for sulfur dioxide specified in the Victorian ERS

Why this indicator?

Prolonged exposure to sulfur dioxide can lead to increases in respiratory illnesses such as chronic bronchitis. The effect of sulfur dioxide on health is increased by the presence of airborne particles. Acute effects can also occur, particularly irritation of the upper respiratory tract and the eyes, with asthmatics being most sensitive to these effects.

NB: This SoE 2023 indicator was 'A:04 Sulfur dioxide' in the SoE 2018 Report.

Why this assessment in 2023?

Sulfur dioxide concentrations have rarely exceeded air-quality standards in Victoria this century. There have been no significant trends in sulfur dioxide concentrations in Victoria since the 1980s, except for some isolated spikes in Altona North and Traralgon in the 1990s and 2000s.

A:06 Population exposure to air pollution

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	(years with significant bushfires) (other years)			New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator

Data source(s):	EPA Victoria
Measure(s):	Percentage of total population exposed to $PM_{2.5}$ air pollution concentrations exceeding Victorian air pollution standards

Why this indicator?

Health impacts from air pollution is an important environmental health issue. Its magnitude depends on population exposure to air pollution.

NB: This is a new indicator that was not included in the SoE 2018 Report. This indicator has been included to align with Victoria's legislative requirement to report population exposure to air pollution. It replaces 'A:08 Emissions of major air pollutants by sector' from the SoE 2018 Report, with commentary and data on the sources of air pollution emissions now presented for each pollutant in indicators A:01 to A:05.

Why this assessment in 2023?

Of the years when population exposure to $PM_{2.5}$ concentrations have been estimated, there is a large range in the percentage of the Victorian population being exposed to annual $PM_{2.5}$ concentrations exceeding the air-quality standard.

Seventy-nine percent of the Victorian population was exposed to annual $PM_{2.5}$ concentrations exceeding the air-quality standard in a year with significant bushfire smoke impacts (2020) compared with 18% in a year without significant bushfire smoke impacts (2021).

A:07 Pollen

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide				New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator

Data source(s):	University of Melbourne
Measure(s):	Grass pollen counts Other pollen counts

Why this indicator?

Grass pollen is a focus in Victoria because it is a major outdoor allergen and impacts the health services.

NB: This is a new SoE 2023 indicator that was not included in the SoE 2018 Report. This indicator has been included to address a gap on pollen in previous state of the environment reports.

Why this assessment in 2023?

Across the eight sites that monitor pollen in Victoria, there has been a generally increasing trend in the number of days of extreme or high grass pollen in Victoria during grass pollen seasons since 2017. Demonstrating the effect of increasing grass pollen, Bendigo recorded 59 days of extreme or high grass pollen levels in the most recently completed grass pollen season (October to December 2021).

Most recently, the increasing grass pollen has been influenced by a multi-year La Niña state that has been leading to increased rainfall and grass pollen. This is the basis for the trend assessment of deteriorating. However, from 2017 to 2019 (prior to the La Niña state), there was still an average of 20 to 40 days of extreme or high grass pollen per season across Victoria.

A:08 Odour

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide						

Data source(s):	EPA Victoria
Measure(s):	Number of odour pollution reports

Why this indicator?

Impacts from odour are a significant issue in Victoria, both in terms of amenity and complaints to regulators. Excessive exposure to odour can have serious impacts on liveability. Short-term exposure to offensive odour can cause health effects such as irritation of the eyes, nose and throat, coughing, nausea and headaches. It can also affect sleep and the ability to exercise.

NB: This is a modified SoE 2023 indicator that was formed by disaggregating the measures of the SoE 2018 indicator 'A:06 Odour and noise' to provide a greater focus on odour pollution than previous state of the environment reports.

Why this assessment in 2023?

Odour is generally the type of pollution most frequently reported to EPA Victoria, with the regulator receiving more than 3,000 odour reports in each of the past nine years. This highlights a significant number of odour impacts occurring in Victoria. A fair status has been assessed to reflect this impact while also being cognisant of EPA Victoria's achievements in supporting and regulating industry to improve odour-management practices that reduce odour impacts on communities over time.

A:09 Noise

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		↙			↙	

Data source(s):	EPA Victoria
Measure(s):	Noise pollution reports Modelled noise level exposures

Why this indicator?

Impacts from noise are a significant issue in Victoria, both in terms of amenity and complaints to regulators. Excessive exposure to noise can have serious impacts on liveability and human health.

NB: This is a modified SoE 2023 indicator that was formed by disaggregating the measures of the SoE 2018 indicator 'A:06 Odour and noise' to provide a greater focus on noise pollution than previous state of the environment reports.

Why this assessment in 2023?

Noise was the type of pollution most frequently reported to EPA Victoria in 2020–21. Prior to 2020–21, noise was generally the type of pollution second-most frequently reported to EPA Victoria. However, since the shift to remote working in Victoria from March 2020 due to the COVID-19 pandemic, there has been a sharp increase in the number of noise pollution reports received by EPA Victoria.

A:10 Light pollution

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		↙			?	

Data source(s):	Academic researchers
Measure(s):	Artificial sky brightness as a ratio to the natural sky brightness

Why this indicator?

Light pollution is excessive or obtrusive artificial light that has an adverse impact on biodiversity and 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, poorly designed outdoor lighting can be inefficient and drain energy resources while carrying a significant financial burden.

NB: This SoE 2023 indicator was 'A:07 Light pollution' in the SoE 2018 Report.

Why this assessment in 2023?

In contrast to the gradual increases in night-time light emissions observed across Melbourne's urban extent, dramatic increases in light pollution have been observed in Melbourne's growth areas. For example, the night-time light emissions in growth areas of Melbourne's outer western suburbs have nearly tripled from 2014 to 2021.

A:11 Health impacts of air pollution

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?			?	

Data source(s):	Academic researchers, EPA Victoria
Measure(s):	Measures of health impacts due to anthropogenic air pollution include: • change in life expectancy from birth • Years of life lost (YLL) • economic cost associated with years of life lost

Why this indicator?

Poor air quality can harm people's health and quality of life, and has been linked to respiratory and cardiovascular health effects, and premature mortality. This indicator tracks progress in reducing the health burden associated with air pollution.

NB: This SoE 2023 indicator was 'A:09 Health impacts of air pollution' in the SoE 2018 Report.

Why this assessment in 2023?

Since the SoE 2018 assessments, researchers have been able to quantify the impact of long-term exposures to $PM_{2.5}$ on mortality. The average annual mortality burden for Victoria from exposure to anthropogenic $PM_{2.5}$, based on data from 2006 to 2016, was estimated to be more than 600 premature deaths. Researchers have determined that this is higher than community standards should allow, and reductions in emissions are recommended to avoid attributable mortality.

A:12 Health impacts of noise pollution

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	(Melbourne) (elsewhere across Victoria)	?		(Melbourne) (rest of Victoria)	?	

Data source(s):	Academic researchers
Measure(s):	The proportion of the population exposed to high levels of road traffic noise in Melbourne

Why this indicator?

Long-term exposure to noise can cause a variety of health effects, including annoyance, sleep disturbance, negative effects on the cardiovascular and metabolic systems, and cognitive impairment in children.

NB: This SoE 2023 indicator was 'A:10 Health impacts of noise pollution' in the SoE 2018 Report.

Why this assessment in 2023?

Approximately 5% of the population in Melbourne was exposed to traffic noise above the risk threshold of 55 dB, based on research published in 2019. However, these estimates were based on road traffic data from 2011 and low-resolution health data. Accordingly, there is low confidence in the status assessment of fair for Melbourne that has been based on these data and research.

A:13 Indoor air quality

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	(schools and aged care facilities) (residential buildings during periods of bushfire smoke) (all other scenarios)	?	(schools and aged care facilities) (residential buildings during periods of bushfire smoke and all other scenarios)		?	

Data source(s):	Academic researchers
Measure(s):	Measured indoor air-quality concentrations of $PM_{2.5}$ and PM_{10}

Why this indicator?

Good indoor air quality is critical for health and wellbeing, given that our modern lifestyles are increasing the amount of time we spend indoors.

NB: This SoE 2023 indicator was 'A:11 Indoor air quality' in the SoE 2018 Report.

Why this assessment in 2023?

$PM_{2.5}$ and PM_{10} concentrations measured in classrooms and aged care facilities were within the World Health Organization guidelines.

An evaluation of existing analyses of indoor air quality during bushfire smoke events found bushfire smoke can substantially increase the levels of pollutants within residential buildings.

A14: Health impacts from pollen

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?		New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator

Data source(s):	ABS, Academic researchers
Measure(s):	Prevalence of allergic rhinitis

Why this indicator?

Pollen from grasses, weeds or trees can trigger symptoms of allergic rhinitis (hay fever) and asthma.

NB: This is a new indicator that was not included in the SoE 2018 Report. This indicator has been included to address a gap on pollen in previous SoE Reports.

Why this assessment in 2023?

Victoria has the second-highest rate (23%) of hay fever in Australia.

Victorian studies on exposure to grass pollen have found that:

- Short-term exposure to grass pollen is associated with reduced lung function and with airway inflammation
- Persistent pollen exposure during infancy is associated with increased risk of subsequent childhood asthma and hay fever.
- Grass pollen exposure is associated with higher re-admission rates for paediatric asthma
- Exposure to grass pollen increases the risk of complications and adverse outcomes among patients undergoing coronary artery stenting to treat their coronary artery disease.

Grass pollen is only one of the types of pollen found in Victoria's air. Other types are often more prevalent and potentially also affect health, although these health impacts have rarely been quantified in Australia because of a lack of data, which is a significant knowledge gap.

Biodiversity

B:01 Changes in land cover

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?			↙	

Data source(s):	DELWP
Measure(s):	Changes in land-cover classes from 1985 to 2019

Why this indicator?

Monitoring change in land cover can provide a statewide view of the loss of natural areas and threats to biodiversity, and guide policy and on-ground action.

NB: This SoE 2023 indicator was 'B:19 Landscape-scale change' in the SoE 2018 Report.

Why this assessment in 2023?

Analysis of DELWP's Land Cover Time Series across Victoria shows an increased area of land-cover classes that are development-based and an overall decrease in those that are nature-based. The long-term trend has been evident across the seven epochs since 1985 and has placed more pressure on Victoria's biodiversity. However, it is not possible to determine a 2023 trend until data on the eighth epoch are released.

B:02 Wetlands

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		↙			?	

Data source(s):	DELWP
Measure(s):	Bioregional conservation status Wetland extent and water regime frequency

Why this indicator?

Wetlands provide important ecosystem services to the environment and communities. Determining the level of threats can guide actions for mitigation.

NB: This SoE 2023 indicator was 'B:16 Wetlands extent and condition' in the SoE 2018 Report.

Why this assessment in 2023?

More than 75% of the wetland ecological vegetation classes (EVCs) across the state's bioregions are either endangered, vulnerable or rare. Drainage, cropping, urbanisation, altered water flows and climate change continue to impact wetland condition. A recent DELWP analysis of wetland water regimes has shown that more than 20% of wetlands show signs of significant stress. Data have improved since the SoE 2018 Report.

B:03 Health and status of Victoria's inland Ramsar wetlands

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Inland Ramsar sites: •Barmah Forest •Edithvale–Seaford Wetlands •Gunbower Forest •Hattah–Kulkyne Lakes •Kerang Wetlands •Lake Albacutya •Western District Lakes		↗			?	
Data source(s):	DELWP, Melbourne Water, PV					
Measure(s):	Governance, management and monitoring Limits of acceptable change					

Why this indicator?

Signatories to the Ramsar Convention have an obligation to maintain/improve the ecological character of the site.

NB: This is a modified 2023 indicator that provides greater focus on inland Ramsar wetlands and was formed by narrowing the measure of the SoE 2018 indicator 'B:17 Health and status of Ramsar wetlands in Victoria'. The coastal Ramsar wetlands are now assessed within the State of the Marine and Coastal Environment reporting.

Criteria used for status assessment

Good: Limits of acceptable change for 5 to 7 inland Ramsar sites are met
Fair: Limits of acceptable change for 4 or 5 inland Ramsar sites are met
Poor: Limits of acceptable change for <4 inland Ramsar sites are met

Why this assessment in 2023?

Weaknesses in the governance, monitoring and management arrangements for Victoria's Ramsar sites were highlighted in the 2016 Victorian Auditor-General's Office's report. In response, those arrangements have been improved by government agencies responsible for site management. Management plans are largely consistent with national standards and most limits of acceptable change are being met at the seven inland Ramsar sites. Environmental watering programs have been positive for several sites on regulated rivers.

B:04 Groundwater-dependent ecosystems

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?			?	
Data source(s):	CSIRO, DELWP, Melbourne Water					
Measure(s):	Health of groundwater-dependent ecosystems					

Why this indicator?

Groundwater is important for maintaining the health of wetlands and other groundwater-dependent ecosystems.

NB: This SoE 2023 indicator was 'WR:10 Groundwater ecosystems' in the 'Water resources' chapter of the SoE 2018 Report.

Why this assessment in 2023?

Knowledge about the location, ecology and status of groundwater-dependent ecosystems is limited. However, their inclusion as values to be considered in environmental assessments for major projects will begin to improve the understanding of them, as will their tracking in the CSIRO Groundwater Dependent Ecosystems Atlas.

B:05 Rivers

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	●	→	●	●	→	●

Data source(s):	CMAs, DELWP
Measure(s):	Number of river basins that have 70% to 100% of their river lengths in good-to-excellent condition Depletion of in-stream woody habitat

Why this indicator?

The health of Victorian rivers is influenced by grazing, clearing, bushfires, invasive species, regulation, water extraction, waste discharges, timber harvesting and urban development. These can cause disturbances in river dynamics, and impact native aquatic species and cultural, social and economic values.

NB: This SoE 2023 indicator was 'B:09 River health' in the SoE 2018 Report.

Criteria used for status assessment

Good: ≥21 river basins have 70% to 100% of their river lengths in good to excellent condition
Fair: 14 to 20 river basins have 70% to 100% of their river lengths in good to excellent condition
Poor: <14 river basins have 70% to 100% of their river lengths in good to excellent condition

Why this assessment in 2023?

Based on data from 2013, river health is poor in western and central Victoria and good in the far east of the state. Only three river basins had 70% to 100% of their river lengths in good to excellent condition. In-stream woody habitat status is poor in the western, southern and north-central parts of the state and good in the north-east and far east. In the longer term, climate change, increasing water demands in urban and rural areas due to population growth, and the intensification of agriculture, could lead to lower flows and declining river health. Some data used in this assessment are now a decade old, hence the moderate confidence.

B:06 Riparian vegetation

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	●	→ (statewide) ↗ (CMA and local reaches level)	●	●	?	●

Data source(s):	DELWP, VEAC
Measure(s):	ISC 2010 streamside zone scores DELWP 2022 recapture of LiDAR data for ISC 2010 Bioregional conservation status of riparian EVCs Protection levels of riparian EVCs

Why this indicator?

The loss of riparian vegetation through clearing, drainage, stock access, channelisation and invasive plants has impacted terrestrial and aquatic plants and animals.

NB: This SoE 2023 indicator was 'B:10 Riparian vegetation habitat extent' in the SoE 2018 Report.

Why this assessment in 2023?

There are no new data to suggest an improvement in statewide status, although local riparian restoration projects have been successful. In regions with significant national parks, such as in the Grampians and East Gippsland, most EVCs are contained within the protected area network. Bioregions where EVCs are endangered or vulnerable with little or none of their current extent protected include the Victorian Volcanic Plain, Gippsland Plain and Central Victorian Uplands, and where most remnants are on private land. The three ISC assessments and DELWP's recent LiDAR-based Stream Change Assessment suggest that the trend is stable on a statewide basis.

B:07 Floodplains

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	●	→	●	●	?	●

Data source(s):	DELWP, VEAC
Measure(s):	Bioregional conservation status of EVCs in river red gum forests along the Murray River and floodwater-dependent EVCs in other bioregions Protection levels for EVCs in terms of 30% of their current extent or 15% of their pre-1750s extent

Why this indicator?

River red gum forests, and other floodwater-dependent EVCs, provide habitat for native plants and animals and cultural and recreational sites.

NB: This is a modified 2023 indicator that allows greater focus on the protection levels and conservation status of floodplain vegetation than previous SoE reports and was formed by broadening the measure of the SoE 2018 indicator 'B:11 Area of functional floodplain'.

Why this assessment in 2023?

Sixty percent of the river red gum EVCs along the Murray River have 30% or more of their current extent in dedicated reserves. However, there are limited data on their condition. Elsewhere, floodwater-dependent EVCs are mostly endangered or vulnerable and have little of their current or pre-1750s extent in the protected area network. Most floodwater-dependent EVCs are on private land. Environmental water delivery projects are being used to return some floodplain wetlands, including Ramsar sites, to more natural flood cycles.

B:08 Grasslands

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Victorian Volcanic Plain, Wimmera Plain, Gippsland Plain and Warrnambool Plain bioregions				New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator

Data source(s):	DELWP, Grassy Plains Networ, VEAC
Measure(s):	Bioregional conservation status Grassland EVCs that have protection coverage above 30% of their current extent or 15% of pre-1750s extent

Why this indicator?

Very little of Victoria's grasslands remain and they continue to be threatened by environmental weeds, introduced predators and herbivores, urban development, fragmentation, conversion to cropping, inadequate levels of protection and the absence of fire.

Why this assessment in 2023?

Of the 15 grassland EVC entries across the four bioregions analysed, 13 are endangered and two have more than 40% of their pre-1750s extent remaining. Three of the 15 grassland EVC entries have any of their remaining area (7% to 14%) within the protected area network. The condition of grasslands continues to deteriorate.

B:09 Alpine

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Victorian Alps bioregion				New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator

Data source(s):	DELWP, VEAC
Measure(s):	Bioregional conservation status Alpine EVCs that have protection coverage above 30% of their current extent or 15% of pre-1750s extent

Why this indicator?

Alpine areas contain diverse flora and fauna and have significant cultural, social and economic values.

Why this assessment in 2023?

There has been virtually no change in the extent of alpine EVCs since the 1750s, and most have greater than 90% of their remaining area in the protected area network. However, 16 of the 18 EVCs are either endangered, vulnerable or rare, with bushfires, invasive species, timber harvesting and climate change affecting their condition.

B:10 Mallee

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Lowan Mallee and Murray Mallee bioregions				New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator

Data source(s):	DELWP, PV, VEAC
Measure(s):	Bioregional conservation status of mallee EVCs Percentage of current and pre-1750s extents within the protected area network of mallee EVCs

Why this indicator?

Mallee landscapes have been degraded by pastoralism, invasive species and changing fire regimes. However, they continue to provide important refuges for threatened species.

NB: This is a new SoE 2023 indicator that was not included in the SoE 2018 Report.

Why this assessment in 2023?

Sixty percent of EVCs in the Lowan Mallee bioregion, and 70% in the Murray Mallee, are either endangered, vulnerable or depleted. Much of what is left in the Lowan Mallee bioregion is within the boundaries of national parks, nature conservation reserves and state forests, as well as on private land. A lower percentage of EVCs in the Murray Mallee bioregion are within the protected area network. There are reports that the abundances of mallee reptiles and some bird species are in decline.

B:11 Heathlands

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide				New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator

Data source(s):	DELWP, VEAC
Measure(s):	Bioregional conservation status Percentage of the current and pre-1750s extent of EVCs within the protected area network

Why this indicator?

Heathlands generally occur within nutrient-poor and fire-prone landscapes and contain diverse flora and fauna that are dependent on them. They have been reduced in extent through land clearing for urban, industrial and agricultural development. Heathlands remain important areas for conservation, culture and recreation.

NB: This is a new SoE 2023 indicator that was not included in the SoE 2018 Report.

Why this assessment in 2023?

Seventy-five percent of the heathland EVCs have retained more than 80% of their pre-1750s extent. However, their percentages within the protected area network across the bioregions are quite mixed and, for many, much of their remaining extent is on private land.

B:12 Threatened terrestrial and freshwater mammals

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		↙			↙	NC*

Data source(s):	DELWP
Measure(s):	Changes in conservation status Action statements Genetic risk ratings

Why this indicator?

This is a modified SoE 2023 indicator that allows a greater focus on mammal species than previous SoE reports and was formed by disaggregating the measures of the SoE 2018 indicators 'B:06 Trends in populations and distributions of threatened terrestrial species' and 'B:06B Vertebrates'. The 2018 assessment provided in this report card is for 'B:06B Vertebrates', as its measure is most comparable to that of the modified 2023 indicator.

Why this assessment in 2023?

The number of threatened mammal species on the FFG Act Threatened List has grown over time and populations continue to decline. One-third are listed as extinct, half of those species that are left have had their conservation status upgraded and two-thirds have genetic risk ratings of high to very high. The 2019–20 bushfires placed further pressure on threatened mammals in eastern and north-eastern Victoria.

** NC indicates that comparisons between the SoE 2018 and SoE 2023 assessments for the modified SoE 2023 indicator would be inappropriate due to the extensive level of variability in the measures and/or data used in the assessment between SoE reports.*

B:13 Threatened wetland-dependent species

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		↙			?	

Data source(s):	DELWP
Measure(s):	Changes in conservation status Action statements Genetic risk ratings

Why this indicator?

Wetlands provide essential services to the environment and communities, including food resources, nurseries and refuges for native wildlife, and as recreational and cultural spaces. The status of wetland-dependent species can be an indicator of wetland health.

NB: This SoE 2023 indicator was 'B:05 Threatened species that are wetland dependent' in the SoE 2018 Report.

Why this assessment in 2023?

Almost three-quarters of the wetland-dependent fauna listed on the FFG Threated List that were reviewed are either critically endangered or endangered, more than 40% have had their status upgraded, and one-third have genetic risk ratings of high to very high. Action statements have only been prepared for one-third of species. The number of wetland-dependent plants that are regarded as threatened (critically endangered, endangered or vulnerable) has also increased. The ongoing decline of wetlands will increase pressure on these already-threatened species, as will sedimentation in some locations due to the 2019–20 bushfires. Threatened wetland-dependent species are not well monitored.

B:14 Threatened terrestrial bird species

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	🔴	↙	🟢	🔴	↙	NC*

Data source(s):	DELWP
Measure(s):	Changes in conservation status Action statements Genetic risk ratings

Why this indicator?

This is a modified SoE 2023 indicator that allows a greater focus on bird species than previous SoE reports and was formed by disaggregating the measures of the SoE 2018 indicators 'B:06 Trends in populations and distributions of threatened terrestrial species' and 'B:06B Vertebrates'. The 2018 assessment provided in this report card is for 'B:06B Vertebrates', as its measure is most comparable to that of the modified 2023 indicator.

Why this assessment in 2023?

The number of terrestrial bird species on the FFG Act Threatened List has grown and populations have declined. More than 60% are either critically endangered or endangered. Fifty percent of listed terrestrial bird species have had had their conservation status upgraded and half of those assigned a genetic risk rating are rated as high to very high. Although 40% have action statements, only one is from the past decade. Along with ongoing threats, the 2019–20 bushfires placed further pressure on threatened bird species in eastern and north-eastern Victoria.

** NC indicates that comparisons between the SoE 2018 and SoE 2023 assessments for the modified SoE 2023 indicator would be inappropriate due to the extensive level of variability in the measures and/or data used in the assessment between SoE reports.*

B:15 Waterbird species in the Murray–Darling Basin

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Southern Murray–Darling Basin	🔴	↙	🟢	🔴	↙	🟡

Data source(s):	Centre for Ecosystem Science, DELWP
Measure(s):	Number, abundance, distribution and conservation status of waterbird species in the Murray–Darling Basin

Why this indicator?

The Eastern Australian Waterbird survey is a large-scale biodiversity dataset that monitors waterbirds, including threatened species, and the health of rivers and wetlands.

NB: This SoE 2023 indicator was 'B:14 Distribution and abundance of waterbirds in the Murray-Darling Basin' in the SoE 2018 Report.

Why this assessment in 2023?

The annual Eastern Australian Waterbird Survey, which has been conducted since 1983, continues to show a long-term decline in waterbird abundance and distribution. Of 48 species monitored in the surveys, half are showing a declining long-term trend in their population.

B:16 Threatened terrestrial and wetland reptile species

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide						NC*

Data source(s):	DELWP
Measure(s):	Changes in conservation status Action statements Genetic risk ratings

Why this indicator?

This is a modified SoE 2023 indicator that allows a greater focus on reptile species than previous SoE reports. It was formed by disaggregating the measures of the SoE 2018 indicators 'B:06 Trends in populations and distributions of threatened terrestrial species' and 'B:06B Vertebrates'. The 2018 assessment provided in this report card is for 'B:06B Vertebrates', as its measure is most comparable to that of the modified 2023 indicator.

Why this assessment in 2023?

The number of terrestrial and wetland reptile species on the FFG Act Threatened List has grown. One of the 40 terrestrial and wetland reptile species listed is extinct, and 16 have had their conservation status upgraded. Of the 36 assigned a genetic risk rating, 33 are rated high to very high. Eleven of the 39 species have action statements; however, only two have been prepared in the past decade. Along with ongoing threats, the 2019–20 bushfires placed further pressure on threatened reptiles in eastern and north-eastern Victoria. Data on threatened reptile species are limited in comparison with that for threatened mammal and bird species.

** Comparisons between the SoE 2018 and SoE 2023 assessments for the modified SoE 2023 indicator would be inappropriate due to extensive variability in the measures and/or data used in the assessment between SoE reports.*

B:17 Threatened large-bodied freshwater fish species

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide						NC*

Data source(s):	DELWP
Measure(s):	Changes in conservation status Action statements Genetic risk ratings

Why this indicator?

Large-bodied fish have a key role in aquatic ecosystems. They are also targeted by recreational fishers in many rivers and streams across Victoria.

NB: This is a modified SoE 2023 indicator that allows a greater focus on large-bodied freshwater fish species than previous SoE reports and was formed by merging the SoE 2018 indicators 'B:04A Trend in population number and distribution of trout cod *(Maccullochella maquariensis)*', 'B:04B Trend in population number and distribution of Macquarie perch (*Macquaria australasica*)' and 'B:13 Distribution and abundance of fish'. The 2018 assessment provided in this report card is for 'B:13 Distribution and abundance of fish', as its measure is most comparable to that of the modified 2023 indicator.

Why this assessment in 2023?

One of the 10 large-bodied fish species on the FFG Act Threatened List is extinct, two are critically endangered and eight are endangered. Four species have had their conservation status upgraded, and two-thirds have genetic risk ratings of high to very high. Although five large-bodied fish species have action statements, only one has been prepared in the past decade. Native Fish Report Cards and other research are improving data on native fish. However, there is no formal analysis of fish status and environmental data.

** NC indicates that comparisons between the SoE 2018 and SoE 2023 assessments for the modified SoE 2023 indicator would be inappropriate due to the extensive level of variability in the measures and/or data used in the assessment between SoE reports.*

B:18 Threatened small-bodied freshwater fish species

Regions(s)	2023 status	2023 trend	2023 confidence		2018 status	2018 trend	2018 data quality
Statewide							NC*

Data source(s):	DELWP
Measure(s):	Changes in conservation status Action statements Genetic risk ratings

Why this indicator?

Small-bodied freshwater fish species, such as the galaxiids, have experienced significant reductions in abundance and distribution, and are at an increasing risk of extinction.

NB: This is a modified SoE 2023 indicator that allows a greater focus on small-bodied freshwater fish species than previous SoE reports and formed by narrowing the measure for the SoE 2018 indicator 'B:13 Distribution and abundance of fish'.

Why this assessment in 2023?

Seventy-five percent of small-bodied freshwater fish species on the FFG Act Threatened List are either critically endangered or endangered. Six of the 20 remaining have had their conservation status upgraded, and 85% have genetic risk ratings of high to very high. Although six have action statements, only three have been prepared in the past decade. There is no formal analysis of fish status and environmental data. Along with ongoing threats, the 2019–20 bushfires placed further pressure on threatened small-bodied freshwater fish species in eastern and north-eastern Victoria.

** NC indicates that comparisons between the SoE 2018 and SoE 2023 assessments for the modified SoE 2023 indicator would be inappropriate due to the extensive level of variability in the measures and/or data used in the assessment between SoE reports.*

B:19 Threatened frog species

Regions(s)	2023 status	2023 trend	2023 confidence		2018 status	2018 trend	2018 data quality
Statewide							

Data source(s):	DELWP
Measure(s):	Changes in conservation status Action statements Genetic risk ratings

Why this indicator?

There have been declines in the populations of native frog species (threatened and non-threatened species) over the past few decades due to habitat loss and degradation, introduced fish species and the chytridiomycosis disease.

NB: This is a modified SoE 2023 indicator formed by merging the SoE 2018 indicators 'B:04D Trend in population number and distribution of spotted tree frog (*Litoria spenceri*)', 'B:04E Trend in population number and distribution of Booroolong tree frog *(Litoria booroolongensis*)', 'B:04F Trend in population number and distribution of Baw Baw frog (Philoria frosti)' and 'B:12 Distribution and abundance of frogs'. The 2018 assessment provided in this report card is for 'B:12 Distribution and abundance of frogs', as its measure is most comparable to that of the modified 2023 indicator.

Why this assessment in 2023?

Fourteen of the 15 frog species on the FFG Act Threatened List are either critically endangered or endangered, three have had their conservation status upgraded and all but one have genetic risk ratings of high to very high. Forty percent have action statements; however, only two have been prepared in the past decade. Only a small number of threatened frog species are the subject of research. Along with ongoing threats, the 2019–20 bushfires have placed further pressure on threatened frogs in eastern and north-eastern Victoria.

B:20 Threatened freshwater invertebrate species

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide				New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator

Data source(s):	DELWP
Measure(s):	Changes in conservation status Action statements Genetic risk ratings

Why this indicator?

Freshwater invertebrates have been poorly studied; however, their importance in aquatic ecosystems is now being more recognised as research expands.

NB: Freshwater invertebrates, such as water bugs and water beetles, were the focus of the SoE 2018 indicator 'B:15 Distribution and abundance of macroinvertebrates'. This new SoE 2023 indicator assesses freshwater crustaceans, mussels, dragonflies, stoneflies, caddisflies and damselflies that are connected to freshwater systems during part, or all, of their life cycle.

Why this assessment in 2023?

Research on freshwater invertebrates is limited and, as a result, the number included on the FFG Threatened List is relatively low. Seventy percent of the crustaceans and mussels assessed here are either critically endangered or endangered. One-third have had their conservation status upgraded and 14 of the 17 have genetic risk ratings of high to very high. One-quarter of threatened crustacean and mussel species have action statements; however, only one has been prepared in the past decade. Nine of the 23 species of dragonflies, stoneflies, caddisflies and damselflies are either critically endangered or endangered and have had their conservation status upgraded. Only one of the species has had an action statement prepared and it was released more than 20 years ago. Of the four assigned a genetic risk rating, all were either high or very high.

B:21 Threatened terrestrial invertebrate species

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide						

Data source(s):	DELWP
Measure(s):	Changes in conservation status Action statements Genetic risk ratings

Why this indicator?

Invertebrates are critically important to the function of terrestrial ecosystems. For example, the loss of terrestrial invertebrate species could have significant consequences for the pollination of plants, the construction of good soil conditions and the food available to birds.

NB: This SoE 2023 indicator was 'B:06C Invertebrates' in the SoE 2018 Report.

Why this assessment in 2023?

There is limited information on threatened terrestrial invertebrate species in Victoria and this is reflected by the relatively small number on the FFG Threatened List compared to the number of listed vertebrate and vascular plant species. Seventy-five percent of listed terrestrial invertebrate species are either critically endangered or endangered. Forty percent have had their conservation status upgraded, while 30% have action statements, none of which were prepared in the past decade. Of the 16 assigned a genetic risk rating, all were rated high to very high. Along with ongoing threats, the 2019–20 bushfires placed further pressure on threatened terrestrial invertebrates in eastern and north-eastern Victoria.

B:22 Threatened terrestrial vascular plant species

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	🔴	↙	🟡	🔴	↙	🟡

Data source(s):	DELWP
Measure(s):	Changes in conservation status Action statements

Why this indicator?

The SoE 2018 Report noted an increasing trend in the number of endangered, vulnerable and rare vascular plants in Victoria.

NB: This SoE 2023 indicator was 'B:06A Vascular plants' in the SoE 2018 Report.

Why this assessment in 2023?

There are 1,527 vascular plant species on the FFG Threatened List, with more than 85% listed as either critically endangered or endangered. Only 10% of listed vascular plant species have action statements. The Australian Threatened Species Index indicates declining populations of vascular plants in Victoria. Along with ongoing threats, the 2019–20 bushfires placed further pressure on threatened vascular plant species in eastern and north-eastern Victoria.

B:23 Threatened terrestrial fungi, lichen, moss and liverwort species

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	🔴	?	🔴	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator

Data source(s):	DELWP
Measure(s):	Changes in conservation status Action statements

Why this indicator?

Fungi, lichen, moss and liverwort species are a critical component of ecosystems, decomposing organic matter, providing food and shelter for various species, and conserving soil. They also act as pioneer plants that make areas more suitable for other organisms. They were not represented by an indicator in previous state of the environment reports.

Why this assessment in 2023?

There is limited research of fungi, lichen, moss and liverwort species, and only 68 species are included on the FFG Act Threatened List. Ninety-four percent of species are either critically endangered or endangered and one is extinct. Of the 67 remaining in the wild, 60 have had their conservation status upgraded, and none have had an action statement prepared. Along with ongoing threats, the 2019–20 bushfires placed further pressure on the species in eastern and north-eastern Victoria.

B:24 Invasive freshwater plant species

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?			?	

Data source(s):	DELWP
Measure(s):	Number, abundance and distribution of freshwater invasive plant species

Why this indicator?

Invasive freshwater plants can alter freshwater habitats, threaten their long-term function and undermine the outcomes of previous investment in waterway management.

NB: This is a modified SoE 2023 indicator that allows greater focus on invasive freshwater plant species and was formed by disaggregating the measures of the SoE 2018 indicator 'B:01 Invasive freshwater plants and animals' into two separate modified indicators in this report.

Why this assessment in 2023?

There is a lack of comprehensive and accurate statewide data on population numbers and trends of invasive freshwater plants and their threatening processes, especially their impacts on native aquatic flora and fauna. Most data are from standing water bodies, irrigation channels and the Murray–Darling Basin. It is likely that the status is poor. Although there are insufficient data to determine trends, there are significant localised programs to remove willows and other aquatic weeds.

B:25 Invasive freshwater animal species

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		↙			?	

Data source(s):	AgVic, DELWP
Measure(s):	Number, abundance and distribution of freshwater invasive animal species

Why this indicator?

Invasive freshwater animal species prey on threatened small-bodied fish and frog species, and outcompete native large-bodied fish.

NB: This is a modified SoE 2023 indicator that allows greater focus on invasive freshwater animal species and was formed by disaggregating the measures of the SoE 2018 indicator 'B:01 Invasive freshwater plants and animals' into two separate modified indicators in this report.

Why this assessment in 2023?

Brown and rainbow trout, redfin perch and other invasive freshwater animal species impact threatened frogs and small-bodied fish. Invasive trout have established self-sustaining populations in many waterways and have been identified as the main threat to galaxiids and other threatened freshwater fish species at high risk of extinction.

B:26 Trend in carp

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	Red	↙	Green	Red	↙	Green

Data source(s):	DELWP
Measure(s):	Abundance and distribution of carp

Why this indicator?

Carp is considered a pest species because it dominates aquatic environments to the detriment of native fish species and freshwater ecosystems.

NB: This indicator was 'B:01A Trend in carp (*Cyprinus carpio*) distribution' in the SoE 2018 Report.

Why this assessment in 2023?

The European carp is a highly successful and invasive fish species that has increased in abundance and range and remains a major threat to native aquatic species. It can represent up to 90% of fish biomass in some rivers. The National Carp Control Plan has focused on research into the effectiveness and impacts of the potential release of a carp virus. A decision on the release is yet to be made.

B:27 Invasive terrestrial plant species

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	Red	↙	Yellow	Red	↙	Green

Data source(s):	AgVic, DELWP
Measure(s):	Number, abundance and distribution of terrestrial invasive plant species

Why this indicator?

Environmental weeds threaten Australia's biodiversity by displacing native plant species, disrupting ecological processes and altering the genetic composition of native plant populations.

NB: This indicator was 'B:02 Invasive terrestrial plants' in the SoE 2018 Report.

Why this assessment in 2023?

The number of naturalised plants and environmental weeds in Victoria continues to grow and their control is a major focus of actions by government agencies, landholders and communities. One-third of the environmental weeds in Victoria have genetic risk ratings ranging from high to very high.

B:28 Priority weed control

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?		New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator

Data source(s):	DELWP
Measure(s):	Achievement of targets for priority weed control

Why this indicator?

Environmental weeds impact native species and their habitats, as well as agricultural productivity. Weed control in priority locations can begin to mitigate these impacts.

NB: This is a new SoE 2023 indicator. Priority weed control was one of five measures considered within 'B:21 Area of management in priority locations' in the SoE 2018 Report. The five measures of the SoE 2018 indicator have been disaggregated into five separate indicators in this report to better target each priority response.

Criteria used for status assessment

Good: ≥75% of target for priority weed control is met

Fair: 50% to <75% of target for priority weed control is met

Poor: <50% of target for priority weed control is met

Why this assessment in 2023?

Although environmental weeds remain a serious problem on both private and public land, control programs, especially after the 2019–20 bushfires, have significantly increased the area of weed management by government agencies. However, data on outcomes for biodiversity are limited, while the available data are insufficient to determine status and trend. The two years of data on achievements since the release of Biodiversity 2037 indicate that they are below its targets.

B:29 Invasive terrestrial herbivore species

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		↙			↙	NC*

Data source(s):	AgVic, DELWP
Measure(s):	Number, abundance and distribution of invasive terrestrial herbivore species

Why this indicator?

Established invasive terrestrial herbivore species in Victoria – deer, horses, rabbits, goats and pigs – are major threats to the state's biodiversity, environmental health, and cultural, economic and social values.

NB: This is a modified SoE 2023 indicator formed by merging the SoE 2018 indicators 'B:03 Invasive terrestrial animal species', 'B:03A Trend in deer populations and their distributions' and 'B:03B Trend in horse populations and their distributions'. The 2018 assessment provided in this report card is for 'B:03 Invasive terrestrial animal species', as its measure is most comparable to that of the modified 2023 indicator.

Why this assessment in 2023?

Invasive terrestrial herbivores are an ongoing threat to native flora and fauna and their habitats. There is no evidence to suggest that the trend is being slowed or reversed.

** NC indicates that comparisons between the SoE 2018 and SoE 2023 assessments for the modified SoE 2023 indicator would be inappropriate due to the extensive level of variability in the measures and/or data used in the assessment between SoE reports.*

B:30 Priority pest herbivore control

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?		New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator

Data source(s):	DELWP
Measure(s):	Achievement of targets for priority pest herbivore control

Why this indicator?

The distribution of invasive terrestrial herbivore species in Victoria is widespread, which means that management resources must be applied in priority locations, where the best results can be achieved. Priority pest herbivore control is a Biodiversity 2037 indicator.

NB: This is a new SoE 2023 indicator. Priority pest herbivore control was one of five measures considered within 'B:21 Area of management in priority locations' in the SoE 2018 Report. The five measures of the SoE 2018 indicator have been disaggregated into five separate indicators in this report to better target each priority response.

Criteria used for status assessment

Good: ≥75% of the target for priority pest herbivore control is met

Fair: 50% to <75% of the target for priority pest herbivore control is met

Poor: <50% of the target for priority pest herbivore control is met

Why this assessment in 2023?

Although there are significant localised pest herbivore control programs, there is no evidence to suggest that the trend is being slowed or reversed. Control programs were expanded in the wake of the 2019–20 bushfires due to concerns that invasive herbivores would flourish and increase the risks to native species. The available data are insufficient to determine status and trend. The two years of data on achievements since the release of Biodiversity 2037 indicate that they are below the targets for control pest herbivores.

B:31 Invasive terrestrial predator species

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		↙			↙	NC*

Data source(s):	AgVic, DELWP
Measure(s):	Number, abundance and distribution of invasive terrestrial predators

Why this indicator?

Foxes and cats kill tens of millions of native animals across Australia each year. They have been a major cause of past species' extinctions and are increasing the risk of future extinctions.
NB: This is a modified SoE 2023 indicator that was formed by narrowing the measure of the SoE 2018 indicator 'B:03 Invasive terrestrial animal species'.

Why this assessment in 2023?

Foxes and cats are continuing to increase in number and spread, and data indicate that their impact on native animals is increasing.

** NC indicates that comparisons between the SoE 2018 and SoE 2023 assessments for the modified SoE 2023 indicator would be inappropriate due to the extensive level of variability in the measures and/or data used in the assessment between SoE reports.*

B:32 Priority pest predator control

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?		New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator
Data source(s):	DELWP					
Measure(s):	Achievement of targets for priority pest predator control					

Why this indicator?

Foxes and cats have a wide distribution, which means that management resources must be applied in priority locations, where the best results can be achieved.

NB: This is a new SoE 2023 indicator. Priority pest predator control was one of five measures considered within 'B:21 Area of management in priority locations' in the SoE 2018 Report. The five measures of the SoE 2018 indicator have been disaggregated into five separate indicators in this report to better target each priority response.

Criteria used for status assessment

Good: ≥75% of the target for priority pest predator control is met

Fair: 50% to <75% of the target for priority pest predator control is met

Poor: <50% of the target for priority pest predator control is met

Why this assessment in 2023?

Although there are localised control programs, there is no evidence to suggest that the trend in fox and cat numbers is being slowed or reversed. The available data are insufficient to determine status and trend. The two years of data on achievements since the release of Biodiversity 2037 indicate that they are below its targets.

B:33 Net gain in the extent and condition of native vegetation

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		↙			↙	
Data source(s):	DELWP					
Measure(s):	Estimates of the overall rate of change in extent and condition of native vegetation on public and private land in Victoria					

Why this indicator?

Victoria is the nation's most cleared state, which has severely impacted its biodiversity. Urban expansion, bushfires, invasive species and climate change are some of the factors leading to the ongoing loss of native vegetation in Victoria. Habitat loss and fragmentation are second only to invasive species as drivers of the increased risk to native species. The success of efforts to reverse the loss of habitat is measured by this indicator, which is also a Biodiversity 2037 indicator.

NB: This SoE 2023 indicator was 'B:18 Net gain in extent and condition of native vegetation' in the SoE 2018 Report.

Criteria used for status assessment

Good: There is a net gain in the extent and condition of native vegetation

Fair: There is no net gain or loss in the extent and condition of native vegetation

Poor: There is a net loss in the extent and condition of native vegetation

Why this assessment in 2023?

There is a continuing net loss (habitat hectares) of native vegetation on private land in Victoria, with a smaller net gain on public land.[365] The main contributors are grazing, removal of trees and fallen logs, environmental weeds, clearing exempt from requiring a permit (e.g. fences and fire protection) and illegal clearing, which has proven difficult to quantify.

365. Habitat hectares' is a method of assessing native vegetation, in terms of both quality and extent. Quality is assessed by scoring habitat attributes at a site in comparison to a reference point (benchmark) for the relevant vegetation type – this provides a 'habitat score'. The habitat score is multiplied by the area of vegetation to determine the amount of habitat hectares. For example, 10 hectares with a habitat score of 60% is six habitat hectares.

B:34 Change in suitable habitat for threatened native species

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?			→	

Data source(s):	DELWP
Measure(s):	Estimating net improvement in suitable habitats of threatened native species across the state under climate change Threatened species target

Why this indicator?

Habitat loss has severely impacted native species in Victoria. What habitat remains can be compromised by invasive species, fire and other factors and become less suitable for native species. This indicator measures estimates of net improvement in suitable habitat achieved for individual species by implemented actions compared with a 'no action' scenario. This is a Biodiversity 2037 indicator.

NB: This indicator was 'B:20 Change in suitable habitat' in the SoE 2018 Report.

Criteria used for status assessment

Good: ≥75% of the target for change in suitable habitat is met

Fair: 50% to <75% of the target for change in suitable habitat is met

Poor: <50% of the target for change in suitable habitat is met

Why this assessment in 2023?

Data from 2019 and 2020 show that the average percentage change in suitable habitat in 50 years for selected threatened species is 11.4%, based upon on-ground management actions. For some species, the percentage change in suitable habitat was much higher than the average (e.g. 30.2% for frogs and 31.4% for mammals). The available data, only up to 2020, were insufficient to determine trend. However, the calculated increases are well below the 100% target in Biodiversity 2037.

B:35 Climate-sensitive ecosystems

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?			?	

Data source(s):	DELWP
Measure(s):	Ecosystem impacts of climate change

Why this indicator?

This indicator monitors the impacts of climate change and the level of climate risk for Victoria's natural ecosystems.

NB: This SoE 2023 indicator was 'CC13: Extent and condition of key climate-sensitive ecosystems' in SoE 2018 Report.

Why this assessment in 2023?

Alpine regions, rain forests and red gum forests are examples of ecosystems under threat from climate change. Climate sensitivity will vary from ecosystem to ecosystem, with some more sensitive than others.

B:36 New, permanently protected areas on private land

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?		New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator

Data source(s):	DELWP, Trust for Nature
Measure(s):	Achievement of the Biodiversity 2037 target for new, permanently protected areas on private land

Why this indicator?

To achieve a comprehensive, adequate and representative protected areas network, which is a national goal, Victoria must fill a gap of 2.1 million hectares. In some regions, the filling of that gap can only be achieved by establishing permanent protection of native vegetation on private land. This indicator assesses progress on filling that gap and is also a Biodiversity 2037 indicator.
NB: This is a new SoE 2023 indicator formed by merging the SoE 2018 indicators 'B:07 The conservation and management of Victorian ecosystems on private land', 'L:10 Land management activities' and disaggregating 'B:21Area of management in priority locations' into five separate indicators

Criteria used for status assessment

Good: ≥75% of the annual target for 10,000 hectares of new, permanently protected areas on private land is met
Fair: 50% to <75% of the annual target for 10,000 hectares of new, permanently protected areas on private land is met
Poor: <50% of the annual target for 10,000 hectares of new, permanently protected areas on private land is met

Why this assessment in 2023?

Trust for Nature continues to slowly expand the number of its reserves and works with landowners to establish covenants to secure native vegetation on their properties. CMAs as well as Landcare and other organisations also work with landholders to improve the conservation and management of biodiversity on private land. Although there have been small increases in permanent protection on private land, the achievements in the two years since the release of Biodiversity 2037 are below its targets. The available data are insufficient to determine trend.

B:37 The conservation of Victorian ecosystems on public land						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	Yellow	→	Green	Yellow	→	Green
Data source(s):	DELWP, PV					
Measure(s):	Progress towards a comprehensive, adequate and representative protected area network					

Why this indicator?

Protected areas, such as national parks and reserves on public land, are the main driver of nature conservation in Victoria and a key indicator for biodiversity health.

NB: This indicator was 'B:08 Conservation of Victorian ecosystems' in the SoE 2018 Report.

Criteria used for status assessment

Good: ≥75% of the annual target of 100,000 hectares to achieve a comprehensive, adequate and representative protected area network by 2037 is met

Fair: 50% to <75% of the annual target of 100,000 hectares to achieve a comprehensive, adequate and representative protected area network by 2037 is met

Poor: <50% of the annual target of 100,000 hectares to achieve a comprehensive, adequate and representative protected area network by 2037 is met

OR

Good: ≥75% of the annual target of 350,000 hectares to meet the 30% by 2030 is met

Fair: 50% to <75% of the annual target of 350,000 hectares to meet the 30% by 2030 is met

Poor: <50% of the annual target of 350,000 hectares to meet the 30% by 2030 is met

Why this assessment in 2023?

The spatial extent of the protected area network has changed little in recent years and continues to constitute nearly 18% of Victorian lands. There remains a gap of 2.1 million hectares between the current parks estate and what is needed for a comprehensive, adequate and representative network.

B:38 Priority revegetation

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?		New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator

Data source(s):	DELWP
Measure(s):	Area (ha) of revegetation in priority locations for connectivity between habitats

Why this indicator?

The loss of habitat is a major factor in the decline in abundance and distribution of native species and their increasingly threatened status. Revegetation can expand and link habitats, and benefit culture, agricultural productivity and recreation. This indicator measures progress in revegetation and is also a Biodiversity 2037 indicator.

NB: This is a new SoE 2023 indicator. Priority revegetation was one of five measures considered within 'B:21 Area of management in priority locations' in the SoE 2018 Report. The five measures of the SoE 2018 indicator have been disaggregated into five separate indicators in this report to better target each priority response.

Criteria used for status assessment

Good: ≥75% of the target for priority revegetation is met

Fair: 50% to <75% of the target for priority revegetation is met

Poor: <50% of the target for priority revegetation is met

Why this assessment in 2023?

Insufficient data were available to determine status or trend for this indicator.

B:39 Victorians value nature

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	(Target 1: All Victorians are connected to nature) (Target 2: More than five million Victorians acting for nature)	→			?	

Data source(s):	DELWP
Measure(s):	Achievement of targets for 'Victorians value nature': • Target 1: All Victorians are connected to nature • Target 2: More than five million Victorians are acting for nature

Why this indicator?

'Victorians value nature' is one of two goals for Biodiversity 2037. The goal has two targets: 'All Victorians are connected to nature' and 'More than five million Victorians are acting for nature'.

NB: This SoE 2023 indicator was 'B:22 Victorians value nature' in the SoE 2018 Report.

Criteria used for status assessment

Good: ≥75% of the target for 'Victorians value nature' is met

Fair: ≥50 to <75% of the target for 'Victorians value nature' is met

Poor: <50% of the target for 'Victorians value nature' is met

Why this assessment in 2023?

The 2019–20 bushfires and the COVID-19 pandemic have restricted the people's engagement in nature-based activities and the achievement of targets under Biodiversity 2037. Surveys show that the target of 'More than five million Victorians acting for nature' has been met, while there has been a shortfall in meeting the target for 'All Victorians connected to nature'.

B:40 Number of Victorian Government organisations that manage environmental assets that contribute to DELWP Standard Output Data

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?			?	

Data source(s):	DELWP
Measure(s):	Percentage of NRM organisations that manage environmental assets that contribute to Standard Output Data

Why this indicator?

The target is for 100% of organisations to contribute Standard Output Data. This aims to ensure that all data for the management of environmental assets are collected and reported to DEECA to provide a statewide picture of the outputs.

Criteria used for status assessment

Good: ≥75% of the target for the number of Victorian Government organisations that manage environmental assets that contribute to DELWP Standard Output Data is met

Fair: ≥50% to <75% of the target for the number of Victorian Government organisations that manage environmental assets that contribute to DELWP Standard Output Data is met

Poor: <50% of the target for the number of Victorian Government organisations that manage environmental assets that contribute to DELWP Standard Output Data is met

Why this assessment in 2023?

The SoE 2018 Report showed that only 12% of Victorian Government organisations that manage Victoria's natural assets have contributed to environmental-economic accounting. Data were unavailable for determining the status and trend in 2023.

Land

L:01 Land-cover classes in Victoria

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	N/A	N/A			N/A	

Data source(s):	AgVic, DELWP
Measure(s):	Percentage of Victoria's area classified by each land-cover class

Why this indicator?

This indicator monitors the mix of land-use and land-cover classes in Victoria, which can influence land health.

Why this assessment in 2023?

Land-cover classes associated with human activities have continued to increase, while natural land-cover classes have continued to decline. However, there are no clear targets regarding a desirable mix of land-cover classes, which prevents an assessment of status.

L:02 Changes in Victoria's land-cover classes

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?		N/A	→	

Data source(s):	AgVic, DELWP
Measure(s):	Changes in the mix and spatial extent of Victoria's land-cover classes

Why this indicator?

Monitoring change in land cover can provide a statewide view of the loss of natural areas and threats to biodiversity, and guide policy and on-ground action.

NB: This SoE 2023 indicator was 'L:02 Changes in major land uses in Victoria' in the SoE 2018 Report and investigated land-use changes rather than changes in land-cover classes.

Why this assessment in 2023?

Analysis of DELWP's Land Cover Time Series across Victoria shows an increased area of land-cover classes that are development-based and an overall decrease in those that are nature-based. The long-term trend has been evident across the seven epochs since 1985 and has placed more pressure on Victoria's biodiversity. However, it is not possible to determine a 2023 trend until data on the 8th epoch are released.

L:03 Changes in land tenure

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	N/A	→			→	

Data source(s):	DELWP
Measure(s):	Percentage of Victoria's area classified as public or private land

Why this indicator?

Changes in land tenure and, as a result, land management practices and land use, can potentially lead to changes in land cover and land health.

Why this assessment in 2023?

A status for this indicator has not been determined. The data available simply identify the statewide mix of publicly- and privately-owned land. There has been no significant shift in public and private land tenure percentages since the SoE 2018 Report.

L:04 Greenfield and infill development in Melbourne

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Melbourne metropolitan area						

Data source(s):	DTP, IV
Measure(s):	Infill and greenfield development in Melbourne

Why this indicator?

Urban development in Melbourne can come at the expense of land health and productive agricultural land, and increase pressure on biodiversity.

Why this assessment in 2023?

Both forms of urban development (greenfield and infill) have their advantages and disadvantages; however, greenfield development can increase pressure on biodiversity and agricultural land. Data on the outcomes for land health from land-use change in Melbourne are limited.

L:05 Soil organic carbon storage

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?			?	

Data source(s):	AgVic
Measure(s):	Victorian SOC at various depths

Why this indicator?

Soil organic carbon (SOC) helps retain soil nutrients, soil structure and soil moisture. Increasing the storage of SOC can help mitigate climate change and enhance farm productivity.

Why this assessment in 2023?

There is a growing interest in the measurement of SOC and a government and community desire to increase it to help mitigate climate change. However, the science indicates that this will be difficult, and a broader carbon-farming initiative could have more chance of success. There are no targets, and available data are insufficient to determine status.

L:06 Area affected by dryland salinity

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	(Murray River catchment) (elsewhere)	(Murray River catchment) (elsewhere)	(Murray River catchment) (elsewhere)	(Murray River catchment) (elsewhere)	(river catchments that drain to the Murray River) (elsewhere)	(Murray River catchment) (elsewhere)

Data source(s):	AgVic, DELWP
Measure(s):	The extent of land affected by dryland salinity

Why this indicator?

Dryland salinity is a threat to productive land uses and biodiversity.

Why this assessment in 2023?

Although salt-affected areas have receded in the northern river basins, dryland salting remains a significant concern. However, there are limited contemporary data on the spatial extent of dryland salinity. The improving trend assessment represents increasing land health due to a reduction in the area of land affected by salinity, not an increase in the area affected by salinity.

L:07 Soil acidification

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?			?	

Data source(s):	AgVic
Measure(s):	Changes in the extent of strongly and very strongly acidic soils

Why this indicator?

Soils that are too acidic, or too alkaline, can restrict growth in crops and pastures and can lead to farming responses that can impact land health.

Why this assessment in 2023?

Levels of soil acidification vary across the state. Agricultural production has elevated soil acidity in medium-rainfall areas. The application of lime is the primary way that farmers reduce soil acidity. There are insufficient data available to determine status and trend for this indicator.

L:08 Soil erosion

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	(wind) (water)	?			↙	
Data source(s):	AgVic, National Landcare Project					
Measure(s):	TVC targets in relation to wind and water erosion					

Why this indicator?

A reduction in total vegetation cover (TVC) can lead to soil erosion by wind and water, and impact agricultural land use, while sedimentation from erosion can impact infrastructure, waterways and wetlands.

Criteria used for status assessment*

Wind erosion

Good: 8 of Victoria's 10 CMA regions have a TVC of >50%

Fair: 5 to 7 of Victoria's 10 CMA regions have a TVC of >50%

Poor: 0 to 4 of Victoria's 10 CMA regions have a TVC of >50%

Water erosion

Good: 8 of Victoria's 10 CMA regions have a TVC of >70%

Fair: 5 to 7 of Victoria's 10 CMA regions have a TVC of >70%

Poor: 0 to 4 of Victoria's 10 CMA regions have a TVC of >70%

Why this assessment in 2023?

Based on the above criteria, there were only two NRM regions in 2018–19 that did not meet the wind erosion target of >50% TVC, and just three NRM regions that did not meet the water erosion target of >70% TVC. However, the available data are for just one year, a period too short for determining trend. A new measure, TVC, has been used for this indicator and explains the difference between the 2018 and 2023 assessments.

**The SoE 2023 assessment criteria are based on a measure different to that used in the SoE 2018 Report. The SoE 2018 Report used percentage of bare ground cover in dryland areas at risk of erosion. This report uses percentage of each CMA region covered by vegetation. This measure is now used to monitor TVC across Australia. The percentage targets are based on methods described by Leys et al. (2020), with >50% TVC for wind erosion and >70% TVC for water erosion.[366] AgVic recommends >70% TVC for pastures on flat and slightly sloping ground (3% slope), 80% to 90% on lighter, more erosion-prone soils, and 90% to 100% for steep hill country (>10% slope) on light and erosion-prone soils.[367]*

366. Leys J, Howorth J, Guerschman J, Bala B, Stewart J 2020, 'Setting targets for National Landcare Program monitoring and reporting vegetation cover for Australia', Office of Environment and Heritage, Sydney, New South Wales.
367. Agriculture Victoria, 'Monitoring groundcover and soil degradation' https://agriculture.vic.gov.au/farm-management/soil/erosion/monitoring-groundcover-and-soil-degradation Accessed 10 September 2022.

L:09 Contaminated sites

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?			?	

Data source(s):	DELWP, EPA Victoria
Measure(s):	Number of contaminated and potentially contaminated land locations

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.

Why this assessment in 2023?

The basis of the status assessment of fair is that several sites in Victoria are known to be contaminated or are the location of current activity involving a relatively high risk of contamination. The subjective interpretation is that contaminated sites are exerting moderate pressure on environmental condition and human health.

The trend is unclear because information is generally 'point-in-time' spatial data.

Although the quality of datasets is good, the confidence for this assessment is low because there are no thresholds available to guide the status assessment. Furthermore, most data presented in this indicator is maintained by EPA Victoria and collected to help regulate and manage contamination; in its current format it is not suited for the broadscale assessment of status or trends in contaminated land.

L:10 Participation in natural resource management activities

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		↗			↗	

Data source(s):	CMAs, Landcare, PV
Measure(s):	Number of volunteers within government- and community-based programs Number of volunteer hours with government- and community-based programs CMA targets and actual figures for participation

Why this indicator?

Individual and community participation can improve environmental stewardship, connect people to nature, and improve physical, mental and emotional health and wellbeing.

NB: This modified SoE 2023 indicator was formed by merging the SoE 2018 indicators 'L:10 Land management activities' and 'L:11 Participation in natural resource management activities'.

Criteria used for status assessment

Good: ≥7 of Victoria's 10 CMA regions meeting their targets for participation in NRM activities

Fair: 3 to 6 of Victoria's 10 CMA regions meeting their targets for participation in NRM activities

Poor: <3 of Victoria's 10 CMA regions meeting their targets for participation in NRM activities

Why this assessment in 2023?

All CMAs met, or exceeded, their targets for event participation across the five years, except for one CMA, which did not meet its target during one of the years. The 2019–20 bushfires briefly affected participation in eastern Victoria and COVID-19 impacted levels of participation in NRM activities. However, the general trend is improving.

L:11 Use of best practice for sustainability outcomes on agricultural lands

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		↗			?	

Data source(s):	DELWP
Measure(s):	Area of land with improved and sustainable agricultural practices in Victoria

Why this indicator?

Land managed using best-practice techniques can maintain and improve land and ecosystem health. This indicator arises from UN SDG Target 2.4, which aims to ensure sustainable food production systems and the implementation of resilient agricultural practices by 2030.

NB: This modified SoE 2023 indicator was formed by merging the SoE 2018 indicators 'L:12 Use of best practice on agricultural lands' and 'L:13 Proportion of agricultural land area under productive and sustainable agriculture'. The 2018 assessment provided above is for 'L:12 Use of best practice on agricultural lands' as its measure is most comparable to that of the modified 2023 indicator.

Criteria used for status assessment

Good: ≥7 of Victoria's 10 CMA regions meet or exceed their targets for improved agricultural practices

Fair: 3 to 7 of Victoria's 10 CMA regions meet or exceed their targets for improved agricultural practices

Poor: <3 of Victoria's 10 CMA regions meet or exceed their targets for improved agricultural practices

Why this assessment in 2023?

There are no clear official targets for the use of best practice on agricultural land, whether it be number of farmers using best-practice techniques or spatial extent of land improved. The above criteria are based on agricultural improvements reported by CMAs, which is a limited data set. The data presented in the indicator assessment narrative suggest that there is an improving trend in best-practice in agriculture.

Forests

Fo:01A Area of forest by type and tenure – forest canopy cover

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?			?	

Data source(s):	DELWP
Measure(s):	Forest canopy cover

Why this indicator?

Canopy cover protects the ground from the force of rainfall, and moderates the force of wind. It acts as an indicator of factors including nutrition, water access, disease, pest infestations and stress. The impact of forest use, in terms of deforestation, degradation, thinning or afforestation, can also be evaluated by canopy cover.

Why this assessment in 2023?

There is insufficient information to assess this indicator.

Fo:01B Area of forest by type and tenure – forest type						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide		?			↗	
Data source(s):	DELWP					
Measure(s):	Change in forest area by broad forest type and impact of natural disturbances, such as bushfire Height and canopy cover in state forests, and parks and reserves					

Why this indicator?

This indicator measures the current level of forest and canopy cover by broad forest type. It demonstrates how the forested area is changing over time. This knowledge is fundamental for the effective management of Victoria's forests.

Why this assessment in 2023?

There is no comparative measure to determine the current status of forest by type and tenure in Victoria. Previous information from the SoE 2018 Report cannot be assessed against the 2022 data due to methodological changes as well as changes in spatial data resolution. This highlights an urgent need for a systematic approach in achieving a long-term monitoring system for sustainable forest management. Trend analysis could not be performed due to a lack of data, as there is no time series data on forest extent by type and tenure. The only meaningful information for this indicator was information on findings about old-growth forest extent.

Fo:01C Area of forest by type and tenure – plantation forest						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide		↙			→	
Data source(s):	ABS					
Measure(s):	Plantation area (ha) New plantation establishment per year Capacity to meet the demand for wood products					

Why this indicator?

Information on the area of existing plantations and the trend in plantation establishment in private areas is important because Victoria is phasing out native timber harvesting by 1 January 2024. This means that Victoria will only be able to supply wood products from plantation forests or other jurisdictions.

Why this assessment in 2023?

There has been minimal new plantation establishment since 2012–13. Plantation area in Victoria for softwood has been stable, while the demand for wood products in Australia is growing, leading to an increasing reliance on imported sawnwood. Meanwhile, export of sawlogs is growing. The Victorian and Commonwealth governments have funded the establishment of new plantation areas in Victoria, but this is not reflected by the data yet, suggesting these may still be at the planning stage.

Total area of plantations has been decreasing since 2013–14, with a steep decline between 2018–19 and 2020–21. New plantation establishment has been minimal for almost a decade.

There is sufficient information on the plantation areas and change in new establishment of plantations in Victoria. The Victorian Forestry Plan (VFP) was developed after the SoE 2018 Report was released, so more information is required to assess this indicator. Reports regarding supply and demand dynamics for the Australian timber industry are available, but a Victorian context is missing. The Victorian Government's announcement to bring forward the end of native timber harvesting by 1 January 2024 may result in increased demand for timber from overseas, as there has been no sign of an increase of plantation areas in Victoria.

Fo:02 Area of forest type by growth stage

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?			↗	

Data source(s):	DELWP
Measure(s):	Change in forest area by growth stage (forest type and height class)

Why this indicator?

This indicator identifies changes in growth stages within forest types and incorporates issues related to the protection status of old growth forest by ecological vegetation classes (EVCs).

Why this assessment in 2023?

There is insufficient information on the changes in growth stages within forest types. Currently, there is only one year of data, which prevents a trend assessment for this indicator.

Fo:03 Area of forest type by growth stage distribution in protected zones

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		↗			↗	

Data source(s):	CAPAD, DELWP
Measure(s):	Change of protected areas by type Implications of changes in protected areas for conservation of threatened species

Why this indicator?

This indicator provides a status of comprehensive, adequate and representative reserve (CAR) areas and changes in the areas of the reserve.

Why this assessment in 2023?

Informal and formal protection areas have been expanding as a consequence of Victorian Government decisions made during this state of environment reporting period. Although the indicator is to assess change in area of protected zones, it is also important that the addition of area is effective for the conservation and restoration of ecosystems. As part of the modernised Regional Forest Agreements (RFAs), the Victorian Government was required to undertake a review of the comprehensiveness, adequacy and representativeness of the CAR Reserve System in December 2021 (Clause 66G (b) in Central Highlands RFA). Findings from this review have not been incorporated into this assessment as the data were not publicly available when this analysis was conducted.

The 2019–20 bushfires impacted 133 reserves, with between 40% and 100% of their area within the fire extent – including where 91% to 100% of their area was within the fire extent.

As part of the VFP, timber harvesting was immediately excluded from more than 96,000 hectares of high conservation value state forest in November 2019. This is a significant contribution to the informal reserve system that provides protection while a process to determine permanent reservation status of these immediate protection areas (IPAs) is underway. Delays in formal protection of IPAs could lead to the degradation of the values each area holds, including biodiversity.

International Union for Conservation of Nature (IUCN) protected areas increased by 6% between 2010 and 2020. More land may be added as a result of the Victorian Government accepting Victorian Environmental Assessment Council (VEAC) assessment recommendations for additional high conservation value area inclusion in formal protection areas.

There remains a need for further research to identify the benefits of different IUCN-protected areas for targeted threatened species.

The quality of data remains unchanged from the SoE 2018 Report as there is no additional information on the benefits of more formal and informal protected areas for threatened species. This would be highly beneficial for indicator assessments.

Fo:04 Fragmentation of native forest cover

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		↙			?	

Data source(s):	DELWP
Measure(s):	Forest fragmentation by bioregion and tenure Information on genetic risk assessment for threatened species

Why this indicator?

Forest fragmentation poses significant threats to biodiversity and endangers the sustainability of ecological goods and services from forested land. This indicator assesses genetic risks to 1,100 Victorian flora and fauna species.

Why this assessment in 2023?

Of Victoria's total land area, about 61% and 27% was classified as interior forest and forest edge in 2022, respectively. Bioregions with the highest proportion of interior forest among forested areas are concentrated in the eastern part of Victoria. This includes the Australian Alps (87%), the South East Corner (81%) and the South Eastern Highlands (78%) bioregions. The Riverina is the most fragmented bioregion and has the highest proportion of forest patches (27%). Results show that state forests and parks and reserves are of high importance for biodiversity conservation due to the high proportion of interior areas in all bioregions.

The genetic risk index shows that approximately 30% of the assessed species have high or very high genetic risk categories. The assessment of the risk to genetic health for 138 species identified by the Victorian and Commonwealth governments is considered of immediate concern as a result of the 2019–20 bushfires.

Due to the technical barriers to ensure accuracy, only a state-scale comparison was possible. The state-level data from 2018 and 2022 demonstrate a large increase in the area of forest edge (~1.26 million ha) and a decrease of interior areas (~0.7 million ha). The increase in forest edge and the decrease in the total interior area may be a result of the 2019–20 bushfires as well as other major factors, including changes in forest-extent mapping methodology and data resolution. In addition, many species increased their genetic risk as a result of the 2019–20 bushfires.

No comprehensive status assessment was conducted due to an absence of functional connectivity assessment in Victoria for different ecosystems, as they have different response patterns to different conditions of fragmentation. The genetic risk index was used as an alternative approach.

Forest fragmentation data were produced for two years (2018 and 2022) by bioregion and tenure, but the comparison of the two years of data were possible at the state scale only, as data resolution deteriorated from 30 m in 2018 to 100 m in 2022, and different analytical methods were applied in the two corresponding years. This makes data confidence rated as fair.

Fo:05 Number of in-situ and ex-situ conservation efforts for forest-dependent species

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?			?	

Data source(s):	DELWP, VicForests, Zoos Victoria
Measure(s):	Effectiveness of in-situ and ex-situ conservation efforts for conservation of forest-dependent species

Why this indicator?

This indicator describes the extent of in-situ and ex-situ conservation efforts for native forest-dependent species. In-situ (on-site) conservation efforts include management of parks and other protected areas, genetic and ecological conservation areas as well as timber harvesting areas and harvesters in state forests that comply with the Code of Practice for Timber Production 2014. Ex-situ (off-site) conservation measures include seed banks, seed orchards, conservation breeding and clonal archives.

Why this assessment in 2023?

Despite government and stakeholder investment towards improving ecological management of native timber harvesting, the spatial extent of native vegetation areas, invasive species management and conservation breeding programs, the conservation status of forest-dependent species is deteriorating and is assessed as poor.

Sufficient information was found from publicly available sources. However, it is unclear whether the conservation efforts are a complete picture of the activities being delivered in Victoria, and whether their outcomes have been fully evaluated.

Fo:06 The status of forest-dependent species at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		↙			↙	

Data source(s):	DELWP
Measure(s):	Number, abundance and distribution of threatened forest-dependent species

Why this indicator?

This indicator describes the status of known forest-dependent species in Victoria and provides information to improve their conservation status and formal designation.

Why this assessment in 2023?

The conservation status of 75 species of VEAC's 84 threatened forest-dependent species is threatened (critically endangered, endangered or vulnerable) under the FFG Act. As a result of the 2019–20 bushfires, 22 forest-dependent species of VEAC's threatened forest-dependent species were identified to be of most concern, because proportions of their modelled habitat were within the fire extent or affected by high-severity fires. The Victorian Government has applied protection measures to those species that were impacted by 2019–20 bushfires and have potential to be impacted by forestry operations. However, the impact of the 2019–20 bushfires has been severe for many forest-dependent species in Victoria, leading to the degradation of their conservation status.

DELWP's prompt response to the 2019–20 bushfires to identify their impact on forest-dependent species, combined with findings from the Major Event Review of the impact on RFAs, and the SoE Biodiversity Update Report, provided sufficient data to assess this indicator.

Fo:07 Degree of disturbance to native forest species caused by invasive species

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?			↙	

Data source(s):	DELWP
Measure(s):	Status of environmental weeds Government's works to mitigate disturbance by invasive species Status of deer abundance and distribution

Why this indicator?

Invasive species are one of the major threats to Victoria's biodiversity. In forest ecosystems, the threats caused by invasive species include species competition, transmission of diseases and soil degradation. This indicator assesses the current state of disturbance caused by invasive species and how their impact has changed with future estimations.

Why this assessment in 2023?

As well as reducing native wildlife populations, the 2019–20 bushfires reduced populations of feral cats and foxes. However, the removal of refugia, such as shrubs, grass cover and hollow logs, as a result of the bushfires promoted higher levels of predation by these invasive animals on native wildlife. To tackle this issue, the Victorian Government invested in implementing invasive species control activities, including aerial shooting. However, given that there is uncertainty about the effectiveness of the Government's efforts in controlling invasive species to protect native forest-dependent species, the status is rated as fair.

The Government has a strategy for controlling invasive species that includes research on the abundance and distribution of deer species and investment in weed management and aerial shooting. However, the discontinuation of data (impact and distribution of weeds, insects and pathogens) that were included in the SoE 2018 Report has resulted in a trend assessment in 2023 of unclear.

There is sufficient information on the status of invasive species and on the Government's management response to tackle invasive species. However, estimations of the abundance and distribution of deer species are needed in order to identify the impact of government response activities, like aerial shooting and weed removal.

Fo:08A Scale and impact of agents and processes affecting forest health and vitality – mortality, dieback, canopy health

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?			?	

Data source(s):	DELWP
Measure(s):	Degree of leaf damage based on mortality, crown dieback and crown defoliation

Why this indicator?

Forest health and vitality are related to a number of natural disturbances that are strongly influenced by climate. In Victoria, natural disturbances can include fire, non-native species invasions, floods, disease outbreaks and climatic events, such as windstorms, extreme temperatures and millennial drought events. These events influence the composition, structure and functions of forests.

The effects of such disturbances, however, are not always negative. Rather, they can be an important part of natural processes essential to the long-term health of ecosystems. Forests have evolved to survive and regenerate from certain natural disturbances. However, recently there have been major shifts in the frequency, scale and intensity of agents and processes that can cause significant disruptions in forest ecosystems, resulting in a dramatic increase in the susceptibility of forest health and vitality. Capturing these shifts through monitoring programs is vital, as predictions indicate that forest ecosystems will be increasingly exposed to these events due to climate change.

Why this assessment in 2023?

There are insufficient data to determine the current status and trend of forest health and vitality. Assessing the status and trend of tree mortality, dieback and canopy health indices is not possible due to lack of comprehensive analyses that use information on the occurrence of processes or agents impacting on forest ecosystem health and vitality, including fire, climatic events, grazing, pathogens, weeds, pests and land clearing.

Fo:08B Scale and impact of agents and processes affecting forest health and vitality – bushfire-affected area and climate

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		↙			↙	

Data source(s):	DELWP
Measure(s):	Bushfire-affected area (ha) Annual mean temperature, by year Number of unusually warm days, by year

Why this indicator?

Victoria's forests are impacted by a range of disturbances, both natural and human-induced. It is important to monitor the impact of major disturbances that could negatively affect the health and vitality of Victoria's forests.

Why this assessment in 2023?

Considering the impact of the 2019–20 bushfires on tolerable fire interval (TFI), it could be estimated that ecosystem resilience has been severely affected. Academic research has identified that even fire-tolerant species altered their composition, making forests more flammable for future fires. Further work to assess and monitor these changes is required.

Bushfire-impacted areas have been increasing. Since 2000, the area exposed to multiple high-severity fires now exceeds 276,000 hectares, and this is expected to continue to increase as Victoria's climate continues to get warmer and drier as a result of climate change. Furthermore, the amount of area burnt while vegetation was below TFI increased significantly as a result of the 2019–20 bushfires. As a result of increased fire frequency and intensity, it is unclear how forests in Victoria would respond to this changed fire regime.

There is sufficient information regarding bushfire impacts and climate, but there is a growing need for information regarding the impact of changed fire regimes on forests.

Fo:09A Area and type of human-induced disturbance – planned burns						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide		↙			?	
Data source(s):	DELWP					
Measure(s):	Annual area of planned burns on public land, by fire management zone Annual planned burn area					

Why this indicator?

Disturbance from human land-use and management activities may result in different biotic responses and disrupt ecological relationships.

Why this assessment in 2023?

The Victorian Government has changed bushfire management activities from a hectare-based approach to a risk-based approach. Using the results of fire modelling, this new approach focuses on areas estimated to have the greatest level of fire impact. Victoria's bushfire risk has been maintained below 70% of its maximum bushfire risk since the introduction of the risk target for the fuel management program. On average, planned burning accounted for more than two-thirds (70%) of the total risk reduction, compared to one-third (30%) for bushfires. A rapidly changing climate has likely worsened the forest fire danger index (FFDI) over the past 40 years. This means it is even more important to mitigate more frequent, severe or higher FFDI through planned burning.

Despite fluctuations in the area receiving planned burns, DEECA has been meeting a statewide residual risk target. The window for planned burning is narrowing, likely as a result of climate change, where the number of days for conducting burns during suitable weather and with appropriate fuel conditions has decreased relative to historical records. This suggests that the trend could continue to deteriorate.

Fo:09B Area and type of human-induced disturbance – grazing						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide		↗			→	
Data source(s):	ABS					
Measure(s):	Information on grazing licences, location and intensity, including its potential impact on forest-dwelling flora					

Why this indicator?

About two-thirds of Australia's land has been modified for human use, primarily for grazing on natural vegetation. Pastoral farming is a major contributor to Australia's economy. However, grazing affects the conservation of ecosystems like grasslands. Studies indicate that grazing by non-native animals, such as cattle and sheep, negatively impacts native plant biodiversity and water yield. To balance land used for nature conservation and agriculture, the Victorian Government has been regulating grazing by issuing licences and permits on public lands.

Why this assessment in 2023?

Data limitations have prevented a status assessment. Currently, there are no data available on the impacts (negative or positive) of grazing in Victoria, and monitoring of grazing licences is also lacking. Thus, there is an urgent need for an evidence-based approach to determine the sustainable level of grazing activity in Victoria.

Fo:10 Total forest ecosystem biomass and carbon pool by forest type, age class and successional stages

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?			?	

Data source(s):	DELWP
Measure(s):	Change of total carbon stock by forest type, age class and successional stages

Why this indicator?

This indicator estimates total forest biomass and the total carbon pool within Victorian forests by forest type and age class. These indices can provide the rate of change of the total forest ecosystem carbon pool over time to increase understanding of how different forest types and age classes have been contributing to carbon sinks.

Why this assessment in 2023?

Forest carbon stock fluctuates depending on the degree and intensity of disturbances. One major factor for the fluctuation of carbon pool in forest ecosystems in Victoria is bushfire, as it burns biomass and releases carbon into the atmosphere on a landscape scale. Released carbon will be sequestrated gradually over time due to post-fire regrowth. This pattern is captured in the Australian Government's FullCAM modelling program. There were approximately 1.1 billion tonnes of carbon in Victoria's forests within RFA regions during 2017, and a net loss of about 55-million tonnes as a result of the 2019–20 bushfires.

The FullCam modelling assumes, under the forest neutrality assumption, that the net loss will be returned gradually due to forest regrowth after the fires. However, this assumption has been challenged, highlighting the need for more research on the impact of more frequent and severe fires on fire-tolerant forests.

There is no information on carbon pool by forest type, age class and successional stage; only data on carbon stock by tenure were available for this assessment. Therefore, the status and trend could not be determined.

Fo:11 Contribution of forest ecosystems to the global greenhouse gas balance

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		↗			↗	

Data source(s):	DCCEEW, DELWP
Measure(s):	CO2-e emissions by sector Amount of net carbon sink under Victoria's LULUCF and significance of the carbon sink amount to mitigate GHG emissions in Victoria

Why this indicator?

Increasing the concentration of GHGs causes an intensification of climate change. Monitoring the contribution of Victorian forest ecosystems to the global GHG balance is an important management strategy, as forest management can have a positive, or negative, impact on the balance.

Why this assessment in 2023?

In 2020, Victoria's land use, land use change and forestry (LULUCF) sector has been a net sink for GHGs. The 21,054 CO2-e was equivalent to about a quarter of Victoria's total emissions in that year. This is a significantly higher proportion than national figures for the LULUCF sector (7.8%). However, Victoria's GHG abatement activities through the Australian Government's Emissions Reduction Fund were mainly achieved by non-forestry sectors, while the forest-related activity under the fund contributed less than 5% in 2020.

There has been a gradual decrease of overall GHG emissions in Victoria, and the LULUCF sector has been increasing net sink contributions over the past 10 years.

Fo:12 Area and percentage of forest and net area of forest available and suitable for wood production						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	Yellow	↙	Green	Red	↙	Green
Data source(s):	DJPR					
Measure(s):	Area and percentage of forest Net area of forest available and suitable for wood production					

Why this indicator?

This indicator represents the area available for timber harvesting over time. It provides important information on forest zoning. An increase or decline in area does not necessarily indicate a change in productive capacity, as the Victorian Government is considering the growing demand for greater protection of forests from timber harvesting and to improve other forest values.

Why this assessment in 2023?

The area available for timber harvesting is decreasing. This is the result of the Victorian Government's effort to protect more areas from timber harvesting to improve other forest values, and to acknowledge the impact of the 2019–20 bushfires.

The impact of the 2019–20 bushfires on the area available for timber harvesting was also reviewed by the Major Event Review of the RFAs. It was found that, as a result of 2019–20 bushfires, the D+ operable inventory reduced the level of flexibility in scheduling areas for harvest to 2030, particularly in East Gippsland. However, the remaining sawlog volumes available under the current Allocation Order appear to be more than sufficient to meet the allowable harvesting levels under the VFP for both ash and mixed species in eastern Victoria. Due to ongoing court and litigation processes, and increasing severe bushfires, the timeline for the VFP to end native timber harvesting was revised from 2030 to 1 January 2024.

Fo:13 Area of native forest harvested

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	🟡	→	🟢	🟡	→	🟢

Data source(s):	DJPR
Measure(s):	Area harvested under the 5-year harvest-area limits Harvest regimes applied for native timber harvesting and their impact on conservation of threatened species

Why this indicator?

This indicator assesses the sustainability of harvest levels and the effects of changes to harvest regimes on other forest values, such as biodiversity.

Why this assessment in 2023?

Area of native forest harvested has been stable. The area of native forest harvested is within the five-year harvest-area limit. Following the 2019–20 bushfires, VicForests introduced a variable retention harvesting system to address concerns about the impact on biodiversity from timber harvesting. As a result, most areas harvested had this system applied. The Victorian Government's decision to bring forward the end of native timber logging to 1 January 2024 and provide support packages for timber workers, sawmill operators and related communities will help to address concerns about biodiversity conservation.

One major difference in native timber harvesting between eastern and western Victoria is related to the application of pre-harvest surveys. In eastern Victoria, the Forest Protection Survey Program has a set target that at least 64% of coupes planned for harvest are to be surveyed. In western Victoria, most coupes are of a silviculture type (e.g. single tree selection, thinning from below, fallen firewood collection), so they have not triggered any survey requirements, such as thinning coupes in the foothill forests of the Midlands/Otways, as they are already meeting basal retention requirements for native species like gliders. Coupes with more intensive silviculture, such as clearfell/seedtree and gap selection, have been restricted to the Mount Cole area, where spotlight surveys were done in 2021 to determine the presence of brush-tailed phascogales prior to the most recent operations. In addition, informal surveys for the Mount Cole grevillia have also been undertaken that targeted areas of likelihood for this species (roadsides and previously disturbed areas).

Fo:14 Annual production of wood products from state forests compared to sustainable harvest levels						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	(wood products) (firewood)	(wood products) (firewood)	(wood products) (firewood)			
Data source(s):	VicForests					
Measure(s):	Annual production of wood products from state forests					

Why this indicator?

This indicator measures the harvest level of wood products for sustainable forest management in terms of total volumes and sustainable yields by major product group (wood products and firewood).

Why this assessment in 2023?

Total timber annual production from state forests has been decreasing. This is in line with the VFP to phase out native timber production by 2030. The volume of wood production for sawlogs appears to be below the maximum harvest levels. Commercial firewood production has been increasing due to strong demand and VicForests anticipates that this trend will continue. Based on the strong demand for commercial firewood, domestic firewood demand may also be strong; however, due to unavailability of data, the status of the volume of domestic firewood production is unknown.

Total wood production has sufficient information to assess status; however, information needs to be collected for domestic firewood to fully assess the status of firewood production.

Fo:15 Proportion of timber harvest area successfully regenerated by forest type

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide						

Data source(s):	DJPR, VicForests
Measure(s):	Regeneration success for the period between 1990 and 2004 Outline of forest area (pre-seed age/pre-mature) at risk from future bushfire Estimate of area burnt but not resown Summary of VicForests' post-harvest regeneration success

Why this indicator?

This indicator measures the productive capacity of forest ecosystems in the state. All forest areas where harvesting was undertaken should be regenerated.

Why this assessment in 2023?

Reports found that there is 17,561 hectares of the potential backlog regeneration area among the areas harvested before 2004. The regeneration status of this area will not be known until an assessment is completed by DEECA. The Major Event Review report found that there is still about 4,000 hectares of logged forest for which regeneration operations are still active, even though they were harvested four and five years ago. DJPR advised that they recently began regeneration stocking surveys for bushfire-impacted coupes that were previously regenerated, still regenerating and recently harvested.

DEECA, in partnership with various agencies, recently resowed fire-killed young ash forests for areas that were previously regenerated after timber harvesting and naturally regenerated after previous bushfires. However, the inability to resow the 8,380 hectares of young, fire-killed ash forests due to a lack of seed stock could result in a shift to different vegetation types.

Large areas of previously regenerated, still-regenerating and recently harvested coupes were impacted by the 2019–20 bushfires. It is possible that more coupes will be impacted by fire events as a result of rapidly changing fire regimes (more frequent and higher intensity bushfires). Although there was a revised timeline of VFP from 2030 to 2024, ongoing management of these areas to successfully regenerate remains a priority.

Data are sufficient to assess status and trend, but additional information on the impact of bushfires, particularly the impact of the 2019–20 bushfires, on mixed-species forest coupes that were successfully regenerated would improve data confidence.

Fo:16 Extent to which the legal framework (laws, regulations, guidelines) supports the conservation and sustainable management of forests						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	●	↗	●	●	↗	●
Data source(s):	ARV, DELWP, DJCS, DJPR, DPC, DTP, GORCP Authority, PV, VPC					
Measure(s):	Number of pieces of legislation is an appropriate measure of the extent to which a legal framework supports good outcomes					

Why this indicator?

This indicator provides current arrangements of legal framework and changes made for the sustainable management of forests.

Why this assessment in 2023?

The legal framework in Victoria that regulates forest management across the state comprises 58 legislative instruments. Major amendments are related to improved protection of biodiversity, and sustainable and ecological native timber harvesting.

New public land legislation to replace the current *Land Act 1958*, the *Crown Land (Reserves) Act 1978* and the *Forests Act 1958* would be needed to further support the conservation and sustainable management of forests.

The passing of the *Forests Legislation Amendment (Compliance and Enforcement) Act 2021* served to improve the regulation of native timber harvesting for sustainable forest management. The Code of Practice for Timber Production 2014 underwent reform in November 2021 and again in June 2022.

Many pieces of legislation have been amended, and new legislation has been enacted for sustainable forest management.

Fo:17 Extent to which the institutional framework supports the conservation and sustainable management of forests

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		↙			↙	

Data source(s):	DELWP
Measure(s):	Overall assessment results of compliant and non-compliant audits

Why this indicator?

Demonstrating Victoria's commitment to building community awareness, regional assessment, and planning and policy review, is critical for continued improvement of managing and conserving the state's forests. This indicator provides a measure of Victoria's institutional framework elements for forest conservation and sustainable forest management. This framework includes forest audits to ensure that commercial timber harvesting activities are compliant with Victoria's environmental regulatory framework.

Why this assessment in 2023?

Environmental audits of timber harvesting operations in state forests have been undertaken since 2002. The Victorian Conservation Regulator (CR) is now responsible for overseeing the Forest Audit Program as part of its regulatory remit. The CR has established the Acquittal of Audit Recommendations, and Overall Environmental Conformance – Forest Audit Program 2015–16 to 2020–21 to enable a high-level comparison of overall conformance by VicForests in each audit theme across several years.

The audit reports contain 73 recommendations to rectify potential environmental impacts. Of the 73 recommendations, four high-priority recommendations that are the responsibility of VicForests remain incomplete or are ongoing (partially complete). All recommendations that are currently incomplete or ongoing for which DEECA is responsible are related to recommendations for changes to the Code of Practice for Timber Production 2014 to improve regulatory clarity and environmental outcomes. Most non-conformances were found to have no environmental impact, negligible environmental impact or minor environmental impact. The incidence of non-conformances with potential for major environmental impact has fluctuated; however, a general decrease has been observed since 2016–17. These non-conformances are monitored closely by the CR. However, VAGO found a number of weaknesses in the CR's effectiveness in regulating timber harvesting operations.

There is sufficient information on the institutional framework that supports the conservation and sustainable management of forests; this includes an audit of the CR by VAGO.

Fo:18 Extent to which the economic framework supports the conservation and sustainable management of forests

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?			?	

Data source(s):	DELWP
Measure(s):	Description of economic framework in Victoria to quantify and evaluate all relevant aspects for the conservation and sustainable management of forests

Why this indicator?

This indicator describes key economic policy changes and initiatives relevant to the timber industry and biodiversity markets across all land tenures, as well as the conservation of private native forests.

Why this assessment in 2023?

The major change in economic framework during this state of environment reporting period was the announcement of the end of native timber harvesting by 1 January 2024. There is economic support for this substantial change in the industry but, as indicator Fo:01C demonstrates, new plantation establishment has not been reflected in the data. The State Budgets in this state of environment reporting period show forest-related investments. However, as the budget information relates only to the monetary investment in forest management, it does not indicate the effectiveness of government investment in supporting conservation and sustainable management of forests. More comprehensive information is, therefore, required to assess this indicator, particularly the outcomes arising from the economic framework.

Fo:19 Capacity to conduct and apply research and development aimed at improving forest management, including development of scientific understanding of forest ecosystem characteristics and functions						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	●	↗	●	●	→	●
Data source(s):	DELWP					
Measure(s):	Number of FTE employees of government agencies and private companies, and in academia, by research activity					

Why this indicator?

This indicator assesses Victoria's capacity to conduct, and apply, research and development to improve sustainable forest management.

Why this assessment in 2023?

In 2018, DELWP commissioned an independent evaluation that found that both the Integrated Forest Ecosystem Research (IFER) and National Hazards Research Australia (NHRA) agreements, while meeting different needs, contributed significantly to the achievement of long-term outcomes for forest and fire research. The evaluation identified several recommendations to further optimise the use of the agreements. These recommendations have since been adopted and have strengthened the outcomes of the head agreements.

As at 2020–21, the number of Victorian Government staff engaged in forest-related research and development activities was 17 full-time equivalent (FTE) staff, a slight decrease from 18 in 2015–16.

The number of academics funded by the Victorian Government in the area of forest research and development increased by approximately eight FTE staff in total. Increases were for FTE staff involved in the focus areas of silviculture, forest health, fauna ecology, climate change, forest carbon, sustainable forest management, spatial analysis, modelling and remote sensing. By contrast, the number of FTE staff involved in fire behaviour and forest hydrology decreased. For 2016–17, topics related to fire, ecology and hydrology accounted for 80% of overall FTE providers, compared to 2020–21, when spatial analysis, modelling and remote sensing, fire ecology, fauna ecology and sustainable forest management accounted for approximately 70% of overall FTE providers within academia.

Fo:20 Investment and expenditure in forest management

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		↙			→	

Data source(s):	DELWP, VicForests
Measure(s):	Expenditure on forest management

Why this indicator?

This indicator measures trends in forest management expenditure, reported as Victorian Government expenditure on forest management related activities within state forests, parks and reserves, as well as VicForests expenditure on forest management.

Why this assessment in 2023?

Reported expenditure on conservation and recreation more than doubled between 2017–18 and 2021–22. Forest and fire management had a spike in expenditure due to support for the response to the severe bushfire events in 2019–20. As a result of a changed timeframe for ceasing native timber harvesting, forestry contract workers will transition to contributing to bushfire risk reduction as a result of growing bushfire risk. This is likely to lead to an increase in forest and fire management after the transition is complete.

VicForests' revenue has been stable since 2012–13 after a fluctuation of between $100 million and $140 million. Total expenditure was within a similar range until 2018–19, which resulted in a net result after tax of between –$5 million and $5 million. However, the net result after tax shifted dramatically between 2019–20 and 2021–22: recording a net loss of $54 million in 2021–22 from continuing operations. This is the largest net loss from continuing operations in 15 years.

Fo:21 Value ($) of forest-derived ecosystem services

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?			?	

Data source(s):	DELWP
Measure(s):	Value ($) of forest-derived ecosystem services

Why this indicator?

Forest ecosystems provide valuable services to the Victorian community. These include maintaining water and soil quality, protecting biodiversity and mitigating global warming. This indicator evaluates these services in monetary terms to better reflect the contribution of Victoria's public forests to the Victorian economy.

Why this assessment in 2023?

Physical and monetary values of forest ecosystem services were provided. Victoria's forest ecosystem services range in total value between an estimated $7 billion and $12 billion, with soil retention affording the largest monetary value among all ecosystem services. This quantification is based on many assumptions, and sometimes estimation was based on alternative options.

Quantifying all forest assets and values in monetary terms poses a challenge. Despite a significant effort to cover most forest ecosystem services, there are still data limitations. Thus, a trend analysis for most ecosystem services was not possible.

Fire

Fi:01 Area of native vegetation burnt in planned fires and bushfires

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	(bushfire) (planned burn)	(bushfire) (planned burn)	(bushfire) (planned burn)			
Data source(s):	DELWP					
Measure(s):	Annual planned burn area on public land Annual total area affected by bushfires					

Why this indicator?

This indicator provides a baseline for the spatial extent and nature of planned burns and bushfires, which is also used to calculate residual risk. As planned burns and bushfires have different distinctive aspects to assess, each are considered separately. This indicator does not evaluate the impact of planned burn and bushfires on environmental values; these are discussed within indicators Fi:02, Fi:03 and Fi:04.

Why this assessment in 2023?

The average annual area of the bushfire extent has increased in the past 20 years. Although bushfire is an important tool for land management, excessive bushfire impacts – with increasing fire intensity and frequency – result in deterioration of environmental, social and economic outcomes in Victoria. CSIRO indicates that these impacts could be worsened by rapidly changing fire weather, so this indicator is assessed as poor. Victoria's bushfire risk has been maintained below 70% of its maximum bushfire risk since the introduction of the risk target for the fuel management program in 2016–17. On average, planned burning accounted for more than two-thirds (70%) of the total risk reduction compared to 30% for bushfires.

Bushfires have a negative impact on native vegetation because of the extent and frequency of burning. The most recent example is the 2019–20 bushfires. Research indicates that the average bushfire extent could increase as the fire season lengthens due to hotter and drier conditions: the window for planned burning is narrowing. This trend is primarily due to anticipated rapid changes of climate, leading to fewer suitable days (in terms of weather and fuel conditions) for planned burns relative to historical records. This suggests that the trend could continue to deteriorate.

Fi:02 Impacts of bushfires

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	●	↙	●	●	?	●

Data source(s):	DJPR, Inspector-General of Emergency Management, Insurance Council of Australia
Measure(s):	Impacts of bushfires on human settlements, human loss, businesses and natural resources

Why this indicator?

This indicator is used to monitor and evaluate the cumulative impacts of bushfires on communities. The Victorian Government's highest priority in bushfire management is the protection of human life. Impact of bushfire on natural resources is discussed in 'Fi:03 Actual fire regimes compared to optimal fire regimes in public forest'.

Why this assessment in 2023?

The status for bushfire impacts in Victoria over the past two decades is poor due to the 2019–20 bushfires and other devastating bushfires.

A comparison between bushfire data from the past two decades with that for the 20th century suggests that the trend in the status of bushfire impacts could be deteriorating. Predictions of increasing bushfire severity, duration, frequency and extent would also suggest a deteriorating trend.

Data for the 2019–20 bushfires were largely sufficient to assess their impact on Victoria's economy and community. Most literature, reports and inquiries provided prospects of the future impacts of bushfires.

Fi:03 Actual fire regimes compared to optimal fire regimes in public forests

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide (public forests)	●	↙	●	●	↙	●

Data source(s):	DELWP
Measure(s):	TFI distribution on public forests between 2007 and 2021 Impact of 2019–20 bushfires on threatened species and communities

Why this indicator?

Inappropriate fire regimes can cause disruption to sustainable ecosystems and result in a loss of biodiversity by changing the long-term structure of plant communities and the composition of fauna communities in public forests.

Why this assessment in 2023?

Many areas are now experiencing increased frequency of fires. The area of public forests below the minimum TFI is increasing and the area with a no-burn history is decreasing. The 2019–20 bushfires had a significant impact on TFI metrics, especially for the East Gippsland RFA region. This would suggest that the status is now 'poor'.

The trend is for an increasing area of public forests to be below the minimum TFI, while the area unburnt is decreasing, thus the deteriorating trend.

There is a high level of confidence in the data. TFI is a key measure of fire interval, which is an important component of ecosystem resilience for plant species. From 2023 onwards, DEECA aims to implement a new set of metrics to improve the ability to quantify and track additional fire regime components, including fire severity, time-since-fire, fire interval and spatial patterns for flora and fauna.

Fi:04 Bushfire risk

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	Yellow	↙	Green	Yellow	↙	Red

Data source(s):	DELWP
Measure(s):	Residual bushfire risk and the role of planned burning Condition of risk to community Bushfire risk to biodiversity

Why this indicator?

Changes in the bushfire risk within fire-affected areas and refugia will influence conservation efforts for threatened species and ecological communities, and also fire-fuel management processes.

Why this assessment in 2023?

Based on the potential thresholds for status, which rely on DEECA risk targets, the status remains as fair. However, the multiple metrics complicate the assessment of this indicator. Residual risk targets are largely achieved by planned burning. The targets are entirely based on risk to human life and property. There are currently no targets for ecosystem resilience. Furthermore, there is currently no definition of what a desirable ecosystem resilience target should be. VAGO's 2020 audit, Reducing Bushfire Risk, concluded that the impact on ecosystem resilience is not well monitored or reported. Planning regulations have not prevented settlements in fire-prone, peri-urban areas. Climate change is exacerbating fire weather and increasing bushfire risk.

A range of factors are influencing changes in bushfire risk, including changes to fire weather, which will increase fire frequency and severity. Thus, the trend is assessed as deteriorating. The trend in biodiversity responses is also assessed as deteriorating. However, movement towards meeting the residual risk targets would suggest an improving trend for one of the three measures.

There is sufficient information on the bushfire impact on communities and environment. The Victorian Government has been regularly updating how state and regions have been meeting their bushfire risk targets and what activities, such as planned burns, have been applied to manage the risk level.

Inland waters

Water quality

WQ:01 Occurrence of algal blooms						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		↙			?	
Data source(s):	DELWP					
Measure(s):	Number, frequency, extent and duration of algal blooms					

Why this indicator?

Algal blooms occur when there are excess nutrients in waterways. Such blooms can produce toxins that have serious health implications for humans, livestock and native animals. They can also block sunlight, preventing aquatic plants from photosynthesising.

Why this assessment in 2023?

Although blue-green algal blooms do not occur statewide, they do occur in a number of waterways. Reports indicate that blue-green algal blooms are increasing in number, frequency, duration and extent, resulting in a downward trend in the assessment. However, data on the spatial extent and the number of blooms are limited.

WQ:02 Dissolved oxygen concentrations in rivers						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
CMAs	(All CMAs)	→		(All CMAs)	→	
Data source(s):	DELWP					
Measure(s):	Attainment of ERS water quality objectives by CMAs for dissolved oxygen					

Why this indicator?

Animals that access oxygen in the water column, such as fish, tadpoles and macroinvertebrates, are highly susceptible to decreases in dissolved oxygen. In some cases, large numbers of fish can die in what are called 'fish kills'.

Criteria used for status assessment

Good: CMAs were rated as good or excellent in attaining ERS water quality objectives for dissolved oxygen

Fair: CMAs were rated as moderate in attaining ERS water quality objectives for dissolved oxygen

Poor: CMAs were rated as poor or very poor in attaining ERS water quality objectives for dissolved oxygen

Why this assessment in 2023?

Data from the Water Measurement Information System indicate that all CMA regions attained the Environmental Reference Standard (ERS) objectives each year between the periods 2010 to 2017 and 2018 to 2021, with stable trends.

WQ:03 Salinity concentrations in rivers

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
CMAs	Good (7 CMAs) Fair (2 CMAs) Poor (1 CMA)	Stable	High	Good (7 CMAs) Fair (2 CMAs) Poor (1 CMA)	Stable	Good

Data source(s):	DELWP
Measure(s):	Attainment of ERS water quality objectives by CMAs for salinity

Why this indicator?

Salinity is an important aspect of water quality: changes to salinity levels can have a profound effect on aquatic biota, either through direct toxicity or disruptions to ecosystem processes and functions.

Criteria used for status assessment

Good: CMAs were rated as good or excellent in attaining ERS water quality objectives for salinity

Fair: CMAs were rated as moderate in attaining ERS water quality objectives for salinity

Poor: CMAs were rated as poor or very poor in attaining ERS water quality objectives for salinity

Why this assessment in 2023?

Data from the Water Measurement Information System indicate a good status for most CMAs in attaining ERS water quality objectives for salinity. Trends for each CMA region were also stable between the periods 2010 to 2017 and 2018 to 2021.

WQ:04 Total nitrogen concentrations in rivers

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
CMAs	Good (3–4 CMAs)* Fair (3 CMAs) Poor (3–2 CMAs)* Unknown (Mallee CMA)	Improving	Good	Good (2 CMAs) Fair (2 CMAs) Poor (5 CMAs) Unknown (Mallee CMA)	Stable	Good
Data source(s):	DELWP					
Measure(s):	Attainment of ERS water quality objectives by CMAs for total nitrogen					

Why this indicator?

Nutrients in aquatic ecosystems play a significant role in primary production. Nitrogen and phosphorus are two key nutrients in freshwater systems. However, when too high, they can lead to algal blooms that can be toxic to aquatic animals and plants, livestock and people engaged in water-based activities.

Criteria used for status assessment

Good: CMAs were rated as good or excellent in attaining ERS water quality objectives for total nitrogen

Fair: CMAs were rated as moderate in attaining ERS water quality objectives for total nitrogen

Poor: CMAs were rated as poor or very poor in attaining ERS water quality objectives for total nitrogen

Why this assessment in 2023?

Data from the Water Measurement Information System indicate a mixed status for attainment of ERS water quality objectives by CMAs for total nitrogen. However, there is an improving trend, with an additional CMA having a good status and one fewer having a poor status.

** The first figure presented in brackets refers to the number of CMAs whose status was based on 2010–17 data and the second figure presented in brackets refers to the number of CMAs based on 2018–21 data.*

WQ:05 Total phosphorus concentrations in rivers

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
CMAs	(2–4 CMAs)* (4 CMAs) (3–1 CMAs)* (Mallee CMA)			(1 CMA) (2 CMAs) (6 CMAs) (Mallee CMA)		
Data source(s):	DELWP					
Measure(s):	Attainment of ERS water quality objectives by CMAs for total phosphorus					

Why this indicator?

Land-use change can lead to run-off containing eroded soil, fertilisers and animal waste that include phosphorus. It can also enter waterways at point-source discharges of treated sewage and stormwater. Increased phosphorus levels in Victoria's waterways can cause algal blooms, which impact fish and other aquatic life.

Criteria used for status assessment

Good: CMAs were rated as good or excellent in attaining ERS water quality objectives for phosphorus

Fair: CMAs were rated as moderate in attaining ERS water quality objectives for phosphorus

Poor: CMAs were rated as poor or very poor in attaining ERS water quality objectives for phosphorus

Why this assessment in 2023?

Data from the Water Measurement Information System indicate a mixed status for attainment of ERS water quality objectives by CMAs for total phosphorus. However, there is an improving trend, with two additional CMAs having a good status and two fewer having a poor status.

** The first figure presented in brackets refers to the number of CMAs whose status was based on 2010–17 data and the second figure presented in brackets refers to the number of CMAs based on 2018–21 data.*

WQ:06 Turbidity levels in rivers						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
CMAs	(5–10 CMAs)* (5–0 CMAs)*			(3 CMAs) (7 CMAs)		
Data source(s):	DELWP					
Measure(s):	Attainment of ERS water quality objectives by CMAs for turbidity					

Why this indicator?

Turbidity, or water cloudiness, is a measure of the level of suspended sediments in the water column. Elevated turbidity can decrease light penetration in waterways, reduce underwater visibility, clog the gills of fish and macroinvertebrates, and limit photosynthesis in aquatic plants.

Criteria used for status assessment

Good: CMAs were rated as good or excellent in attaining ERS water quality objectives for turbidity

Fair: CMAs were rated as moderate in attaining ERS water quality objectives for turbidity

Poor: CMAs were rated as poor or very poor in attaining ERS water quality objectives for turbidity

Why this assessment in 2023?

Data from the Water Measurement Information System indicate a significantly improved status for attainment of ERS water quality objectives by CMAs for turbidity.

** The first figure presented in brackets refers to the number of CMAs whose status was based on 2010–17 data and the second figure presented in brackets refers to the number of CMAs based on 2018–21 data.*

WQ:07 pH levels in rivers

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
CMAs	(10–7 CMAs)* (0–2 CMAs)* (1 CMA)					

Data source(s):	DELWP
Measure(s):	Attainment of ERS water quality objectives by CMAs for pH

Why this indicator?

Aquatic species have a preferred pH range (a measure of acidity). Levels of pH outside those ranges can lead to fish deaths and damage the health of aquatic plants.

Criteria used for status assessment

Good: CMAs were rated as good or excellent in attaining ERS water quality objectives for pH

Fair: CMAs were rated as moderate in attaining ERS water quality objectives for pH

Poor: CMAs were rated as poor or very poor in attaining ERS water quality objectives for pH

Why this assessment in 2023?

Data from the Water Measurement Information System indicate a mixed status for attainment of ERS water quality objectives by CMAs for pH. However, there was a deteriorating trend for three of the CMAs, with two changing from good to fair and one from good to poor.

** The first figure presented in brackets refers to the number of CMAs whose status was based on 2010–17 data and the second figure presented in brackets refers to the number of CMAs based on 2018–21 data.*

WQ:08 Proportion of water bodies with good ambient water quality						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
CMAs	Good (2–1 CMAs)* Fair (3–8 CMAs)* Poor (4–0 CMAs)* Unknown (Mallee CMA)	Improving	High	Poor	Deteriorating	Good
Data source(s):	DELWP, EPA Victoria, Melbourne Water					
Measure(s):	Attainment of ERS water quality objectives by CMAs in a combined score for indicators WQ:03 to WQ:07					

Why this indicator?

This is one of two indicators for Target 6.3 of UN SDG 6: 'Clean water and sanitation'. The purpose of the indicator is to assess whether efforts to improve water quality are successful.

Criteria used for status assessment

Good: CMAs were rated as good or excellent in attaining ERS water quality objectives for indicators WQ:03 to WQ:07 combined

Fair: CMAs were rated as moderate in attaining ERS water quality objectives for indicators WQ:03 to WQ:07 combined

Poor: CMAs were rated as poor or very poor in attaining ERS water quality objectives for indicators WQ:03 to WQ:07 combined

Why this assessment in 2023?

Based on the combined score for indicators WQ:03 to WQ:07, the status is mixed across the CMAs. There has been an improvement from poor to fair for four CMAs; however, one CMA previously rated good is now rated as fair.

** The first figure presented in brackets refers to the number of CMAs whose status was based on 2010–17 data and the second figure presented in brackets refers to the number of CMAs based on 2018–21 data.*

WQ:09 Groundwater quality

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	Grey	?	Grey	Green (eastern Victoria) Red (north-western Victoria) Yellow (elsewhere)	→	Yellow

Data source(s):	DELWP
Measure(s):	Electrical conductivity in bore network

Why this indicator?

Groundwater is an important part of Victoria's rural and urban water supply systems and is vital for groundwater-dependent ecosystems.

NB: This indicator was 'WR:11 Groundwater quality' in the SoE 2018 Report.

Why this assessment in 2023?

Data are insufficient to determine either status or trend for this indicator.

WQ:10 Volume of treated and poorly treated discharges to surface waters and compliance with licence requirements

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	Grey	?	Grey	Grey	?	Red

Data source(s):	EPA Victoria
Measure(s):	Volume, number and quality of treated and poorly treated discharges Number of licences Compliance with licence requirements

Why this indicator?

Point-source discharges to waterways are the major source of contaminants that are potentially harmful to waterways and to those who use them. For example, animal effluents are a major source of nutrients and pathogens.

NB: This is a modified SoE 2023 indicator that enables a broader assessment to include all licensed discharges and was formed by increasing the breadth of the measures of the SoE 2018 indicator 'WQ:09 Volume of sewage discharge to surface waters'.

Criteria used for status assessment

Good: ≥90% of licensed discharges meet discharge limits

Fair: 65% to <90% of licensed discharges meet discharge limits

Poor: <65% of licensed discharges meet discharge limits

Why this assessment in 2023?

There are insufficient data on discharge volumes and licence compliance to determine status or trend for this indicator.

WQ:11 Percentage of inland water pollution reports requiring a field response by EPA Victoria						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide		?		NC*	NC	NC

Data source(s):	EPA Victoria
Measure(s):	Percentage of inland water pollution reports requiring a field response EPA Victoria achievement of targets for the pollution performance measure in its Strategic Plan 2022–2037

Why this indicator?

Water pollution can harm animals and plants, harm human health and have other social and economic impacts.

NB: This is a modified SoE 2023 indicator that adopts a new measure that focuses on EPA Victoria's performance in its response to pollution reports from communities, and the severity of the pollution reported. This indicator was formed by modifying the measure of the SoE 2018 indicator 'WQ:10 Reported inland water pollution incidents'.

Criteria used for status assessment

Good: ≥90% of the pollution performance measure target is met

Fair: 65% to 90% of the pollution performance measure target is met

Poor: <65% of the pollution performance measure target is met

Why this assessment in 2023?

Currently there are insufficient data to determine status or trend for this indicator.

** NC indicates that comparisons between the SoE 2018 and SoE 2023 assessments for the modified SoE 2023 indicator would be inappropriate due to the extensive level of variability in the measures and/or data used in the assessment between SoE reports.*

Water resources

WR:01 Water resources and storage trends						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	Fair	Declining (long term) Improving (short term)	High	Fair	Stable	Good
Data source(s):	DELWP					
Measure(s):	Water storage levels in Victoria as a percentage of capacity Projected changes in run-off and inflows					

Why this indicator?

The quality and quantity of Victoria's water resources are vital for human health and wellbeing, and for accommodating anticipated population growth. Projected declines in run-off and inflows to water storages have implications for aquatic biodiversity, agriculture and human welfare.

NB: This modified SoE 2023 indicator has been formed by merging the SoE 2018 indicators 'WR:01 Water resources and storage trends' and 'WR:02 Projected runoff to dams and catchments'. The 2018 assessment provided in this report card is for 'WR:01 Water resources and storage trends', as its measure is most comparable to that of the modified 2023 indicator.

Criteria used for status assessment

Good: Over a 10-year period, Victoria's water storage levels are on average at ≥70% storage capacity

Fair: Over a 10-year period, Victoria's water storage levels are on average between 50% to <70% storage capacity

Poor: Over a 10-year period, Victoria's water storage levels are <50% storage capacity

Why this assessment in 2023?

Victoria's water storages and river flows are well monitored, with data publicly reported in the annual Victorian water accounts and the online Current Water Snapshot. Although three wet years since the SoE 2018 Report have seen an upwards trend in water storage levels, the long-term trend is declining.

WR:02 Interception of surface water by small farm dams

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	(southern rivers) (northern rivers)					

Data source(s):	DELWP
Measure(s):	Likelihood of dams contributing to a long-term decline in available surface water

Why this indicator?

Small farms dams are an important water resource for farming operations and can also provide habitat for aquatic life. However, they intercept water that would normally flow into waterways, placing pressure on a river basin's water balance and ultimately influencing the allocation of surface water to consumptive uses and the environment.

NB: This is a modified SoE 2023 indicator that provides greater focus on the impacts of small dams and was formed by modifying the measure of the SoE 2018 indicator 'WR:05 Number of dams, weirs and levees'.

Criteria used for status assessment

Good: Interception by small farms dams has a low likelihood of contributing to a long-term decline in available surface water

Fair: Interception by small farms dams has a moderate likelihood of contributing to a long-term decline in available surface water

Poor: Interception by small farms dams has a high likelihood of contributing to a long-term decline in available surface water

Why this assessment in 2023?

There are insufficient data to determine a statewide status, hence the focus on southern rivers (the future release of the LTWRA for northern basins will fill that gap). Based on the above criteria, the likelihood of small farm dams impacting surface water availability ranges from good to poor, with the overall result rated as fair. Spatial data on the dams are well documented in the Victorian water accounts. The growth rate in the number of dams has slowed; however, the trend in terms of impact continues to deteriorate.

WR:03 Surface water harvested for consumptive use						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	Fair (yellow)	Deteriorating (↙)	High (green)	Poor (red)	Stable (→)	Good (green)
Data source(s):	DELWP					
Measure(s):	Total surface water diversions Water leaving basins					

Why this indicator?

Water consumption reduces the water available to support aquatic ecosystems and increases the impact of dry conditions on biodiversity. Climate change will reduce the inflows and outflows of river basins.

NB: This indicator was 'WR:06 Surface water harvested for consumptive use' in the SoE 2018 Report.

Criteria used for status assessment

Good: On average, over a 5-year period, ≥21 of Victoria's 28 river basins had ≥75% of water leaving the basin

Fair: On average, over a 5-year period, 14 to 20 of Victoria's 28 river basins had ≥75% of water leaving the basin

Poor: On average, over a 5-year period, <14 of Victoria's 28 river basins had ≥75% of water leaving the basin

Why this assessment in 2023?

Water flows and consumption are very well monitored across the state. Sixteen of the 28 basins have ≥75% of stream flows leaving the basin. This indicates a status of fair — an improvement on the poor assessment in SoE 2018 Report. This difference is due to the use of assessment criteria for this indicator, and to wetter years since the SoE 2018 Report. Climate change projections indicate that the trend will deteriorate. However, the data are variable and fluctuate due to weather patterns.

** The Mallee Basin does not have recorded stream flows, so only 28 of the state's 29 basins are used in the assessment criteria. In the Millicent Basin, all stream flows are diverted, with none leaving the basin.*

WR:04 Percentage of compliance with entitlements for the take of surface water

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide						

Data source(s):	DELWP
Measure(s):	Percentage of compliance with extraction entitlements for surface water

Why this indicator?

The use of extraction entitlements supports the best-practice management of water resources and reduces impacts on aquatic ecosystems.

NB: This is a modified SoE 2023 indicator formed by modifying the measure for the SoE 2018 indicator 'WR:07 Percentage of waterways and groundwater areas subject to extraction, with a limit on extraction' in the SoE 2018 Report.

Why this assessment in 2023?

Although the volume of water taken in each of Victoria's river basins over the past four years is below the bulk entitlements, and there is compliance with the take and use licences for unregulated surface water, the entitlements have not been set based on an ecologically sustainable level of take.

Rising numbers of potential breaches of the Victorian *Water Act 1989* by individual consumers of non-urban water are largely due to improved monitoring and enforcement actions, not increasing volumes of water theft. With up to 3.6% of non-urban water stolen, the Victorian Government has set a target of 1%. It is anticipated that progress towards this target will be assessed in the SoE 2028 Report.

WR:05 Water recycling

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide						

Data source(s):	DELWP
Measure(s):	Volume and percentage of wastewater recycled

Why this indicator?

Recycled water is largely independent of rainfall and can be a reliable source of water in an uncertain climate. It is suitable for a wide range of uses, helps reduce pressure on water resources, makes cities and towns more resilient and can provide water for delivery to wetlands and waterways.

NB: This SoE 2023 indicator was 'WR:08 Water recycling' in the SoE 2018 Report.

Why this assessment in 2023?

The production of recycled water varies due to fluctuating demand, variable weather patterns and the volume of wastewater produced. Over the 5-year period from 2016–17 to 2020–21, the percentage of wastewater recycled ranged from 17% to 22% and then back to 17%, with an associated reduction in the volume of recycled water.

WR:06 Percentage of agricultural land with improved irrigation						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide					?	
Data source(s):	CMAs					
Measure(s):	Percentage of agricultural land with improved irrigation infrastructure Efficiency of water use Water recovery outcomes					

Why this indicator?

Improving irrigation practice, such as developing crops that require less water and making irrigation practices and equipment more efficient, can significantly benefit the environment by increasing water recovery and providing opportunities to enhance flow regimes.

NB: This SoE 2023 indicator was 'WR:09 Percentage of agricultural land with improved irrigation' in the SoE 2018 Report.

Why this assessment in 2023?

Current data are not reflective of irrigation improvements made by irrigators without government assistance. There are data on overall investment improvements to irrigation districts; however, they are not at the farm level. Both the Australian and Victorian governments are investing heavily in the modernisation of irrigation for agriculture. This will result in improvements to on-farm irrigation in terms of water efficiency and water recovery. Environmental outcomes are less clear. Analysis is difficult because the use of water for irrigation fluctuates from year to year due to weather conditions and economics.

WR:07 Groundwater levels, consumption and use

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	Yellow	→ (most shallow aquifers); ↙ (shallow aquifers in northern region; lower aquifers in Gippsland and northern region)	Green	Yellow	→	Green

Data source(s):	DELWP
Measure(s):	Groundwater levels for shallow, middle and lower aquifers Groundwater consumption as a percentage of total entitlement

Why this indicator?

Trends in groundwater levels can be used to monitor the impact of extraction, land-use change and climate change.

NB: This modified SoE 2023 indicator has been formed by merging the SoE 2018 indicators 'WR:12 Groundwater levels' and 'WR:13 Groundwater harvested for consumptive use'. The 2018 assessment provided in this report card is for 'WR:13 Groundwater harvested for consumptive use', as its measure is most comparable to that of the modified 2023 indicator.

Why this assessment in 2023?

For the 5-year trend from 2016–17 to 2020–21, shallow (unconfined) aquifers are largely stable, except in the northern region. For middle and lower (confined) aquifers, some in the Gippsland Basin and northern Victoria are declining. In the longer term, groundwater levels generally are expected to decline. Data on the outcomes of this long-term change are limited. Caution needs to be applied when determining the statewide status because it averages across a large number of aquifers, each of which has different characteristics and can be connected to other aquifers that are not monitored.

WR:08 Condition of flow regimes

Regions(s)	2023 status	2023 trend	2023 confidence		2018 status	2018 trend	2018 data quality
Statewide	Poor	Stable	High		Poor	Deteriorating	Good
Data source(s):	DELWP						
Measure(s):	Streamflow as a percentage of the long-term average						

Why this indicator?

Low streamflow can have ecological impacts. The species that live in and around waterways rely on well-established flow patterns for successful foraging, breeding and movement throughout the landscape. Changes in streamflow patterns have cascading effects on the health of waterways and ecosystems that rely on groundwater.

Less water flowing in Victorian waterways increases the likelihood of more harmful algal blooms occurring that have the potential to affect the safety of Victoria's water supplies for drinking, supporting stock and for recreation.

NB: This SoE 2023 indicator was 'WR:03 Condition of flow regimes' in the SoE 2018 Report.

Why this assessment in 2023?

For many catchments in Victoria, the run-off response to rainfall has declined this century, particularly during the Millennium Drought. This means that, for a given amount of rainfall, Victoria's catchments have been getting less streamflow than in past decades

Because streamflow has been below the long-term average for most years this century, the status for this indicator has been assessed as poor. The trend has been rated as stable, because below-average streamflow was recorded in four of the five years for the SoE 2023 reporting period (2016-17 to 2020-21), which was the same as the previous five-yearly reporting period (2011-12 to 2015-16*).

** The SoE 2023 reporting period represents the years which data are available since the SoE 2018 Report as opposed to the 5-year SoE 2023 reporting cycle (2018-22). Data from 2022 for this indicator will be incorporated into the assessment for the SoE 2028 Report.*

WR:09 Delivering water for the environment

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	Yellow	→	Yellow	Yellow	→	Green

Data source(s):	VEWH
Measure(s):	Achievement of required potential watering actions Percentage of flow recommendations fully, partially or not achieved for rivers and wetlands, with and without the contribution of water for the environment

Why this indicator?

Environmental water is critical for the protection of plants and animals, and for the overall health of rivers, wetlands, floodplains and estuaries. It also has social, cultural and economic benefits.

This indicator is designed to assess how much water is being delivered under environmental entitlements and how that delivery is helping to achieve the scientifically recommended water regime.

NB: This SoE 2023 indicator was 'WR:04 Delivering water for the environment' in the SoE 2018 Report.

Why this assessment in 2023?

The Victorian Environmental Water Holder (VEWH) fully achieves most of its planned annual watering actions. However, despite this level of achievement, there remains a significant shortfall to fully achieve the scientifically recommended flow regimes. This highlights a significant gap between what Victorian river systems need from a hydrological perspective and what the VEWH can currently achieve from its environmental watering program.

The results show that water for the environment is having a greater impact on fully achieving wetland watering requirements than it is on fully achieving optimum river flows. However, these results include assessments for only those rivers and wetlands where environmental water is being delivered, which incorporates most of the regulated rivers in Victoria but only a small percentage of regulated wetlands.

Based on water for the environment being shown to contribute to the achievement of flow recommendations in all regions, but river systems still generally not fully achieving the scientifically recommended flow regimes, the status of this indicator has been assessed as fair. The confidence is rated as moderate because the contribution of water for the environment to achieving each of the intended hydrological outcomes is variable. Further research is underway to quantify this and will be included in the indicator assessment in the SoE 2028 Report.

Energy

E:01 Primary energy consumption

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide						

Data source(s):	BP, DCCEEW
Measure(s):	Primary energy consumption Primary energy consumption per capita GHG emissions from the energy sector GHG emissions from the energy sector per capita

Why this indicator?

Victoria's primary energy system is by far the most significant source of the state's GHG emissions. This indicator is designed to analyse Victoria's energy consumption and consequent emissions, and to assess whether the state is making progress towards net zero GHG emissions.

NB: This SoE 2023 indicator was 'E:02 Total energy consumption by fuel' in the SoE 2018 Report.

Why this assessment in 2023?

The status for this indicator has been assessed as fair due to primary energy consumption per capita in Victoria remaining high relative to most G20 countries, but low relative to the national figure. Furthermore, even though a significant reduction (51%) of GHG emissions per capita from the energy sector was achieved during the past decade, an even greater reduction (68%) is required during the next decade to meet the International Energy Agency's (IEA) 2030 progress target for the objective of net zero emissions by 2050.

Despite the fair rating for the status of this indicator, the substantial reductions in primary energy consumption and GHG emissions from the energy sector, particularly over the most recent decade, are the basis for the improving trend assessment for this indicator.

E:02 Primary energy consumption by source

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide						

Data source(s):	DCCEEW
Measure(s):	Primary energy consumption in Victoria, by fuel source

Why this indicator?

Meeting Victoria's climate change mitigation goals requires a large-scale energy transition.

Victoria will require an almost complete transformation of its energy system away from the current dominance of fossil fuels to low- and zero-emissions energy resources, if it is to transition to a net zero GHG emissions economy by 2050.

Why this assessment in 2023?

While the increasing substitution of coal for renewables in electricity production is positive and reflected in a trend assessment of improving for this indicator, the electricity generation, transport and fuel combustion subsectors remain responsible for more than 95% of Victoria's net GHG emissions, as of 2020. Because energy consumption from a range of fuels and subsectors comprises nearly all of Victoria's net GHG emissions, the status assessment for this indicator is fair, which is in line with the status assessment for indicator 'CCM:11 Annual greenhouse gas emissions' in this report.

E:03 Electricity consumption

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide						

Data source(s):	Australian Energy Market Operator, BP, DCCEEW
Measure(s):	Electricity generation per capita GHG emissions from electricity generation as a percentage of Victoria's total net GHG emissions Per capita operational demand Electricity delivered on transmission networks per connection Electricity delivered on distribution networks per connection

Why this indicator?

At a subsector level, the highest contributor to GHG emissions in Victoria in 2020 was the production of electricity, responsible for 50% of the state's net emissions (and 51% of the state's net energy sector emissions). This means that electricity generation and consumption is a critical area for Victoria to improve on the path to net zero GHG emissions by 2050.

NB: This SoE 2023 indicator was 'E:05 Total electricity consumption' in the SoE 2018 Report.

Why this assessment in 2023?

The status for this indicator has been assessed as good due to the substantial decline in electrical demand measured as throughput on distribution networks, transmission networks or operating demand, which will have resulted in a commensurate reduction in fossil fuel electricity production.

E:04 Electricity generation by fuel

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide						

Data source(s):	Australian Energy Market Operator, BP, DCCEEW
Measure(s):	Generation of electricity, by fuel type Share of electricity generation, by fuel type Generation of electricity, by fuel type per capita Renewable electricity generation per capita Rooftop solar installation of percentage of dwellings in each region Rooftop solar electricity generation as percentage of Operating Demand in each NEM region

Why this indicator?

The Victorian Government has legislated renewable energy targets (the proportion of electricity in Victoria to be produced from renewable sources) of 25% by 2020, 40% by 2025, and 50% by 2030.

This indicator helps track the progress of renewable energy as a share of electricity generation in Victoria, balanced against fossil fuels such as brown coal.

NB: This SoE 2023 indicator was 'E:06 Total electricity generation by fuel' in the SoE 2018 Report.

Why this assessment in 2023?

The dominance of coal for electricity generation in Victoria offsets the relatively high penetration of renewable sources when benchmarked against G20 countries. This is the basis of a status assessment of fair for this indicator.

E:05 Gas consumption

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide				New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator

Data source(s):	Australian Energy Market Operator, DCCEEW
Measure(s):	Gas consumption Gas consumption per capita Gas distributed on distribution networks per capita

Why this indicator?

More than two million Victorian homes and businesses use gas – more users than any other state or territory. Gas prices are rising steadily, GHG emissions from gas are a significant component of state emissions and international events are causing uncertainty in gas supply and price around the world. This means that reducing gas consumption and associated GHG emissions within Victoria's gas sector is an important and immediate focus area for the state.

NB: This is a new SoE 2023 indicator that was not included in the SoE 2018 Report. This indicator has been included to address a gap on gas consumption in previous state of the environment reports.

Why this assessment in 2023?

The status of this indicator has been assessed as poor taking into consideration the small decline in per capita gas consumption in Victoria (in comparison to electricity), an under-performance in Victoria relative to South Australia and New South Wales for gas distribution per customer, and international events causing uncertainty in gas supply and price around the world.

E:06 Energy in transport

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide						

Data source(s):	DCCEEW
Measure(s):	Energy used in transport GHG emissions from transport

Why this indicator?

At a subsector level, the second-highest contributor to GHG emissions in Victoria in 2020 was transport, responsible for 25% of the state's net emissions. This means that transport energy consumption is an important area for Victoria to improve on the path to net zero GHG emissions by 2050.

NB: This SoE 2023 indicator was 'E:08 Energy used in the transport sector' in the SoE 2018 Report.

Why this assessment in 2023?

Victoria's performance in energy consumption (and GHG) in transport is poor compared with GHG emissions in stationary energy.

The trend has been assessed as improving because energy use and GHG emissions from the transport subsector are both less than in the previous state of the environment reporting period, and the assessment must reflect observed measurements. However, this assessment for trend is almost certainly due to a reduction in travel associated with COVID-19 restrictions and is highly likely to be only temporary.

It is expected that transport energy usage and GHG emissions will increase back to near pre-pandemic levels during the next state of the environment reporting period.

Waste and resource recovery

W:01 Total waste generation						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide						
Data source(s):	SV					
Measure(s):	Annual amount of managed waste generated (tonnes) by all source sectors, not including hazardous waste					

Why this indicator?

Depending on how it is managed, as well as its composition, waste can have significant social, economic and environmental impacts. GHGs, particulate matter and other pollutant by-products are emitted into the atmosphere from the transport, disposal and reprocessing of waste. These contribute to climate change and reduce air quality, which has implications for human health. Hazardous leachates produced by landfilled waste can contaminate surrounding soil and groundwater systems, threatening biodiversity and degrading ecosystems. Disposed materials represent a loss of natural resources and other inputs used in the product chain, such as water and energy, which can further impact water scarcity and the depletion of natural resources. The financial burden incurred by governments and communities also increases, as the management of higher volumes of waste demands more waste management and material recovery infrastructure.

Criteria used for status assessment

No national or statewide standards, thresholds or strategic targets currently exist for waste generation. The assessment in the SoE 2023 Report is based upon comparisons with the data used in determining the status and trend within the SoE 2018 Report.

Why this assessment in 2023?

Total waste generation has been on an upward trajectory from 2014–15 to 2019–20, following a short period of decline from 2012–13 to 2013–14. In 2019–20, Victoria had discarded more waste than in any other year.

The amount of waste produced increased at a more rapid rate (10%) and peaked at a higher level (15.9 Mt) during the SoE 2023 reporting period than what was demonstrated during the SoE 2018 reporting period (7% and 12.9 Mt, respectively). The construction and demolition (C&D) sector contributed nearly half of the state's total generated waste during 2018–19 and 2019–20, primarily due to a sharp rise in aggregates, masonry and soil waste prompted by an upturn in infrastructure development projects. By contrast, waste levels were comparably lower among the municipal solid waste (MSW) and commercial and industrial (C&I) sectors.

COVID-19 restrictions and kerbside waste collection system reforms affected the patterns of waste generation among the C&I and MSW sectors between 2018–19 and 2019–20, leading to increasing levels of household organics and glass, and reductions in the generation of these waste streams by business and industry.

Due to issues associated with the quality and comprehensiveness of annual waste data, highlighted by several recent audit and inquiry reports, coupled with a lack of established thresholds or policy targets for this indicator, the data confidence has been assessed as moderate.

W:02 Generation of waste per capita

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?			→	

Data source(s):	ABS, SV
Measure(s):	Annual amount of non-hazardous waste generated from the MSW and C&I sectors per person (kg)

Why this indicator?

Waste per capita provides a metric for assessing individual waste generation by accounting for changes in population levels. In having a clear understanding of the true pattern of waste generation, the efficacy of policy and programs aimed at reducing waste generation can be evaluated, as can progress towards targets under the circular economy policy.

NB: The measure for this modified SoE 2023 has broadened from that of the SoE 2018 indicator 'W:02 Generation of municipal waste per capita' to include waste generation from both the MSW and C&I sectors in order to align with that of the circular economy policy target.

Criteria used for status assessment

Good: Achieving Victoria's target of 15% reduction in waste per capita by 2030 (based on waste projection models)[368]

Fair: Achieving within 5% of Victoria's target of reduction in waste per capita (10%–14%) by 2030 (based on waste projection models)

Poor: Achieving less than 10% reduction in waste per capita by 2030 (based on waste projection models)

Why this assessment in 2023?

Waste generation per capita exhibited a gradual increase across 2017–18 and 2019–20. However, it is important to note that comparisons with assessment results from the SoE 2018 Report cannot be undertaken as the calculations for per capita waste have been modified in the SoE 2023 Report.

Recyclable material made up more than half (54%–56%) of per capita waste totals annually. However, with continual growth in the amount of garbage generated per person across the 3-year period, the rate of diversion from landfill declined. It is projected that, by 2030, waste generation per capita will be 10% less than it was in 2018–19 (baseline). Although this exceeds the state reduction target of 15%, it does meet the more conservative national target, which aims for a 10% reduction.

The true pattern of per capita waste over the 3-year period was affected by the influx of large quantities of stockpiled household recyclables that were released from storage and managed. Whether further impacts from the clearance of stored materials on per capita waste generation are unclear, as information on stockpiling is not consistently disclosed by annual waste survey participants.

Data confidence was rated as low due to the issues of data quality and limited data availability.

368. SV has developed a waste projection model which tracks and projects future solid waste flows in Victoria using two sources of information, one being the total amount of waste recovered derived from the Victorian Recycling Industries Annual Survey and the second being EPA data on the amount of material deposited at landfills. Future projections are based on the last known landfilled figure and projected into the future using population estimates. The interactive dashboard is publicly available and is accessed at https://www.sustainability.vic.gov.au/research-data-and-insights/waste-data/interactive-waste-data/victorias-waste-projection-model. It should be noted that the predictive modelling is expected to be updated during 2023 which may have different projections for 2030 than reported within the SoE 2023 Report.

W:03 Total food waste generation

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide						

Data source(s):	DCCEEW, SV
Measure(s):	Annual amounts of food waste generated (tonnes) by all source sectors

Why this indicator?

Increasing amounts of generated food waste entering landfill have significant social, economic and environmental impacts in terms of leachates, emission of GHGs, lost natural resources and economic costs, and also contribute to food insecurity.

Criteria used for status assessment

Good: Achieving Victoria's target of halving food waste from the 2018–19 baseline by 2030 (based on waste projection models)

Fair: Achieving within 5% of Victoria's target of halving food waste from the 2018–19 baseline (45%–49%) by 2030 (based on waste projection models)

Poor: Achieving less than 45% reduction in Victoria's food waste from the 2018–19 baseline by 2030 (based on waste projection models)

Why this assessment in 2023?

Based on the limited data available, the amount of food waste generated and recovered (biomass, composting) has been decreasing overall in Victoria from 2006–07 to 2018–19 (most recent data). Reductions in food waste generation were also observed within the SoE 2018 reporting period. However, during the SoE 2023 reporting period, the amount of food waste being produced and disposed of has been increasing overall, by 5% and 12% respectively, while recovery decreased by 5%. Decreasing diversion rates, coupled with increasing levels of disposal, has meant food waste continues to represent a dominant waste stream entering landfill. This was particularly evident during 2018–19, where 16% of the state's total disposed waste was composed of food material.

While the MSW sector was the major contributor to the state's total generated food waste, due in large part to the combined effects of preparing too much food and misunderstanding of food labelling, much of the recent increase in generation and landfilling of food waste was driven by the C&I sector, particularly food retailers and hospitality businesses. Limited access to recycling collection services was cited as the primary factor for weak recovery among segments of this source sector. This limitation extends to the MSW sector as well, resulting in high contamination levels and low-quality recycled material, although reforms to household recycling services are working to improve food waste recovery within the MSW sector.

Data confidence was rated as low, particularly due to the exclusion of food waste generated on farms and in many food processing operations, and other limitations on data availability.

W:04 Diversion rate

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	Poor (red)	Stable (→)	Low (red)	Fair (yellow)	Stable (→)	Good (green)

Data source(s):	SV
Measure(s):	Percentage of generated non-hazardous waste that is diverted from landfill

Why this indicator?

Diversion rate is a measure of how much generated waste is diverted from landfill with the intention of recycling or reuse. This metric serves as an important benchmark for assessing the effectiveness of the state's recycling program and tracking progress towards the transition to a circular economy.

Criteria used for status assessment

Good: Achieving Victoria's target of diverting 80% of waste from landfill by 2030 (based on waste projection models)

Fair: Achieving within 5% of Victoria's target of diverting waste from landfill (75%–79%) by 2030 (based on waste projection models)

Poor: Achieving less than 75% diversion of waste from landfill by 2030 (based on waste projection models)

Why this assessment in 2023?

The diversion rate increased overall by 10% between 2010–11 and 2019–20, and reached its highest level of 70% during 2018–19 and 2019–20. When comparing the trend between the SoE 2018 Report and the SoE 2023 Report, the diversion rate increased at an overall similar level of 1% for the 5-year period.

Since 2017–18, the proportion of waste diverted from landfill has remained stable, increasing by 1%, while the rate at which waste is generated increased by 10%. This means that more waste has been entering landfill each year, with much of this disposed material being recoverable.

The materials with the strongest diversion rates in 2019–20 included metals, aggregates, masonry and soil, and glass, while the diversion of plastics from landfill remained low. Unlike in previous years, the majority (90%) of recovered material was reprocessed within Victoria, leading to a recycling rate of 67%, up from 65% in 2018–19. A number of external factors that severely impacted Victoria's waste and resource recovery sector between 2018 and 2021 contributed to the deterioration, or lack of progress, of waste diversion. At the start of January 2018, China began to stringently enforce restrictions on the importation of recycled materials under its National Sword policy, which effectively removed a key international market for trading sorted recyclables. This has created volatility in global and domestic pricing for recovered materials. With limited export destinations available, the vulnerabilities within Victoria's waste and resource recovery sector were exposed. As a result, excessive stockpiling of combustible materials and the landfilling of household recyclables increased.

With stagnating diversion rates and increasing amounts of waste being landfilled, including recyclable materials, the waste projection model indicates that Victoria will not achieve its target of diverting 80% of waste from landfill by 2030.

W:05 Litter and illegal dumping

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
151 survey sites primarily located across Melbourne suburbs **15 rural highway survey sites**		→			↗	

Data source(s):	KAB, SV
Measure(s):	Number of litter items counted within defined survey sites

Why this indicator?

Litter and illegal dumping impact the health of humans, wildlife and ecosystems, as well as reducing aesthetic values. Problematic litter streams, particularly plastics, are non-biodegradable. They accumulate and persist as tiny fragments in the environment and are difficult to recover.

Criteria used for status assessment

No national or statewide standards, thresholds or strategic targets currently exist for litter and illegal dumping. The assessment in the SoE 2023 Report is based upon comparisons with the data used in determining the status and trend within the SoE 2018 Report.

Why this assessment in 2023?

Understanding the extent of litter and illegal dumping in Victoria is a challenge. Methodological limitations of surveys, particularly underrepresentation of non-urban sites, further constrains evaluating the extent of litter and dumping levels.

The amount of litter has been decreasing overall between 2009–10 and 2018–19 (latest data) but has seen slight increases beginning in 2017–18. During the most recent litter survey, the number of litter items declined from 5,398 litter items to 5,074 litter items across the 151 urban sites and from 112 to 108 items along the 15 rural highway sites. Beaches and parks had less volume of litter than sites within the built environment, suggesting that litter reduction campaigns targeted at coastal environments are effective in promoting behaviour change. Driving much of this observed decline in litter was a reduction in the number of cigarette butts.

Illegal dumping rates, on the other hand, have been on the rise since 2015–16, increasing from 18 Kt to 21 Kt by 2019–20 (most current data). The largest growth occurred in 2018–19, when the amount of litter dumped illegally spiked to 31 Kt, likely as a result of higher landfill levy costs and COVID-19 restrictions.

W:06 Total hazardous waste managed

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide						

Data source(s):	DCCEEW, EPA Victoria, SV
Measure(s):	Hazardous waste arisings (tonnes) per year

Why this indicator?

Hazardous waste contains contaminants that place the environment and human health at risk if inappropriately managed. Monitoring hazardous waste arisings is critical to identifying future infrastructure needs and ensuring that these materials are properly treated, recovered and disposed of.

Criteria used for status assessment

No national or statewide standards, thresholds or strategic targets currently exist for hazardous waste generation. Thus, the assessment in the SoE 2023 Report is based upon comparisons with the data used in determining the status and trend within the SoE 2018 Report.

Why this assessment in 2023?

Hazardous waste in Victoria has been increasing overall since 2010–11, from 9 Kt to its highest level of 1.72 Mt in 2019–20. The level of overall increase was higher during the SoE 2023 reporting period (24%) than that of the SoE 2018 reporting period (5%). Much of the upward trajectory in hazardous waste arisings in recent years has been driven by greater amounts of asbestos, waste oil/water and contaminated soils being generated and managed. By 2019–10, large-scale development projects, in particular Victoria's Big Build, resulted in unprecedented growth of contaminated soils, which became the largest single contributor (59%) to hazardous waste arisings in the state. The COVID-19 pandemic is also likely to have contributed to a steep rise in clinical waste from the healthcare and aged care sectors during 2019–20. The pandemic response resulted in greater interstate movement of hazardous waste in order to cope with the influx of personal protective equipment.

Recovery of hazardous waste has also been increasing. Recycling increased overall by 15% between 2014–15 and 2019–20. Contaminated soils demonstrated the strongest level of recovery among all hazardous waste categories in 2019–20, making up 26% of the total amount of hazardous waste recovered (192 Kt). Despite increasing recovery rates, growth in hazardous waste arisings resulted in a decrease in the proportion of hazardous waste that was recycled, declining from 19% to 11%.

Excessive stockpiling of hazardous waste proved to be a significant management challenge, leading to a high occurrence of emergency incidents between 2017 and 2019. Some incidents had significant public safety and environmental repercussions.

Commissioner *for* Environmental Sustainability Victoria

Appendix E
References

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Appendix E. References

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Abbreviations

ÆKOS .... Australian Ecological Knowledge and Observation System
ABS .... Australian Bureau of Statistics
ACS .... Australian Climate Service
AgVic .... Agriculture Victoria
AI .... artificial intelligence
AIMS .... Australian Institute of Marine Science
ALA .... Atlas of Living Australia
ALOS .... Advanced Land Observing Satellite
ARD .... analysis ready data
ARIES .... Artificial Intelligence for Ecosystem Services
ARV .... Alpine Resorts Victoria
BEAST .... Bayesian Evolutionary Analysis Sampling Trees
Biodiversity 2037 .... Protecting Victoria's Environment: Biodiversity 2037
BOM .... Australian Bureau of Meteorology
BP .... British Petroleum
C&D .... construction and demolition
C&I .... commercial and industrial
CAPAD .... Collaborative Australian Protected Areas Database
CAR .... comprehensive, adequate and representative
CC Act .... *Climate Change Act 2017*
CES .... Commissioner for Environmental Sustainability
CES Act .... *Commissioner for Environmental Sustainability Act 2003*
CHIME .... Copernicus Hyperspectral Imaging Mission for the Environment
CISS .... Centre for Invasive Species Solutions
CMA .... Victorian Catchment Management Authority
CMIP6 .... Climate Model Intercomparison Project Phase 6
CO2-e .... carbon dioxide equivalent
COTS .... crown-of-thorns starfish
CR .... Victorian Conservation Regulator
CSDILA .... Centre for Spatial Data Infrastructures and Land Administration
CSIRO .... Commonwealth Scientific and Industrial Research Organisation
dB .... decibel
DCCEEW .... Commonwealth Department of Climate Change, Energy, the Environment and Water
DCM .... Digital Cadastre Modernisation
DEA .... Digital Earth Australia

DEECA .... Victorian Department of Energy, Environment and Climate Action

DELWP .... Victorian Department of Environment, Land, Water and Planning

DEM .... digital elevation model

DJCS .... Victorian Department of Justice and Community Safety

DJPR .... Victorian Department of Jobs, Precincts and Regions

DMSP .... Defense Meteorological Satellite Program

DOH .... Victorian Department of Health

DPC .... Victorian Department of Premier and Cabinet

DPI .... New South Wales Department of Primary Industries

DTP .... Victorian Department of Transport and Planning

DTV .... Digital Twin Victoria

eDNA .... environmental DNA

eDTV .... environmental Digital Twin Victoria

EEA .... environmental-economic account

EO .... Earth observation

EPA Victoria .... Environment Protection Authority Victoria

ERS .... Environmental Reference Standard

ESD .... ecological sustainable development

ESM .... Ensemble of Small Models

EVC .... ecological vegetation class

FFDI .... forest fire danger index

FFG Act .... *Flora and Fauna Guarantee Act 1988*

FTE .... full-time-equivalent

GBIF .... Global Biodiversity Information Facility

GDE .... groundwater-dependant ecosystem

GDP .... gross domestic product

GEO .... Group on Earth Observations

GHG .... greenhouse gas

GIS .... geographical information system

GLOW .... Global Wetlands Project (Griffith University, QLD)

GORCP .... Great Ocean Road Coast and Parks

GPS / GNSS .... Global Positioning System/Global Navigation Satellite System

GSP .... gross state product

GWh .... gigawatt hour

GWOS .... Global Wetlands Observing System

Ha .... hectare
HAPS .... High Altitude Pseudo Satellites
HDM .... habitat distribution model
ICARUS .... International Cooperation for Animal Research Using Space
ICESat .... Ice, Cloud, and Land Elevation Satellite
IEA .... International Energy Agency
IFER .... Integrated Forest Ecosystem Research
IMOS .... Integrated Marine Observing System
IMU .... inertial measurement unit
InSAR .... Interferometric Synthetic Aperture Radar
IoT .... Internet of Things
IPA .... immediate protection area
IPCC .... Intergovernmental Panel on Climate Change
IR .... infrared
ISC .... Index of Stream Condition
IUCN .... International Union for Conservation of Nature
IV .... Infrastructure Victoria
JFMP .... Joint Fuel Management Program
JRSRP .... Joint Remote Sensing Research Program
KAB .... Keep Australia Beautiful
Kt .... kilo-tonne
kW .... kilowatt
LGA .... local government area
LiDAR .... Light Detection and Ranging
LTERN .... Long Term Ecological Research Network
LULUCF .... land use, land use change and forestry
MiDAR .... real-time multi-spectral video
ML .... machine learning
MODIS .... Moderate Resolution Imaging Spectroradiometer
MSW .... municipal solid waste
Mt .... mega-tonne
MW .... megawatt
MWh .... megawatt hour
NASA .... United States National Aeronautics and Space Administration
NDVI .... Normalized Difference Vegetation Index

NEON	National Ecological Observatory Network
NESP	Natural Environmental Science Program
NHRA	Natural Hazards Research Australia
NOAA	United States National Oceanic and Atmospheric Administration
NRM	natural resource management
ODC	Open Data Cube
PALSAR	Phased Arrayed L-band Synthetic Aperture Radar
pH	potential of hydrogen
PM_{10}	particles less than 10 micrometres in diameter
$PM_{2.5}$	particles less than 2.5 micrometres in diameter
PolSAR	Polarimetric Synthetic Aperture Radar
PRISM	Portable Remote Imaging Spectrometer
PV	Parks Victoria
RCP8.5	Representative Concentration Pathway 8.5 W/m^2
RFA	Regional Forest Agreement
RFID	United States National Aeronautics and Space Administration
RIPPA	Robot for Intelligent Perception and Precision Application
ROV	remotely operated vehicles
RPV	remotely piloted vehicle
RS	remote sensing
RTK	real-time kinematic positioning
SA2	Statistical Area 2
SAM	species abundance model
SAR	Synthetic Aperture Radar
SBAS	Satellite Based Augmentation System
SDG	Sustainable Development Goal
SDM	species distribution model
SEEA	System of Environmental Economic Accounting
SMCE	State of the Marine and Coastal Environment
SNA	specific needs analysis
SOC	soil organic carbon
SoE	State of the Environment
SV	Sustainability Victoria
SWIFFT	Victorian State Wide Integrated Flora and Fauna Teams

TERN .... Terrestrial Ecosystem Research Network
TFI .... tolerable fire interval
TRP .... Timber Release Plan
TVC .... total vegetation cover
TWh .... terra-watt hour
UK .... United Kingdom
UN .... United Nations
UNEP .... United Nations Environmental Programme
US .... United States
UV .... ultraviolet
VaaS .... Vicmap-as-a-Service
VAGO .... Victorian Auditor-General's Office
VAR .... vector autoregression
VCP19 .... Victorian Climate Projections 2019
VEAC .... Victorian Environmental Assessment Council
VEWH .... Victorian Environmental Water Holder
VFP .... Victorian Forestry Plan
VIIRS .... Visible Infrared Imaging Radiometer Suite
VPC .... Victorian Plantations Corporation
VVB .... Visualising Victoria's Biodiversity
WISE .... Canadian WaterSat Imaging Spectrometer Experiment
WMIS .... water monitoring information system
YLL .... years of life lost

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