

Marine and Coastal **Environments**

The information, data and indicators presented in this chapter focus on the marine and coastal environments of Victoria. Although some of the indicators build on the comprehensive assessment of marine science for Port Phillip Bay and Western Port that was presented in State of the Bays 2016, not all the science is repeated here, and the reader should refer to that earlier work for a complete presentation of the science.

In terms of the integration of this chapter with the other chapters in SoE 2018, marine water quality, estuarine health and marine biodiversity are all reported on here, but note two important exclusions:

- Only coastal Ramsar sites and wetlands are presented in this chapter; refer to the Biodiversity chapter for inland sites.
- 2. Sea-level rise and associated impacts are reported on in the Climate Change Impacts chapter.

Background

Massive sand dunes bookend the Victorian coastline at its borders with South Australia and New South Wales. Connecting Discovery Bay in the west to the east's Cape Howe Wilderness Zone are 2,500 km of rock stacks, granite islands, sheer cliffs, intertidal platforms, dominant headlands, extensive mudflats, fringing saltmarsh and mangroves, sandy beaches, large bays, coastal lagoons and more than 100 estuaries.

Facing south, Victoria's coastline looks out on the cool temperate waters of the Southern Ocean, where 75% of red algae species, 85% of fish species and 95% of seagrass species are found nowhere else, giving them local, national and international significance.¹ Beneath Victoria's 10,000 km² of coastal waters are subtidal reefs, deep canyons, seagrass meadows, sponge gardens and sandy and muddy seabeds that support a rich marine life of more than 12,000 plant and animal species.²

The Victorian Government and local governments have worked to improve marine and coastal planning, protection and management through the following processes: legislation, regulation, institutional policy-setting, strategic and statutory planning, and the creation of conservation reserves. Local communities have also engaged in consultation, monitoring and habitat-restoration works. But the pressures on coastal and marine environments have continued to build, largely driven by the resource-intensive demands of population growth and climate change.

The success or otherwise of these responses has in recent years been measured by State of the Environment reports in 2008 and 2013, State of Bays 2016 report, and the Gippsland Lakes Condition Report 2018. This chapter builds on the research and evaluation of these earlier reports while also looking towards 2021 (when the first of five-yearly State of the Marine and Coastal Environment reports will be released) and 2030 (the time horizon of the United Nations Sustainable Development Goals targets).

Government of South Australia 2013, 'State of the Environment Report 2013', Adelaide, South Australia http://w ant.html Accessed 4 December 2018.

PV 2018, 'Sea Search manual: A guide for community-based monitoring of Victoria's marine national parks and marine sanctuaries', Melbourne, Victoria.

Pressures on Marine and Coastal Environments

A 2012 Ipsos poll for the Victorian Coastal Council showed that the top four marine and coastal issues for Victorians were overfishing/illegal fishing, pollution, development and stormwater pollution. Compared to earlier polls, fewer respondents believed the coast was well-managed and twothirds felt that the sea level was rising due to climate change, and this was causing erosion and flooding.³ This section reviews these and other pressures.

Population growth and urbanisation

The rate of population growth in Victoria's coastal populations varies by region. In parts of the south-west coast, populations are stable or in decline. From 2011 to 2016, the Barwon Heads – Ocean Grove population grew by more than 28%, Torquay-Jan Juc, 27%, the Surf Coast and Bellarine Peninsula, 18%, and the Bass Coast, 11%.4

Most population growth is occurring on the Mornington and Bellarine peninsulas, driven by the expansion of Melbourne and Geelong and the 'sea change' phenomenon. Towns within commuting distance of Melbourne and Geelong are expanding and becoming 'dormitory suburbs' or places to retire. In towns bordering the Gippsland Lakes, retirees are responsible for an annual growth rate of more than 2%. According to the 2012 Ipsos poll, growth like this will continue: 7% of respondents who lived more than 5 km from the coast said that they planned to move to the coast within five years.5

The Victorian Coastal Council describes the impacts of population growth:

> ... biodiversity and habitat loss, water degradation in coastal waters, wetlands, lakes and rivers, coastal habitat loss, damage to wetlands, the introduction of pest plants and animals, coastal erosion, destruction of coastal ecosystems, loss of cultural heritage, conversion of productive agricultural land and impacts on scenic coastal landscapes, views and vistas. Socially, it can lead to pressures on the particular values and character of coastal areas and settlements the very reason people choose to move to or visit a place.6

Ipsos Consultants 2012, 'Coastal and marine environment community attitudes and behaviour: wave four report', prepared for Victorian Coastal Council, Ipsos Consultants, Melbourne, p.7

ABS 2016, 'Quick Stats 2016', www.abs.gov.au/websitedbs/censushome. cument&ngvpos=220/ Accessed 4

^{5.} Ipsos Consultants 2012, 'Coastal and marine environment community attitudes and behaviour: wave four report', prepared for Victorian Coastal Council, Ipsos Consultants, Melbourne, p.4.

Victorian Coastal Council 2017, 'Population and growth', http://vcc Accessed 4 December 2018.

Victoria's coastline attracts significant numbers of tourists. Growing numbers of domestic and international visitors will place further stress on marine and coastal environments, building pressure on authorities to increase access with new roads, car parks and other visitor management and attractions infrastructure. Visitor numbers in the four key coastal tourism regions of the Great Ocean Road - Geelong and Bellarine Peninsula, Mornington Peninsula and Phillip Island⁷ – increased substantially between 2013 and 2018. Across the regions, all annual increases were as follows: domestic daytrip visitors - between 2% and 7.2%; domestic overnight visitors – between 5.4% and 8.5%; and international overnight visitors between 6% and 14%.8 The Great Ocean Road had the highest numbers of international visitors but on Phillip Island and the Mornington Peninsula their numbers increased at a faster rate.

About 96% of Victoria's coast is within public land which abutts the high-water mark, although in many places it is a very narrow strip squeezed between rising seas and coastal development. The Victorian Coastal Strategy 2014 acknowledged the coastal squeeze and that it could lead to a loss of public open space and community access:

> If the coastal resources that maintain biological diversity such as saltmarshes and mangroves are to adapt to the impacts of sea-level rise and urban encroachment, outlays to 'buy-back' land will be required. Also, in some circumstances, incorporation of private land, to replace eroded public land, may be warranted to ensure community access to parts of the beach.9

Habitat loss, fragmentation, degradation and disturbance

Coastal and catchment development over the past two centuries has led to significant losses of coastal ecological vegetation classes (EVCs), with some now endangered, vulnerable or depleted. Coastal alkaline scrub has been reduced to 22% of its original cover on the Victorian Volcanic Plain, 10 31% on the Otway Plain and 56% on the Gippsland Plain. The Otway Plain has just 26% of its pre-1750s cover of coastal saltmarsh – Port Phillip Bay, only 50%.11

Migratory shorebirds, 35 species of which visit Australia, have been severely affected by the loss of habitats along their international flyways, particularly in the Yellow Sea. However, habitat loss has also occurred in Australia due to population growth, urbanisation and agricultural development. A 2015 Commonwealth report found that 'estuaries and permanent wetlands of the coastal lowlands have experienced the most losses, especially in the southern parts of the continent'. 12 Other threats include: disturbance from human activities; pollution; climate change; invasive species; and harvesting of intertidal prey such as fish, urchins and sea weeds.

Altered catchments can also lead to habitat degradation. The permanent opening of the entrance to the Gippsland Lakes and catchment dam construction have changed the site's ecology by leading to increased salinity, reduced bank vegetation, mobilised bank sediments and reduced light penetration, which has impacted seagrass. 13

Although visitor numbers for the four selected regions include some visitation to areas away from the coast, for the other two regions with coastal boundaries, Melbourne and East Gippsland (includes mountain areas), the coast may not be the main attractor. Data for these two regions have been excluded.

DEDJTR (Tourism, Events and Visitor Economy Research Unit) 2018, 'Regional tourism summaries for Great Ocean Road, Geelong and the Bellarine, Mornington Peninsula and Phillip Island for the year ending March 2018', Melbourne, Victoria, http I-visitation Accessed 4

Victorian Coastal Council 2014, 'Victorian coastal strategy', Victorian Coastal Council, Melbourne, Victoria, p.24.

VEAC 2017, 'Statewide assessment of public land: statewide EVCs bioregional conservation status', Melbourne, Victoria.

^{11.} Sinclair S, Boon P 2012, 'Changes in the area of coastal marsh in Victoria since the mid 19th century', *Cunninghamia* 12 (2), pp. 153–176.

^{12.} Department of the Environment and Energy 2015, 'Wildlife conservation plan for migratory shorebirds', Canberra, Australian Capital Territory, p.14.

Boon P. Cook P. Woodland R 2015, 'The Gippsland Lakes: management 13. challenges posed by long-term environmental change', Marine and Freshwater Research 67 (6), pp.721-737 http Accessed 4 December 2018.

Marine and coastal wildlife can also suffer the effects of human disturbance. Since 1980, Birdlife Australia volunteers have been conducting biennial counts for beach-nesting birds, including the hooded plover (*Thinornis rubricollis rubricollis*). Its Victorian population was in serious decline but the work of community volunteers and coastal managers to protect breeding sites and improve regulations, education and enforcement has seen numbers slowly increase. However, its conservation status remains 'vulnerable' and threats such as coastal development, dogs, racehorses, vehicles, foxes, cats, sea-level rise and disturbance (dune stabilisation, beach cleaning and seaweed removal) are more generally on the increase. 14

Water pollution

Coastal urbanisation increases runoff, with Port Phillip Bay each year receiving 540 billion litres of stormwater from more than 300 outfalls annually. Stormwater can also contain hydrocarbons, pesticides, detergents, leaves, garden clippings, animal faeces and plastics, along with sewage from leaking, broken or overflowing sewers. The Yarra River, which flows through a large catchment containing urban, industrial and agricultural uses, discharges 14,000 tonnes of sediment into the bay annually, along with 650 tonnes of nutrients in fertiliser, litter, heavy metals and bacteria. Stormwater 16.

Beyond Port Phillip Bay, agricultural uses influence water quality by causing nutrient and sediment pollution that threatens estuaries and coastal ecosystems. For example, in Corner Inlet there are strong connections across catchment nutrients and sediments, algal blooms, reduced light-penetration and seagrass decline, which in turn impacts the inlet's commercial and recreational fisheries. This was 'the first strong evidence that the activities in the catchment are contributing to habitat loss and productivity costs to the fishery'.¹⁷

Eighteen ocean outfalls are found along the open coast and are used to discharge sewage and other waste that have undergone various levels of treatment. Total annual discharges have been estimated at 323 GL, with annual total nitrogen loads of 3,811 tonnes and annual total phosphorous loads of 2,784 tonnes.¹⁸

Maguire G, Cullen M, Mead R 2014, 'Managing the hooded plover in Victoria: a site by site assessment of threats and prioritisation of management investment on Parks Victoria managed land, Birdlife Australia, Melbourne, Victoria https://parkweb.vic.gov.au/ data/assets, pdf file/0007/679030/managing-hooded-plover-birdlife-australia.pdf Accessed 4 December 2018.

EPA 2018, 'Yarra and Bay', www.yarraandbay.vic.gov.au/issues/ stormwater Accessed 4 December 2018.

^{16.} Ibid

Ford J, Barclay K, Day R 2016, 'Using local knowledge to understand and manage ecosystem-related decline in fisheries productivity', Fisheries Research and Development Corporation Final Project Report, Melbourne, Victoria.

Clean Ocean Foundation 2018, 'The national outfall database community report', Australia http://www.cleanocean.org/news/the-national-outfall-database-community-report Accessed 4 December 2018.

Litter and marine debris

Of the litter found on Port Phillip Bay beaches, 95% washes off suburban streets and into the stormwater system. 19 In 2012–13, litter control programs removed 7,850 tonnes of litter and debris from waterways around Melbourne.²⁰ It has been estimated that 820 million pieces of litter are discharged into Port Phillip Bay from the Yarra and Maribyrnong rivers each year.²¹

In 1991, an EPA Victoria tagged litter survey estimated that 4-5 million pieces of plastic were entering Melbourne waterways annually, with most washed up on beaches along Port Phillip Bay's east coast.²² For 12 months from March 2016, members of BeachPatrol Australia, a Melbourne-based community group, conducted daily collections of plastic along a 35-metre stretch of the Port Melbourne Beach.²³ By the survey's end, 126,000 pieces of plastic litter had been collected, with 60% greater than 5 mm and 15% smaller than 5 mm. A Port Phillip EcoCentre survey²⁴ found that plastic film remnants were the second-most collected items, with plastic bags and wrappers third. Nurdles (microplastics) were found on 12 of 23 Port Phillip Bay beaches, although coordinators believed this number may have been understated because volunteers were reluctant to invest time in collecting such small items.

In addition to being an eyesore on beaches and waterways, litter and marine debris impact marine life. From 1997 to 2013, researchers found 359 entangled Australian fur seals (mainly juveniles and pups) at Seal Rocks at Phillip Island, equivalent to 1% of the site's population. The researchers found that commercial fishing operations were the main source of entanglement materials that included trawl nets, fishing line and box straps. They determined that neither the decline in regional fishing intensity nor changing seal population size influenced the incidence of entanglements.²⁵

Fishing-related gear, balloons and plastic bags posed the greatest entanglement risk to marine fauna.26 Between 2010 and 2013, the Zoos Victoria Seal the Loop Program collected 21.7 km of fishing line in specially designed bins dotted along the Victorian coastline.²⁷ By 2013, the bins were collecting 25 metres daily or 9 kilometres annually. Zoos Victoria and Phillip Island Nature Parks have now launched the 'When balloons fly, seabirds die' campaign to educate the community about the impact that balloons are having on marine life and to urge people to stop using balloons outdoors. A 2016 CSIRO paper noted that short-tailed shearwaters on Australia's east coast ingested 82% of all balloons recorded in a survey of marine debris, possibly due to the balloons resembling the birds' main prey, the red arrow squid.²⁸

CES 2016, 'State of the Bays 2016', Melbourne, Victoria,

EPA 2018, 'Litter', Melbourne, Victoria sues/litter Accessed 4 December 2018.

^{21.} Preiss B 2018, 'A tale of two beaches, where volunteers fight to keep tide of city's litter at bay', The Age 7 July 2018.

EPA 1993, 'Backyard to bay: tagged litter report', Melbourne, Victoria. 22. Headifen R 2017, 'A new survey method to determine plastic rubbish in Port Phillip Bay', BeachPatrol Australia.

Port Phillip EcoCentre 2017, 'Turn off the tap – catchment to bay litter prevention and monitoring. Final report', Port Phillip EcoCentre, St . Kilda, Victoria.

McIntosh RR, Kirkwood R, Sutherland DR, Dann P 2015, 'Drivers and annual estimates of marine wildlife entanglement rates: a long-term case study with Australian fur seals,' Marine Pollution Bulletin 101, pp. 716-723.

Wilcox C, Mallos NJ, Leonard GH, Rodriguez A, Hardesty BD 2016, 'Using expert elicitation to estimate the impacts of plastic pollution on marine wildlife', Marine Policy 65, pp. 107-114.

Zoos Victoria 2013, 'Seal the Loop 2012-2013 report', Zoos Victoria, Melbourne, Victoria.

Roman L, Schuyler QA, Hardesty BD, Townsend KA 2016, 'Anthropogenic debris ingestion by avifauna in eastern Australia', PLoS One, 11(8) one.0158343 Accessed 4 December 2018

Climate Change

The south-eastern waters of Australia are one of 10 global hotspots for rising sea-surface temperatures – the rate is almost four times faster than the global average.²⁹ This has energised the East Australian Current. It now reaches the coast of Tasmania, 350 kilometres further south than where it was 60 years ago, transporting warm waters and subtropical species such as cobia to Victoria.

In June 2018, the Victorian Coastal Council released *Victoria's Coast and Marine Environments under Projected Climate Change: Impacts, Research Gaps and Priorities.* The report stated that:

Victoria's coastal regions are expected to have a warmer climate year-round, more hot days and warm spells, harsher fire weather and longer fire seasons, less rainfall in winter and spring, more frequent and more intense downpours, rising sea level, increased frequency and height of extreme sea-level events, increased wave height in winter, increased frequency of easterly winds, and warmer and more acidic oceans.³⁰

The report notes that since 1880, Victoria's sea level has risen 22.5 cm, while projecting rises in sea level of 8-20 cm by 2030 and 20-59 cm by 2070, and of sea-surface temperatures by 1.1–2.5°C by 2070. In the offshore areas, the report suggests that rising water temperatures may decrease oxygen levels and reduce fisheries production. Along with the economic effects of rising water temperature, the report found that declining stocks of fish will also affect the island colonies of the Australian fur seal, little penguins and shorttailed shearwaters that rely on these stocks for food. The report recommends regular monitoring and reporting on the health of these colonies, which would be an important indicator of ocean health and climate change.

Closer to shore, the report found that, if the effects of climate change are not halted, then the ecological functions of seagrasses and kelps will be reduced, as will the protection they afford the coast. Other changes that the report highlights include, the loss of intertidal flats, platforms and beaches; closed estuaries; increased salinity and flooding; and the prevalence of more tropical species.

Climate change will also impact food security and human health, culture and livelihoods. A recent ecological sensitivity assessment³¹ suggests that blacklip abalone and southern rock lobster (the two mainstays of Victorian commercial fisheries) and black bream and King George whiting (very popular targets of recreational fishers) are the most sensitive to climate change due to factors such as altered habitats, increased water temperatures, changing estuarine salinity and invasion by other species such as urchins. Southern calamari and Australian salmon will also be affected. The same research also showed that the catches of many commercial species had declined and that other stressors such as overfishing, invasive species, habitat loss, degradation of seagrass beds, and pollution in intertidal zones and juvenile nursery areas will exacerbate the impacts and reduce the ability of species to adapt to environmental change.

The loss of giant kelp forests (*Macrocystis pyrifera*), once in a strip stretching along much of the Victorian coast, may in part be due to climate change and its associated rise in sea-surface temperatures. Small patches in the Otway, Central, Flinders and Twofold Shelf marine bioregions are all that remain, with water pollution, sedimentation and storms other factors in the decline.³²

Hobday A, Pecl G 2013, 'Identification of global marine hotspots: sentinels for change and vanguards for adaptation action', Reviews in Fish Biology and Fisheries, 24(2), pp. 415-425 https://link.springer.com/article/10.1007/s11160-013-9326-6 Accessed 4 December 2018.

Victorian Coastal Council 2018, 'Victoria's coast and marine environments under projected climate change: impacts, research gaps and priorities', Melbourne, Victoria.

Pecl GT, Ward TM, Doubleday ZA, Clarke S, Day J, Dixon C, Frusher S, Gibbs P, Hobday AJ, Hutchinson N, Jennings S, Jones K, Li X, Spooner D, Stoklosa R 2014, 'Rapid assessment of fisheries species sensitivity to climate change', Climatic Change, 127(3-4), pp. 505–520 https://link.springer.com/article/10.1007/s10584-014-1284-z Accessed 4 December 2018

^{32.} Department of the Environment and Energy 2009, 'Advice to the Minister for Environment Protection, Heritage and the Arts from the Threatened Species Scientific Committee (the Committee) on an Amendment to the List of Threatened Ecological Communities under the Environment Protection and Biodiversity Conservation Act 1999', Canberra, Australian Capital Territory.

Commercial and recreational fishing

Commercial fishers have been operating in Victorian waters since the 19th century, using nets, dredges, pots, hooks and hand collection to harvest various marine species. In September 2017, there were 627 commercial licences across all Victorian fisheries, targeting more than 40 finfish and 30 species of molluscs, crustaceans, sharks and rays.33

Reduced fish populations, bycatch, entanglement of wildlife in discarded fishing gear, vessel impacts and changes to trophic structures are some of the impacts of fishing on marine and coastal environments. But the closure of most commercial fishing in Port Phillip Bay and Western Port, and lower catches elsewhere, has reduced the industry's pressure on stocks. However, this change will limit future data on fish stocks and require an expanded role for the monitoring of recreational fishing.

Although there are more than 100 fish species recorded in Victorian bays and inlets, recreational fishers target about a dozen species, with snapper (Pagrus auratus), King George whiting (Sillaginodes punctata) and black bream (Acanthopagrus butcheri) as the most prized. In 2000-01, 88% of recreation catches came from Port Phillip Bay, and those for snapper (211 tonnes) and King George whiting (93 tonnes) were higher than the respective commercial catches of 53 tonnes and 85 tonnes.34

Assessing the broader impact of recreational fishing in Victoria's marine and coastal environments will require clarity on the number of recreational fishers in Victoria. Although only 271,395 Victorian recreational fishing licences were sold in $2016-17^{35}$ across the five categories, three previous estimates have angler participation in the state at 549,000,³⁶ 721,000³⁷ and 830,000³⁸ (adult residents), while the Victorian Government is committed to increasing angler numbers to 1 million through its Target One Million program.³⁹

^{33.} VFA 2018, 'Commercial fish production', Melbourne, Victoria http://doi.org/10.1016/j.com/http://doi December 2018.

Ryan KL, Morison AK, Conron S 2009, 'Evaluating methods of obtaining total recreational catch estimates for individual Victorian bay and inlet recreational fisheries', Project No. 2003/047. A report for the Department of Primary Industries, Melbourne, Victoria, and Fisheries Research and Development Corporation, Canberra, Australian Capital Territory

VFA 2017, 'Recreational fishing licence trust account 2016–17: a report to each House of Parliament on the disbursement of recreational fishing licence revenue', Melbourne, Victoria.

Henry G, Lyle J 2003, 'The national recreational and indigenous fishing survey', Project No. 1999/158, A report for the Australian Governmen Department of Agriculture, Fisheries and Forestr. Canberra, Australian Capital Territory

VFA 2010, 'Economic study of recreational fishing in Victoria – headline results VRFish', Melbourne, Victoria https://vfa.v -fishing-inictoria-headline-results-vrfish Accessed 4 December 2018.

Ernst and Young 2015, 'Economic study of recreational fishing in Victoria', a report for VFA Melbourne, Victoria.

VFA 2018, 'Target one million budget 2015–2019', Melbourne, Victoria Accessed 4 December 2018.

Ports, shipping and boating

Port operations and shipping activity can impact marine and coastal environments by causing habitat damage and loss, increased turbidity (from dredging), localised beach accretion and erosion, an increased risk of spills, air pollution and the introduction and spread of invasive marine species. Most of the invasive marine species in Port Phillip Bay arrived on the hulls or in the ballast water of visiting ships, thousands of which visit the Port of Melbourne and Geelong Port each year.

Concerns like these, along with social, economic and logistical considerations, saw the Victorian Government seek advice from Infrastructure Victoria on the best location for a second container port – the Port of Melbourne is Australia's largest and busiest and will likely outgrow its current site. After extensive investigations, Infrastructure Victoria recommended Bay West in Port Phillip Bay, rather than an expansion of the Port of Hastings, but indicated that operation of the new port would not be required until 2055. 40 Both locations are Ramsar sites: port construction and its associated infrastructure could impact on those wetland habitats.

Recreational boating has become an increasingly popular activity in Victoria. In 1962, an aerial survey of Port Phillip Bay identified 1,208 recreational boats, 41 but by 2015 there were 117,000 identified in Port Phillip Bay and Western Port. 42 Boating infrastructure such as breakwaters and car parks can have localised impacts on coastal and marine environments. Sandringham Harbour's breakwater has altered longshore drifting of sand and has led to significant coastal erosion. Harbour construction and expansion, along with associated road access, car parking, boat ramps and clubhouses, can reduce public open space. In the case of the proposed expansion of the Beaumaris Motor Yacht Squadron, development would further bury internationally significant land and marine fossil beds already impacted by the existing harbour infrastructure.43

Invasive marine species

More than 160 introduced marine species are now resident in Port Phillip Bay. Few impact local marine habitats and species. Those of greatest concern are the northern Pacific seastar (Asterias amurensis), the European fan worm (Sabella spallanzanii), the European green shore crab (Carcinus maenas), Japanese kelp (Undaria pinnatifida), the New Zealand screw shell (Maoricolpus roseus) and the Pacific oyster (Crassostrea gigas). The Asian date mussel (Musculista senhousia), cordgrass (Spartina anglica and Spartina x townsendii sp.), dead man's finger (Codium fragile ssp.) and red algae (Grateloupia turuturu) are also of concern. Invasive marine species prey on - or outcompete - native species for space, food and light.

The eradication of invasive marine species is only possible in very limited circumstances, and so the primary management focus is the prevention of their introduction and spread. But the growing number of vessels operating in Victorian waters could undermine these efforts. For example, Japanese kelp was initially confined to northern Port Phillip Bay, but its range has expanded to the southern bay and also Apollo Bay Harbour (where eradication has proved impossible). Japanese kelp has recently been detected in Port Welshpool.

Invasive marine species in the Gippsland Lakes include the Pacific oyster (*Crassotrea gigas*), the European green shore crab (*Carcinus maenas*), the Asian date mussel (*Musculista senhousia*) and the introduced green macroalgae, *Codium fragile* (subsp. *fragile*).⁴⁴ Also recorded were three species listed on the National Introduced Marine Pest Information System database: pleated sea squirt (*Styela plicata*), stalked ascidian (*Styela clava*) and sea vase (*Ciona intestinalis*).

^{40.} Infrastructure Victoria 2017, 'Advice on securing Victoria's port capacity', Melbourne, Victoria.

Lynch D 1966, 'Port Phillip survey 1957–1963: the fisheries', Memoirs of the National Museum of Victoria 27, pp.16.

^{42.} Boating Industry Association of Victoria 2015, 'Boating industry snapshot: drivers of growth in Victoria', Melbourne, Victoria.

Smith B 2015, 'World-class fossil site in Beaumaris threatened by marina expansion plans', The Age 20 February 2015.

Hirst A, Bott N 2016, 'Gippsland Lakes: existing threats and future monitoring', Centre for Environmental Sustainability and Remediation, RMIT, Melbourne. Victoria.

Overabundant native animals

Increasing numbers of native sea urchins are causing the loss of marine habitats in Port Phillip Bay, Nooramunga and Beware Reef Marine Sanctuary.

Intact kelp beds can resist invasions by exotic marine plants, provide habitat for fish targeted by recreational fishers, and be popular sites for snorkelling and diving. But along the northern shores of Port Phillip Bay, grazing by the purple sea urchin (Heliocidaris erythrogramma) has led to a 90% reduction in kelp in the bay's marine sanctuaries. 45 In March 2018, Parks Victoria, Deakin University and volunteer citizen scientists carried out a cull of urchins in Jawbone and Point Cooke Marine Sanctuaries, 46 with the aim of keeping urchin numbers low for at least two years to allow the kelp beds to recover. If successful, the program will be expanded to other areas in the bay. A current project by the University of Melbourne, Deakin University and Parks Victoria aims to manage urchin numbers and also trial kelp restoration techniques outside protected areas.

In eastern Victoria, the small Beware Reef Marine Sanctuary has also suffered an outbreak of the black-spined sea urchin (Centrostephanus rodgersii), a native of New South Wales carried south at a rate of approximately 16 km's each year by the warming East Australian Current.⁴⁷ The urchins graze on kelp and other algae, creating areas of bare rock or urchin barrens. The Friends of Beware Reef, and Parks Victoria, staff culled 2,500 urchins in early 2018, 48 and a draft native animal impact management plan has now been prepared by the agency.

Sydney's gloomy octopus (Octopus tetricus) has also extended its range on the East Australian Current. Scientists were first alerted to its spread when citizen scientists reported sightings to the smart app, Redmap. Further research⁴⁹ confirmed the extended range of the octopus, which is a predator of commercially targeted abalone and rock lobster.

^{45.} Deakin University 2018, 'Sea urchin cull in Port Phillip Bay to help restore kelp forests', media release, 15 March 2018, Deakin University, Geelong.

^{46.}

PV 2018. 'Centrostepohanus rodgersii (black-spined sea urchin) impact management plan', Melbourne, Victoria.

PV 2018, 'United against the urchin front in East Gippsland', media release, Melbourne, Victoria.

Ramos JE, Pecl GT, Moltschaniwskyj NA, Semmens JM, Souza CA Strugnell JM 2018, 'Population genetic signatures of a climate change driven marine range extension', Scientific Reports, 8(9558), pp. 1-12.

Environmental weeds

Environmental weeds are a major problem for coastal habitats, especially near township gardens and farms, from where they often spread. They compete with and prevent regeneration of indigenous native plants, alter coastscapes, increase bushfire risk and reduce available habitat for wildlife. Some Australian native species, such as acacia, eucalypt, melaleuca and allocasuarina, have also become weeds, introduced through past dune stabilisation projects.⁵⁰

Oil and gas exploration and production

Oil and gas have been flowing from Bass Strait since the 1960s, and in western Victoria from the early 2000s. In May 2018 the Victorian Government⁵¹ released five new blocks for oil and gas exploration near existing gas production areas in the Otway Basin off Victoria's west coast, while new production wells in the Gippsland Basin are set to produce gas in 2019.

SoE 2013 noted that exploration and production of oil and gas can disturb seabed habitats. Seismic testing may impact on cetaceans, and there is also the risk of spills during operations.⁵²

In 2007, the CSIRO Wealth from Oceans flagship program investigated the contribution that the extraction of water and hydrocarbons from the Gippsland Basin, along with the effects of extreme wave conditions and sea-level rise, could make to land subsidence and inundation along the Ninetymile Beach. CSIRO's modelling predicted that by 2056, under a realistic scenario, the coast could subside by 480 mm, whereas in a worst-case scenario the figure was 1,208 mm. However, the contribution of land subsidence to the predicted levels of inundation ranged between 1% and 20% – the larger figure for a small area with a low combined risk of inundation. The CSIRO study concluded that:

'the simulations conducted predict that subsidence due to fluid extraction, although small in comparison, will exacerbate the risk of inundation of the coastline due to extreme storm tide and wave conditions with larger parts of the Gippsland Coastline potentially being affected.⁵³

Mark Trengove Ecological Services 2013, 'Barwon Coast vegetation management plan final draft', Geelong, Victoria prepared for Barwon Coast Committee of Management.

The Hon Pallas T, MP 2018, 'Offshore gas exploration to build future supply', media release, Melbourne, Victoria.

ply', media release, Melbourne, Victoria. 52. CES 2013, 'State of the environment report', Melbourne, Victoria.

Freij-Ayoub R, Underschultz J, Li F, Trefry C, Hennig A, Otto C, McInnes K 2007, 'Simulation of coastal subsidence and storm wave inundation risk in the Gippsland Basin', CSIRO Petroleum Report 07-003, Bentley, Western Australia.

The Bass Strait oil and gas rigs are ageing and will eventually have to be decommissioned. They could be viewed as waste, dismantled and removed from the marine environment. Alternatively, they could be left where they stand, continuing to act as artificial reefs should evidence show that any environmental outcomes would be equal to or better than if they were removed. But the disused rigs could also attract invasive species, alter food webs and become navigational hazards.

Droughts and Floods

During the millennium drought (1996-2010) there were significant seagrass losses in Port Phillip Bay. 54 Land-based nitrogen inputs during the millennium drought dropped by 64%; northern Pacific seastar (A. amurensis) arrived in the bay in 1995 and its biomass rose to 56% of resident fish biomass in 2000; and in the centre of the bay, fish biomass dropped 69%.55 The reduced productivity during the drought caused most of the loss in fish biomass. However, A. amurensis was implicated in a sharp decline of three species the eastern shovelnose stingaree (Trygonoptera imitata), southern eagle ray (Myliobatis australis) and globefish (Diodon nicthemerus) - due to competition for food. The improvement plan for the Western Treatment Plant also led to a reduction in nutrient discharges.56

The end of the millennium drought was followed by major flooding across Victoria in 2010–11. Floods send large volumes of sediments and nutrients into estuaries, bays and offshore waters, significantly affecting water quality and the health of receiving waters.

Jenkins G, Keogh M, Ball D, Cook P, Ferguson A, Gay J, Hirst A, Lee R, Longmore A, Macreadie P, Nayer S, Sherman C, Smith T, Ross J, York P 2015, 'Seagrass resilience in Port Phillip Bay: final report to the Seagrass and Reefs Program for Port Phillip Bay, University of Melbourne, Melbourne, Victoria htt Accessed 4 December 2018.

Hirst A, Parry G 2016, 'Decadal decline in demersal fish biomass coincident with a prolonged drought and the introduction of an exotic

starfish', Marine Ecology Progress Series, 544, pp.37-52. Hirst AJ, Werner GF, Heislers S, White CA, Spooner D 2011, 'Port Phillip Bay Annual Trawl Sub-Program Milestone Report No. 4 (2011)', Fisheries Victoria Technical Report Series No. 139, Queenscliff, Victoria.

Marine and Coastal Policy, Management and Monitoring Challenges

Policy and management challenges

Key future challenges for the marine and coastal environment of Victoria include:

- ensuring effective community engagement in the ecologically sustainable management of coastal and nearshore environments
- implementing an effective and ecosystembased marine spatial planning framework to ensure equitable access to resources, while ensuring the needs of the natural environment are met
- improving and simplifying coastal management governance and oversight
- adapting to climate change and the impacts of population growth
- identifying and filling gaps in the marine and coastal conservation estate
- developing dispute resolution and arbitration mechanisms that are specifically related to the unique challenges in the marine and coastal environment.

Data and monitoring challenges

Data and monitoring challenges include:

- expanding monitoring programs beyond localised areas within Port Phillip Bay, Western Port and the Gippsland Lakes
- broadening monitoring, from species to ecosystems
- publicly releasing fisheries data on the impacts of commercial and recreational fishing on bycatch, habitats, threatened species and trophic structures
- adapting monitoring programs to cover the loss of fisheries data from the closure of commercial bays and estuaries to commercial fishing
- aligning the research priorities of agencies, academic institutions and citizen scientists with the needs of marine and coastal management
- developing historical ecological baselines
- monitoring the loss of coastal foreshore reserves, and their EVCs, from erosion.

Current Victorian Government Settings: Legislation, Policy, Programs

There have been many efforts by successive Victorian governments to improve marine and coastal planning, protection and management. This section briefly reviews the most recent.

Victoria's new Marine and Coastal Act 2018 (the Act) provides improved governance and oversight of the marine and coastal environment and aims

- establish an integrated and coordinated whole-of-government approach to protect and manage Victoria's marine and coastal environment
- provide for integrated and coordinated policy, planning, management, decision-making and reporting across catchment, coastal and marine areas
- establish objectives and guiding principles for ecologically sustainable planning, management and decision-making.

Recognising the need to plan for and manage the impacts of climate change is a significant addition to coastal management in Victoria – as is the acknowledgement of Traditional Owner groups' knowledge, rights and aspirations for land and sea country.

Under the Act, the number of advisory bodies has been simplified by phasing out the regional coastal boards and Victorian Coastal Council and establishing the statewide advisory Marine and Coastal Council. The council will be responsible for providing advice on the implementation of the Act by agencies including the Department of Environment, Land, Water and Planning (DELWP) and will be able to establish subcommittees – for example, a science panel.

The Act establishes statutory documents for planning and management of the marine and coastal environment at statewide, regional and local levels. This includes the preparation of a Marine and Coastal Policy, and a Marine and Coastal Strategy, every five years by DELWP. These both require agreement across relevant portfolios and are intended to help deal with key challenges such as the impacts of climate change and population growth. The policy will include a marine spatial planning framework to help achieve integrated and coordinated planning and management of the marine environment.

The new legislation requires that a State of the Marine and Coastal Environment report be prepared every five years by the Commissioner for Environmental Sustainability, with the first due in 2021. This report will monitor trends in a variety of indicators to help measure the condition of the marine and coastal environment and any changes. This information will be used to better inform ecologically sustainable policy, planning and decision-making.

The Act introduces a new partnership approach for planning for significant regional issues impacting the marine and coastal environment. Regional and strategic partnerships (RASPs) will be formed in certain areas, and they will produce tools to address regional issues. Tools may include coastal hazard assessments, adaptation plans or other regional plans. Importantly, these partnerships can formally include community and non-government members to boost public involvement.

Environmental management plans will consider a broad range of threats to the health of the marine environment and aim to identify actions to address them. Catchment management authorities (CMAs) are also now required to better plan for impacts on the marine and coastal environment through Regional Catchment Strategies, and possibly RASPs.

Local-level planning will provide opportunities for the community's voice to be heard, and the government anticipates a more streamlined process for consents to use, develop or undertake works on public land.

The new Act also aims to help address a key technical gap by enabling organisations advising on coastal flooding (namely, coastal CMAs and Melbourne Water) to be consulted on matters relating to coastal erosion.

The Victorian Environmental Assessment Council (VEAC) is currently preparing a report on the environmental, economic and social values of Victoria's marine environments which will inform the Victorian Government's preparation of the statewide marine and coastal policy and marine spatial planning framework under the *Marine and Coastal Act 2018*. VEAC is also investigating coastal reserves and will:

- review the number and types (reservation status) of coastal reserves in Victoria
- identify reserves with high environmental, cultural heritage, social and economic values, and identify values at risk from the impacts of climate change
- identify current and emerging uses of the coastal reserves
- compile an inventory, including spatial distribution, of values and uses of the coastal reserves

A revised State Environment Protection Policy (Waters) commenced on 19 October 2018.

The purpose of this new policy is to provide a framework to protect and improve the quality of Victoria's waters, while its objectives are to:

- achieve the level of environmental quality required to support the beneficial uses of waters
- ensure that pollution to waters from both diffuse and point sources is managed in an integrated way to deliver the best outcome for the community as a whole
- protect and improve environmental quality through consistent, equitable and proportionate regulatory decisions that focus on outcomes and use the best available information.

The policy also includes various environmental quality indicators, regional targets and priority areas, pollutant load reduction targets, and rules and obligations. It also identifies high conservation-value areas: high-value wetlands (including wetlands of international importance listed under Ramsar) and areas of significance for spawning, nursery, breeding, roosting and feeding of aquatic species and fauna.

The vision for the *Port Phillip Bay Environmental Management Plan 2017–2027* ⁵⁷ is of a 'healthy Port Phillip Bay that is valued and cared for by all Victorians'. This 2017 plan replaced the 2001 plan and contains a broader set of priorities and actions. The seven priorities are: connect and inspire, empower action, nutrients and pollutants, litter, pathogens (human health), habitats and marine life, and marine biosecurity.

Victoria's Climate Change Adaptation Plan 2017–2020⁵⁸ will build a detailed understanding of the state's exposure to climate change risks and impacts, catalyse partnerships for integrated and effective responses, and tackle immediate priorities to reduce climate change risks. The plan will work to ensure up-to-date information on the coastal impacts of climate change, provide guidance to managers on coastal adaptation, ensure sea-level-rise benchmarks are based on the best science, and provide resourcing through the Climate-Ready Victorian Infrastructure – Critical Coastal Protection Assets Program (2015–2019), which includes works to repair, renew and protect cliffs, seawalls and groynes across the state. Local Coastal Hazard Assessments will also be used to provide a more detailed analysis of climate change risks and impacts.

^{57.} DELWP 2017, 'Port Phillip Bay environmental management plan 2017-2027', Melbourne, Victoria.

DELWP 2017, 'Victoria's climate change adaptation plan 2017-2020', Melbourne, Victoria.

The Invasive Plants and Animals Policy Framework (IPAPF) presents the overarching Victorian Government approach to the management of existing and potential invasive species. The IPAPF incorporates a biosecurity approach to ensure that Victoria maintains a comprehensive planning framework to guide the management of invasive species. The Department of Economic Development, Jobs, Transport and Resources is developing a whole-of-government marine pest module under the IPAPF to guide the management of marine pests in the state. The scope of this module will encompass exotic invasive marine plants, marine algae, marine invertebrate animals and marine fish.

The Victorian Waterway Management Strategy addresses:

- the direct management of estuaries, for example the use of risk-based assessments (such as the Estuary Entrance Management Support System) to inform artificial estuary openings
- the management of upstream waters and their catchments and associated inputs to estuaries and coastal environments - through, for example, riparian revegetation and stock exclusion delivered through the Victorian Waterway Management Program and initiatives such as the Regional Riparian Action Plan.

The Parks Victoria Act 1998 was reviewed and then replaced with the Parks Victoria Act 2018. The new Act establishes Parks Victoria as an independent statutory authority, no longer acting as a service agency to government and with management powers granted to its board rather than delegated by the secretary of DELWP. The Act aims to strengthen Parks Victoria's role of protecting, conserving and enhancing Victoria's parks and waterways.

In 2017, the Victorian Government established the Victorian Fisheries Authority to support the development of recreational and commercial fishing and aquaculture in Victoria, regulate fisheries and provide advice to government on a range of fisheries management opportunities.

The 2021 State of the Marine and Coastal Environment report will be able to evaluate the implementation of these polices, strategies and plans.

Marine and Coastal Environmental Indicators

Overview of indicator status assessment

This section of the chapter provides the status assessments for 24 indicators that cover: coastal wetlands and estuaries; intertidal and subtidal reefs; seabirds, shorebirds and waterbirds; pressures on the marine and coastal environments; and conservation in protected areas. Assessments for some of the indicators in *State of the Bays 2016* report have been reproduced here, while the summaries that accompanied them have been abridged. This is also the case for those indicators applied to the Gippsland Lakes, with the status, trends and summaries sourced from the *Gippsland Lakes Condition Report* 2018.

For the indicators added for SoE 2018, the assessment of their status and trends has been hampered by a lack of available data. In most cases the data has either been absent, out of date or gathered over an insufficient time period. Without robust data it is not possible to determine the status and trends for many of these indicators.

Marine and coastal environments that aren't part of Victoria's marine conservation estate are surveyed infrequently. Some areas have only been surveyed once, and in many instances, there is no recent data. What monitoring that does occur is largely undertaken by academic institutions, non-government organisations and volunteers, with public agencies constrained in their efforts by limited resources. The work of volunteer organisations – such as Birdlife Australia, The Nature Conservancy, the Victorian National Parks Association (ReefWatch and nature conservation reviews) and groups and individuals involved in Sea Search, EstuaryWatch, Coastcare, Reef Life Survey, Landcare and other programs – has been pivotal in maintaining a degree of monitoring. This voluntary effort requires ongoing support and should be complemented by a significant increase in government agency monitoring.

In summary, marine and coastal data is limited in the following ways:

- The focus of marine data collection has been on the 5% of coastal waters in marine national parks and sanctuaries, leaving 95% of coastal waters largely unmonitored.
- Data is very often inadequate to determine status and trends for many indicators, with the gap between monitoring periods too long (or the research has not been repeated).
- Comparisons are often between pre-1750s and current data with no recent data to establish contemporary trends.
- Data collected may not be meaningful or may be insufficient for the indicators that are being assessed.
- The analysis and public reporting on data collected are at times minimal, with data on websites sometimes requiring specific browsers and/or login security details and/or presented in file formats that are not directly useable by the community.
- Changing data collection methodologies and terminologies make comparison over time and between different databases difficult.
- The coastal environment is often included in statewide analyses without separate or specific treatment.
- Government agencies' reliance on limited data collections, while universities, other research institutions and the community have much to offer

The development of a Marine Knowledge Framework, as recommended by the *State of the Bays 2016* report, will extend to coastal environments and begin to address these issues.

Indicator Assessments

Legend

Status

N/A Not Applicable

The indicator assessment is based on future projections or the change in environmental condition and providing a status assessment is not applicable. Only a trend assessment is provided.



Unknown

Data is insufficient to make an assessment of status and trends.



Environmental condition is under significant stress, OR pressure is likely to have significant impact on environmental condition/ human health. OR inadequate protection of natural ecosystems and biodiversity is evident.



Environmental condition is neither positive or negative and may be variable across Victoria, OR pressure is likely to have limited impact on environmental condition/human health, OR moderate protection of natural ecosystems and biodiversity is evident.

Good

Environmental condition is healthy across Victoria, OR pressure is likely to have negligible impact on environmental condition/ human health, OR comprehensive protection of natural ecosystems and biodiversity is evident.

Trend

N/A Not applicable

This indicator assessment is based on current environmental condition only and it is not applicable to provide a trend assessment. Only a status assessment is provided.



Unclear



Deteriorating



Stable



Improving

Data quality



Evidence and consensus too low to make an assessment



Limited evidence or limited

consensus



Good

Adequate high-quality evidence and high level of consensus

List of acronyms for Marine and Coastal Environments indicators:

All Gippsland Lakes (GLA)

Beware Reef Marine Sanctuary (BRMS)

Corangamite Catchment Management Authority (CCMA)

Corner Inlet (CI)

East Gippsland Catchment Management Authority (EGCMA)

Glenelg Hopkins Catchment Management Authority (GCMA)

Marine National Parks and Sanctuaries (MNPS)

Nooramunga Marine & Coastal Park (NMCP)

Northern Port Phillip Bay (NPPB)

Other Marine & Coastal Areas (OMAC)

Port Phillip Bay (PPB)

Phillip Island (PI)

Southern Port Phillip Bay (SPPB)

St Kilda (STK)

West Gippsland Catchment Management Authority (WGCMA)

Western Port (WPT)

Summary **Status** Trend GOOD POOR FAIR UNKNOWN Western Port Indicator has retained 90-95% of its pre-1750s mangrove MC:01 Mangrove extent habitat that was estimated at 1320 hectares. NMCP OMAC Losses have been caused by harvesting, land Region claim for industrial and port development and Western Port the drainage of adjacent land. (WPT), Corner Inlet Corner Inlet and Nooramunga Mangroves are DATA QUALITY (CI), Nooramunga at their southern-most limit in Corner Inlet Marine & Coastal Good and Nooramunga, where 80% of the pre-1750s Park (NMCP), Other cover remains Marine & Coastal Areas (OMAC) Other marine and coastal areas Measures On a statewide basis, 90% of the pre-1750 extent of mangroves remains. Spatial extent Spatial extent may be expanding in response to climate Data custodian change. **DELWP Biodiversity** There is insufficient data to determine condition of manaroves. Port Phillip Bay Indicator OMAC? About 50% of Port Phillip Bay's pre-1750s PPR MC:02 Saltmarsh saltmarsh cover of 3710 hectares remains extent ? OMAC PPB GLA GLA today. WPT WPT V Region **Western Port** Port Phillip Bay (PPB), In Western Port, 90-95% of saltmarsh that Western Port (WPT), once covered 1460 hectares remains today. All Gippsland Lakes DATA QUALITY (GLA), Other Marine **Gippsland Lakes** Fair - PPB & WPT & Coastal Areas Historical mapping of the various lakes (OMAC) indicates that between 80-100% of pre-1750s Measures saltmarsh has been retained. DATA QUALITY Spatial extent Other marine and coastal areas Poor - GLA & OMAC Data custodian Of 30 coastal sectors surveyed and compared to pre-1750 extent, 7 had 35-65% of saltmarsh

DELWP Biodiversity

remaining, 7 were 100% intact, one had expanded to 130% and 14 ranged between

There is insufficient data to determine

condition of mangroves.

70-95%.

	Summary	Status UNKNOWN	POOR	FAIR	GOOD	Trend
Indicator MC:03 Seagrass condition Region Western Port (WPT), Other Marine & Coastal Areas (OMAC), Port Phillip Bay (PPB), Corner Inlet (CI), All Gippsland Lakes (GLA) Measures Changes in extent Changes in percentage cover, density and epiphytes Data custodian	Baywide extent of seagrasses is relatively constant, while there can be large changes in cover in localised areas. Western Port Variability in Zostera beds; stable Amphibolis antarctica beds, Seagrass in Yaringa Marine National Park in good condition. Gippsland Lakes A decline in seagrass extent and an increase in seagrass density have been measured, but with only limited data. Corner Inlet Subtidal seagrass extent had varied over time, but recent data reveals that it declined on average by 0.5 km² per year between 1965 and 2013, with algal blooms and turbidity both impacting on light penetration. There is limited data on density and epiphytes.	WPT OMAC DATA QUALITY Fair		GLA CI	PPB	WPT ? GLA ? PPB / OMAC ? CI
Indicator MC:04 Seagrass-dependent fish	Port Phillip Bay There is insufficient data for an assessment of status and trends.	PPB				?
Region Port Phillip Bay (PPB), Western Port (WPT), Other Marine & Coastal Areas (OMAC) All Gippsland Lakes (GLA)	Western Port There is insufficient data for an assessment of status and trends. Gippsland Lakes Fish assemblages and seagrass condition at 30 sites were highly variable and insufficient to assess status and trends.	WPT OMAC GLA DATA QUALITY POOR				
Measures Change in relative abundance, diversity and biomass of seagrass-dependent fish Data custodian DELWP Biodiversity; PV	Other marine and coastal areas There is insufficient data for an assessment of status and trends.					

Summary **Status Trend** GOOD POOR Until the completion of the Index of Estuarine Indicator Condition in 2020, there will be insufficient MC:05 Estuarine data for an assessment of status and trends. condition Region Victoria DATA QUALITY Measures Poor Index of Estuarine Condition covering five themes: physical form, hydrology, water quality, flora, fauna Data custodian DELWP Catchments, Waterways, Cities and Towns Port Phillip Bay WPT ? Indicator OMAC ? MC:06 Mobile Mobile invertebrates have remained in good condition since 2003 in the bay's Marine WPT MNPS PPB ? invertebrates on intertidal reefs National Parks and Marine Sanctuaries only. OMAC $MNPS \rightarrow$ PPR Western Port Region Port Phillip Bay(PPB) Western Port has few reefs and limited data Marine National about them. There has been an observed loss Parks & Sanctuaries in invertebrate diversity at Crawfish Rock due DATA QUALITY (MNPS), Western Port to high turbidity. Good - MNPS (WPT), Other Marine Other marine and coastal areas & Coastal Areas (OMAC) Mobile invertebrates are in good condition in Marine National Parks and Sanctuaries only. Measures Data are insufficient on reefs outside those Census (count) DATA QUALITY protected areas. Total diversity of Poor - OMAC, PPB & WPT mobile invertebrates Extent of mobile invertebrates Patchiness or fragmentation (i.e. connectivity) Data custodian PV Intertidal Reef Monitoring Program, Sea Search/Museum of Victoria ad-hoc

survevs

	Summary	Status UNKNOWN POOR FAIR	Trend
Indicator	Marine National Parks and Marine Sanctuaries		OMAC?
MC:07 Sessile	Good condition in nine parks, and fair		MNPS 7
invertebrates on intertidal reefs	condition in three parks.	OMAC	MNPS
Region	Other marine and coastal areas		
Marine National Parks & Sanctuaries (MNPS), Other Marine & Coastal Areas (OMAC)	Data are limited for sites outside Victoria's marine protected areas.	DATA QUALITY Good - MNPS	
Measures			
Change in percentage cover of sessile invertebrates			
Total diversity of sessile invertebrates		Poor - OMAC	
Spatial extent of sessile invertebrates			
Number of non- indigenous/invasive species and extent			
Patchiness or fragmentation (i.e. connectivity)			
Data custodian			
PV Intertidal Reef Monitoring Program, Sea Search/Museum of Victoria ad-hoc surveys			

Indicator

MC:08 Mobile megafaunal invertebrates on subtidal reefs

Region

Marine National Parks & Sanctuaries (MNPS), Northern Port Phillip Bay (NPPB) , Southern Port Phillip Bay (SPPB), Other Marine & Coastal Areas (OMAC)

Measures

Change in abundance of large molluscs, echinoderms and crustaceans

Change in sizeclass distribution of selected species

Data custodian

Parks Victoria; Reef Life Survey

Port Phillip Bay: Marine National Parks and Marine Sanctuaries only

Health of megafaunal invertebrates in Port Phillip Heads Marine National Park is good, unknown in Point Cooke and Jawbone Marine Sanctuaries and fair at Ricketts Point Marine Sanctuary.

Other marine and coastal areas

Summary

Mobile megafaunal data is limited outside Victoria's Marine Protected Areas. Mobile megafaunal invertebrates are rated as good in 12 parks, fair in one park and unknown in another. Trend data is not available.

Status UNKNOWN	POOR	FAIR	GOOD	Trend
				OMAC?
OMAC	NPPB		MNPS SPPB	NPPB $ d$



DATA QUALITY

Good - MNPS, NPPB & SPPB



DATA QUALITY

Poor - OMAC

Indicator

MC:09 Subtidal reef fish

Region

Southern Port Phillip Bay (SPPB), Marine National Parks & Sanctuaries (MNPS), Northern Port Phillip Bay (NPPB), Other Marine & Coastal Areas (OMAC)

Measures

Abundance

Diversity

Biomass

Size-class distribution

Data custodian

DELWP Biodiversity; PV

Port Phillip Bay

In southern Port Phillip Bay, the health of reef fish communities was rated as 'good', reflecting the improving health of the ecosystem. Health of reef fish communities was rated as unknown in Jawbone Marine Sanctuary and fair in Point Cooke and Ricketts Point Marine Sanctuaries.

Other marine and coastal areas

Large mobile fish (including sharks and rays) on subtidal reefs in Marine National Parks and Sanctuaries beyond Port Phillip Bay are good in 14 parks, fair in one and unknown in one. Data is limited outside Victoria's Marine Protected Areas.









OMAC?
NPPB?
MNPS?
SPPB7



DATA QUALITY

Good - SPPB & MNPS



DATA QUALITY

Fair - NPPB



DATA QUALITY

Poor - OMAC

Indicator

MC:10 Macroalgaedominated subtidal reefs

Region

Southern Port Phillip Bay (SPPB), Marine National Parks & Sanctuaries (MNPS),Northern Port Phillip Bay (NPPB), Other Marine & Coastal Areas (OMAC)

Measures

Change in percentage cover

Diversity of macroalgae

Patchiness and fragmentation (i.e. connectivity)

Data custodian

PV Reef Life Survey

Port Phillip Bays

Summary

Information is only available for Marine National Parks and Sanctuaries. Subtidal reefs in the Port Phillip Heads Marine National Park are healthy – with the exception of decreasing numbers of seastars and an increasing risk of invasive marine species. Kelp has been replaced by purple sea urchin barrens, coralline algae and filamentous brown algae at Point Cooke Marine Sanctuary, while kelp has also declined at Jawbone and Ricketts Point marine sanctuaries

Other marine and coastal Areas

Information is only available for Marine National Parks and Sanctuaries. Brown algae communities on subtidal reefs are in good condition in 14 parks and fair in 3.



DATA QUALITY

Good - SPPB & MNPS



DATA QUALITY

Poor - NPPB & OMAC

Indicator

MC:11 Macroalgae on intertidal reefs

Region

Marine National Parks & Sanctuaries (MNPS), Port Phillip Bay (PPB), Other Marine & Coastal Areas (OMAC)

Measures

Presence/absence of indicator species

Change in percentage cover, diversity and extent of macroalgae

Data custodian

PV Intertidal Reef Monitoring Program; Sea Search/Museum of Victoria ad-hoc surveys

Port Phillip Bay Marine National Parks and **Sanctuaries**

Monitoring data from the bay's Marine National Parks and Sanctuaries indicates that macroalgae is in good condition.

Other marine and coastal areas

Monitoring data from Parks Victoria indicates that macroalgae condition is fair to good in Marine National Parks and Sanctuaries. Data is insufficient to determine status or trends outside these protected areas.



DATA QUALITY

Good - PPB & MNPS



DATA QUALITY

Poor - OMAC

Summary Status Trend GOOD UNKNOWN POOR FAIR Indicator There has been a decline trend in the number OMAC 🛚 PBB of migratory shorebirds visiting the Victorian \forall MC:12 Migratory coast, heavily influenced by the loss of habitats CI PBB \vee OMAC shorebirds along their flyways, especially around the CI Region Yellow Sea in China. Numbers are also affected Port Phillip Bay by periods of drought and high rainfall within (PPB), Corner Inlet Australia, which alters wetlands extent. DATA QUALITY (CI), Other Marine Fair - PPB & CI& OMAC & Coastal Areas (OMAC) Measures Number of individuals (counts) Data custodian DELWP Biodiversity; Birdlife Australia; Victorian Wader Studies Group Penguin numbers have been variable at the Indicator OMAC? large Phillip Island colony (32,000 breeding STK MC:13 Little penguins adults) but have improved in recent years. The РΙ OMAC STK Region smaller St Kilda Breakwater colony (1400) has Ы St Kilda(STK), Phillip been slowly growing since the first penguins Island (PI), Other arrived in the 1960s. But increasing visitor Marine & Coatal pressure and marine debris are issues of Areas (OMAC) DATA QUALITY concern. There is limited data on the other Measures penguin colonies along the Victorian coast. Good - STK & PI Mean number of individuals recorded DATA QUALITY in standardised Poor - OMAC counts Mean numbers occupying burrows Number of chicks fledged per breeding female/pair weight in grams Data custodian Phillip Island Nature Park/Earthcare

St Kilda

Summary Status Trend GOOD UNKNOWN POOR FAIR OMAC? Indicator The numbers of fish-eating birds in Western CI 7 Port have been in decline while those in Corner MC:14 Piscivorous WPT 🛚 Inlet have been increasing. Data for other (fish-eating) birds OMAC CI marine and coastal areas are insufficient to WPT Region determine status and trends. Corner Inlet (CI), Western Port (WPT), DATA QUALITY Other Marine & Good - CI & WPT Coastal Areas (OMAC) Measures Total counts of terns, DATA QUALITY cormorants and Poor OMAC Australian pelican in summer (February) and winter (June-July) Data custodian ARI, Birdlife Australia; Deakin University

Indicator

MC:15 Marine and coastal Waterbirds

Region

Western Port (WPT), All Gippland Lakes (GLA), Other Marine & Coastal Areas (OMAC), Port Phillip Bay (PPB)

Measures

Total counts of waterbirds

Data custodian

Birdlife Australia (Western Port Waterbird Survey)/ DELWP

The number of waterbirds at any given location is heavily influenced by the availability of suitable wetland habitats, food supply and predation in their Victorian and Australian ranges. Research at the Western Treatment Plant and in Western Port has recorded declining numbers for various species. The large size of the Gippsland Lakes has limited the number and location of bird counts, but diversity and abundance have been assessed as fair from the available data.



DATA QUALITY

Poor - OMAC & PPB

Indicator

MC:16 Overabundant sea urchins on subtidal reefs

Region

Southern Port
Phillip Bay (SPPB),
Beware Reef Marine
Sanctuary (BRMS),
Nooramunga Marine
& Coastal Park
(NMCP), Northern
Phillip Bay (NPPB)
Other Marine and
Coastal Parks
(OMAC)

Measures

Urchin density Level of impact

Data custodian

PV and Reef Life Survey. Melbourne University and Fisheries Victoria also undertook a one-off snapshot monitoring exercise (2014).

Summary

Sea urchins have become over abundant on reefs in northern Port Phillip Bay and Beware Reef Marine Sanctuary, and in seagrass in Nooramunga Marine and Coastal Park. Culling programs have been carried out at each location. Urchins have also been observed in increased numbers at Cape Howe and Point Hicks but data from other marine and coastal areas are limited.



DATA QUALITY

Fair -SPPB, BRMS, NMCP & NPPB



DATA QUALITY

POOR - OMAC

Indicator

MC:17 Invasive marine species

Region

Port Phillip Bay (PPB), Other Marine & Coastal Areas (OMAC)

Measures

Number of introduced plant and animal species

New incursions

Threat, distribution and abundance

Spatial area affected

Expansions of existing areas

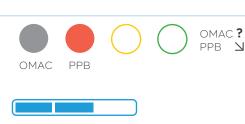
Risks to native habitats and species

Data custodian

DELWP Biodiversity; DEDJTR Biosecurity and Agriculture Services; PV

Port Philip Bay

There are more than 160 invasive marine species recorded in Port Phillip Bay, but only a small number that are of ongoing serious concern. There have been outbreaks of invasive marine species in other marine and coastal areas, but there is no systematic monitoring to determine their location, status or trend.



DATA QUALITY

Fair - PPB



DATA QUALITY

Poor - OMAC

Summary Status Trend GOOD UNKNOWN POOR FAIR Indicator Port Phillip Bay WPT MC:18 Catchment EPA water-quality report cards from 2012-13 GCMA ? inputs into coastal to 2016–17 for the bay's catchments showed a WPT PPB EGCMA PPB 7 waters/reefs higher percentage of catchments with fair to GCMA CCMA CCMA ? very good ratings than those with very poor to **WGCMA** Region WGCMA poor ratings. Water quality was better in the Port Phillip Bay (PPB), EGCMA ? middle and upper reaches of the catchments.

Western Port (WPT), Glenelg Hopkins CMA, West Gippsland CMA, Corangamite CMA, Other Marine & Coastal Areas (OMAC)

Measures

Annual load by pollutant

Nutrients

Water clarity (turbidity)

Dissolved oxygen

Salinity (conductivity)

рΗ

Metals

Data custodian

DELWP Catchments, Waterways, Cities and Towns; EPA Victoria

Western Port

The EPA's first report card for Western Port in 2016-17 revealed that 78% of the catchment area was rated from very poor to fair, even though water quality in the bay itself was rated as good.

Other marine and coastal areas

The Catchment Management Authorities (CMAs) with coastal boundaries have rated the condition and water quality of their catchments poor (Glenelg; Port Phillip and Westernport), moderate (Corangamite; West Gippsland) and good (East Gippsland).

DATA QUALITY

Good - PPB & WPT & CMAs

Indicator

MC:19 Point-source discharges to marine waters

Region

Victoria

Measures

Reported as volume by treatment category (primary, secondary, tertiary)

Data custodian

EPA Victoria

Water quality data is collected inside and outside the mixing zones at each of 18 ocean outfalls along Victoria's coast, but reporting and analysis are limited. However, reports submitted to EPA indicate that each outfall is meeting its licence conditions. Although there have been overall improvements in the quality of stormwater discharges to Port Phillip Bay, there is limited data on individual discharges.



DATA QUALITY

Poor

	Summary	Status UNKNOWN PC	OR FAIR	GOOD	Trend
Indicator MC:20 Harmful algae blooms reefs Region Port Phillip Bay (PPB), All Gippsland Lakes (GLA), Other Marine & Coastal Areas (OMAC) Measures Bloom type Abundance Diversity Extent Duration Data custodian EPA Victoria	Algal blooms can impact marine life and human health and usually appear after heavy rainfall and subsequent warm and sunny weather. Both Port Phillip Bay and the Gippsland Lakes have experienced algal blooms (seven between 1997 and 2016). However, data on their extent and frequency beyond those two areas is limited.	DATA QUALITY Good - PPB 8 DATA QUALITY Poor - OMAC			OMAC ? PPB → GLA ?
Indicator MC:21 Enterococci bacteria Region Port Phillip Bay (PPB), Other Marine & Coastal Areas (OMAC) Measures Number of bacteria cells (Enterococci) per 100 ml of water sample Percentage of beaches meeting SEPP Data custodian EPA Victoria	Except for data collection at a small number of ocean outfalls, the focus of <i>Enterococci</i> bacteria monitoring is to determine the safety of water-based recreational activities at Port Phillip Bay's beaches. The monitoring has shown that in recent years, 94-97% of beaches have met water-quality objectives - an improvement on earlier years.	OMAC DATA QUALITY Good - PPB DATA QUALITY Poor - OMAC		PPB	OMAC ?

Summary	Status UNKNOWN	POOR	FAIR	GOOD	Trend
Although the status of commercially targeted stocks is assessed regularly by fisheries agencies, such assessments do not cover the other measures listed here. Data on those is limited or unavailable.	DATA QUALIT	<u> </u>			?
	Poor				
	Although the status of commercially targeted stocks is assessed regularly by fisheries agencies, such assessments do not cover the other measures listed here. Data on those is	Although the status of commercially targeted stocks is assessed regularly by fisheries agencies, such assessments do not cover the other measures listed here. Data on those is limited or unavailable.	Although the status of commercially targeted stocks is assessed regularly by fisheries agencies, such assessments do not cover the other measures listed here. Data on those is limited or unavailable.	Although the status of commercially targeted stocks is assessed regularly by fisheries agencies, such assessments do not cover the other measures listed here. Data on those is limited or unavailable.	Although the status of commercially targeted stocks is assessed regularly by fisheries agencies, such assessments do not cover the other measures listed here. Data on those is limited or unavailable.

	Summary	Status UNKNOWN POOR FAIR	Trend
Indicator MC:23 Conservation of coastal ecosystems in protected areas Region Victoria	National parks and other conservation areas extend along approximately 70% of the Victorian coastline but there are limited data on threatened and invasive species, while a number of threatened ecological vegetation classes could be given greater protection.	DATA QUALITY Fair	$\bigcirc \rightarrow$
Measures			
Area of conservation by type of conservation class Area by total extent and region extent			
Proportion of ecosystem types under protection			
Threatened species represented in conservation areas			
Extent and impact of invasive species			
Data custodian			
DELWP Biodiversity			

Status Summary Trend UNKNOWN POOR FAIR GOOD Although marine protected areas cover Indicator approximately 11% of Victoria's marine MC:24 Conservation waters, their spatial extent is skewed to of marine GLA and East Five marine Corner Inlet/Nooramunga and Wilsons Gipplsand bioregions ecosystems in Promontory, indicating that the network is Inlets protected areas failing to meet the National Representative Region System of Marine Protected Areas principles All Gippsland Lakes of comprehensiveness, adequacy and DATA QUALITY (GLA) and East representativeness across all five marine Gippsland Inlets Good bioregions. Five marine bioregions Measures Area of conservation by type of conservation class Area by total extent and region extent Proportion of ecosystem types under protection Threatened species represented in conservation areas Data custodian **DELWP** Biodiversity

Coastal Wetlands and Estuaries

There are at least 16 coastal wetland EVCs, of which the most common and spatially extensive are: mangrove shrubland (EVC 140), coastal saltmarsh (EVC 9), estuarine wetland (EVC 10), brackish grassland (EVC 934), brackish wetland (EVC 656), seagrass meadows (EVC 845) and saline aquatic meadow (EVC 854).59

The most recent inventory⁶⁰ of coastal wetlands estimated there were 19,212 hectares of coastal saltmarsh, 5,177 hectares of mangroves and 3,227 hectares of estuarine wetland along the Victorian coastline. Of these, 218 hectares of mangroves and 6,390 hectares of coastal saltmarsh were on private land.

Six areas of coastal wetlands in Victoria have been listed under the Ramsar Convention: Corner Inlet (including Nooramunga) (67,186 hectares), Edithvale-Seaford Wetlands (262 hectares), Gippsland Lakes (60,015 hectares), Glenelg Estuary and Discovery Bay (22,289 hectares), Port Phillip Bay (Western Shoreline) and Bellarine Peninsula (22,897 hectares), and Western Port (59,297 hectares).

There has been growing scientific interest in the monitoring and assessment of estuary condition in Victoria's more than 100 estuaries since the release of the National Land and Water Resources Audit of 2002,61 and the subsequent development of the Index of Estuarine Condition in Victoria, due for release in 2020 and based on five themes: physical form, hydrology, water quality, flora and fauna. Even so, saline coastal wetlands and estuaries remain very poorly studied habitats in south-eastern Australia.62

Rises in sea level, and carbon dioxide, and air and water temperatures and increased storm intensity. along with changing rainfall patterns and wave regimes, will impact on coastal wetlands already affected by population growth and its associated coastal development, land reclamation and levee bank construction.

This section reviews indicators for mangroves, saltmarsh, seagrass, seagrass-dependent fish and estuaries.

DELWP 2016, 'Climate change vulnerability and adaptive capacity of 59. coastal wetlands. Decision Support Framework - Volume Two', Melbourne, Victoria.

Boon Pl, Allen R, Carr G, Frood D, Harty C, Mcmahon A, Mathews S, Rosengren N, Sinclair S, White M, Yugovic J 2014, 'Coastal wetlands of Victoria, south-eastern Australia: providing the inventory and condition information needed for their effective management and conservation, Aquatic Conservation Marine and Freshwater Ecosystems, 25(4), pp.

^{61.} National Land and Water Resources 2002, 'Australian catchment river and estuary assessment', Canberra, Australian Capital Territory.

Sinclair S, Boon P 2012, 'Changes in the area of coastal marsh in Victoria since the mid 19th century', *Cunninghamia*, 12 (2), pp. 153–176.



Data custodian DELWP Biodiversity

Rationale

Saltmarshes and mangroves are critical habitats for many marine and coastal species, and provide many ecosystem services for coastal communities. Measured negative changes in mangrove extent may signal the need for management responses.

Summary

Western Port

Western Port has retained 90–95% of its pre-1750s mangrove habitat, estimated at 1,320 hectares.⁶³ Losses have been caused by harvesting in the 19th century to produce barilla ash, land claim for industrial and port development, and the drainage of adjacent land.⁶⁴ In some areas, mangroves have expanded in area, including encroaching on saltmarsh, yet it is still unclear whether they are advancing seawards or landwards.65

Corner Inlet and Nooramunga

Mangroves are at their southern-most limit in Corner Inlet and Nooramunga, where 80% of the pre-1750s cover remains. Corner Inlet/Nooramunga has the most extensive stands of mangrove along Victoria's coast: 846 hectares in Corner Inlet and 2,241 hectares in Nooramunga (compared with 1,230 hectares in Western Port and 84 hectares in the lower Barwon region).

Other Marine and Coastal Areas

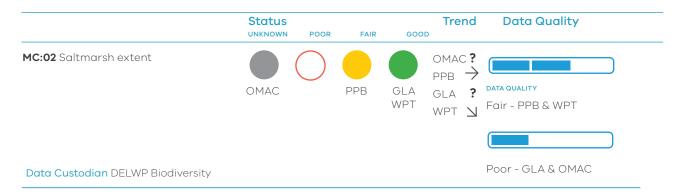
A survey of 30 coastal sectors compared pre-1750s and current mangrove (and saltmarsh) extents. Of the 30 coastal sectors analysed, only 14 had mangroves present.⁶⁶ On a statewide basis, 90% of the pre-1750's extent of mangroves remains. Most coastal sectors have 100% remaining, except for Corner Inlet and Western Port, with 80% and 90% respectively; Shallow Inlet, where all of an estimated 250 hectares have been lost; and Anderson Inlet, where mangrove extent has increased. There are some indications that mangroves may be expanding in extent and increasing in vigour in response to climate change.67

Boon PI, Allen R, Carr G, Frood D, Harty C, Mcmahon A, Mathews S, Rosengren N, Sinclair S, White M, Yugovic J 2011, 'Mangroves and coastal saltmarsh of Victoria: distribution, condition, threats and manage ment', Institute for Sustainability and Innovation, Victoria University, Melbourne, Victoria.

Melbourne Water Corporation 2011, 'Understanding the Western Port environment', Melbourne, Victoria.

Boon PI, Allen R, Carr G, Frood D, Harty C, Mcmahon A, Mathews S, Rosengren N, Sinclair S, White M, Yugovic J 2015, 'Coastal wetlands of Victoria, south-eastern Australia: providing the inventory and condition information needed for their effective management and conservation', Aquatic Conservation: Marine and Freshwater Ecosystems, 25(4), pp.

Boon PI 2017, 'Are mangroves in Victoria (south-eastern Australia) already responding to climate change?', Marine and Freshwater Research, 68(12), pp. 2366-2374.



Rationale

This indicator measures the spatial extent of saltmarsh, a critical habitat for many species, and will assist management responses.

Summary

Port Phillip Bay

About 50% of Port Phillip Bay's pre-1750s saltmarsh cover of 3,710 hectares remains today.⁶⁸ The losses are the result of Melbourne's growth, port development, conversion to evaporating ponds for saltworks, housing at Sanctuary Lakes and the creation of the Western Treatment Plant. Monitoring of four sites in Port Phillip Bay between 2008 and 2011 found no detectable change outside expected variability in saltmarsh health. 69 Parks Victoria will carry out an assessment of saltmarsh in Port Phillip Heads Marine National Park using remote-sensing data.

Western Port

In Western Port, 90-95% of saltmarsh that once covered 1,460 hectares⁷⁰ remains today. In addition to the impact of mangrove encroachment and subsequent saltmarsh displacement along tidal creeks, significant portions of saltmarsh were removed for gariculture. Saltmarsh has returned in some areas, particularly around the northern and western shores of Western Port, for example near Tooradin airport; however, concerns over declining saltmarsh extent remain, with erosion a problem on the eastern shoreline.71 Although loss of saltmarsh to mangrove habitat in Western Port is low (5–10% of saltmarsh area) compared with 30% across south-east Australia, it remains a challenge for managers.⁷²

The saltmarshes of Western Port face a number of threats (see Figure MC.1). For example, sealevel rise will increase the time that water covers saltmarsh, facilitating mangrove encroachment. This has been occurring at several sites including Rhyll, Koo Wee Rup, French Island and Quail Island.73

CES 2016, 'State of the Bays 2016', Melbourne, Victoria.

Sinclair S, Boon PI 2012, 'Changes in the area of coastal marsh in Victoria since the mid 19th century', *Cunninghamia*, 12(2), pp. 153–176. CES 2016, 'State of the Bays 2016', Melbourne, Victoria.

^{71.}

Ihid

Ibid

Gippsland Lakes

Historical mapping⁷⁴ of lakes Reeve, Victoria and Wellington indicates that between 65% and 100% of pre-1750s saltmarsh has been retained in the Gippsland Lakes:

the Gippsland Lakes area presented particular problems for calculating depletion statistics, as there have been potentially large gains or proportionally smaller losses along this section of the Victorian coast, especially for Lake Wellington. The primary difficulty is with existing areas of coastal saltmarsh, some of which are natural occurrences, some of which seem to be expansions of saltmarsh since European colonization.75

Saltmarsh and other areas of saline coastal wetland around the Gippsland Lakes are especially complex spatially and temporally, and this has made it impossible to resolve changes in post-European extent. Future sea-level rise and storm surges, exacerbated by ongoing dredging of the entrance, are expected to reduce saltmarsh extent,76 although increasing salinisation caused by the 1889 opening of the artificial entrance may see areas of saltmarsh increase and areas of nonhalophytic fringing vegetation, such as common reed, decline.77,78

Other Marine and Coastal Areas

A survey of 30 coastal sectors that compared pre-1750s and current mangrove (and saltmarsh) extents found seven of the coastal sectors had 35–65% of saltmarsh remaining. Seven were 100% intact, one had expanded to 130% (Lang Lang), and the other fourteen ranged from 70–95%.^{79,80}

The intensity levels of 20 impacts across 30 coastal sectors where saltmarsh is present were identified (see Figure MC.1). The most intense and more common impacts were land claim (total removal of pre-existing wetland for uses including agriculture and port development), landfill and spoil dumping, vehicle access and stock grazing.

^{74.} Sinclair S, Boon PI 2012, 'Changes in the area of coastal marsh in Victoria since the mid 19th century', Cunninghamia, 12(2), pp. 153–176.

⁷⁵

Boon PI, Cook P, Woodland R 2016, 'The challenges posed by chronic 76. environmental change in the Gippsland Lakes Ramsar site', Marine and Freshwater Research, 67(6), pp. 721-737.

Bird E 1966, 'The impact of man on the Gippsland Lakes, Australia', In Geography as Human Ecology. Methodology by Example, (eds. S Eyre and G Jones), Edward Arnold, London, Great Britain, pp. 55–73.

⁷⁸ Boon PI, Frood D, Oates A, Reside J, Rosengren N 2018, 'Why has Phragmites australis persisted in the increasingly saline Gippsland Lakes? A test of three competing hypotheses', Marine and Freshwater Research, 10.1071/MF18145 Accessed 4 December 2018.

Boon PI, Allen R, Carr G, Frood D, Harty C, Mcmahon A, Mathews S, Rosengren N, Sinclair S, White M, Yugovic J 2015, 'Coastal wetlands of Victoria, south-eastern Australia: providing the inventory and condition information needed for their effective management and conservation' Aquatic Conservation: Marine and Freshwater Ecosystems, 25(4), pp. 454-479.

Boon PI, Allen R, Carr G, Frood D, Harty C, Mcmahon A, Mathews S, Rosengren N, Sinclair S, White M, Yugovic J 2011, 'Mangroves and coastal saltmarsh of Victoria: distribution, condition, threats and management', Institute for Sustainability and Innovation, Victoria University, Melbourne, Victoria

Sector	Land-claim	Landfill and spoil	Tidal restriction	Stormwater input	Shell-grit mining	Salt production	Treatment ponds	Vehicle access	Stock grazing	Deer, goats, pigs	Weed invasion	Spartina	Inappropriate rehabilitation	Inappropriate recreation	Boat-wash	Overdevelopment	Mowing	Landward barrier (artificial)	Landward barrier (land use)	Landward barrier (topographic)
Glenelg	- 1			W					- 1		- 1			- 1	- 1	W		1	W	1
Fawthrop-Belfast	W	1		W					- 1		-1			- 1	-1	W		1	W	1
Western estuaries	- 1			?		ne.	- 1	1	W		-1		- 1	- 1	T	W			W	1
Aire-Gellibrand	W							- [W		W								w	W
Surf-coast estuaries	- 1			W			Ţ		- 1		1		T	1		W		I	W	W
Breamlea	- 1	-	w	- 1			W	- 1	W		- 1			- 1		W		w	w	W
Connewarre	- 1	1	W	- 1	- 1			- 1	- 1	1	T	- 1	- 1	- 1	T	W	1	w	w	w
Bellarine Lakes	- 1		Na	- 1				-1	- 1		?			- 1		W		1	1	1
Salt Lagoon			Na	?		100		- 1			?			?		W		I	w	w
Swan Bay	- 1	- 1	1	- 1	- [- 1	- 1		- [- 1	W	- 1	1	W	1
Mud Island	,														- [Ţ
Port Phillip	- 1		1	- 1	?	- 1	W	- 1	?	- 10	?		- 1	1	- 1	-		w	w	Ī
The Inlets	- 1	- 1		W				- 1	- 1		- 1	-1						w	w	
Western Port	- 1	-		- 1				- 1	1		- 1			- 1	- 1	W		1	w	1
French Island						- 1		- 1	T	W	T	140			T				T	Ι
Rhyll Inlet	- 1	-1		W				- 1	- 1		- 1			- 1		W		I	w	
Lang Lang coast								- 1	- 1		-	×							w	
Bass River	- 1							T	- 1		- 1	- 1						w	w	
Powlett-Kilcunda	W							- 1	W		- 1			- 1		W		1	w	
Anderson Inlet	W	1		- 1				1	T		- 1	W	-1	1	1	w		w	w	
Shallow Inlet	W			- 1							I				- 1			w	w	
Wilsons Promontory										1	?				- 1					,
Corner Inlet	W		- 1	1				1	T.	1	-1	- 1		?	L	T		w	w	W
Nooramunga Coast	W		- 1	?				- 1	I.	- 1	?	- 1		- 1	1	T			I	
Nooramunga Is.			1					1	1	T	?	?			?					
Jack Smith Lake			Na	?.				- 1	- 1	T	?				iw.			w	w	1?
Lake Reeve	1	1	1					- 1	1	1	- 1	18				- 1		I	w	
Lakes Victoria & King	- 1							- 1	T	T	1			1	1			I	w	1?
Lake Wellington	- 1		I	¥				1	T	T	1	18			Т			w	w	I
East Gippsland Inlets	W		1	?				1	W	T	?			?	?			1	1	W

Figure MC.1 An assessment of saltmarsh degradation according to degrading processes throughout Victoria, assessed sector-by-sector81

Note: The intensity of impact is colour-coded where red is high, orange is medium and yellow is low. The letter 'I' and 'w' within a cell refers to whether the impact is widely or locally evident. A '?' indicates uncertainty as to impacts in that sector. 'Na' is not applicable, and the final three columns are not coded, as it is currently impossible to gauge sealevel rise impacts.

Boon Pl, Allen R, Carr G, Frood D, Harty C, Mcmahon A, Mathews S, Rosengren N, Sinclair S, White M, Yugovic J 2015, 'Coostal wetlands of Victoria, south-eastern Australia: providing the inventory and condition information needed for their effective management and conservation, Aquatic Conservation: Marine and Freshwater Ecosystems, 25(4), pp.

Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
WPT OMAC		GLA CI	PPB	WPT ? GLA ? PPB > OMAC? CI \(\sum_{\text{V}} \)	DATA QUALITY Fair
	UNKNOWN	UNKNOWN POOR WPT	UNKNOWN POOR FAIR WPT GLA	UNKNOWN POOR FAIR GOOD WPT GLA PPB	UNKNOWN POOR FAIR GOOD WPT ? GLA ? WPT GLA PPB PPB →

Seagrass meadows are critical habitat for many marine species, including fish targeted by commercial and recreational fishers, provide shoreline protection and store significant amounts of carbon. Changes in their condition can have environmental, social and economic effects.

Summary

Port Phillip Bay

The health of seagrass was assessed at three sites in Port Phillip Bay from 2004–5 to 2006–7 (as well as sites in Western Port and Corner Inlet), establishing a baseline dataset for future monitoring and comparison.⁸² Along with aerial mapping to determine changes in percentage cover, the researchers monitored a large range of seagrass variables including shoot length, density and biomass, along with epiphyte cover, epifauna, water temperature and light. Aerial mapping for Port Phillip Bay showed reductions in seagrass cover at Point Richards and Blairgowrie, an increase at Kirk Point and no change at Swan Bay.

Baywide extent of seagrasses is relatively constant while there can be large changes in cover in localised areas: 'For example, in regional areas such as Blairgowrie, St Leonards and Bellarine Bank, there has been a long-term increase in seagrass cover from the 1950s to the late 1990s but then a dramatic decline in the 2000s.'83 During the millennium drought (1996–2010), there was a large

reduction in seagrass extent in Port Phillip Bay, where the Bellarine Bank reduced by more than 90% from 2000 to 2011.84 Seagrasses in sheltered areas (Corio Bay, Point Henry, Swan Bay) were relatively stable or 'persistent', whereas those in exposed areas (southern bay, Bellarine Bank) were 'ephemeral' and heavily influenced by nutrient loadings.85

A review of aerial photos of the Bellarine Bank from 2009 to 2014, found that 'the rapid decline in seagrass since the onset of the millennium drought is consistent with a decline in nutrient loadings to the bay; however, it may also reflect changes in other pressures such as prevailing winds and bay circulation patterns'.86

Western Port

During the 1970s and 1980s, Western Port lost 70% of its seagrass due to excessive sediment inflows and coastal bank erosion that smothered seagrass and reduced light penetration. A CSIRO study⁸⁷ for Melbourne Water estimated that 32% of the sediment was sourced from the erosion of a ninekilometre stretch of shoreline in the bay's northeastern corner between the mouth of the Yallock Creek and the Lang Lang caravan park.

A 2011 review of Western Port seagrass research revealed that the seagrass decline was followed by an increase from the mid-1990s to 1999. Most variability was observed in the Zostera-dominated beds, while Amphibolis antarctica beds remained relatively stable.88 In the north of the bay, seagrass in Yaringa Marine National Park was rated in 'good' condition in 2017.89

Ball D, Hirst A, Parry G, Heislers S, Blake S, Werner G, Young P, Coots A 2010, Victorian multi-regional seagrass health assessment 2004–07', Fisheries Victoria Technical Report No.66, Department of Primary Industries, Queenscliff, Victoria

Jenkins G, Keogh M, Ball D, Cook P, Ferguson A, Gay J, Hirst A, Lee R, Longmore A, Macreadie P, Nayer S, Sherman C, Smith T, Ross J, York P 2015, 'Seagrass resilience in Port Phillip Bay: final report to the Seagrass and Reefs Program for Port Phillip Bay, University of Melbourne, Melbourne, Victoria http://www.pir.sa.go e in Port Phillip Bay.pdf Accessed 4 December 2018.

⁸⁴ 85. Ibid

Ibid 86.

Wilkinson SN, Anstee JM, Joehnk KD, Karim F, Lorenz Z, Glover M, Coleman R 2016, 'Western Port sediment supply, seagrass interactions and remote sensing', Report to Melbourne Water Corporation, CSIRO, Melbourne, Australia.

CES 2016, 'State of the Bays 2016', Melbourne, Victoria

Gippsland Lakes

The Gippsland Lakes Condition Report noted the natural variability of seagrass in temperate Australia and revealed that, between 1997 and 2016, seagrass extent had declined in the area. But this snapshot of two endpoints, with no monitoring data points in between 1997 to 2016, was insufficient to determine whether the reduction would be sustained. Ocnversely, over the same period seagrass density had increased from 50% to 63%. The report rated seagrass extent as 'fair' and its condition as 'good'.

Corner Inlet

There was an observed decline in seagrass cover in Corner Inlet (except for Granite Island), 92 where seagrass extent had declined on average by 0.5 km² per year between 1965 and 2013, with algal blooms and turbidity both impacting on light penetration. 93

The ecological character description ⁹⁴ for the Corner Inlet Ramsar site indicated a decline in *Posidonia australis* seagrass due to reduced water quality, stating that 'die-off of *P. australis* and possibly the occurrence of blooms of filamentous algae 'slub' are consistent with the effects of nutrient enrichment', ⁹⁵ and that 'dense seagrass beds, mostly comprised of *P. australis*, were observed to have declined in extent, whereas there was an increase in the distribution of sparse seagrass'. ⁹⁶

Other Marine and Coastal Areas

Aerial surveys of seagrass extent in Anderson, Shallow, Corner, Tamboon, Wingan and Mallacoota inlets were conducted in 1998 and 1999, but none have been repeated. Therefore, current data for these areas is not available.

Carey J, Howe S, Pocklington J, Rodrigue M, Campbell A, Addison P, Bathgate R 2017, 'Report on condition of Yaringa Marine National Park 2002 to 2013', Parks Victoria Technical Series No. 112, Melbourne Victoria.

^{90.} East Gippsland Catchment Management Authority, 'State of the Gippsland Lakes: Technical Report', (Publication pending).

^{91.} Ibi

Ball D, Hirst A, Parry G, Heislers S, Blake S, Werner G, Young P, Coots A 2010, 'Victorian multi-regional seagrass health assessment 2004–07', Fisheries Victoria Technical Report No.66, Department of Primary Industries, Queenscliff, Victoria.

Ford J, Barclay K, Day R 2016, 'Using local knowledge to understand and manage ecosystem-related decline in fisheries productivity', Fisheries Research and Development Corporation Final Project Report, Melbourne. Victoria.

Department of Sustainability, Environment, Water, Population and Communities 2011, 'Ecological character description of the Corner Inlet Ramsar site – final report', Canberra, Australian Capital Territory.

^{95.} Ibio

^{96.} Ibic

	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
MC:04 Seagrass-dependent fish					?	
	PPB					DATA QUALITY
	WPT					Poor
Data Custodian DELWP Biodiversity, PV	OMAC GLA					

Seagrass meadows are used by many fish species for breeding, feeding and shelter. Any change in population numbers and diversity (evenness of species distribution) of seagrass-dependent fish could indicate changes in seagrass health with potential environmental, social and economic effects.

Summary

Port Phillip Bay

Fish species, biomass and diversity within Port Phillip Bay seagrass beds were monitored at three sites from 2008 to 2012.97 The research concluded that a loss of seagrass or reduction in seagrass condition at varied depth ranges may affect individual fish species differently. The data is insufficient to determine status or trends.

Western Port

Zostera muelleri seagrass is dominant, with high species richness (the number of species). That includes the spotted pipefish (Stigmatopora argus and other conservation-listed syngnathids), grass whiting (Haletta semifasciata), little weed whiting (Neoodax balteatus) and leatherjackets (Monacanthidae spp.), as well as providing an important area for settling King George whiting larvae. Amphibolis antarctica seagrass dominates the entrance to Western Port and also has high fish species richness, including the sixspine leatherjacket (Meuschenia freycineti), little weed whiting, weedy seadragon (Phyllopteryx taeniolatus-conservation-listed), and is being habitat for southern calamari squid (Sepioteuthis australis) and King George whiting. The maintenance of fish biodiversity in Western Port relies on the persistence of significant areas of Z. muelleri, particularly in the intertidal, shallow subtidal zone.98

In another Western Port study, night-time trawls were used to survey seagrass fish in Yaringa Marine National Park. The six trawls collected 14,073 organisms: 12,734 crustacea, 514 fish, 791 molluscs, 33 polychaetes and 1 pynogonida.99

Again, there is insufficient data for an assessment of status and trends.

Hutchison N, Jenkins G, Brown A 2012, 'Variation with depth in temperate segarass-associated fish assemblages in southern Victoria. Australia', Estuaries and Coasts, 37(4), pp. 801-814.

Jenkins G, Kenner T, Brown A 2013, 'Determining the specificity of fish-habitat relationships in Western Port', Centre for Aquatic Pollution Identification and Management, Technical Report No.26, Melbourne Victoria.

Kirkman H, Stevenson I, Avery L 2016, 'The juvenile fish and macroinvertebrates of Yaringa Marine Sanctuary in Western Port', Western Port Seagrass Partnership, Western Port, Victoria.

Gippsland Lakes

Fish assemblages and seagrass condition were assessed at 30 sites in the Gippsland Lakes from September 2008 to April 2012. Seagrass extent and qualitative condition rose and then fell during the assessment period. Fish species were generally consistent with those expected in shallow Victorian estuaries and represented a range of functional guilds, including estuarine resident species, species that depend on estuarine habitats to complete their lifecycle, and species that use estuaries opportunistically. Relative abundances were highly variable among sampling rounds and variation in per cent abundances also varied. 100 The assessment provided a good baseline of data to monitor future changes but is insufficient to determine status and trends.

Other Marine and Coastal Areas

There is insufficient data to assess status and trends.

^{100.} Warry F, Hindell J 2012, 'Fish assemblages and seagrass condition of the Gippsland Lakes: 2012', Unpublished client report for the Gippsland Lakes Ministerial Advisory Committee, Arthur Rylah Institute for Environmental Research, Heidelberg, Victoria.

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
MC:05 Estuarine condition					?	
Data Custodian Catchments, Waterways, Cities and Towns						DATA QUALITY Poor

Estuaries provide important ecosystem services that have environmental, economic, cultural and social benefits dependent on estuarine health.

Summary

The National Land and Water Resources Audit (2002), 101 assessed the condition of a selection of Victorian estuaries and found the following:

- 14 were categorised as near pristine (including East Gippsland Lowlands bioregion)
- 20 were largely unmodified (including Warrnambool Plain, Otway Plain, Otway Ranges and Wilsons Promontory bioregions)
- 23 were modified (including Port Phillip Bay and on the Warrnambool, Otway and Gippsland plains bioregions)
- 4 were extremely modified (including Laverton and Kororoit creeks, the Gippsland Lakes and the Merri River).

To support the development of the Index of Estuarine Condition, a separate assessment from the above 2002 audit, 101 estuaries were analysed from 2010 to 2012.102 Most estuaries had readings of either 'good' or 'excellent' for form and hydrology, whereas for water quality and flora, most were assessed as 'moderate' or 'good'. Estuaries in the Otway Ranges, around Wilsons Promontory and in Croajingolong National Park were more likely to be assessed as 'good' to 'excellent', whereas those with developed catchments, for example Mordialloc Creek in Port Phillip Bay, recorded lower scores.

Until the completion of the Index of Estuarine Condition in 2020, there is insufficient data to assess status and trends.

National Land and Water Resources 2002, 'Australian Catchment River and Estuary Assessment', Canberra, Australian Capital Territory.

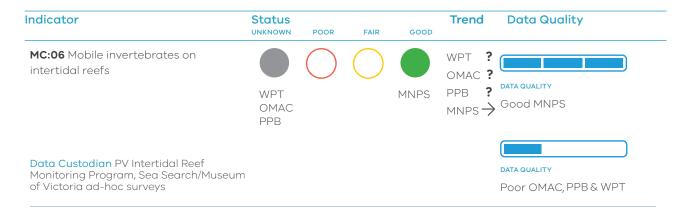
Pope A, Barton J, Quinn G 2015, 'Victorian index of estuary condition: implementation trial final report', School of Life and Environmental Sciences, Deakin University Warrnambool, Victoria.

Intertidal and Subtidal Reefs

The intertidal and subtidal reefs in Victoria's coastal waters support a diverse and colourful range of marine plants and animals. Intertidal reefs are popular with people who enjoy rock-pool rambling, while subtidal reefs are a magnet for divers and snorkellers, and also a focus for black lip abalone (Haliotis rubra) and greenlip abalone (Haliotis laevigata) fishery.

On rocky shores in the intertidal zone, and for the seaweeds, molluscs, worms, sea squirts, crabs and other animals and plants living there, the environment is constantly changing due to tidal and wave action. Some species are mobile and move across the rocks, while others are sessile (stationary). On the deeper subtidal reefs, seaweeds such as bull kelp provide shelter for reef fish and rock lobsters, and the rocky surfaces are grazed by abalone and sea urchins.

This section assesses the status of invertebrates, fish and macroalgae that are found on Victoria's reefs.



Intertidal invertebrates are important food sources for marine and coastal animals and also popular with people rambling across shore platforms. Any declines in populations or cover could indicate the effects of illegal harvesting, trampling, reduced water quality or climate change.

Summary

Port Phillip Bay

Data for mobile invertebrates from Parks Victoria's Intertidal Reef Monitoring Program indicate that in the bay's marine national park and sanctuaries they have remained in 'good' condition since 2003.

Western Port

Western Port has few reefs but there are three notable ones:

- Crawfish Rock
- 2. a small San Remo reef significant for opisthobranchs (soft-bodied marine snails), listed in the Flora and Fauna Guarantee Act 1988,
- 3. intertidal reefs along the south-west coast, particularly Honeysuckle Reef.

A loss of diversity is evident at Crawfish Rock, most likely a result of high turbidity in the North Arm. 103

Parks Victoria draft control charts assess the condition of mobile invertebrates in marine national parks beyond Port Phillip Bay as 'good'.

Other Marine and Coastal Areas

Melbourne Water Corporation 2011, 'Understanding the Western Port environment: a summary of current knowledge and priorities for future research', Melbourne, Victoria.

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
MC:07 Sessile invertebrates on intertidal reefs					OMAC? MNPS→	
	OMAC			MNPS		Good MNPS
Data Custodian PV Intertidal Reef Monitoring Program, Sea Search/Museum of Victoria ad-hoc surveys						DATA QUALITY Poor OMAC

Sessile invertebrates are important food sources for marine and coastal animals. Declining populations or cover could indicate impacts from illegal harvesting, trampling, reduced water quality, invasive species or climate change.

Summary

Parks Victoria has prepared draft control charts for several marine national parks and sanctuaries to track changes in indicators of key natural values and impacts of threats. Sessile invertebrates are a key ecological attribute on intertidal reefs in 12 parks, with their condition assessed as 'good' in nine parks and 'fair' in three. However, there is no data for reefs outside the boundaries of protected areas.

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
MC:08 Mobile megafaunal invertebrates on subtidal reefs	OMAC	NPPB		MNPS SPPB	OMAC ? MNPS ? NPPB \(\frac{1}{2} \) SPPB \(\frac{1}{2} \)	DATA QUALITY Good MNPS, NPPB, SPPB
Data Custodian Parks Victoria; Reef life survey						Poor OMAC

Some mobile megafaunal invertebrates, such as abalone and rock lobster, are key species in marine national parks and sanctuaries. Outside the park boundaries they are targeted by commercial and recreational fishers. Monitoring can assist Parks Victoria's compliance program, and provide data on trends in catches and stocks to support fisheries management.

Summary

Port Phillip Bay

The subtidal reef biota (macroalgae, invertebrates and fish) for a number of marine national parks and sanctuaries (and reference sites outside) were surveyed between 2011 and 2013, with the results compared with earlier surveys and published in Park's Victoria's Technical Report Series. 104

For the three marine sanctuaries¹⁰⁵ in the north of Port Phillip Bay – Point Cooke, Jawbone and Ricketts Point – blacklip abalone at Point Cooke had been replaced by purple sea urchins, which had also become dominant at Jawbone and were heavily grazing Ricketts Point. However, invertebrate species richness and diversity were stable at Ricketts Point, and the total abundance of species increased significantly at Jawbone, driven by increased urchin numbers.

The Reef Ecosystem Evaluation Framework (REEF) evaluation survey determined that species' community assemblages and the ecosystem health of reefs vary regionally within Port Phillip Bay (generally, northern and western reefs are considered to have diminished quality). 106 Megafaunal invertebrates are diverse in the north of the bay, in part due to the additional nutrients from the Western Treatment Plant, Yarra River and Kororoit Creek inflows. 107

The last survey of native seastars at Port Phillip Heads revealed some seastar communities were diseased with necrosis (across Victoria, native seastar numbers have fallen over the past decade, with very low numbers recorded for the past seven years; the cause of this decline is unknown). 108 Greenlip abalone are recovering in terms of abundance and size – both in marine protected areas and at reference sites outside these areas. 109

Parks Victoria control charts rated the health of megafaunal invertebrates as 'good' in the Port Phillip Heads Marine National Park in the south of the bay, while in the north the ratings were 'unknown' in Point Cooke and Jawbone and 'fair' in Ricketts Point

^{104.} The survey reports can be found at https://parkweb.vic.gov.au/park-2 Accessed 4 December 2018.

Survey reports for the subtidal reef biota in the three sanctuaries can be found at https://p cientific-management/technical-series2 Accessed 4 December 2018.

Johnson CR, Swearer SE, Ling SD, Reeves S, Kriegisch N, Treml EA, Ford JR, Fobert E, Black KP, Weston K, Sherman CDH 2015, 'The reef ecosystem evaluation framework (REEF): managing resilience in temperate environments', Melbourne, Victoria, pp. 1-39

^{107.} CES 2016, 'State of the Bays 2016', Melbourne, Victoria.

Edmunds M. Stewart K and Pritchard K 2010, 'Victorian Subtidal Reef Monitoring Program: the reef biota at Port Phillip Heads Marine National Park', Volume 4, Parks Victoria Technical Series No. 63, Melbourne, Victoria.

Other Marine and Coastal Areas

At Cape Howe Marine National Park, the 2011–2013 survey and review of earlier research found that the abundances of the long-spined sea urchin and blacklip abalone were high, abalone abundance having increased since the park's establishment in 2002, while urchin numbers had remained stable. The density of purple and long-spined sea urchins had increased at Beware Reef Marine Sanctuary towards the end of the survey period, having earlier been in decline. The total number of invertebrates had also declined. The survey bear to the survey have the survey have the survey bear to the survey have also declined. The total number of invertebrates had also declined.

The densities of blacklip abalone and purple sea urchin, along with the total numbers of invertebrates (half of baseline levels), had declined at Wilsons Promontory Marine National Park. Invertebrate abundances, again including blacklip abalone and purple sea urchin, also declined at Bunurong Marine National Park.¹¹²

Invertebrate densities increased in the Point Addis Marine National Park, 113 while at Eagle Rock Marine Sanctuary, 114 species richness and diversity were in slight decline, and blacklip abalone abundance in sharp decline after 2009. Marengo Reefs Marine Sanctuary experienced fluctuating species richness and diversity, but there was a declining trend for blacklip abalone abundance and total invertebrate abundance was at its lowest at the end of the survey period. 115 Inside the Merri Marine Sanctuary, southern rock lobster (Jasus edwardsii) abundance was double that outside the boundaries, while biomass was three to five times greater. Invertebrate abundance was low and stable and blacklip abalone densities were low. 116

Parks Victoria draft control charts assessed mobile megafaunal invertebrates as 'good' in 12 of the parks, 'fair' in 1 and 'unknown' in 1. There is no data on trends.

Abalone abundance more generally has been impacted by 'abalone viral ganglioneuritis (AVG); previous distributions of fishing pressure and overharvesting; illegal, unreported and unregulated fishing; possible growth in recreational fishing; and competition from other benthic organisms, particularly sea urchins'. 117

Edmunds M, Woods B 2017, 'Victorian Subtidal Reef Monitoring Program: The reef biota at Cape Howe Marine National Park, December 2014', Parks Victoria Technical Series No. 99. Parks Victoria, Melbourne, Victoria.

Edmunds M, Hallein E, Flynn A 2014, 'Victorian subtidal reef monitoring program: the reef biota at Beware Reef Marine Sanctuary', Parks Victoria Technical Series No. 88. Melbourne. Victoria

ria Technical Series No. 88, Melbourne, Victoria.

112. Davis S, Pritchard K, Edmunds M 2011, 'Victorian subtidal reef monitoring program: the reef biota at Bunurong Marine National Park, May 2011, 'Parks Victoria Technical Series No. 84 Melbourne Victoria

Woods B, Edmunds M, Brown H 2014, 'Victorian subtidal reef monitoring program: the reef biota at Point Addis Marine National Park', Parks Victoria Technical Series No. 94, Melbourne, Victoria.

Edmunds M, Brown H, Woods B 2014, 'Victorian subtidal reef monitoring program: the reef biota at Eagle Rock Marine Sanctuary', Parks Victoria Technical Series No. 89, Melbourne, Victoria.

McArthur M, Smith A, Davis, S, Edmunds M, Pritchard K 2011, 'Victorian subtidal reef monitoring program: the reef biota at Marengo Reefs Marine Sanctuary, Parks Victoria Technical Series No. 85, Melbourne, Victoria.

Woods B, Edmunds M 2013, 'Victorian subtidal reef monitoring program: the reef biota at Merri Marine Sanctuary', Parks Victoria Technical Series No. 87, Melbourne, Victoria.

Department of Primary Industries 2012, 'Abalone Recovery Review Workshop', Fisheries Victoria Management Report Series No. 83, Melbourne, Victoria.

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
MC:09 Subtidal reef fish	OMAC		NPPB	MNPS SPPB	OMAC? NPPB? MNPS? SPPB✓	DATA QUALITY Good SPPB & MNPS DATA QUALITY Fair NPPB DATA QUALITY
Data Custodian DELWP Biodiversity, PV						Poor OMAC

Reef fish are highly visible and colourful elements of subtidal reefs. They are key species in marine national parks and sanctuaries and are popular with divers and snorkellers. Monitored changes in their populations could indicate excessive harvesting, water pollution or climate change, and could alert agencies to the need for management action.

Summary

Port Phillip Bay

A 17-year assessment comprised of three separate studies, spanning from 1992 to 2009, of fish assemblages on shallow rocky reefs in Port Phillip Bay found significant increases in diversity and changes in faunal composition between 17 (+38%) and 7 (+151%) years, providing evidence of long-term changes in faunal composition and diversity within the bay. 118 Lower diversity in 2003–04 compared to 1992 could be explained by a slow recovery following the cessation of scallop dredging or from the effects of drought. The highest fish diversity was found on the bay's east coast reefs with significant changes within fish assemblages, including increased abundance of the southern hulafish (Trachinops caudimaculatus), zebra fish (Girella zebra) and scalyfin (Parma victoriae), was possibly due to improved environmental conditions.

Data from Parks Victoria's long-term Subtidal Reef Monitoring Program, two rounds of Reef Life Survey monitoring data at The Heads and several years of surveys in the three marine sanctuaries in the bay's north have been integrated with Parks Victoria's control charts and provide a good dataset for the bay's reef fish.

The sanctuaries generally had a low number of fish species and abundance with no consistent trends, with the southern hulafish (T. caudimaculatus) dominating the fish assemblages. 119 In southern Port Phillip Bay, the health of reef fish communities was rated as 'good'. Reflecting the improving health of the ecosystem there, western blue groper numbers, which used to be abundant, were increasing at Nepean Bay and Point Lonsdale, 120 and were reported at nearby South Channel Fort, as well as Barwon Bluff and Beware Reef marine sanctuaries along the open coast. In the bay's northern sanctuaries, the health of reef fish communities was rated as 'unknown' in Jawbone and 'fair' in Point Cooke and Ricketts Point.

Jung C, Swearer S, Jenkins G 2010, 'Changes in diversity in the fish assemblage of a southern Australian embayment: consistent spatial structuring at decadal scales', Marine and Freshwater Research, 61, pp. 1425-143.

The surveys for the three Marine Sanctuaries are from the Parks Victoria Technical Series, https://parkweb.vic.gov.ar -and-scientific-management/technical-series2 Accessed 4 December 2018.

CES 2016, State of the Bays report 2016', Melbourne, Victoria. Edmunds M, Woods B 2017, 'Victorian subtidal reef monitoring program: the reef biota at Cape Howe Marine National Park', Parks Victoria Technical Series No. 99, Melbourne, Victoria.

Other Marine and Coastal Areas

At Cape Howe Marine National Park, a 2011–13
Parks Victoria long-term Subtidal Reef Monitoring
Program survey, and review of earlier research,
found that the biomass of fished species had
increased, but there was an observed change
in their size, with smaller individuals more
abundant.¹²¹ Fish species richness and diversity
had also increased over the survey period. Beware
Reef Marine Sanctuary was characterised by high
abundance of butterfly perch, while purple wrasse
and blue throat wrasse had decreased in density.
The abundance of banded morwong had declined
between 2004 and 2011 (but increased in 2013).¹²²

Purple wrasse had declined in abundance at Wilsons Promontory Marine National Park, while butterfly perch (*Caesioperca iepidoptera*) and barber perch (*Caesioperca rascor*) had increased. However, there had been a substantial decline in fish abundance, biomass and diversity (evenness of species distribution), but not in species richness (the number of species). A decline in the abundance of fish over 200 mm in length was observed at Bunurong Marine National Park, along with low fish density, but total fish abundance fluctuated.¹²³

Marine sanctuaries along the west coast – Eagle Rock, Marengo Reefs and Merri – varied in their recorded data. Blue throat wrasse (*Notolabrus tetricus*) abundance had increased at Eagle Rock, along with total fish abundance, species richness and diversity in the latter half of the survey period.¹²⁴ However, at Merri, the three indices had experienced slight declines,¹²⁵ while at Marengo Reefs there were no trends in species richness and

diversity but a decline in the abundance of larger fish across the species.¹²⁶ There were no changes in fish abundance, richness and diversity at Point Addis Marine National Park.¹²⁷

In a comment that reflects the data more generally in Victoria's coastal waters, the authors of the report on Marengo Reefs Marine Sanctuary noted that:

The results in this report present a snapshot in time for community structures and species population trends, which operate over long time scales. As monitoring continues and longer-term datasets are accumulated (over multiple years to decades) the programme will be able to more adequately reflect the average trends and ecological patterns occurring in the system.¹²⁸

Parks Victoria's integrated dataset and control charts show that the condition of large mobile fish (including sharks and rays) on subtidal reefs in marine national parks and sanctuaries beyond Port Phillip Bay was assessed as 'good' in 14 parks, 'fair' in 1 and 'unknown' in 1.

Edmunds M, Hallein E, Flynn A 2014, 'Victorian subtidal reef monitoring program: the reef biota at Beware Reef Marine Sanctuary', Parks Victoria Technical Series No. 88, Melbourne, Victoria.

ria Technical Series No. 88, Melbourne, Victoria.

Davis S, Pritchard K, Edmunds M 2011, 'Victorian subtidal reef monitoring program: the reef biota at Bunurong Marine National Park, Parks Victoria Technical Series No. 84, Melbourne, Victoria.

^{124.} Edmunds M, Brown H, Woods B 2014, 'Victorian subtidal reef monitoring program: the reef biota at Eagle Rock Marine Sanctuary', Parks Victoria Technical Series No. 89, Melbourne, Victoria.

^{125.} Woods B, Edmunds M 2013, 'Victorian subtidal reef monitoring program: the reef biota at Merri Marine Sanctuary', Parks Victoria Technical Series No. 87, Melbourne, Victoria.

McArthur M, Smith A, Davis, S, Edmunds M, Pritchard K 2011, 'Victorian subtidal reef monitoring program: the reef biota at Marengo Reefs Marine Sanctuary, Parks Victoria Technical Series No. 85, Melbourne, Victoria.

^{127.} Woods B, Edmunds M and Brown H 2014, 'Victorian Subtidal Reef Monitoring Program: The reef biota at Point Addis Marine National Park, June 2013', Parks Victoria Technical Series No. 94, Melbourne, Victoria.

McArthur M, Smith A, Davis, S, Edmunds M, Pritchard K 2011, 'Victorian subtidal reef monitoring program: the reef biota at Marengo Reefs Marine Sanctuary, Parks Victoria Technical Series No. 85, Melbourne, Victoria.

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data quality
MC:10 Macroalgae-dominated subtidal reefs Data Custodian PV Reef Life Survey	OMAC		NPPB	SPPB MNPS	OMAC? NPPB? MNPS? SPPB \(\sqrt{1}\)	DATA QUALITY Good - SPPB & MNPS DATA QUALITY POOR - NPPB & OMAC

Macroalgal communities on subtidal reefs provide shelter, nursery and feeding areas for reef fish and other marine species. Broken stems washed ashore form beach wrack that is used as food for invertebrates living on beaches and mudflats, which in turn become food for migratory and resident shorebirds. Changes in the condition of macroalgal beds can have broad implications for marine and coastal species.

Summary

Port Phillip Bay

Parks Victoria's Subtidal Reef Monitoring Program has demonstrated that reefs in the Port Phillip Heads Marine National Park are healthy – with the exception of decreasing numbers of seastars. Anecdotally, Undaria and kelp dieback disease is an increasing risk in the south – and potentially other pests and diseases are too.¹²⁹

At Point Cooke Marine Sanctuary, 130 a macroalgal cover of common kelp (Macrocystis pyrifera) has been replaced by purple sea urchin (Heliocidaris erythrogramma) barrens, coralline algae and filamentous brown algae, possibly due to changes in water quality and catchment inputs that have led to reduced nutrients and restrictions on kelp growth. However, at Jawbone Marine Sanctuary, there are no trends in species abundance richness and diversity although common kelp (M. pyrifera)

Most reefs in the north are low-wave energy and have been permanently changed by purple sea urchins (H. erythrogramma) and the highlyinvasiveJapanese kelp (Undaria pinnatifida), which exploits the disturbance caused by the urchins. 131 Their ecological status is highly variable and trends are currently unknown.

Other Marine and Coastal Areas

The subtidal reef biota (macroalgae, invertebrates and fish) for a number of marine national parks and sanctuaries (and reference sites outside) were surveyed between 2011 and 2013, with the results compared with earlier surveys and published in Park's Victoria's Technical Report Series. 132

Although the cover of crayweed (Phyllospora comosa) had declined in Cape Howe Marine National Park, algal species richness and diversity had increased with greater abundance of smaller understorey species. 133 Algal species richness fluctuated at Beware Reef, while algal assemblages were little changed. However, common kelp (M. pyrifera) abundance declined, while bull kelp (Durvillaea potatorum) cover increased. 134

cover has declined. Along the bay's east coast, species richness and diversity have fluctuated at Ricketts Point Marine Sanctuary, but algal cover has declined.

^{129.} CES 2016, 'State of the Bays 2016', Melbourne, Victoria.

Woods B, Donnelly, Edmunds M 2013, 'Victorian subtidal reef monitoring program: the reef biota at Point Cooke Marine Sanctuary', Parks Victoria Technical Series No. 99, Melbourne, Victoria.

CES 2016, 'State of the Bays 2016', Melbourne, Victoria.

The survey reports can be found at https://parkweb.vic.gov.au/ ientific-manage-Accessed 4 December 2018.

Edmunds M, Woods B 2014, 'Victorian subtidal reef monitoring program: the reef biota at Cape Howe Marine National Park', Parks Victoria Technical Series No. 99, Melbourne, Victoria.

Edmunds M, Hallein E, Flynn A 2014, 'Victorian subtidal reef monitoring program: the reef biota at Beware Reef Marine Sanctuary', Parks Victoria Technical Series No. 88, Melbourne, Victoria.

Macroalgae abundance remained high in Wilsons Promontory¹³⁵ and Bunurong¹³⁶ marine national parks, while species richness and diversity were high at Point Addis Marine National Park,¹³⁷ although there was a substantial loss of common kelp (*M. pyrifera*) by the end of the survey period. The abundance, richness and diversity of macroalgal species was stable throughout the survey period in Eagle Rock Marine Sanctuary,¹³⁸ while there were no clear trends in Marengo Reefs¹³⁹ and Merri¹⁴⁰ marine sanctuaries.

The condition of brown algae communities on subtidal reefs has been assessed in Parks Victoria draft control charts for marine national parks and sanctuaries. On subtidal reefs the assessment revealed them to be in 'good' condition in 14 parks and 'fair' in 30.

Woods B, Donnelly D, Edmunds M 2014, 'Victorian subtidal reef monitoring program: the reef biota at Point Cooke Marine Sanctuary', Parks Victoria Technical Paper Series No. 93, Melbourne, Victoria.

Davis S, Pritchard K, Edmunds M 2011, 'Victorian subtidal reef monitoring program: the reef biota at Bunurong Marine National Park', Parks Victoria Technical Series No. 84, Melbourne, Victoria.

^{137.} Woods B, Edmunds M, Brown H 2014, 'Victorian subtidal reef monitoring program: the reef biota at Point Addis Marine National Park', Parks Victoria Technical Series No. 94, Melbourne, Victoria.

Edmunds M, Brown H, Woods B 2014, 'Victorian subtidal reef monitoring program: the reef biota at Eagle Rock Marine Sanctuary', Parks Victoria Technical Series No. 89, Melbourne, Victoria.

McArthur M, Smith A, Davis, S, Edmunds M, Pritchard K 2011, 'Victorian subtidal reef monitoring program: the reef biota at Marengo Reefs Marine Sanctuary, Parks Victoria Technical Series No. 85, Melbourne, Victoria.

Woods B, Edmunds M 2013, 'Victorian subtidal reef monitoring program: the reef biota at Merri Marine Sanctuary', Parks Victoria Technical Series No. 87, Melbourne, Victoria.



Macroalgae are an important source of food and shelter for many marine species, and provide shoreline protection. Changes in this intertidal community may be a sign of other changes occurring in the marine environment that require management action.

Summary

Port Phillip Bay

Neptune's necklace (Hormosira banksii) is an intertidal algae that forms large beds and habitats for macroinvertebrate grazers, predators, scavengers and microfauna. Data for macroalgae, sessile and mobile invertebrate indicators from the Intertidal Reef Monitoring Program indicate these reef communities have remained in 'good' condition since 2003, with H. banksii cover increasing steadily since 2009.141 However, water quality is an issue for intertidal habitats near Point Cooke Marine Sanctuary and Boags Rocks, close to the Eastern and Western treatment plants, in Hobsons Bay (affecting Jawbone Marine Sanctuary), along the bay's northeastern shoreline (affecting Ricketts Point Marine Sanctuary) and stormwater inflows.

Other Marine and Coastal Areas

The condition of brown algae communities on intertidal reefs has been assessed in Parks Victoria draft control charts for marine national parks and sanctuaries. The communities were assessed as being in 'good' condition in five parks, 'fair' in six parks and 'poor' in one park.

^{141.} CES 2016, 'State of the Bays 2016', Melbourne, Victoria.

Seabirds, Shorebirds and Waterbirds

Seabirds, shorebirds and waterbirds are the most visible elements of marine and coastal animal life. Albatrosses, pelicans, penguins, spoonbills, sandpipers, hooded plovers and other birds rely on healthy marine and coastal environments, some for feeding and others for breeding. Trends in their numbers and distribution can provide important data for agencies responsible for habitat management and species conservation.

Reduced bird numbers may indicate a change in the availability of prey species, perhaps due to fishing pressure, climate change or catchment-based water pollution. Declining populations may also suggest the loss or degradation of their habitat in Victoria or elsewhere. Conserving their habitat in Victoria can provide refuges for bird species suffering habitat loss in other parts of their range.

To support the conservation of threatened international migratory species that visit each year, Australia has signed a number of international agreements that it must uphold, while resident threatened birds are listed under various statutes that require species conservation measures.

This section reviews indicators for migratory shorebirds, penguins, fish-eating birds and waterbirds.

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
MC:12 Migratory shorebirds Data Custodian DELWP Biodiversity; Birdlife Australia; Victorian Wader Studies Group	OMAC		PBB CI		OMAC Z PBB Z CI Z	DATA QUALITY Fair - PPB & C I& OMAC

Measuring trends in the distribution and abundance of migratory shorebirds can assist federal and state agencies and community organisations to protect habitats and minimise threats.

Summary

Port Phillip Bay

Since 1981, red-necked stint (Calidris ruficollis), curlew sandpipers (Calidris ferruginea) and sharptailed sandpipers (Calidris acuminate) have been counted during high tide twice a year at eight coastal sites in Port Phillip Bay. Their numbers are declining in-line with populations throughout the world over the past 20 years, largely due to the development and reclamation of intertidal flats in Asia, especially the Yellow Sea. However, periods of drought and high rainfall can cause variations in wetland coverage and affect shorebird distribution in Australia (for example, there were fewer sharptailed sandpipers (C. acuminate) on the intertidal areas of Port Phillip Bay, reflecting their movement to inland areas after drought).142

Corner Inlet

A review of 30 years of data (1981–2011) for migratory shorebird numbers in Corner Inlet and Nooramunga revealed a decline of 23% in the combined numbers of all species, down from 35,000-40,000 to 25,000-30,000.143 Ten species declined, one increased and five showed no significant change Although there was uncertainty on the causes, the authors suggested that habitat loss along the birds' flyway could be the main factor.

Other Marine and Coastal Areas

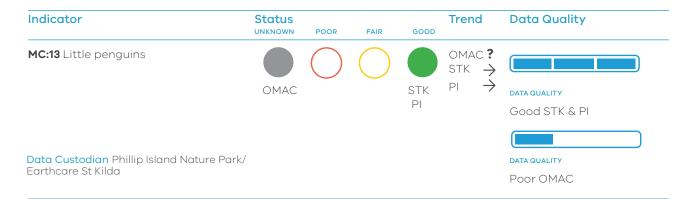
Birdlife Australia data¹⁴⁴ on numbers of the rednecked stint (C. ruficollis), curlew sandpipers (C. ferruginea) and sharp-tailed sandpipers (C. acuminate) along coastal areas (counts also include inland areas) show considerable fluctuations from year to year since the 1980s and 1990s but also quite low numbers. Red-necked stint (C. ruficollis) numbers in East Gippsland peaked in 1999 but have since declined, while on the Bass Coast the peak occurred in 2013 before a decline. The Bellarine Peninsula has the highest numbers. For the eastern curlew (Numenius madagascariensis), counts are higher along the east coast than the west, with increased sightings in East Gippsland and the Bass Coast. Short-tailed shearwater (Ardenna tenuirostris) counts have increased on the Bellarine Peninsula and Bass Coast, with fluctuating counts elsewhere. However, the most recent data indicates that each species has experienced reductions in sightings in the past few years.

Rising sea levels and reduced intertidal areas, as well as incremental losses from coastal development, could reduce the available habitat for shorebirds and lead to reductions in their numbers in Victoria.

^{142.} Loyn RH, Rogers DI, Swindley RJ, Stamation K, Macak P, Menkhorst P 2014, 'Waterbird monitoring at the Western Treatment Plant, 2000–12: the effects of climate and sewage treatment processes on waterbird populations', Arthur Rylah Institute for Environmental Research Technical Report Series No. 256, Heidelberg, Victoria.

Minton C, Dann P, Ewing A, Taylor S, Jessop R, Anton P, Clemens R 2012, 'Trends of shorebirds in Corner Inlet, Victoria, 1982–2011', *Stilt*, 61, pp. 3-18

Birdlife Australia, https://birdata.birdlife.org.au Accessed 4 December 2018



The health of little penguin (*E. minor*) colonies in terms of numbers, breeding success and body weight can indicate trends in the general health of the marine environment. Little penguin colonies at Phillip Island and St Kilda have also become major tourist assets, with any decline in their health having potential economic impacts.

Summary

Phillip Island

The numbers of little penguins (*E. minor*) at the Phillip Island Nature Park rose and fell during the 1980s and 1990s but suffered a significant reduction in 1995 and 1998 after pilchard stocks were possibly decimated by a disease originating in fish meal used in tuna farms off the South Australian coast. ¹⁴⁵ In recent years, penguin numbers have risen to 32,000 breeding adults.

St Kilda Harbour Breakwater

Penguins first appeared at the St Kilda Harbour breakwater in 1960, but nesting birds were not seen for another two to three years. Since then penguin numbers have steadily grown and are now estimated at 1,400. Volunteers from the local community group, Earthcare St Kilda, have for many years monitored the colony (including microchipping of birds and measuring their weight) and acted as guides for the many people who visit the colony each night. From 2007 to 2017,

 Ward TM, Hoedt F, McLeay L, Dimmlich WF, Kinloch M, Jckson G, Mc-Garvey R, Rogers PJ, Jones K 2001, 'Effects of the 1995 and 1998 mass mortality events on the spawning biomass of sardine, Sardinops sagax, in South Australian waters', ICES Journal of Marine Science, 58, pp. 865–875. volunteers microchipped 1,411 chicks, of which 522 returned to the colony- a return rate of least 36%. Monash University has also carried out surveys at the colony. As penguin numbers have grown, the colony has spread further along the breakwater.

Tourism sector promotion has encouraged more people to visit each night, increasing pressure on the colony. On winter nights there are 200 to 400 visitors, growing to 600 in summer and totalling approximately 140,000 per year. 146 Between 2013–14 and 2016–17, volunteers collected 6 km of fishing line and 372 hooks, as well as 2,500 kg of litter. 147 Penguin entanglements with recreational fishing lines and hooks and the presence of litter in burrows has also been reported, while the use of flash photography by tourists is also an ongoing problem impacting on the health of the penguin colony.

Other Marine and Coastal Areas

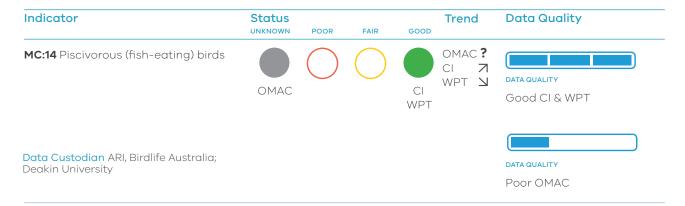
The Phillip Island and St Kilda penguin colonies are only two of more than twenty along the Victorian coast. Others include Lawrence Rocks, Deen Maar, Middle and Merri islands, the islands off Wilsons Promontory, and Gabo Island (the world's largest known colony with 15,000–20,000 pairs). Penguin surveys have been carried out at Gabo Island, at a small colony (68–70 active nests 149) at London Bridge (Port Campbell) and around Wilsons Promontory, but there is no systematic monitoring of the small-island colonies.

^{146.} Earthcare St Kilda 2018, 'Penguin report 2016-17', St Kilda, Victoria.

^{47.} Ibid

Birdife International 2018, 'Data Zone', http://datazone.birdlife.org/site/factsheet/gabo-and-tullaberga-islands-iba-australia/text Accessed 4 December 2018.

Berlincourt M, Arnould J 2014, 'At-sea associations in foraging little penguins', PLoS ONE 9(8), e105065.doi:10.1371/journal.pone.0105065 Accessed 4 December 2018



Population numbers and trends in fish-eating birds can assist agencies in monitoring and management.

Summary

Western Port and West Corner Inlet

Trends in the numbers of piscivorous waterbirds have been assessed in Western Port from 1974, and in West Corner Inlet since 1987. There were opposing population trends for each location, with terns (Hydroprogne caspia, Thalasseus bergii, Sternula nereis and Sternula albifrons), cormorants (Phalacrocorax carbo, Phalacrocorax varius, Phalacrocorax sulcirostris, Microcarbo melanoleucos, and Phalacrocorax fuscescens) and the Australian pelican (Pelecanus conspicillatus) decreasing at Western Port, while increasing in West Corner Inlet. Reduced tern numbers, especially for the crested (T. bergii) and fairy terns (S. nereis), accounted for most of the Western Port decline, most likely due to their reduced use of the bay for feeding, as breeding numbers increased substantially at its western entrance. The results suggest that feeding conditions for terns (and to a lesser extent for cormorants and pelicans) in Western Port have deteriorated compared with feeding conditions in West Corner Inlet.

Other Marine and Coastal Areas

The abundance, distribution and diversity of seabirds on 15 of Wilsons Promontory's offshore islands were surveyed in a Parks Victoria project. The results indicated that there were an estimated 839,034 short-tailed shearwaters (*A. tenuirostris*), 26,146 little penguins (*E. minor*), 19,025 common diving petrels (*Pelecanoides urinatrix*) and 4,082 fairy prion (*Pachyptila turtur*) breeding pairs in the region. Previous abundances for most species are not available; however, for the short-tailed shearwater, the estimated number of breeding pairs represents a decline of 36%.

However, there is insufficient data here and elsewhere to determine status and trends in other marine and coastal areas.

^{150.} Menkhorst PW, Loyn RH, Liu C, Hansen B, Mackay M, Dann P 2015, 'Trends in numbers of piscivorous birds in Western Port and West Corner Inlet, Victoria, 1987–2012', Arthur Rylah Institute for Environmental Research, Unpublished client report, Heidelberg, Victoria.

^{151.} Parks Victoria 2018, 'Seal and seabird research', http://parkweb.vic.gov.au/park-management/environment/research-and-scientific-management/marine-research2/seal-and-seabird-research Accessed 4 December 2018.

Indicator	Status UNKNOWN	POOR	FAIR	Trend	Data Quality
MC:15 Marine and coastal Waterbirds	OMAC PPB		WPT GLA	OMAC? WPT \(\frac{\sqrt{2}}{\sqrt{2}} \) PPB ? GLA (Trend depend on species)	DATA QUALITY GOOD WPT & GLA
Data Custodian Birdlife Australia (Western Port Waterbird Survey)/DELWP					Poor OMAC & PPB

Maintaining a robust set of time-series data on waterbird numbers can assist agencies in monitoring and management.

Summary

Port Phillip Bay

Melbourne Water's 2003 Environment Improvement Plan for the Western Treatment Plant aimed to reduce nutrient loads to the bay. A 12-year survey¹⁵² to determine whether this would impact waterfowl numbers concluded that they were more influenced by season and climate than actions to reduce nutrient discharges. There was an observed small declining trend in waterfowl numbers from 2000 to 2012 (mainly filter-feeding and diving ducks and coot). Ibis numbers dropped after the breaking of the millennium drought but the beginnings of a recovery were observed. The numbers of nesting pied cormorants doubled between 2002-2003 and 2010-2012.

Western Port

A 40 year study measuring trends in waterbird numbers in Western Port, that of 39 species (including 10 shorebirds), 22 species had declined, including four species of duck, five species of fish-eating bird (cormorants, terns and pelicans),

1 species each of grebe, gull and heron. 153 The decline in waterbirds reflects diminishing wetland availability, local reductions in fish prey, increased predation pressure and changes in inland wetland resources.154

Gippsland Lakes

The number of waterbirds in the Gippsland Lakes is related to a range of factors, including the availability of suitable habitat throughout their range in eastern Australia, which is quite variable in response to changes in rainfall. Although complete counts of waterbirds are not carried out across the larger expanse of the Gippsland Lakes, available data from the past five years record 79 waterbird species, 6 fewer than previously recorded. 155 The Gippsland Lakes Condition Report has assessed waterbird diversity (species richness) as 'fair', while there is insufficient data to assess waterbird abundance in the different functional groups, including fish-eating species, ducks, herbivores and waders.

Other Marine and Coastal Areas

There is insufficient data to assess status and trends.

Loyn RH, Rogers DI, Swindley RJ, Stamation K, Macak P, Menkhorst P 2014, 'Waterbird monitoring at the Western Treatment Plant, 2000–12: the effects of climate and sewage treatment processes on waterbird populations', Arthur Rylah Institute for Environmental Research Technical Report Series No. 256, Heidelberg, Victoria.

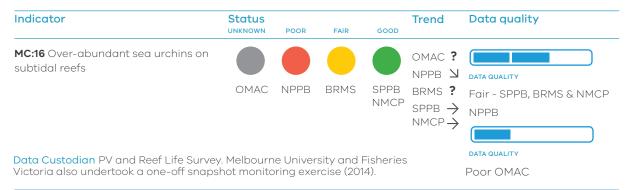
^{153.} Hansen BD, Menkhorst P, Moloney P, Loyn RH 2015, 'Long-term declines in multiple waterbird species in a tidal embayment, south-east Australia', Austral Ecology, 40(5), pp. 515-527.

Ibid

East Gippsland Catchment Management Authority, 'State of the Gippsland Lakes: Technical Report', (Publication pending).

Pressures

Victoria's marine and coastal environments face many pressures. Major have been outlined at the beginning of this chapter. They include coastal and catchment development, population growth, water pollution, fisheries, invasive and overabundant species, and climate change. This section assesses a brief list of pressure indicators, which could be reviewed and expanded on for the State of the Marine and Coastal Environment 2021 report. The State of the Bays 2016 report included a number of water quality indicators for Port Phillip Bay and Western Port. These have not been reproduced here.



The monitoring of overabundant native sea urchins, which create urchin barrens, is critical to ensure management responses are effective in their control.

Summary

Port Phillip Bay

Grazing by increased numbers of the native purple sea urchin (*H. erythrogramma*) has led to a 90% reduction of kelp in Port Phillip Bay's marine sanctuaries. ¹⁵⁶ In March 2018, Parks Victoria, Deakin University and volunteer citizen scientists culled the urchins in Point Cooke and Jawbone Marine Sanctuaries. If successful, the culling program will be expanded to other areas in the bay. These sea urchins are not as abundant in the bay's south.

Nooramunga Marine and Coastal Park

Thousands of purple sea urchins (*H. erythrogramma*) invaded meadows of the broadleaf *Posidonia australis* seagrass (important feeding, breeding and nursery areas for marine life) and created large areas of bare sand. ¹⁵⁷ Parks Victoria staff, officers from the Victorian Fisheries Authority and volunteers used hammers to smash 57,000 urchins by hand in 2017. Parks Victoria has also worked with the Victorian Fisheries Authority and Seafood Industry Victoria to establish a short-term urchin fishery to help manage overabundant native urchins.

Other Marine and Coastal Areas

Urchins are also found in Beware Reef Marine Sanctuary, Cape Howe and Point Hicks marine national parks and the reefs outside their boundaries. Urchin culling was carried out early in 2018 by Parks Victoria staff in partnership with Friends of Beware Reef. A native animal impact management plan has been prepared by Parks Victoria and further urchin management and monitoring is planned.

Deakin University 2018, 'Sea urchin cull in Port Phillip Bay to help restore kelp forests', Media release, 15 March 2018, Deakin University, Geelona, Victoria.

Parks Victoria 2017, 'Seagrass meadows saved from sea urchin attack', Media release 28 July 2017, Melbourne, Victoria.

Parks Victoria 2018, 'United against the urchin front in East Gippsland', Media release, 16 May 2018, Melbourne, Victoria.

Indicator	Status unknown	POOR	FAIR	GOOD	Trend	Data Quality
MC:17 Invasive marine species					OMAC ?	DATA QUALITY
	OMAC	PPB				Fair PPB
						DATA QUALITY
Data Custodian DELWP Biodiversity; DEL Agriculture Services; PV	OJTR Biosecur	ity and				Poor OMAC

Invasive marine species can change the ecology of areas affected. Monitoring is critical to determine whether their range is expanding, with new incursions requiring rapid management responses.

Summary

Port Phillip Bay

More than 160 introduced marine species are now resident in Port Phillip Bay. Those of greatest concern are the northern Pacific seastar (Asterias amurensis), European fan worm (Sabella spallanzanii), European green shore crab (Carcinus maenas), Japanese kelp (Undaria pinnatifida), New Zealand screw shell (Maoricolpus roseus) and the Pacific oyster (Crassostrea gigas).

Experiments manipulated the density of the European fan worm (S. spallanzanii) to determine its ecological impacts in Port Phillip Bay, with results showing changes in the composition of macrofauna in the surrounding sediments, providing habitat for epibiota (both fauna and flora) on Sabella tubes, and a reduction in the biomass of microphytobenthos on the surrounding sediments. Of greatest concern was the indirect impact on nutrient cycling. 159

The northern Pacific seastar (A. amurensis) was shown to have caused changes in fish populations in Port Phillip Bay, principally among fish species that feed on molluscs and polychaetes in areas where A. amurensis densities were highest.160 The fish species impacted were the eastern shovelnose stingaree (Trygonoptera imitata), southern eagle ray (Myliobatis australis) and globefish (Diodon nicthemerus).

Parks Victoria has studied Undaria pinnatifida in the marine sanctuaries of Port Phillip Bay and reported that eradication efforts have little impact on the kelp's overall abundance. The analysis also concluded that there was little evidence that the kelp had an ecological effect.¹⁶¹ The influences on U. pinnatifida abundance included urchin-grazing levels, the cover of canopy-forming algae, and wave and nutrient regimes.

Other Marine and Coastal Areas

Few areas along the Victorian coast have been surveyed for marine pests, but there has been a number of outbreaks beyond Port Phillip Bay:

- U. pinnatifida to Apollo Bay Harbour and Port Welshpool
- A. amurensis in San Remo, Inverloch (now eradicated), Waratah Bay, Tidal River (Wilsons Promontory) and Port Welshpool¹⁶²
- S. spallanzanii at Portland Harbour
- C. gigas in Western Port and the Gippsland Lakes.

A. amurensis has expanded its range due to anthropogenic factors such as translocation on vessels and larval dispersal, which have enabled its spread along the east coast of Victoria. 163

Ross J. Longmore A. Keough M 2013, 'Spatially variable effects of a maine pest on ecosystem function', Oecologia, 172(2), pp. 525-538.

Parry G, Hirst A 2015, 'Decadal decline in demersal fish biomass coincident with a prolonged drought and the introduction of an exotic starfish', Marine Ecology Progress Series 544, pp. 37-52.

Crockett P, Johnson K, Brenker M, Ierodiacanou D, Carnell P 2017, 'Undaria pinnatifida in Port Phillip Bay marine sanctuaries: removal strategies and interactions with the native algal canopy', Parks Victoria Technical Series No. 113, Melbourne, Victoria.

Parks Victoria 2018, 'Marine pests', Melbourne, Victoria http://parkweb. vic.gov.au/park-management/environment/weeds-and-pests/marine-pests Accessed 4 December 2018

Richardson MF, Sherman CDH, Lee RS, Bott NJ, Hirst AJ 2016, 'Multiple dispersal vectors drive range expansion in an invasive marine species', Molecular Ecology, 25(20), pp. 5001-5014.

Indicator	Status UNKNOWN	POOR	FAIR G	Trend	Data Quality
MC:18 Catchment inputs into coastal watersl reefs		WPT GCMA	PPB EGG CCMA WGCMA	WPT ? GCMA ? CCMA ? WGCMA ?	DATA QUALITY Good - PPB & WPT & CMAs
Data Custodian DELWP Catchments, Water ways, Cities and Towns; EPA Victoria	er-			EGCMA ?	

Sediments and other pollutants discharged from catchments into bays, estuaries and the open coast can severely impact water quality, with implications for marine life as well as the health of people engaged in water-based recreational activities. Regular monitoring can detect changes requiring management and planning responses.

Summary

Port Phillip Bay and Western Port

EPA Victoria has been producing report cards on the catchments of Port Phillip Bay and Western Port since 2012–13,164 based on a water-quality index that combines the results from EPA Victoria's monitoring sites. The report cards from 2012–13 to 2016–17 for Port Phillip Bay (five catchments discharge into the bay) have been summarised. (In general, the catchments with 'very good' and 'good' ratings are forested upper catchments, those with 'fair' ratings are in rural areas in the middle of the catchments, and those rated 'poor' to 'very poor' are in the lower reaches of rivers and creeks that flow through urban areas, especially small urban tributaries. However, when assessing the water-quality index at six monitoring sites within Port Phillip Bay's waters, 19.6% of bay waters were rated as 'very good' (central bay to

the entrance), and 80.4% as 'good' (Hobsons Bay and eastern and western shores). No areas of the bay were rated as either 'fair', 'poor' or 'very poor' (and includes the 2016–17 Western Port catchment for comparison). For each year, the water quality index is separated into five ratings, based on water data collation and analysis, with an overall score presented as a percentage. The overall score combines the results of a number of standard water quality parameters: nutrients, water clarity, dissolved oxygen, salinity, pH, metals and algae. During this period, the combined 'poor' and 'very poor' ratings have changed little, although a greater percentage of the catchments were rated as 'very poor' (see Table MC.2 for ratings definition). The 'good' to 'very good' ratings have been relatively stable. In 2016–17 the combined 'good' to 'very good' rating for Port Phillip Bay was much higher than that for Western Port. EPA Victoria reported that 'water quality in Port Phillip Bay had improved since 2002'.165

In general, the catchments with 'very good' and 'good' ratings are forested upper catchments; those with 'fair' ratings are in rural areas in the middle of the catchments; and those rated 'poor' to 'very poor' are in the lower reaches of rivers and creeks that flow through urban areas, especially small urban tributaries. However, when assessing the water quality index at six monitoring sites within Port Phillip Bay's waters, 19.6% of bay waters were rated as 'very good' (central bay to the entrance), and 80.4% as 'good' (Hobsons Bay and eastern and western shores). No areas of the bay were rated as either 'fair', 'poor' or 'very poor'.

^{164.} EPA 2018, 'Port Phillip Bay, Western Port and Gippsland Lakes report December 2018.

^{165.} EPA 2018, 'Port Phillip Bay report card for July 2016-June 2017,' https:// phillip-bay#top of report Accessed 4 December 2018.

Table MC.1 Water-quality report card for Port Phillip Bay and its catchments, 2012–13 to 2016–17, with a comparison to Western Port for 2016–17¹⁶⁶

	2012-13	2013-14	2014-2015	2015-16	2016-17	2016-17
Water quality index rating	Port Phillip Bay	Western Port				
	%	%	%	%	%	%
Very good	13.0	17.0	15.0	9.0	5.0	18.4
Good	20.0	24.0	25.0	26.0	32.8	2.9
Fair	29.0	21.0	21.0	25.0	22.4	40.4
Poor	15.0	23.0	8.0	12.0	9.0	22.6
Very poor	23.0	15.0	31.0	28.0	30.8	15.7

Table MC.2 EPA report card ratings and their descriptions

Rating	Description
Very good	Near-natural high-quality waterways
Good	Meets Victorian water-quality standards
Moderate	Some evidence of stress
Poor	Under considerable stress
Very Poor	Under severe stress

^{166.} EPA 2018, 'Port Phillip Bay, Western Port and Gippsland Lakes report card', https://yarraandbay.vic.gov.au/report-card Accessed 4 December 2018.

Other Marine and Coastal Areas

The Catchment Condition and Management Report 2017 from the Victorian Catchment Management Council (VCMC) assessed catchment condition across the state. The assessment presented here is only for the five regional catchments with coastal boundaries (see Table MC.3 Assessment of catchment condition for the five catchments with coastal boundaries by the Victorian Catchment Management Council).167 This assessment is based on qualitative information drawn from the Catchment Condition and Management Report 2017 and annual reports generated by each Catchment Management Authority for the past five years. Condition is rated on a three-point scale as 'good', moderate' or 'poor' for the years 2012 to 2016. The Glenelg Hopkins catchment rated 'poor' on water, biodiversity and coasts, while the Port Phillip and Western Port catchments were rated 'poor' on land and water, and East Gippsland received 'good' ratings for all but the coasts, which rated 'moderate'.

The report also analysed trends in catchment condition and catchment management. It concluded that between 1997 and 2017, catchment condition for land, biodiversity and coasts was 'declining' while for water it was 'stable'. Catchment management trends were positive for land and biodiversity, highly positive for water and neutral for coasts. The low ratings for biodiversity included

impacts of settlement, weather variability and climate change, continuing native vegetation loss, and the impacts of pest plants and animals.¹⁶⁸

A study of 14 Victorian estuaries showed that increased inorganic nitrogen loading from rivers was reflected in increased dominance of macroalgae over seagrass. These findings underscore the critical role of catchment-derived nitrogen in contributing to primary producer communities and support the growing consensus that nitrogen loads (in addition to phosphorous) must be managed to effectively alleviate eutrophication in estuaries. To

An analysis of eutrophication processes in estuaries compared the percentage of fertilised land within a catchment, dissolved inorganic nitrogen loads, catchment-to-estuary area ratio and flushing time as predictors of the proportion of macroalgae to total vegetation within 14 estuaries in south-eastern Australia. Process Results found that when the fertilised land in a catchment exceeded 24% of its area, macroalgae became dominant in estuaries.

In Corner Inlet, declines in seagrass, the key fish habitat, was intrinsically linked with the activities in the broader region through catchment runoff and addition of excess nutrients and sediments from land.¹⁷⁴

Table MC.3 Assessment of catchment condition for the five catchments with coastal boundaries by the Victorian Catchment Management Council¹⁷⁵

Regional catchment	Land	Water	Biodiversity	Coasts
Glenelg Hopkins	Moderate	Poor	Poor	Poor
Corangamite	Moderate	Moderate	Moderate	Moderate
Port Phillip and Western Port	Poor	Poor	Moderate	Moderate
West Gippsland	Moderate	Moderate	Moderate	Moderate
East Gippsland	Good	Good	Good	Moderate

Victorian Catchment Management Council 2017, 'Catchment condition and management report', Melbourne, Victoria.

^{168.} Ibid

^{169.} Woodland RJ, Thomson JR, Mac Nally R, Reich P, Evrard V, Wary FY, Walker JP, Cook PLM 2015, 'Nitrogen loads explain primary productivity in estuaries at the ecosystem scale,' Limnology and Oceanography, 60(5), pp.1751-1762.

^{170.} Ibid

Cook PLM, Warry FY, Reich P, Mac Nally R, Woodland RJ 2018, 'Catchment land use predicts benthic vegetation in small estuaries', PeerJ 6, e4378; DOI 10.7717/peerj.4378 Accessed 4 December 2018.

^{172.} From Wingan Inlet to the Moyne River.

Cook PLM, Warry FY, Reich P, Mac Nally R, Woodland RJ 2018, 'Catchment land use predicts benthic vegetation in small estuaries', PeerJ 6, e4378; DOI 10.7717/peerj.4378 Accessed 4 December 2018.

Ford J, Barclay K, Day R 2016, 'Using local knowledge to understand and manage ecosystem-related decline in fisheries productivity', Fisheries Research and Development Corporation Final Project Report, Melbourne, Victoria.

Victorian Catchment Management Council 2017, 'Catchment condition and management report', Melbourne, Victoria.

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
MC:19 Point source discharges to marine waters					?	DATA QUALITY
Data Custodian EPA Victoria						Poor

Sediments, litter and other pollutants discharged from stormwater outlets and coastal outfalls can severely impact water quality, with implications for marine life as well as the health of people engaged in water-based recreational activities. Regular monitoring can detect changes requiring management and planning responses.

Summary

The discharges of waste from 18 outfalls, including the Eastern and Western treatment plants, are regularly monitored by the agencies responsible for them, including data collection outside the mixing zones to establish background readings. Each outfall is licensed by EPA Victoria and must satisfy a number of licence conditions and submit an annual performance statement.

The Clean Ocean Foundation has developed a national oceans database that uploads discharge volumes, treatment levels and water-quality data for each outfall around the Australian coast. The base year for data on the website is 2015. The purpose of the database is to address the needs of government and the community to understand the health and environmental impacts that occur from sewerage outfalls around Australia.176

Total annual discharges from the Victorian outfalls have been estimated at 323 GL, with annual total nitrogen loads of 3,811 tonnes and total phosphorous loads of 2,784 tonnes.¹⁷⁷ By far the two largest daily discharges, with approximate numbers, are at Boags Rock (0.35 GL) and the Werribee Treatment Plant (0.42 GL), followed by Black Rock (0.05 GL), Delray Beach (0.03 GL), McGaurans Beach (0.025 GL) and Warrnambool (0.013 GL). The daily discharges of the remaining outfalls range from 0.00007 GL to 0.003 GL. 178

A partial review of the annual performance statements for some of the outfalls was conducted for this chapter. Except for several odour complaints, each outfall was compliant with licence conditions. However, there is insufficient data to determine status and trends.

There is no data available on point-source stormwater discharges.

^{176.} Clean Ocean Foundation 2018, http://www.clean cean.org/nationaloutfall-database.html Accessed 4 December 2018.

Clean Ocean Foundation 2018, http://www.cleanocean.org/n utfall-database-community-report Accessed 4 December 2018

^{178.}



Algal blooms can be harmful to marine species, ecosystems and human health (primary contact and seafood contamination). Monitoring their characteristics provides data for real-time advice to the community and to help determine management responses that minimise their impact and reduce the likelihood of their occurrence in the future.

Summary

Port Phillip Bay

Marine algae occur naturally in all marine waters and drive food webs. But under the right conditions they can rapidly increase to create an algal bloom. Algal blooms can develop in the days or weeks after heavy rain, particularly during periods of warm, sunny and calm weather. They generally dissipate within a few days and one to two weeks.¹⁷⁹ However, those that occur periodically in Hobsons Bay can produce paralytic shellfish poisoning toxins, which in the past have been at concentrations that could kill anyone who ate mussels from that region.¹⁸⁰

Gippsland Lakes

The Gippsland Lakes are periodically affected by algal blooms that can extend over large areas. There were seven algal blooms in the Gippsland Lakes between 1997 and 2016 but incomplete long-term records make it difficult to determine trends in frequency and extent.¹⁸¹

Other Marine and Coastal Areas

In response to research on the link between seagrass decline and fisheries productivity in Corner Inlet, the West Gippsland Catchment Management Authority stated that there was a clear link between catchment nutrients/sediment, algal blooms and seagrass decline. Prior to this research, there was limited documentation on the type and extent of algal blooms in Corner Inlet. Research has identified two types of blooms, one which appears to be fuelled by nutrients coming from the natural breakdown of seagrass and has been occurring for many decades, and the other fuelled by nutrients originating in the catchment and which is increasing in impact over the past decade. This information is important in informing the ongoing nutrient/sediment reduction work in the catchment and the associated monitoring requirements.182

^{179.} CES 2016, 'State of the Bays 2016', Melbourne, Victoria.

Australian Associated Press 2002, 'Shellfish warning for Port Phillip Bay', The Age 24 December 2002.

East Gippsland Catchment Management Authority, 'State of the Gippsland Lakes: Technical Report', (Publication pending).

land Lakes: Technical Report', (Publication pending).

Ford J, Barclay K, Day R 2016, 'Using local knowledge to understand and manage ecosystem-related decline in fisheries productivity', Fisheries Research and Development Corporation Final Project Report, Melbourne, Victoria.

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
MC:21 Enterococci bacteria	OMAC			PPB	OMAC? PPB →	DATA QUALITY Good PPB
Data Custodian EPA Victoria						DATA QUALITY Poor OMAC

Although Enterococci bacteria naturally occur in human intestines, elevated levels in coastal waters indicate faecal contamination and risks for people engaging in water-based recreation.

Summary

Port Phillip Bay

Each summer EPA Victoria monitors weekly Enterococci levels at 36 beach locations in Port Phillip Bay. From 2013–14 to 2017–18, water-quality objectives for swimming were met at 94-97% of the 36 Port Phillip Bay beaches monitored. The one beach that failed to meet the objectives by the end of the 2016–17 summer was Mordialloc Beach, which experienced a higher number of days with poor water quality (not the whole season) due to stormwater pollution from Mordialloc Creek. In the past, fewer Melbourne beaches met the objectives due to rainfall events: for example, in 2012 to 2013, only 67% of Melbourne's beaches met the water quality objectives for swimming. 183

Other Marine and Coastal Areas

Enterococci bacteria are monitored for some of Victoria's coastal outfalls, but data is limited.

^{183.} EPA 2017, 'Beach Report 2016–17 Summer Highlights Report', Melbourne, Victoria https://yarraandbay.vic.gov.au/beach-highlights-report Accessed 4 December 2018.

Indicator	Status				Trend	Data Quality	
	UNKNOWN	POOR	FAIR	GOOD			
MC:22 Impacts of fisheries production					?	DATA QUALITY	
Data Custodian VFA						Poor	

Assessing the ecological impacts of fisheries on biodiversity, ecological communities and ecosystem health can contribute to assessments of fisheries, ecological sustainability and support marine spatial planning and management.

Summary

Reduced fish populations, bycatch, entanglement of wildlife in discarded fishing gear, vessel impacts and changes to trophic structures are some of the impacts of fishing on marine and coastal environments. But the closure of most commercial fishing in Port Phillip Bay and Western Port, and lower catches elsewhere, has reduced the industry's pressure on fish stocks. Along with fisheries closures, commercial catches have declined due to:

- management responses to reduce pressure on fish stocks
- licence buybacks to improve fishery economic viability
- changes in fisher effort, such as moving to fisheries with better financial returns
- fishing practices and economic drivers
- closure of commercial fishing in bays and inlets to increase opportunities for recreational fishers
- spread of disease for example abalone viral ganglioneuritis (AVG)
- grazing by overabundant native fauna for example, sea urchins
- predation by or competition with invasive marine species - for example the northern Pacific seastar.

The fisheries closures will limit future catch data on fish stocks. Regular assessment of the ecological impacts of Victoria's commercial and recreational fisheries will require additional data, and its analysis and public reporting. The return of trawl surveys in Port Phillip Bay would help fill the data gap. A broadening of the recreational fishing surveys and angler diary programs, to open coast waters and include a larger number of participants, would also contribute to a better understanding. A national FRDC-funded project currently under way is considering practical bycatch monitoring and reporting priorities and approaches. 184 Reporting on interactions with protected species is now required for all relevant Victorian commercial fisheries and can inform the 2021 State of the Marine and Coastal Environment report.

Currently there is insufficient data to assess the various measures for this indicator.

^{184.} FRDC 2018, 'Guidelines on a tiered, risk-based approach to bycatch management', http://www.frdc.com.au/project?id=2918 Canberra, Australian Capital Territory.

Conservation in Protected Areas

In its 2017 Catchment Condition and Management Report, the VCMC was unable to make any sound assessment of the condition of coasts and marine areas, due to lack of information.¹⁸⁵ The report also noted that for coasts, monitoring of their condition is still very fragmented, focused on specific locations or issues. VCMC has used regional information to make a general assessment of the condition of coasts as 'declining' over the past 20 years.186

The criterion used by the Council to assess the condition of coasts was mangrove and saltmarsh protection. This statewide report also noted coastal condition assessments made by some of the CMAs with coastal boundaries, which used the level of protection for coasts as their criteria. The Glenelg Hopkins CMA rated its coast as 'generally poor' and coastal vegetation as 'largely fragmented'. For the East Gippsland CMA, its coast was rated as in a 'stable' condition. The Corangamite CMA coast was assessed as 'moderate' to 'good' but in decline.

The VCMC report and the assessments by regional catchment authorities raises the issue of protection levels for mangrove and saltmarsh. In this section, that is broadened to consider the protection status for coastal EVCs and the five marine bioregions.

Assessing the status of the marine conservation estate can be done in several ways. One is to measure the estate against international benchmarks for levels of protection, such as those of the World Summit on Sustainable Development, the Convention on Biological Diversity's Aichi Targets, the Millennium Development Goals (now superseded by the Sustainable Development Goals), or targets established by the World Parks Congress and the IUCN World Conservation Congress. A second way of assessing the status of the marine conservation estate is to measure it

against the CAR Principles of comprehensiveness, adequacy and representativeness (the CAR Principles),187 which together have provided the foundation for the National Representative System of Marine Protected Areas. The Australian Government, and all states and Northern Territory governments have together committed to its completion.

There have been no new marine or coastal conservation areas proclaimed since the 2008 State of the Environment report, and with the exception of cetaceans, seabirds, Australian fur seals and other charismatic fauna, there has been limited monitoring of threatened species within existing areas.

Actions to conserve marine and coastal ecosystems are not confined to protected areas, although they are a most effective way of conserving biodiversity and are the focus of this section. For example, the Victorian Coastal Strategy 2014 provides guidance for agencies and statutory decision-making along the Victorian coast and in marine environments, with a primary principle to ensure the protection of significant environmental and cultural values. The new Marine and Coastal Act 2018 and its associated policy and strategy (in preparation) aims to support this. There is a range of management tools that can – and are – used to address threats to the marine habitats, which are important for fishing and other values. These include reducing and intercepting catchment pollution and agricultural runoff; preventing marine pest introductions; giving protection to individual species such as blue groper; and restricting the take of species of stingrays, skates and guitar fish.

Victorian Catchment Management Council 2017, 'Catchment condition and management report', Melbourne, Victoria.

Ibid

ANZECC TFMPA 1998, 'Guidelines for establishing the National Representative System of Marine Protected Areas', Australian and New Zealand Environment and Conservation Council, Task Force on Marine Protected Areas, Canberra, Australian Capital Territory.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
MC:23 Conservation of coastal ecosystems in protected areas					\rightarrow	DATA QUALITY
Data Custodian DELWP Biodiversity						Fair

By assessing the area and type of coastal ecosystems with formal protection and the degree of protection, it is possible to then determine whether Australia (and Victoria) is meeting international benchmarks for protection and if the protected areas are, according to the principles of the National Representative System of Marine Protected Areas, comprehensive, adequate and representative (CAR).

Summary

The Port Phillip and Westernport CMA identified that between 2004 and 2007, the conservation status of 10 coastal EVCs on the Gippsland Plain bioregion had worsened, and three had improved (see Table MC.5). Data of this kind is unavailable for other bioregions along the coast. Although many coastal EVCs are endangered or vulnerable, only two coastal communities are listed in the *Flora and Fauna Guarantee Act 1995*: coastal moonah woodland (coastal alkaline scrub) and warm temperate rainforest (coastal East Gippsland).

The protection levels for coastal ecological EVCs vary. Those that occur in the Wilsons Promontory bioregions have 100% of what remains in the bioregion protected within the Wilson's Promontory National Park. However, others on the coastal plains receive far less protection. For example, remaining estuarine wetland has only 7%, 1%, 4% and 0% of its extent in conservation reserves on the Warrnambool Plain, Otway Ranges, Otway Plain and Victorian Volcanic Plain bioregions respectively. Parks Victoria manages around 70% of the Victorian coast as national and state parks

or as coastal reserves. However, analysis indicates that a number of coastal EVCs have limited coverage in protected areas (Table MC.5).

Coastal EVCs that are either vulnerable or endangered in two or more bioregions are coast banksia woodland, coastal saltmarsh, estuarine wetland, coastal headland scrub, coastal tussock grassland, coastal saltmarsh/mangrove shrubland mosaic, coastal alkaline scrub and coast banksia woodland/coastal dune scrub mosaic. Those that have experienced substantial declines in their extent, and which are endangered, vulnerable, depleted or rare with limited protection in conservation areas, are coastal dune scrub/ coastal dune grassland mosaic, estuarine wetland, mangrove shrubland, coastal dune scrub, coastal headland scrub, coastal tussock grassland, brackish wetland, coastal alkaline scrub and coast banksia woodland/coastal dune scrub mosaic. These are largely the EVCs of the sand dunes and coastal wetlands. However, of the remaining estuarine wetland in those four bioregions, 23%, 40%, 55% and 17% respectively is on public land with the potential for increased protection. Although coast-specific EVCs have been impacted by changing coastal land use, hinterland EVCs such as woodlands and grasslands that range to the coast have also been impacted (these are not analysed here).

Of the 10 bioregions with coastal boundaries, those where vegetation loss is most pronounced are the Warrnambool Plain (between Portland and Princetown), the Otway Plain (largely from Aireys Inlet to Altona) and the Gippsland Plain (from eastern Melbourne to the Gippsland Lakes).

^{188.} Port Phillip and Western Port CMA 2008, 'Summary of changes to the bioregional conservation status ratings resulting from updated 2007 native vegetation datasets - Port Phillip and Western Port CMA region', http://www.spiffa.org/uploads/2/6/7/5/2675656/native_veg_plan_changes_to_bioregional_conservation_status_ppwcma_region_010208.pdf Accessed 4 December 2018.

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Table MC.4 Changes in the conservation status of some Victorian coastal EVCs¹⁸⁹

EVC		Change in conservation status					
Conservation status deteriorated							
1	Coastal dune scrub/coastal dune grassland mosaic	Least concern to depleted					
12	Wet swale herbland	Rare to vulnerable					
160	Coastal dune scrub	Least concern to depleted					
163	Coastal tussock grassland	Least concern to vulnerable					
858	Coastal alkaline scrub	Depleted to vulnerable					
904	Coast banksia woodland/swamp scrub mosaic	Rare to vulnerable					
906	Brackish grassland/swamp scrub mosaic	Rare to endangered					
909	Coastal dune scrub/bird colony succulent herbland mosaic	Least concern to depleted					
934	Brackish grassland	Rare to endangered					
935	Estuarine wetland/estuarine swamp scrub mosaic	Least concern to depleted					
	Conservation status improved						
879	Coastal dune grassland	Endangered to depleted					
900	Coastal saltmarsh/coastal dune grassland/coastal dune scrub/coastal headland scrub mosaic	Endangered to vulnerable					
922	Coastal alkaline scrub/bird colony succulent herbland mosaic	Endangered to vulnerable					

189. Ibid

Indicator	Status			Trend	Data Quality	
	UNKNOWN POOR	POOR	FAIR	GOOD		
MC:24 Conservation of marine ecosystems in protected areas					\rightarrow	
Data Custodian DELWP Biodiversity	GLA ar Gippls Inlets		Five m biores			data quality Good

By assessing the area and type of marine ecosystems with formal protection, it is possible to then determine whether Australia (and Victoria) is meeting international benchmarks for marine protection and if the network is, according to the principles of the National Representative System of Marine Protected Areas, comprehensive, adequate and representative (CAR).

Summary

Parks Victoria manages 24 marine national parks and sanctuaries established in 2002. Extractive resource use is not permitted in these parks, which cover 53,076 hectares or 5.2% of Victoria's marine waters. Another six marine protected areas, established in 1986 and 1991 in South and West Gippsland, allow extractive commercial and recreational use and cover 53,030 hectares, 190 or also 5.2% of marine waters, and provide only partial protection. In total, Victoria's marine protected areas cover 106,106 hectares or 10.4% of state waters.

The final report of VEAC's Statewide Assessment of Public Land noted in 2017 that it is evident from preliminary assessments based on available information that the existing system of no-take marine protected areas has some gaps in representation, and individual marine protected areas may not meet the adequacy criterion.¹⁹¹ The report recommended that, Victoria's marine environment be reviewed for the comprehensiveness, adequacy and representativeness of its marine protected areas when current work on marine habitat mapping and classification is completed and available.¹⁹²

An analysis of the protection levels provided in each of the five marine bioregions — and Shallow Inlet, the Gippsland Lakes and the inlets of East Gippsland — for this chapter has indicated that on a bioregional basis, Victoria's marine protected areas fall below the Aichi Target of 10% and likely do not satisfy the CAR Principles of the National Representative System of Marine Protected Areas. Percentage protection levels for the Otway, Central and Twofold Shelf marine bioregions are considerably lower than the Aichi Target 11, while the Flinders and Victoria Embayments bioregion only reach the target with the inclusion of partially protected areas. Such protection levels are seen as having fewer conservation benefits than highlevel protection. 193 The Gippsland Lakes and East Gippsland inlets have no marine protected area coverage.

^{190.} This figure excludes the terrestrial areas in the Corner Inlet, Shallow Inlet and Nooramunga Marine and Coastal Parks which comprise 10%, 20% and 40% of each, respectively (data in VEAC's 2014 Marine investigation, p.99).

^{191.} VEAC 2017, 'Statewide assessment of public land', Melbourne, Victoria.

^{193.} Denny C, Babcock R 2004, 'Do partial marine reserves protect reef fish assemblages?' *Biological Conservation*, 116, pp. 119–29.

Table MC.5 Coastal EVCs and their conservation status by bioregion¹⁹⁴

Ecological Vegetation Class	Pre-1750s	Current	
Ecological Vegetation Class	(ha)	(ha)	
1 Coastal Dune Scrub/Coastal Dune Grassland Mosaic	18,255	12,140	
2 Coast Banksia Woodland	9,676	6,090	
5 Coastal Sand Heathland	154	14	
9 Coastal Saltmarsh	15,813	12,47	
10 Estuarine Wetland	10,276	8,484	
11 Coastal Lagoon Wetland	863	85	
12 Wet Swale Herbland	4,768	4,768	
140 Mangrove Shrubland	5,387	4,24	
144 Coast Banksia Woodland/Warm Temperate Rainforest Mosaic	244	148	
154 Bird Colony Shrubland	413	41	
160 Coastal Dune Scrub	5,320	4,119	
161 Coastal Headland Scrub	8,218	5,67	
162 Coastal Headland Scrub/Coastal Tussock Grassland Mosaic	2,151	1,33	
163 Coastal Tussock Grassland	2,484	2,08	
181 Coast Gully Thicket	346	219	
302 Coastal Saltmarsh/Mangrove Shrubland Mosaic	5,928	4,50	
309 Calcareous Swale Grassland	559	559	
311 Berm Grassy Shrubland	191	12	
656 Brackish Wetland	1,314	66:	
665 Coastal Mallee Scrub	597	33	
858 Coastal Alkaline Scrub	29,910	17,12	
876 Spray-zone Coastal Shrubland	155	14	
900 Coastal Saltmarsh/Coastal Dune Grassland/Coastal Dune Scrub/Coastal Headland Scrub Mosaic	153	63	
904 Coast Banksia Woodland/Swamp Scrub Mosaic	327	6	
906 Brackish Grassland/Swamp Scrub Mosiac	153	1	
909 Coastal Dune Scrub/Bird Colony Succulent Herbland Mosaic	148	13	
914 Estuarine Flats Grassland	560	15	
919 Coastal Headland Scrub/Coast Banksia Woodland Mosaic	357	60	
921 Coast Banksia Woodland/Coastal Dune Scrub Mosaic	1,288	87	
922 Coastal Alkaline Scrub/Bird Colony Succulent Herbland Mosaic	120	5	
934 Brackish Grassland	749	59	
935 Estuarine Wetland/Estuarine Swamp Scrub Mosaic	533	160	
TOTAL Pre-1750s cover	127,410		
TOTAL current cover		88,384	
Remaining (%)		69.4	

194. Shears NT, Grace RV, Usmar NR, Kerr V, Babcock RC 2006, 'Long-term trends in lobster populations in a partially protected vs. no-take marine park', *Biological Conservation*, 132(2), pp. 222–231.

^{*} table continued on following page

	Glenelg Plain	Warrnambool Plain	Otway Ranges	Otway Plain	Victorian Volcanic Plain	Gippsland
	Fidili					Plain
1		V 67/51/9/7	D 86/28/50/8	D 75/37/31/7	D 91/0/91/0	D 50/32/7/11
2						V 41/13/8/20
5	R 98/0/98/0					
9				E 26/4/12/10	V 51/22/10/19	LC 86/53/8/25
10		D 83/7/23/53	E 80/1/40/39	E 89/4/55/30	E 19/0/17/2	LC 81/31/16/34
11						V 93/0/69/24
12						V 100/100/0/0
140				V 96/0/72/24	V 59/5/7/47	LC 79/56/6/17
144						E 100/0/98/1
154		R 72/72/0/0		R 85/85/0/0		
160		D 72/6/35/31				D 20/13/4/3
161	E 84/37/29/18	V 61/47/6/8	D 83/32/13/39	V 87/57/18/12	V 35/0/27/7	D 59/41/12/8
162		V 88/78/4/7				D 44/14/13/18
163		V 88/78/4/7	V 92/48/4/40	V 72/14/25/33	V 54/13/33/9	V 84/72/3/10
181		E 64/44/8/12				
302				E 81/10/46/25	E 63/11/19/33	V 69/30/2/37
309						V 100/100/0/0
311				E 58/58/0/0		E 66/2/39/25
656	V 99/0/95/4				E 51/0/3/48	E 17/0/14/3
665	E 56/33/1/22					
858	E 64/52/2/10			E 31/1/8/22	E 22/11/7/4	V 56/40/2/14
876	E 89/77/9/2					
900					E 9/4/3/2	V 48/14/15/20
904						V 20/2/13/4
906					E 2/0/1/1	E 28/0/6/21
909						D 89/85/0/3
914					NS 0/0/0/0	E 28/4/7/17
919						V 19/0/16/3
921					V 27/0/16/11	V 68/3/54/12
922						V 44/23/1/20
934						E 8/0/5/3
935						D 30/15/2/13
TOTAL	1,462	9,818	1978	12,575	4,981	62,802
TOTAL	1,083	6,921	1,657	7,384	2,486	39,971
(%)	74.1	70.5	83.8	58.7	49.9	63.6

Future Focus

Create a Marine and Coastal Knowledge **Framework**

The key recommendation of State of the Bays 2016 was the development of a marine framework as a mechanism for 'addressing knowledge gaps, reducing uncertainties and forming the future evidence base for assessing management interventions and environmental outcomes'.195 DELWP has begun the development of the Marine Knowledge Framework, which is specific to marine science in Western Port and Port Phillip Bay.

In preparation for the State of the Marine and Coastal Environment 2021 report, the framework needs to be expanded to include:

- the development and implementation of a marine and coastal knowledge strategy with clear goals, actions, outcomes, timelines and evaluation that integrates agency and academic research, citizen science and Traditional Owner ecological knowledge
- a comprehensive review of marine and coastal indicators, with the data needs of the indicators given priority in data collection, analysis and reporting, and the indicators measured regularly to identify trends
- measurement of ecological function, condition and changes in marine and coastal ecosystems (including the 95% of coastal waters outside parks and sanctuaries, which are rarely monitored)
- assessment of the distribution of marine species responding to climate change
- understanding of marine and coastal attitudes, perceptions of, and connections for, Victorians (through polling)
- assessment of the ecological impacts of commercial and recreational fisheries

- assessment of the impacts of coastal urbanisation, development, population growth and increasing number of visitors to the coast
- assessment of water quality along the open coast.

Recommendation 10: That DELWP expand the Marine Knowledge Framework to include all state marine and coastal environments.

^{195.} Lester S, Halpern B 2008, 'Biological responses in marine no-take reserves versus partially protected areas', Marine Ecology Progress Series, 367, pp. 49-56.

Accounting for the Environment

Coastal and marine accounts can be used to assess the socio-economic benefits coastal and marine ecosystems provide to Victoria, such as recreation, tourism, aquaculture and protection of coastal built and natural assets

Coastal and marine accounts can be linked to land accounts, water accounts and waste (residual flow) accounts to enhance understanding of the links between asset management in catchment areas and the marine environment. By linking economic activity associated with land use in catchments – via water and waste accounts – to the condition of coastal and marine ecosystems, it is possible to build a more comprehensive picture of the impact of land use (see land accounts discussion in the Land chapter) on ecosystem services and benefits.

Coastal and marine ecosystems provide a wide range of ecosystem services. The quantity of ecosystem services produced is dependent on the extent and condition of ecosystem assets. The extent and condition of coastal and marine assets is impacted by a range of factors including climate change, flows of nutrients, sediments, toxicants and pathogens from catchments, and invasive species. A qualitative example of ecosystem accounting – from assets to benefits – is set out in Table MC.6.

Table MC.6 Qualitative example of ecosystem accounting for Victorian coastal and marine areas

Asset extent	Asset condition	Ecosystem services	Benefits
Cliffs	There is no universal condition	Plants, algae and animals	
Dunes	metric for coastal and marine	for food	animal consumption
Beach	ecosystem assets.	Nutrients for aquaculture	Avoided impacts of
	Potential metrics include:	Climate regulation	climate change
Saltmarsh	 habitat hectares (for EVCs 	Water quality regulation	Coastal asset protection
Mangrove	in coastal areas)	, , ,	Recreation and tourism
Seagrass	 denitrification efficiency 	Water flow regulation	Avoided health impacts
Reef	(muddy sediments)	Opportunities for	•
Macroalgae	Condition measure should	recreation and tourism	Information and knowledge
<u> </u>	relate to ecosystem services	Opportunities for cultural	<u> </u>
Sandy sediments	produced by the asset.	connection	Cultural connection
Muddy sediments		Landscape	Visual amenity

There is growing interest in coastal and marine ecosystem accounting around the world, reflecting a growing appreciation of the significant role these ecosystems play in supporting economies, communities and climate regulation.

Victorian marine and coastal assets can be classified using the hierarchical Combined Biotope Classification Scheme (CBiCS). 196 CBiCS provides a unified scheme for classifying all marine habitats and biotopes and is consistent with the terrestrial classification of vegetation biotopes and biotope complexes (for example, EVCs and EVC communities in Victoria). In 2016, CBiCS was used to produce pilot ecosystem accounts for Port Phillip Bay.¹⁹⁷ Using a hierarchical classification system such as CBiCS means that data can be aggregated to higher levels for reporting purposes (Figure MC.2 Combined Biotope Classification Scheme (CBiCS) hierarchy). This means that data collected at more granular levels can be aggregated and used for a variety of purposes.

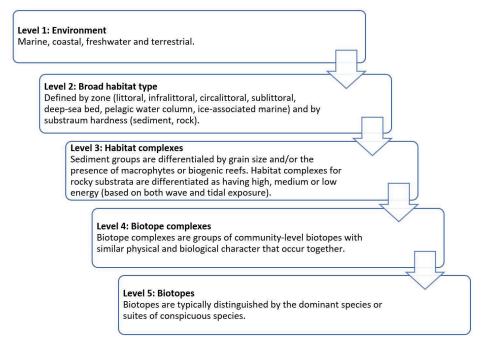


Figure MC.2 Combined Biotope Classification Scheme (CBiCS) hierarchy¹⁹⁸

Franco AD, Bussotti S, Navone A 2009, 'Evaluating effects of total and partial restrictions to fishing on Mediterranean rocky-reef fish assemblages', Marine Ecology Progress Series, 387, pp. 275–285.

Sciberras M, Jenkins SR, Mant R, Kaiser MJ, Hawkins SJ, Pullin AS 2015, 'Evaluating the relative conservation value of fully and partially protected marine areas', Fish and Fisheries, 16(1), pp. 58-77.

^{198.} VEAC 2017, 'Statewide assessment of public land', Melbourne, Victoria.

Case Study: Marine and Coastal Ecosystem Accounting for Port Phillip Bay

Pilot ecosystem accounts were developed for Port Phillip Bay in 2016 to support State of the Bays reports.¹⁹⁹ For this study, Port Phillip Bay was divided into five geographic areas: Central, Corio, Exchange, Hobsons and Intertidal (see Figure MC.3 Geographic aggregations for Port Phillip Bay accounts).

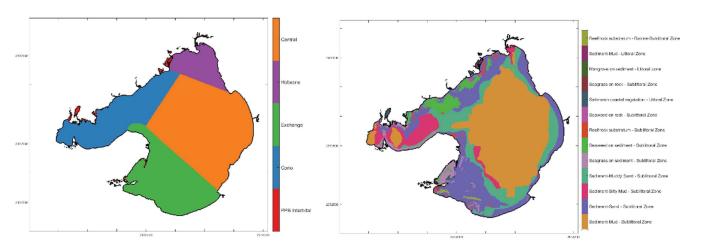


Figure MC.3 Geographic aggregations for Port Phillip Bay accounts²⁰⁰

Bay habitats (illustrated in Figure MC.4 Port Phillip Bay habitats) show very large areas of muddy sediment in the centre of the bay and in Corio Bay (in the western arm of the bay), which are responsible for water filtration services (the removal of nitrogen from the water). On the western side of the bay, there are also large areas of seaweed communities, seagrass and coastal salt marshes, which are important habitat for a number of species.

Figure MC.4 Port Phillip Bay habitats²⁰¹

Port Phillip Bay ecosystem assets are classified under CBiCS (Table MC.7 Port Phillip Bay ecosystem assets) and presented at the broad habitat level and habitat complex level. This could be further disaggregated to biotope complex level, where it can be used to inform decision-making.

Commissioner for Environmental Sustainability 2016, 'State of the Bays 2016', Commissioner for Environmental Sustainability, Melbourne, p.205.

Combined Biotope Classification Scheme 2018, www.cbics.org Accessed 4 December 2018.

Eigenraam M, McCormick F, Contreras Z 2016, 'Marine and coastal ecosystem accounting: Port Phillip Bay', DELWP, Melbourne, Victoria.

Table MC.7 Port Phillip Bay ecosystem assets²⁰²

Broad	Habitat complex	Central	Corio	Exchange	Hobsons	Intertidal	Total
habitat	Habitat Complex	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)
Littoral	Mangrove					4	4
sediment	Mud					274	275
	Saltmarsh		87	475	5	1,868	2,435
Total littoral s	sediment		87	475	5	2,147	2,714
Sublittoral	Ravine			798		11	809
rock	Rock (unclassed)	299	471	760	902	48	2,481
	Seagrass			209			209
	Seaweed		298	64	3	5	369
Total sublitto	ral rock	299	769	1,832	904	63	3,868
Sublittoral	Mud	69,923	3,391	7,393	3,922	234	84,863
sediment	Muddy sand	8,935	5,898	10,656	3,872	8	29,369
	Sand	5,800	11,064	23,458	6,921	312	47,555
	Seagrass	1	3,280	3,524	123	209	7,138
	Seaweed		7,087	352	431	14	7,884
	Silty mud	141	9,737	2,113	905	28	12,925
Total sublitto	ral sediment	84,800	40,457	47,498	16,175	804	189,734
Total		85,099	41,313	49,804	17,085	3,014	196,315

With the availability of time-series data, changes in asset type could be recorded and used to track and evaluate the impacts of policy and programs.

Where information is available, it is possible to assess the ecosystem services provided by environmental assets and value the benefits to people. For example, it is estimated that Port Phillip Bay processes over 5,000 tonnes of nitrogen per year. The value of this service is estimated at around \$11 billion per year, which represents the costs that would be incurred to achieve equivalent denitrification through alternative means, such as upgrading infrastructure or wetland enhancement.

A case study of ecosystem services provided by seagrass in Port Phillip Bay was undertaken in 2016 (Figure MC.5 Seagrass in an environmentaleconomic accounting framework, Port Phillip Bay). Services and benefits listed are those that could be identified, quantified or valued in the study. It is not an exhaustive list.

^{202.} Adapted from Edmunds M, Flynn A 2015, 'A Victorian marine biotope classification scheme', Australian Marine Ecology Report, Melbourne, Victoria.

Asset

7,347 hectares of seagrass across Port Phillip Bay

Composition:

- 209 hectares of Amphibolis stands
- •138 hectares Halophila beds
- 6,444 hectares Zostera and Ruppia beds

•556 hectares unspecified

Location:

- •3,733 hectares in Exchange area
- •3,280 hectares in Corio area
- 209 hectares in Intertidal area
- •123 hectares in Hobsons area
- •1 hectare in Central area

Condition

A condition measure for seagrass heath is currently not available

Services

Provisioning

Uncultivated marine plants, algae and animals for food

Nutrients and natural feed for cultivated biological resources (aquaculture)

Regulating

Climate regulation - carbon sequestration and storage (280,700 tonnes of carbon stored)

Water cycle regulation nutrient cycling, oxygenisation

Water flows regulation, mass flow regulation

Maintenance of habitat and nursery populations (minimum 343 tonnes of fish stock enhancement)

Cultural

Recreation

Information and knowledge Spirtitual and symbolic

Non-use — existence and ecosystem capital for future generations

Benefits

Seafood

Climate change mitigation (\$2.9— 16.0 million carbon stored; up to \$0.06—\$0.35 million sequestered per year)

Clean water

Coastal erosion prevention

Fish stock enhancement (minimum \$6.1 million per year)

Recreational fishing, diving, snorkling

Figure MC.5 Seagrass in an environmental-economic accounting framework, Port Phillip Bay²⁰³

^{203.} Eigenraam M, McCormick F, Contreras Z 2016, 'Marine and coastal ecosystem accounting: Port Phillip Bay', DELWP, Melbourne, Victoria.



Water Resources

This chapter includes assessments of Victoria's water resources and storage, projected runoff to dams and catchments, condition of flow regimes and delivery of water for the environment, surface water harvested for consumptive use, and water recycling. Groundwater is also included in this chapter, with indicators for groundwater ecosystems, quality, levels and consumptive use.

Background

Water is used for a variety of purposes, including domestic use, primary production (particularly irrigation), power generation and industry. The quality of Victoria's water resources is vital for human health and wellbeing and for accommodating its anticipated population growth. Victoria's Traditional Owners and Aboriginal Victorians have managed water sustainability over thousands of generations.

In 2016, the Victorian Government released its water plan, Water for Victoria, which sets out strategic directions and proposed actions to meet the water security challenges facing Victoria principally those arising from climate change and population growth.¹ The plan outlines the significant challenge posed by rapid population growth, coupled with a reducing water supply associated with climate change. Figure WR.1 shows that under the median climate change scenario, we will need to add to Melbourne's supplies by 2035. Figure WR.2 displays the water supply mix in 2015 and the potential diverse mix of supplies needed in 2050.²

In addition to these concerning predictions, a report released by Melbourne Water in 2017 suggested that a rapid-change scenario (higher growth in water demands and 'high' climate change) would lead to water resource shortfalls in Melbourne from as early as 2028.3

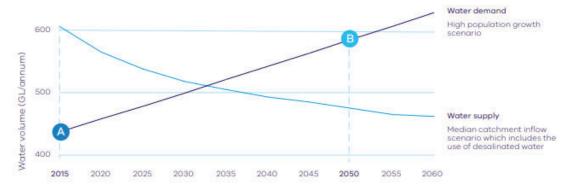


Figure WR.1 Projected water supply and demand for Melbourne.⁴

DELWP 2016, 'Water for Victoria Water Plan', East Melbourne, Victoria ter-Plan-strategy2.pdf Accessed 3 December 2018

Melbourne Water Corporation 2017, 'Melbourne Water System Strategy', Melbourne, Victoria https://www.melbourne Accessed 3 December 2018.

DELWP 2016, 'Water for Victoria Water Plan', East Melbourne, Victoria Water-Plan-strategy2.pdf Accessed 3 December 2018.

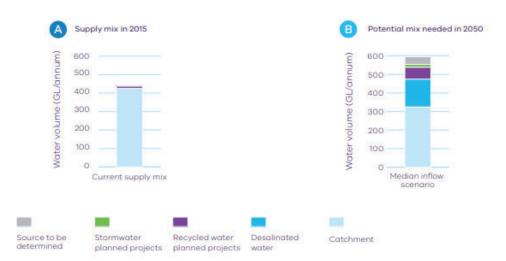


Figure WR.2 Current (2015) and potential (2050) water supply mix for Melbourne.⁵

The availability and quality of water is important for economic prosperity, especially for primary production industries. Victoria's total food and fibre exports were valued at \$12.8 billion in 2016–17. Irrigated agriculture is the largest water user in the state, with a net worth of \$4.2 billion in 2016-17.6,7 Victoria's total water consumption increased over the past century, peaking in the 1990s, then dropping in response to water restrictions imposed during the millennium drought of 1996 to 2010. The severity of water shortages was particularly marked in central and western Victoria, where some storages held less than 10% of capacity at the end of the drought. Since the millennium drought, rainfall reductions have continued during Victoria's cooler months. This trend is expected to continue, leading to an overall reduction in average annual rainfall.8

The availability and quality of surface and groundwater resources is mainly determined by streamflow and rainfall, as well as impacts of landuse on catchment hydrology. There has been an overall decrease in streamflow of approximately 50% over the past 20 years.⁹ Streamflow in Victoria

is highly variable, with most basins receiving only a fraction of their average flow in most years this century. Generally dry conditions are punctuated by wet years with flows well in excess of the average, replenishing storages and river systems. This was seen during 2016, when Victoria experienced its wettest year since 2011, with rainfall 19% above average. This caused flooding across western and northern Victoria.¹⁰

The effects of climate change are already influencing the frequency of extreme weather events, as discussed in CC:12 (Occurrence and impacts of extreme weather). Extreme weather events create an annual level of uncertainty for streamflow, water quality and resource availability. However, the overall long-term projection for streamflow is that it will decrease by a greater proportion than rainfall, due to the interaction between rainfall and catchment hydrology.¹¹

^{5.} Ibid

DEDJTR, 'Food and fibre', Melbourne, Victoria https://economicdevelopment.vic.gov.au/priority-industries-sectors/food-and-fibre# Accessed 3 December 2018.

Australian Bureau of Statistics 2018, '4610.0.55.008 - Gross Value of Irrigated Agricultural Production, 2016-17', Canberra, ACT. <a href="http://www.abs.gov.au/AUSSTATS/abs@nsf/Lookup/4610.0.55.008Main+Featurabs-2016/17/2016-17/2016

DELWP 2016, 'Water for Victoria Water Plan', East Melbourne, Victoria https://www.water.vic.gov.au/_data/assets/pdf_file/0030/58827/ Water-Plan-strategy2.pdf Accessed 3 December 2018.

^{9.} Ibic

Victorian Environmental Water Holder 2017, 'Reflections Water for the Environment in Victoria 2016-2017', East Melbourne, Victoria http://www.vewh.vic.gov.au/_data/assets/pdf_file/0010/445564/ Reflections-Water-for-the-Environment-2016-2017.pdf Accessed 3 December 2018.

DELWP 2016, 'Water for Victoria Water Plan', East Melbourne, Victoria https://www.water.vic.gov.au/_data/assets/pdf_file/0030/58827/ Water-Plan-strategy2.pdf Accessed 3 December 2018.

In some rivers, up to half of the water that would have naturally flowed is removed each year to provide water for farms, homes and industries.¹² Almost all Victorian catchments, rivers and larger streams have been modified to some degree, with inland waters being transformed into a complex and extensive system for harvesting, transporting and controlling the movement of water. There are 134 declared water supply catchments across Victoria and about 52 major storages, with at least one major on-stream storage constructed in 19 of Victoria's 29 river basins. In addition, there are about 450,000 farm dams in Victoria. As a result, many river systems in Victoria are now environmentally degraded because of impacts on natural flow regimes.13

As demand for water has increased in Victoria, especially during periods of hot weather, the use of groundwater to complement surface-water sources has increased. Groundwater is now an important resource for agriculture, industry and domestic use. Groundwater resources are used across 70 Victorian cities and towns as either a supplementary or primary water supply. In some regional areas, groundwater is the sole source of water. Groundwater is an increasingly valuable water resource as surface water becomes scarcer.

Water resources, use and consumption (including entitlements and trade) are overseen by the Victorian Government. Decision-making and management is delegated to the water sector, comprised of urban, regional and rural water corporations, Catchment Management Authorities (CMAs) and the Victorian Environmental Water Holder (VEWH). The Victorian water sector provides approximately 6,000 jobs across the state and is responsible for the largest proportion of government CO2-e emissions, with almost 1 million tonnes emitted per annum.14 The largest proportion of these emissions originates from sewage treatment - a service that will need to increase in-line with Victoria's projected population growth.

Critical challenges facing Victoria's water resources now and in the future include:

- meeting the water consumption needs of Victoria's growing population, projected to reach 10.1 million by 2051. Water demand for Melbourne is projected to increase by approximately 50% by 2065, 15,16 increasing pressures on assets, infrastructure, treatment plants and wastewater services, which require ongoing monitoring and maintenance.
- meeting primary industry water resource needs in response to Victoria's growing population and resource consumption. This includes managing the increasing pressures on services such as irrigation, drainage and storage.
- addressing water resource availability and flow regimes to support aquatic life amid climate change, particularly during extreme weather events such as floods and droughts
- addressing the increased dependency on groundwater as a water resource, particularly during periods of drought or less-than-average rainfall, which can lead to unsustainable use
- better utilisation of the water available from stormwater
- facilitating innovation in water resources and infrastructure to upgrade existing sewerage treatment facilities and develop new sewerage treatment approaches to reduce CO2 emissions
- continuing to develop processes and protocols to enable transparent and accountable collaboration on infrastructure projects across organisational boundaries to deliver sustainable, integrated water management solutions

Victorian Environmental Water Holder 2017, 'Reflections Water for the Environment in Victoria 2016-2017', East Melbourne, Victoria lections-Water-for-the-Environment-2016-2017.pdf Accessed 3 December 2018

DELWP 2014, 'Dams in Victoria', East Melbourne, Victoria https://www. Factsheet-FINALv4b.pdf Accessed 3 December 2018.

^{14.} DELWP 2016, 'Water for Victoria Water Plan', East Melbourne, Victoria Water-Plan-strategy2 pdf Accessed 3 December 2018

Melbourne Water Corporation 2017, 'Melbourne Water System Strategy', Melbourne, Victoria https://www.me

Current Victorian Government Settings: Legislation, Policy, Programs

Water for Victoria (2016) sets out strategic directions and proposed actions to meet the state's water security challenges, principally climate change and population growth. The government invested \$537 million to deliver Water for Victoria over a four-year period.

Major areas of investment aligned to the strategic aims of *Water for Victoria* have included \$222 million to improve waterway and catchment health in regional Victoria, \$60 million to strengthen water entitlement and planning processes, \$151 million for water and irrigation infrastructure (including \$42 million in the 2018–19 Victorian budget towards water security infrastructure in the East Grampians and Mitiamo), and \$20 million to respond to the challenges of climate change.

Water for Victoria recognises the value water has for Traditional Owners and Aboriginal Victorians. Funding of \$9.7 million has been provided to support economic development and an Aboriginal Water Program. The objectives of the Aboriginal Water Program are to:

- recognise Aboriginal values and objectives of water
- include Aboriginal values and traditional ecological knowledge in water planning
- support Aboriginal access to water for economic development
- build capacity to increase Aboriginal participation in water management.

In 2018, the Department of Environment, Land, Water and Planning (DELWP) established the Water Grid Partnership.¹⁷ The partnership will oversee the operation of Victoria's water grid and create a forum for delivering the best possible solutions to Victoria's water security challenges.¹⁸ The partnership builds on recent grid investments, including the \$80.6 million South West Loddon Pipeline, the \$85.2 million East Grampians Pipeline and the \$43 million Lance Creek Water Connection.¹⁹

In 2017, DELWP published the *Integrated Water Management Framework for Victoria*. The framework aims to help government, the water sector and the community work together to improve planning, management and delivery of water in Victoria's towns and cities.

Melbourne Water published the *Melbourne Water System Strategy* in 2017, which presented a system view of water resource management across Melbourne and the surrounding region over the next 50 years.²¹

Victoria contributed to the development of the Basin Plan, published by the Murray–Darling Basin Authority in 2012.²² The Basin Plan is a coordinated approach to water management across the Murray–Darling Basin's four states (South Australia, Victoria, New South Wales and Queensland) and the Australian Capital Territory, and is designed to ensure that water taken from the Murray–Darling Basin for consumptive use is sustainable.

DELWP, 'Victoria's water grid', East Melbourne, Victoria https://www.watervic.gov.au/water-grid-and-markets/the-grid Accessed 3 December 2018

^{18.} lb

Ibid
 DELWP 2017, 'Integrated Water Management Framework for Victoria', East Melbourne, Victoria https://www.watervic.gov.au/ data/assets/pdf file/0022/81544/DELWP-IWM-Framework-FINAL-FOR-WEB.pdf Accessed 3 December 2018.

^{21.} Melbourne Water Corporation 2017, 'Melbourne Water System
Strategy', Melbourne, Victoria https://www.melbournewater.com.au/
sites/default/files/2017-09/Melbourne-Water-System-Strategy_0.pd

Accepted Design 12 (1)

21. Melbourne Water System Strategy_0.pd

Accessed 3 December 2018.

22. Murray-Darling Basin Authority, 'Developing the Basin Plan', https://www.mdba.gov.au/basin-plan-roll-out/basin-plan/developing-basin-plan Accessed 3 December 2018.

The water sector, responsible for the largest proportion of government CO2-e emissions, is participating in the Climate Change Adaptation Action Plan.23 Victoria's 19 water corporations have pledged to reduce their collective emissions by approximately 350,000 tonnes – or 42% – by 2025.24,25

DELWP used the Victorian Climate Initiative outputs to develop Guidelines for Assessing the Impact of Climate Change on Water Supplies in Victoria.26 This document was produced to help Victoria's water sector plan for the impacts of climate change on water supplies.

DELWP also oversees the Victorian Water and Climate Initiative that supports research into the impact of climate change and climate variability on Victoria's water resources. This includes three research projects undertaken with the University of Melbourne, the Bureau of Meteorology (BoM) and CSIRO.27

^{23.} DELWP, 'Climate Change', East Melbourne, Victoria https://www.water. ce/climate-change Accessed 3 December 2018.

DELWP 2018, 'Delivering Water for Victoria Progress Report', East <u> 1919.pdf</u> Accessed 3 December 2018.

DELWP 2016, 'Guidelines for Assessing the Impact of Climate Change on Water Supplies in Victoria: FINAL, December 2016 v7.0', East Melbourne, Victoria https://www.water.vic.gov.au/file/0014/52331/Guidelines-for-Assessing-the-Imp Change-on-Water-Availability-in-Victoria.pdf Accessed 3 December

DELWP, 'The Victorian Water and Climate Initiative', East Melbourne, initiative Accessed 3 December 2018.

Indicator Assessment

Legend

Status

N/A Not Applicable

The indicator assessment is based on future projections or the change in environmental condition and providing a status assessment is not applicable. Only a trend assessment is provided.



Unknown

Data is insufficient to make an assessment of status and trends.



Environmental condition is under significant stress, OR pressure is likely to have significant impact on environmental condition/ human health, OR inadequate protection of natural ecosystems and biodiversity is evident.

Fair

Environmental condition is neither positive or negative and may be variable across Victoria, OR pressure is likely to have limited impact on environmental condition/human health, OR moderate protection of natural ecosystems and biodiversity is evident.

Good

Environmental condition is healthy across Victoria, OR pressure is likely to have negligible impact on environmental condition/ human health, OR comprehensive protection of natural ecosystems and biodiversity is evident.

Trend

N/A Not applicable

This indicator assessment is based on current environmental condition only and it is not applicable to provide a trend assessment. Only a status assessment is provided.



Unclear



Deteriorating



Stable



Improving

Data quality

Evidence and consensus too low to make an assessment



Limited evidence or limited consensus

Water storages are at approximately 65% capacity (as at February 2018). There has only

been a small decline in water storage levels as

a percentage of capacity during the past five



Good

Adequate high-quality evidence and high level of consensus

WATER RESOURCES

Summary

years.

WR:01 Water resources and storage trends

Region

Indicator

Victoria

Measures

Water storage levels in Victoria as a percentage of capacity

Data custodian

DELWP

Status

POOR

FAIR

GOOD



Trend

DATA QUALITY

Good

Summary Status **Trend** UNKNOWN POOR FAIR GOOD Indicator Annual runoff is projected to decrease by N/A 5-15% across most of Victoria by 2040 and WR:02 Projected 10-30% by 2065 (relative to a baseline period runoff to dams and from 1975-2014), with the largest reductions catchments expected to occur in the south west. Region DATA QUALITY Victoria Good **Measures** Projected changes in runoff for 2065 under an intermediate climate change scenario Data custodian BoM, CSIRO Indicator Streamflow as a percentage of the long-term annual average streamflow was below 100% WR:03 Condition of in all regions as at 2015-16, with declines flow regimes observed in all regions from 2011-12. Region Victoria DATA QUALITY Measures Good Streamflow as a percentage of the long-term annual average streamflow Data custodian DELWP Indicator For each year from 2011-12 to 2017-18, 55-70% of the environmental entitlement was delivered. WR:04 Delivering Nearly twice as much water was delivered in water for the 2017-18 compared with 2011-12. environment Region DATA QUALITY Victoria Good Measures (i) Managed environmental water delivery (ii) Total volume delivered as a percentage of environmental entitlements Data custodian VEWH

	Summary	Status Trend
Indicator WR:05 Number of dams, weirs and levees Region Victoria Measures Storage capacity from dams Data custodian DELWP	Victoria has about 450,000 dams. Together, Victoria's dams have an estimated total storage capacity of about 13,400,000 ML. It is unclear exactly how this capacity has changed over time.	PATA QUALITY Fair (no trend or spatial data available)
Indicator WR:06 Surface water harvested for consumptive use Region Victoria Measures Total surface water diversions Data custodian DELWP	The volume of surface water taken under entitlements has been reasonably consistent since 2011-12.	DATA QUALITY Good
Indicator WR:07 Percentage of waterways and groundwater areas, subject to extraction, with a limit on extraction Region Victoria Measures Volume of water (ML) taken for different consumptive uses under surface water and groundwater entitlements Data custodian DELWP	Irrigation continues to be the largest consumptive use of surface water in the state, comprising 78% of all water taken from 2011-12 to 2015-16. Irrigation, commercial and salinity control was the largest consumptive use of groundwater in the state, comprising 76% of all water taken between 2012-13 and 2015-16.	DATA QUALITY Good

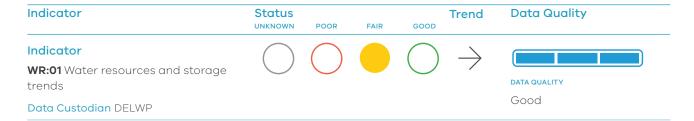
	Summary	Status Trend
Indicator WR:08 Water recycling Region Victoria Measures Volume and percentage of wastewater recycled Data custodian DELWP	The volume of wastewater recycled increased from 87,000 ML to 96,000 ML from 2011-12 to 2015-16, representing just under 20% of the total wastewater produced in the state.	DATA QUALITY Good
Indicator WR:09 Percentage of agricultural land with improved irrigation Region Victoria Measures Area of agricultural land with suitable irrigation infrastructure Data custodian CMAs	Approximately 27,000 hectares of agricultural lar has been upgraded with improved irrigation during the four financial years from 2013-14 to 2016-17, which represents less than 3% of Victoria's total area of irrigated agriculture.	POOR (need data on the total area of irrigated land and the area of irrigated land that needs improved irrigation)
Indicator WR:10 Groundwater ecosystems Region Victoria Measures Number of flora and fauna species identified as being affected by a decline in groundwater quality Data custodian None	No data is available to determine the number of flora and fauna species affected by changes in groundwater quality.	Poor (no data available to provide a status or trend assessment)

Status Summary Trend UNKNOWN POOR FAIR GOOD Across Victoria, groundwater salinity generally Indicator reduces from west to east, with a peak in the WR:11 Groundwater north-west of the state and minimums in the quality Good in eastern Victoria, Poor in north alpine region and far east of the state. western Victoria and Fair elsewhere Region Victoria Measures DATA QUALITY Baseline watertable Fair (no trends can be determined salinity from private bores) Data custodian DELWP Indicator Groundwater levels in shallow aquifers have mostly remained stable in the reporting period, WR:12 Groundwater except for a small number of areas including levels Stable for most shallow the Loddon Highlands. Declines in lower Region aguifers and Deteriorating aquifers have occurred in Gippsland (related for lower aquifers in the Victoria to mining activities) and northern Victoria (due Gippsland basin and northern to periods of low rainfall and groundwater Measures region, and confined aquifers extractions). Groundwater levels around Western Port and the in middle, lower and Otway Ranges. shallow aquifers Data custodian DELWP Fair (data not available across the state) Indicator Average licensed groundwater use is 30% of the total entitlement in groundwater WR:13 Groundwater management units. During prolonged dry harvested for periods such as the millennium drought, consumptive use average groundwater use increases to Region DATA QUALITY approximately 50% of entitlement. Victoria Good Measures Groundwater use as a percentage of total

entitlement

Data custodian

DELWP



Water storage volumes in Victoria are closely linked to rainfall, with storage volumes at their lowest levels during periods of extended drought. In a typical annual cycle, Victoria's water storage volumes are drawn-down during late autumn, then replenished by cool-season rainfall that leads to winter and spring inflows. A projected decline in cool-season rainfall this century, as discussed in indicator CC:05 (Projected changes to average rainfall), is expected to reduce Victoria's water storage volumes.

Victoria's major water storages can hold nearly 12,500,000 ML. Melbourne's storage accounts for 15% of this capacity, and the state's major regional storages the remaining 85%.

The data presented for this indicator covers the period from June 2012 to February 2018. Water storage levels were reasonably high at the beginning of this period – at nearly 90% for regional Victoria and just above 70% for Melbourne. This was due to 2010 and 2011 being wet years in Victoria, which replenished water storages after the millennium drought. Between June 2012 and February 2018, the minimum storage levels in Victoria occurred during autumn 2016, after water storages reduced during dry years in 2014 and 2015. This data is displayed in Figure WR.3 and Figure WR.4.

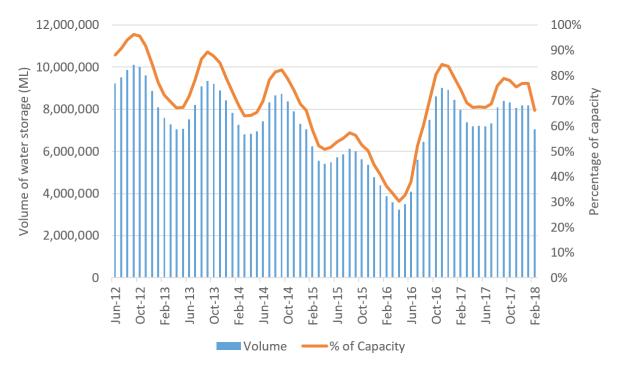


Figure WR.3 Water storage levels in regional Victoria, June 2012 to February 2018

Note: Levels are expressed by volume (ML) on the primary y-axis, and as percentage of total storage capacity on the secondary y-axis. (Data source: DELWP, 2018)

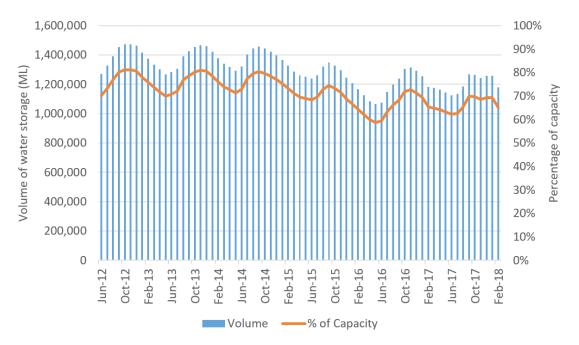


Figure WR.4 Water storage levels in Melbourne, June 2012 to February 2018

Note: Levels are expressed by volume (ML) on the primary y-axis, and as percentage of total storage capacity on the secondary y-axis.

(Data source: DELWP, 2018)

Melbourne storage volumes peaked in the periods September to December 2012, and October to December 2013, both times exceeding 80% of the storage capacity. Regional storage volumes peaked from July to November 2012, rising to more than 90% of the regional storage capacity.

Since SoE 2013, Melbourne's water storage levels were at their lowest (60%) in the three months from April to June 2016. The lowest level in the previous SoE reporting period was 30% in June 2009, towards the end of the millennium drought.

Regional water storages are typically more vulnerable than storages in Melbourne. This has been the case for the past six years, when regional water storage volumes have fluctuated more than Melbourne's. Regional water storage dropped to 30% of capacity in April 2016. However, like the low

for Melbourne, this was better than the minimum capacity recorded at the end of the millennium drought in regional Victoria, where water storage levels dropped below 20% during the autumns of 2007 to 2009.²⁸ (The regional figures presented here are the totals for all of regional Victoria, so the percentage storage levels at some regional basins relative to their capacity will be lower than the overall regional figure.)

The results presented here suggest that Victoria's water storage volumes will be drawn-down for longer periods as the state continues to shift to a predominantly drier climate, with more frequent and severe drought conditions.

DELWP 2017, 'Victorian Water Accounts 2015-16', East Melbourne, Victoria https://waterregister.vic.gov.au/images/documents/ VWA. 2015-2016.pdf Accessed 3 December 2018.

This, together with population growth, will most likely mean that Victoria will draw heavily on water from the Victorian Desalination Plant on the Bass Coast. Victorians will also have to use water more efficiently, preferably going beyond the savings made as part of the original Target 155, which saved an estimated 53 GL of water during the millennium drought.²⁹ Another problem to address is that fewer than 30% of new homes in Victoria currently include a rainwater tank (which helps to reduce demand), compared to more than 90% of new homes in New South Wales.30

The status assessment for this indicator has been listed as fair, because water storages are at approximately 65% capacity (as at February 2018). The trend has been listed as stable because, although water storages have decreased slightly since February 2013, there has only been a small decline in water storage levels as a percentage of capacity during the past five years.

Melbourne Water Corporation 2017, 'Melbourne Water System Strategy', Melbourne, Victoria https://www.melbourney Accessed 3 December 2018.

DELWP 2018, 'Draft Issues Paper for the Improving Stormwater Management Advisory Committee June 2018', East Melbourne, Victoria https://s3.ap-southeast-2.amazonaws.com/hdp.au.prod.app.vic-engage.files/5215/2758/2405/Issues_Paper.pdf
Accessed 3
December 2018.

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
WR:02 Projected runoff to dams and catchments	N/A				\supset	
Data Custodian BoM, CSIRO						Good

Victoria's catchments have diverse characteristics due to climatic, topological and vegetative factors, which lead to variability in runoff across the state. Figure WR.5 shows that greater runoff has occurred from 1975 to 2014 in the alpine region and coastal areas, while the north-west of Victoria has very little runoff.³¹

Victoria's streamflows are expected to continue declining, in-line with projected reductions in cool-season rainfall. Cool-season rainfall is particularly important for dam-filling.³³ Annual

runoff is projected to decrease by 5 to 15% across most of Victoria by 2040, and by 10 to 30% by 2065 (relative to the baseline period 1975 to 2014), with the largest reductions expected in the south-west. Figure WR.6 shows projected changes in runoff in 2065 following climate change in an 'intermediate emissions scenario'.³⁴

Based on the size of these reductions, the trend for this indicator has been assessed as deteriorating. (No status assessment has been provided as the indicator is based on projections.)

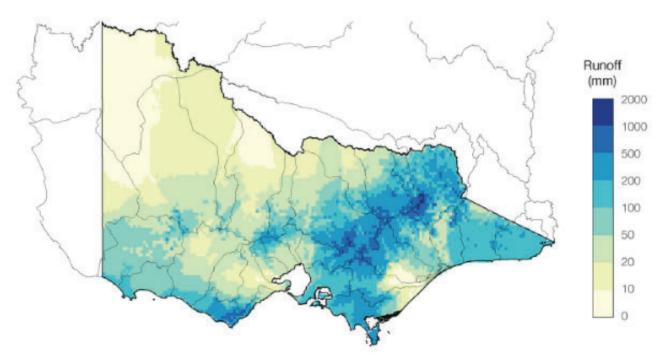


Figure WR.5 Runoff across Victoria, 1975–2014.³² (Data source: Victorian Climate Initiative, 2018)

Hope P, Timbal B, Hendon H, Ekström M, Potter N 2017, 'A synthesis of findings from the Victorian Climate Initiative (VicCl)', Bureau of Meteorology, Australia.

^{32.}

^{33.} Ibi

^{34.} Ib

Flow Regimes

A flow regime is a specific combination of the timing, size and duration of river flow events. It is a key driver of river and floodplain wetland ecosystems. Each river has its own flow regime, which influences river morphology, biodiversity and the processes that sustain aquatic ecosystems.

A history of works to rivers and large streams, designed to store, drain and change the direction and speed of water as it moves through the landscape, has altered Victorian flow regimes and reduced the volume of water available to the environment. With less rainfall predicted under climate change, reduced average streamflows will impact the health and condition of all rivers, streams and associated tributaries, and reduce water availability for resource use.

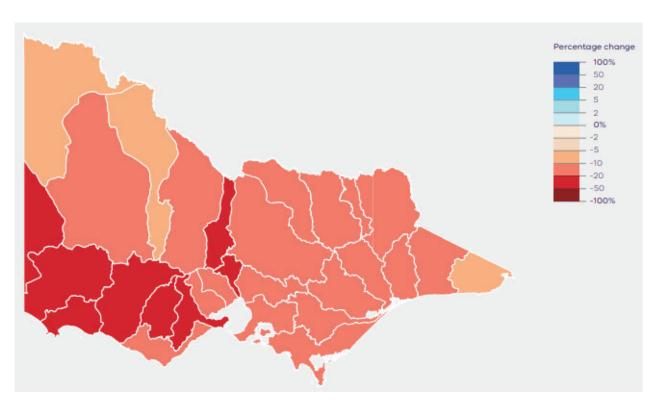


Figure WR.6 Projected changes in runoff for 2065 (intermediate emissions scenario).

(Data Source: DELWP, 2018)35

DELWP 2016, 'Water for Victoria Water Plan', East Melbourne, Victoria https://www.water.vic.gov.au/__data/assets/pdf_file/00 Water-Plan-strategy2.pdf Accessed 3 December 2018.

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
WR:03 Condition of flow regimes					\supset	
Data Custodian DELWP						Good

Streamflow in Victoria is highly variable. Most years are generally dry, which is related to less flow. The occasional very wet year leads to flows well in excess of the average, replenishing storages and river systems.

The following factors impact on natural flow regimes:

- presence of dams and other barriers
- regulation of flow
- extraction of water for consumption
- channel modification
- changes in land use
- the impact of stormwater.

These pressures affect groundwater and wetlands, as well as rivers. Indirect pressures, such as the clearing of vegetation, agriculture, groundwater extraction, farm dams, plantation forestry and regrowth following bushfires, also alter catchment hydrology.

The main pressures on flow regimes noted in SoE 2013 remain.³⁶ These include:

Regulation of flow by major storages, weirs and levees. At least one major on-stream storage occurs in 65% of Victoria's river basins. Storages often result in large decreases in flow immediately downstream. For example, there has been a significant reduction in flow immediately downstream of the Upper Yarra Dam. River regulation can significantly reduce the volume of high flows to below natural levels, and can also increase the duration of low flows, with significant impacts on biodiversity and ecological processes.

- In irrigation areas, flow regimes are dictated by the needs of consumers, rather than environmental requirements. Consequently, river regulation in systems that support irrigation areas may reverse the seasonality of natural flows (that is, flows that are not impaired by artificial means such as weirs and reservoirs). Large volumes of water are released for irrigation during summer and autumn, when flows would typically be lower, and less water is released during winter, when flows would typically be greater. This has caused significant changes in some Victorian ecological communities - diminishing, for example, the reproductive success of many aquatic species – and growing downstream demand can exacerbate impacts.
- Extraction of water for consumption reduces the volume of water available for the environment. As competition for water resources has increased, the cumulative impacts of water harvesting have become more acute. These pressures were compounded by the millennium drought, which led to streamflows well below the long-term average. Diversion caps are in place, and entitlements have rules that assure allocation of held water to the environment, limiting the impact of extraction of water for consumption.
- Changes to the catchment have altered hydrology in rivers and streams.
 Approximately half of Victoria's native vegetation has been cleared, increasing surface-water runoff and recharge to groundwater. This has placed pressure on terrestrial systems as well as inland waters.

Commissioner for Environmental Sustainability 2013, 'State of the Environment report 2013', Melbourne, Victoria https://www.ces.vic. gov.au/sites/default/files/publication-documents/2013%20SoE%20 report%20full.pdf Accessed 3 December 2018.

- The proliferation of farm dams reduces streamflow by intercepting runoff. As inflows decline, dams catch a higher proportion of water, which means that dams will have a bigger impact on flow regimes during drier conditions.
- Widespread reforestation, through plantation forestry or smaller-scale agroforestry activities can change the hydrology of catchments by intercepting groundwater recharge. Young, rapidly growing trees can use much more water than mature forest. Fire may also affect water availability through its effects on vegetation.
- **Urbanisation** affects streamflow by making it much more variable, reducing low-flow rates and, after heavy rain, increasing peak-flow rates and shortening their duration.
- The construction of levee banks to prevent the flooding of land and property can isolate the river from the floodplain.

Streamflow is equivalent to 'catchment inflow' and can vary substantially between months. Figure WR.7 is a summary of the streamflow status at June 2017, expressed as the percentage of the 100-year long-term average flow at 27 representative hydrologic stations across the state. As at June 2017, streamflow is lowest (below 10% as a proportion of the long-term average) in the north-west of the state and greatest (between 40 to 80% as a proportion of the long-term average) from Melbourne's north-eastern fringe down to Wonthaggi, as well as in pockets around Warrnambool and the east of Bairnsdale.

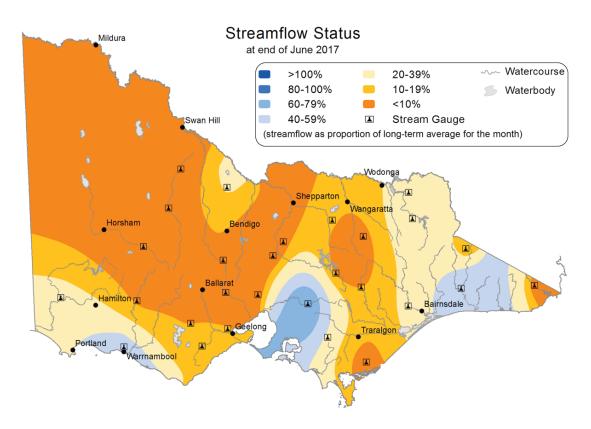


Figure WR.7 Streamflow status as at June 2017 (Data source: DELWP, 2018)

Since 2003–04, annual total Victorian streamflow peaked in 2010–11 and 2011–12, at 175% and 124% of the 100-year long-term annual streamflow respectively, before declining in recent years (Figure WR.8). This decline has led to the trend assessment of deteriorating for this indicator. Annual total Victorian streamflow in 2015–16 represented 50% of the long-term average, which was the lowest level since 2009–10, towards the end of the millennium drought. The relatively low streamflow in 2015–16 is the reason the status assessment for this indicator has been listed as poor.

During the past five years, nearly all river basins have been much drier than the long-term average (Figure WR.9). As an average for 2011–12 to 2015–16, the Avoca and Wimmera basins recorded streamflows less than 25% of the long-term average. The driest basins in 2015–16 were the Glenelg, Corangamite, Hopkins, Wimmera and Avoca basins, which all received below 15% of their long-term average streamflows. A few basins recorded higher streamflows relative to their long-term averages, notably the East Gippsland, Snowy and Tambo basins, which were near 150% of their long-term average streamflows during 2015–16.

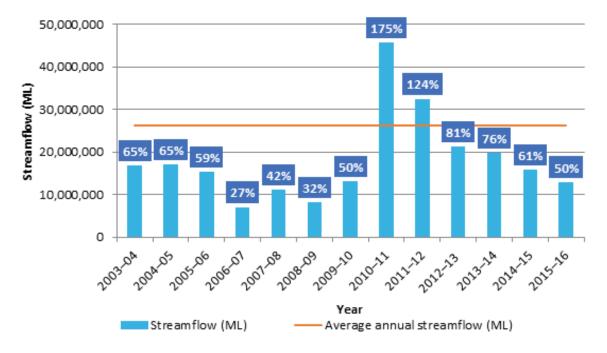


Figure WR.8 Victorian streamflow compared to long-term average

Note: Values above each column represent annual streamflow as a percentage of the average Victorian 100-year long-term annual streamflow. The horizontal line represents the average Victorian 100-year long-term annual streamflow. (Data source: DELWP, 2018)

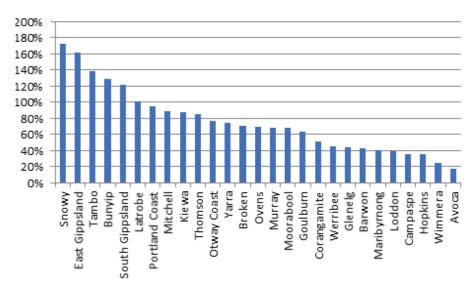


Figure WR.9 Average Victorian streamflow at river basins for 2011–12 to 2015–16 compared to the long-term averages at each river basin

Note: Values above 100% represent streamflows above the 100-year long-term annual streamflow.

(Data source: DELWP, 2018)

Figure WR.10 summarises streamflow as a percentage of the long-term annual average streamflow at a regional level. During the most recent five years of available data, streamflows as a percentage of the 100-year long-term annual average peaked in all regions in 2011–12, except for the western region, which peaked in 2013-14. The Gippsland region has had the greatest streamflow, relative to its long-term average, while the western region has had the lowest streamflow, relative to its long-term average.

The variability of the projections, and the expected increase in the frequency and severity of extreme weather events, means that water resource managers will need adaptive management processes to quickly respond as the environment changes.

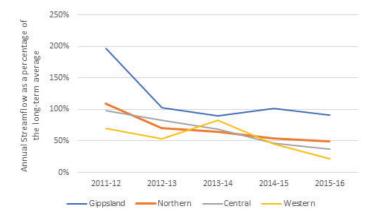


Figure WR.10 Victorian annual streamflows, by region for 2011–12 to 2015–16 compared to long-term averages

(Data source: DELWP, 2018)



The objective of environmental water in Victoria is to preserve the environmental values and health of water ecosystems, including their biodiversity, ecological functioning and quality of water. this is provided in three ways:

- Environmental water entitlements: α volume of water held by the environment in perpetuity. In general, the entitlements are a share of the available resource (inflows) in storages that can be released to meet specific environmental needs.
- Obligations on consumptive entitlements (passing flows): the volume of water that water corporations or licensed diverters are obliged to provide out of storage, or past a diversion point, before water can be taken for consumptive use.
- 'Above cap' water: the water available above limits on consumptive volumes of surface and groundwater. Most water available to the environment is 'above cap' water, which can be a very unreliable source of water.

In regulated systems, environmental water is mainly 'set aside' through environmental water entitlements or water shares. In unregulated systems and in groundwater aquifers, environmental water is primarily provided through management of existing diversions via licence conditions, rostering and restriction rules (for example, water left in the system contributes to environmental needs but cannot be actively managed).

In the 2017–18 watering year, a total of 88 river reaches and 83 wetlands (representing a minority of Victoria's river system) were provided with environmental flows to maintain or improve the health of the ecosystem (Figure WR.11).37 This held environmental water is actively managed to meet specific environmental objectives, such as fish spawning triggers or maintaining critical habitat during drought for aquatic species and birds. The number of sites watered typically fluctuates due to climatic conditions and infrastructure improvements.38 There was a substantial increase in 2013-14 due to an increase in the volume of water held in environmental entitlements, increased availability of Australian Government water for the environment, and infrastructure improvements that allowed delivery to a larger number of floodplain and wetland sites.³⁹ More wetlands and reaches were actively watered in 2017–18 amid dry conditions, as water availability was high, and because site managers were delivering many environmental flows to capitalise on the environmental gains achieved in the previous wet year.40

Victorian Environmental Water Holder, 'Victoria's rivers and wetlands get a helping hand from watering plan', East Melbourne, Victoria Accessed 3 December 2018

^{38.} Ibid

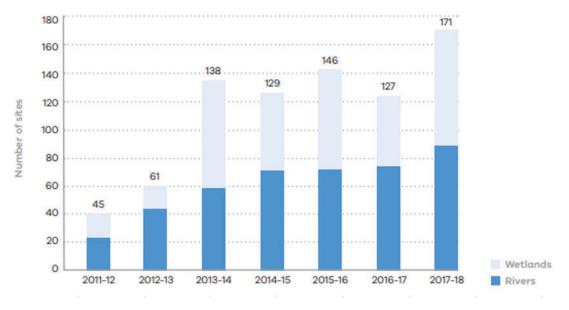


Figure WR.11 Number of river reaches and wetlands watered since 2011–12.41

Managed environmental water is vital in regulated river systems where water storages and extraction alter natural streamflow. Alteration of natural streamflow can include a reduction in the size and frequency of flood events, as water is captured and stored for consumptive use, and reversal of seasonal flows (for example, more flow in summer for irrigation purposes, and less in winter, despite generally more rain).

Wetlands that rarely or never receive natural inundation may also receive held environmental water.

In unregulated systems, it is also vital that a sustainable level of water remains in the waterway to allow environmental processes to take place. Licences and rules on diversion help protect this sustainable level. Environmental flows help to maintain aquatic ecosystem health by:

- improving the quality and connectivity of instream habitat
- inundating wetlands as well as floodplain and riparian vegetation
- improving water quality
- providing conditions required for aquatic fauna life histories (for example, fish breeding).

Held environmental water was affected by drought conditions between 2006-07 and 2009-10, severely decreasing river flows across much of Victoria. However, less than 50% of available water was used over this period, with only 22% used in 2006-07. With greater river flows in 2010-11, the volume of available environmental water increased fivefold, and almost 70% of the available water was used for environmental purposes.42

Victorian Environmental Water Holder 2018, 'Annual Report 2017-18', East Melbourne, Victoria http://www.ve WH-Annual-Report-2017-18 web.pdf Accessed 3 December 2018

Commissioner for Environmental Sustainability 2013, 'State of the Environment report 2013', Melbourne, Victoria https report%20full.pdf Accessed 3 December 2018

Managed environmental water availability and delivery for the four Victorian regions since 2011–12 are shown in Table WR.1 to Table WR.3. The overwhelming majority, 84%, of this water was delivered from the northern region river systems. Much of the water delivered from the Murray, Goulburn and other systems may be recredited to VEWH accounts for use at downstream sites along the Murray River. For data from 2011–12, the total volume delivered across Victoria peaked in 2017–18 and volume as a percentage of the total held environmental water peaked in 2013–14 (73% of the total reserve).

Table WR.1 Managed environmental water availability (ML) by region, 2011–12 to 2017–18⁴³

Area	2011–12	2012-13	2013-14	2014-15	2015-16	2016-17	2017–18
Southern Victoria (Gippsland + Central)	75,651	85,050	111,257	108,951	88,263	109,823	123,741
Gippsland Region	Not	Not	48,124	52,219	48,081	53,648	73,186
Central Region	reported separately	reported separately	63,133	56,732	40,182	56,176	50,554
Western Region	69,211	82,296	60,401	45,347	16,373	53,582	79,126
Northern Region	575,854	597,789	933,883	840,247	999,130	882,239	1,179,140
Total state	720,716	765,135	1,105,541	994,545	1,103,766	1,045,644	1,382,007

Table WR.2 Managed environmental water delivery (ML) by region, 2011–12 to 2017–18⁴⁴

Area	2011–12	2012-13	2013-14	2014-15	2015-16	2016-17	2017–18
Southern Victoria (Gippsland + Central)	33,008	41,060	49,130	62,974	40,922	48,478	76,606
Gippsland Region	Not	Not	27,351	28,872	28,797	20,637	45,180
Central Region	reported separately	reported separately	21,780	34,102	12,125	27,841	31,426
Western Region	18,345	50,277	30,004	33,720	8,112	13,585	39,664
Northern Region	427,858	345,904	730,543	549,073	640,498	644,405	802,830
Total state	479,212	437,242	809,678	645,767	689,532	706,468	920,100

^{43.} Victorian Environmental Water Holder 2018, 'Annual Report 2017-18', East Melbourne, Victoria http://www.vewh.vic.gov.au/__data/assets/pdf_file/0006/506373/VEWH-Annual-Report-2017-18_web.pdf_Accessed 3 December 2018.

^{44.} Ibio

Table WR.3 Total volume delivered as a percentage of environmental entitlements by region, 2011–12 to 2017–18⁴⁵

A	2011–12	2012-13	2013-14	2014-15	2015-16	2016-17	2017–18
Area	%	%	%	%	%	%	%
Southern Victoria (Gippsland + Central)	44	48	44	58	46	44	62
Gippsland Region	Not reported	Not reported	57	55	60	38	62
Central Region	separately	separately	34	60	30	50	62
Western Region	27	61	50	74	50	25	50
Northern Region	74	58	78	65	64	73	68
Total state	66	57	73	65	62	68	67

Environmental needs are assessed and balanced with consumptive needs. The long-term water resources assessment, due in 2019, will describe any changes to overall water availability seen since 2005, as well as whether any change has fallen proportionately across environmental or consumptive needs.46

As part of its work to manage environmental water in Victoria, DELWP - in consultation with CMAs, Melbourne Water and VEWH – operates a Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP). VEFMAP was established by the Victorian Government in 2005 to monitor and assess ecosystem responses to environmental watering in priority rivers across Victoria.47 The Biodiversity chapter contains more information on recent findings from VEFMAP.

DELWP, 'Assessment process: Long-Term Water Resource Assessment', East Melbourne, Victoria https://www.water.vic.gov.au/ planning-and-entitlements/long-term-water-resource-assessment/ ltwra-assessment Accessed 3 December 2018.

47. DELWP 2017, 'Victorian Environmental Flows Monitoring and

Assessment Program – Stage 6', East Melbourne, https://www.ari. Stage-6.pdf Accessed 3 December 2018.

Indicator	Status	2002	EAID	6000	Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
WR:05 Number of dams, weirs and levees					?	
						DATA QUALITY
Data Custodian DELWP						Fair (no trend or spatial data available)

Victoria has about 450,000 dams, indicating how important dams are to the state's economy and way of life. Victoria's dams range in size, from major storages such as Dartmouth Dam (about 4,000,000 ML), Lake Eildon (about 3,300,000 ML) and the Thomson Dam (about 1,070,000 ML) to dams the size of swimming pools on farms and personal properties. These smaller, privately owned dams are the most common type of dam in Victoria, although data is limited on their size and location.

Together, Victoria's dams have an estimated total storage capacity of about 13,400,000 ML.⁴⁸ It is unclear exactly how this capacity has changed over time, although there may have been an increase in capacity during the millennium drought.

Most dams in Victoria have been built to store rainfall when it is plentiful, for use in times when it is most needed. Victorians depend on dams to supply water to their homes, businesses, industries and farms.

A weir is a low dam built across a waterway to raise the level of water upstream or regulate its flow.⁴⁹

Levees are an important part of Victoria's flood management infrastructure and can be highly effective in containing flood waters. However, without proper planning and management, including maintenance, they can become ineffective or even add to flood risk, and hamper flood response and recovery.

Connectivity of waterways is a key characteristic of a healthy aquatic ecosystem, as it allows unrestricted movement of fish. Aquatic habitats and waterways have been modified by the construction of dams, weirs and culverts to provide hydropower, irrigation and navigation. This provides important community benefits, but it has also changed how rivers flow, altered water quality, and reduced river connectivity.

Fish need to be able to move freely among habitats to successfully complete all stages of their life-history. Fish move upstream and downstream (often up to many hundreds of kilometres), as well as into and out of connected wetlands and floodplains. Fish undertake these movements for various reasons including spawning, feeding and dispersal.⁵⁰

Modification of natural flow regimes may affect biodiversity, alter riverine habitat and facilitate the invasion of exotic species. Flow variability and volume underpin many ecosystem processes in inland waters, regulating the transport of nutrients, sediment and salt within inland waters and onto associated floodplains. Changes to flow variability and volume, combined with altered land-use practices, have contributed to poor water quality due to nutrient contamination (see indicators WQ:05 and WQ:06).

DELWP 2014, 'Dams in Victoria', East Melbourne, Victoria https://www.watervic.gov.au/ data/assets/pdf. file/0018/54126/Dam-Safety-Eactspeet-FINAL v4b pdf Accessed 3 December 2018

DELWP 2015, 'DELWP Output data standards', East Melbourne, Victoria https://www.watervic.gov.au/ data/assets/pdf. file/0016/120463/DELWP-OutputDataStandard-web-V4.0.pdf Accessed 3 December 2018.

DELWP, 'Fishways and fish movement', East Melbourne, Victoria https://www.ari.vic.gov.au/research/rivers-and-estuaries/fishwaysand-fish-movement Accessed 3 December 2018.

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
WR:06 Surface water harvested for consumptive use				\bigcirc	\rightarrow	
Data Custodian DELWP						Good

Water Consumption

The percentage of total streamflow leaving a river basin is a marker for the pressure that consumption exerts in each basin. Water consumption reduces the water available to support aquatic ecosystems and increases the impact of dry conditions on biodiversity. During times of low flow, there is increased pressure on aquatic ecosystems as water resources become scarce. During periods of reduced rainfall, most of the available water is extracted to supply domestic, industrial and agricultural needs. In some cases, it is likely that too much water is being taken out of many of Victoria's rivers, wetlands and aguifers. Indicator WQ:11 (Proportion of bodies of water with good ambient water quality) finds that only 26% of the river basins assessed from 2010 to 2017 were rated as having good water quality.

The data for this indicator is based on the five years of data (2011–12 to 2015–16) available since SoE 2013. The volume of water leaving Victorian basins peaked in 2011–12 (approximately 26,700,000 ML), and progressively declined across the reporting period, with the lowest volume leaving Victorian basins observed in 2015–16 (approximately 10,600,000 ML). As a percentage of total inflow volume, the water reaching the basin outlets was reasonably consistent during the most recent five years of data, with a peak of 83% reaching the basin outlets in 2011–12 compared to a low of 75% in 2013-14.

The basins that experienced the lowest proportions of water leaving the basin as a percentage of total flows in 2015–16 were the Avoca (0%), Wimmera (7%), Moorabool (14%), Werribee (25%), Loddon (29%), and Maribyrnong (30%) basins. This indicates that consumption is exerting more pressure on aquatic ecosystems in these basins. The proportion of annual flows leaving the basin in 2015–16 was more than 90% in eight basins, predominantly in the south of the state, where demand is low. A similar pattern was evident in previous years across the reporting period. The East Gippsland and Snowy basins generally recorded the highest proportion of total flows leaving their basins, while the Avoca, Wimmera, Loddon, Moorabool and Werribee basins recorded the lowest proportions.

The volume of surface water taken under entitlements has been reasonably consistent since 2011–12 (Figure WR.12), with greater variability occurring earlier in the century. In 2015-16, 61% of the total volume of surface-water entitlements was diverted for consumptive use. The majority (87%) of diverted surface water occurred under bulk entitlement in 2015–16. The Murray and Goulburn basins accounted for 73% of Victoria's surfacewater bulk entitlements and volumes taken in 2015-16.

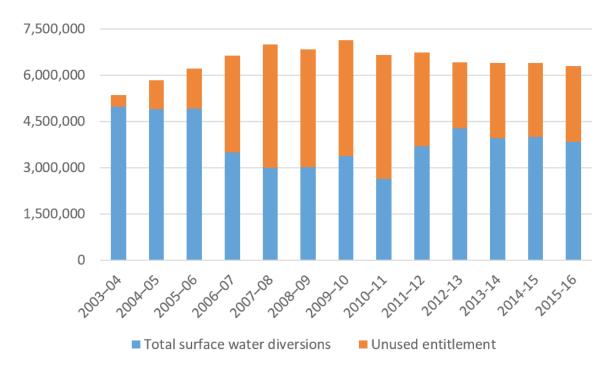
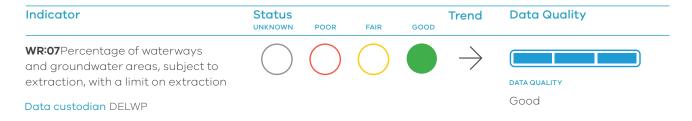


Figure WR.12 Total surface-water diversions and unused entitlements (ML) from 2003–04 to 2015–16

(Data source: DELWP, 2018)

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Surface-water entitlements are used for many different purposes, but they can be broadly classified according to the following end-uses of water:

- irrigation (agriculture)
- domestic and stock (rural household use and stock watering)
- urban (town water supply for households and businesses) and commercial (major nonagricultural water use)
- power generation (a separate category, due to the water-intensive nature of its operations).51

Irrigation continues to be the largest consumptive use of surface water in the state, comprising 78% of all water taken from 2011-12 to 2015-16 (Figure WR.13). Urban and commercial use represented 16% of all surface-water consumptive use over the same period, followed by domestic/stock and power generation uses.

The volume of water taken for consumptive use under Victorian surface-water entitlements between 2011-12 and 2015-16 peaked in 2012-13 at approximately 4,300 GL, and was lowest in 2011–12 at approximately 3,700 GL. The main driver of this decrease since 2012–13 has been a reduction in the use of surface water for irrigation (Figure WR.14).

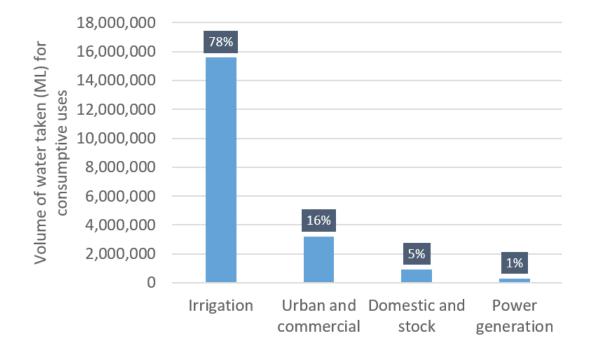


Figure WR.13 Volume of water (ML) taken for different consumptive uses under surface-water entitlements, Victoria, 2011-12 to 2015-16 (Data source: DELWP, 2018)

DELWP 2017, 'Victorian Water Accounts 2015-16', East Melbourne, VWA 2015-2016.pdf Accessed 3 December 2018

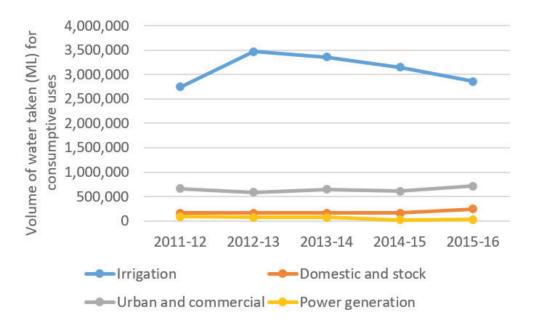


Figure WR.14 Volume (ML) of water taken for different consumptive uses under surface-water entitlements, Victoria, 2011–12 to 2015–16 (Data source: DELWP, 2018)

Sustainable diversion limits will operate from 2019 in the southern basin of the Murray-Darling Basin (in northern Victoria), replacing the current cap system in the southern basin. Sustainable diversion limits are the maximum long-term average quantities of water that can be taken each year for consumptive use from the Murray-Darling Basin's water resources. The Commonwealth's Water Act 2007 requires that the limits reflect an environmentally sustainable level of take. The final Murray-Darling Basin Plan, agreed to by New South Wales, Queensland, South Australia, Victoria and the Australian Capital Territory, sets a sustainable diversion limit for each catchment and aguifer in the basin, as well as an overall limit for the whole basin.52

A total of 73 cities and towns have a groundwater entitlement for primary or supplementary water supply. In 2015–16, 57 of these cities and towns recorded some level of groundwater extraction. The largest urban users were Portland, Sale and Geelong, each with extraction of between 1,800 ML and 1,900 ML.

Irrigation, commercial and salinity control was the largest consumptive use of groundwater in the state, comprising 76% of all water taken between 2012–13 and 2015–16 (Figure WR.15). There are 29,789 stock and domestic bores in Victoria. Domestic and stock use (48,349 ML) was estimated to account for about 13% of total groundwater use in 2015–16. The total volume of groundwater extracted for urban use was 2% of the total groundwater extracted over the reporting period.

DELWP, "Murray-Darling Basin Plan (Basin Plan)", East Melbourne, Victoria https://www.watervic.gov.au/murray-darling-basin/murray-darling-basin-plan Accessed 3 December 2018.

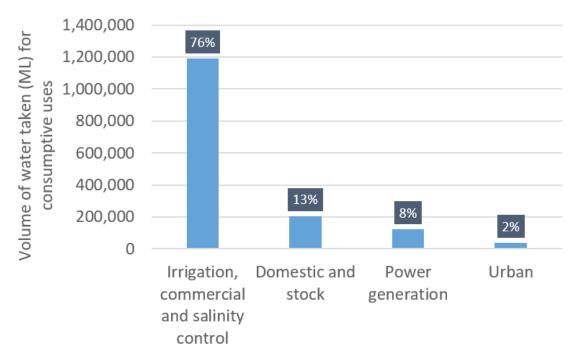


Figure WR.15 Volume of water (ML) taken for different consumptive uses by groundwater extraction, Victoria, 2012–13 to 2015–16

Note: Data by type of end-use was unavailable for 2011–12.

(Data source: DELWP, 2018)

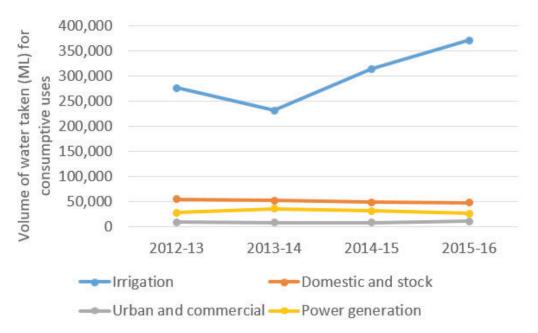


Figure WR.16 Volume (ML) of water taken for different consumptive uses by groundwater extraction, Victoria, 2012-13 to 2015-16

(Data source: DELWP, 2018)

Water Recycling

Victoria remains heavily reliant on surface-water sources, although groundwater and recycled water are becoming increasingly important resources. Water recycling uses surface water harvested for consumptive use and wastewater obtained from water recovery projects, such as wastewater treatment plants and irrigation systems. This recycled water is often used for non-human consumptive activities – for example, by councils to water parks, reserves and roadside trees.

Indicator	Status			Trend	Data Quality
	UNKNOWN POOF	R FAIR	GOOD		
WR:08 Water recycling				\supset	
Data custodian DELWP					Good

Recycled water is suitable for a wide range of uses. Increasing community expectations for more sustainable development has meant an increased interest in treating and recycling sewage or wastewater in Victoria in recent years. Wastewater is treated to a standard that is specified for non-drinking use. Once treated, the recycled water is delivered by water corporations to customers through a separate pipe system, which has been installed in some new developments.

The common uses of recycled water include:

- firefighting
- irrigating crops including those that can be eaten raw (such as lettuce)
- watering parks, gardens and sportsgrounds
- flushing toilets
- washing cars
- washing laundry.⁵³

Farmers and irrigators are the largest users of recycled water in the state.⁵⁴ This means demand for recycled water changes with the seasons and climate, increasing especially during droughts. Demand is likely to become more consistent as more new housing estates with dual-pipe systems are built in Melbourne's growth corridors.⁵⁵

Water authorities are also working with the water industry to find new ways to use recycled water, such as refilling natural underground reservoirs (aquifers) that are overused or have poor-quality water. ⁵⁶ Victoria does not currently recycle water for drinking.

The assessment for this indicator is based on data for 2011–12 to 2015–16. The total volume of wastewater produced in Victoria peaked in 2011–12 at 473,602 ML and was relatively consistent over the reporting period. Approximately 60 to 70% of all wastewater produced in Victoria is discharged to the ocean each year, while up to 20% may be discharged to the environment each year. The remaining wastewater produced in Victoria is recycled.

^{53.} Melbourne Water Corporation, 'Recycled water', Melbourne, Victoria https://www.melbournewater.com.au/community-and-education/about-our-water/recycled-water Accessed 3 December 2018.

^{54.} Ibid 55. Ibid

^{56.} Ibi

The volume of water recycled in Melbourne in 2015-16 (defined as water treated in the Bunyip, Werribee and Yarra basins) was 39,583 ML, representing 12% of the total wastewater produced in Melbourne. The percentage of recycled water was higher outside Melbourne, where weather conditions, the availability of land and access to potential purchasers (such as agricultural producers) are more favourable. Excluding the wastewater recycled in Melbourne, the remainder of the state recycled 31% (or 37,032 ML) of the wastewater available for re-use in 2015-16.

Figure WR.17 shows the trend in recycled water over the reporting period. The percentage of wastewater recycled from the total wastewater produced in the state varied from 14% to 18% over the reporting period, and the volume of wastewater recycled peaked in 2015-16 at 95,600 ML (Figure WR.17). Increasing the volume and percentage of wastewater recycled will help tackle the water supply shortfall discussed in indicator WR:01 (Water resources and storage trends).

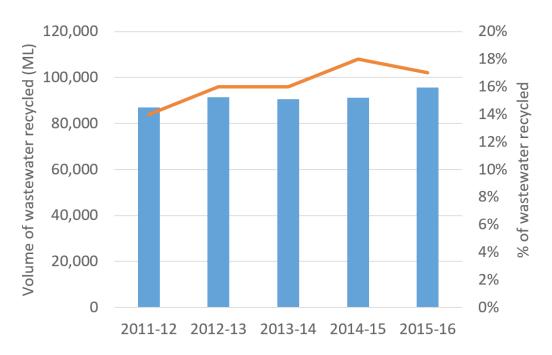


Figure WR.17 Wastewater recycling in Victoria, 2011–12 to 2015–16 (Data source: DELWP, 2018)

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Agriculture accounted for 41% of the end-use of recycled water across the reporting period. 'Within treatment processes' and 'beneficial allocations' accounted for 20% and 19% respectively. The percentage of recycled water for retail use and urban/industrial use increased. In 2015–16, the use of recycled water as a beneficial allocation decreased markedly, possibly due to a growing market for recycled water for retail, urban and industrial uses.

Beneficial allocation is defined by the Essential Services Commission as treated effluent discharged to a waterway for recognised environmental purposes (as prescribed by Environment Protection Authority Victoria). The process is positive for the environment; however, it is better to offset the extraction done in the first place rather than contribute back to the water cycle some of what has been taken out elsewhere.

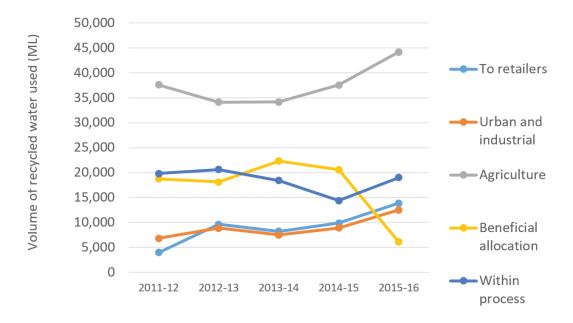


Figure WR.18 End-use of recycled water, 2011–12 to 2015–16 (Data source: DELWP, 2018)

Essential Services Commission 2018, Water Performance Indicator Definitions', Melbourne, Victoria https://www.esc.vic.gov.au/sites/default/files/documents/water-performance-indicator-definitions.pdf Accessed 3 December 2018.

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Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
WR:09 Percentage of agricultural land with approved irrigation					?	
Data Custodian CMAs						DATA QUALITY (need data on the total area of irrigated POOT land and the area of irrigated land that needs improved irrigation)

Irrigated agriculture is responsible for 78% of the state's surface-water consumption and contributes \$4.2 billion or 30% of Victoria's total gross value of \$14 billion for agricultural production.58 (For more information see indicator WR:07 Percentage of waterways and groundwater areas, subject to water extraction, with a limit on extraction).

The sector's strong influence on water resources means that improving the efficiency of irrigation equipment on agricultural land can significantly benefit the environment, by increasing water storage volumes and enhancing flow regimes.

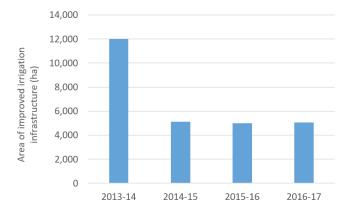


Figure WR.19 Area (ha) of Victorian land with improved irrigation infrastructure (Data source: CMAs, 2018)

The area of agricultural land with improved irrigation systems has been reported annually in CMA Actions and Achievements reports since 2013-14.59,60,61,62 This output records the area where irrigation infrastructure has been installed, modified or maintained. 63 Approximately 27,000 hectares of agricultural land was upgraded with improved irrigation from 2013-14 to 2016-17 (Figure WR.19) – less than 3% of Victoria's total area of irrigated agriculture. More than 90% of the irrigation infrastructure improvements were in the Goulburn Broken catchment.

These results indicate an improvement in irrigation efficiency. However, it is unclear how much agricultural land uses unsatisfactory irrigation systems. The data on improvements to irrigated agriculture is not coordinated between programs, or captured by category to determine what the improvements were (for example, channel-lining or improved cropping cycles). Such detail would provide insight to methods and inform future approaches.

Victorian Catchment Management Authorities 2017, 'Actions & Achievements Report 2016-17', Corangamite CMA, East Gippsland CMA, Glenelg Hopkins CMA, Goulburn Broken CMA, Mallee CMA, North Central CMA, North East CMA, Port Phillip and Westernport CMA, West Gippsland CMA, Wimmera CMA, Colac, Bairnsdal Hamilton, Shepparton, Irymple, Huntly, Wodonga, Frankston, Traralgon, Horsham, Victoria.
Victorian Catchment Management Authorities 2017, 'Actions &

Achievements Report 2015-16', Corangamite CMA, East Gippsland CMA, Glenelg Hopkins CMA, Goulburn Broken CMA, Mallee CMA, North Central CMA, North East CMA, Port Phillip and Westernport CMA, West Gippsland CMA, Wimmera CMA, Colac, Bairnsdale, Hamilton, Shepparton, Irymple, Huntly, Wodonga, Frankston, Traralgon, Horsham, Victoria.

Victorian Catchment Management Authorities 2015, 'Actions & Achievements Report 2014-15', Corangamite CMA, East Gippsland CMA, Glenelg Hopkins CMA, Goulburn Broken CMA, Mallee CMA, North Central CMA, North East CMA, Port Phillip and Westernport CMA, West Gippsland CMA, Wimmera CMA, Colac, Bairnsdale Hamilton, Shepparton, Irymple, Huntly, Wodonga, Frankston, Traralgon, Horsham, Victoria.

Victorian Catchment Management Authorities 2014, 'Actions & Achievements Report 2013-14', Corangamite CMA, East Gippsland CMA, Glenelg Hopkins CMA, Goulburn Broken CMA, Mallee CMA, North Central CMA, North East CMA, Port Phillip and Westernport CMA, West Gippsland CMA, Wimmera CMA, Colac, Bairnsdale, Hamilton, Shepparton, Irymple, Huntly, Wodonga, Frankston, Traralgon, Horsham, Victoria.

DELWP 2015, 'DELWP Output data standards', East Melbourne, Victoria https://www.wa Accessed 3 December 2018

Australian Bureau of Statistics 2018, '4610 0 55 008 - Gross Value of Irrigated Agricultural Production, 2016-17', Canberra, Australia https://doi.org/10.1016/j.com/pdf/ tures12016-17?OpenDocument Accessed 3 December 2018.

Groundwater

Groundwater levels are greatly affected by climate trends, with periods of flood and drought influencing groundwater recharge and extraction.

Indicator	Status	POOR	FAIR	GOOD	Trend	Data Quality
WR:10 Groundwater ecosystems						
		\bigcup		\bigcup		
						DATA QUALITY
Data Custodian None						Poor (no data available to provide a status or trend assessment)

Groundwater is often connected to rivers and wetlands, and most rivers derive baseflow from groundwater, but the significance of baseflow to overall flow levels varies significantly in space and time. This connectivity means that groundwater is important for maintaining the health of rivers, floodplain wetlands and other groundwater-dependent ecosystems.⁶⁴

Salinisation is a direct threat to groundwater ecosystems, with a wide range of plants and animals susceptible to changes in salinity. The health of livestock can be affected, reducing agricultural productivity. Pollutant contamination and groundwater extractions can also have an effect on groundwater-dependent ecosystems.

In SoE 2013, fewer than 10 flora and fauna species were identified as being affected by a decline in groundwater quality. ⁶⁵ No data is available to confirm whether or not this number has changed significantly in the past five years.

Commissioner for Environmental Sustainability 2013, 'State of the Environment report 2013', Melbourne, Victoria https://www.ces.vic.gov.au/sites/default/files/publication-documents/2013%20SoE%20report%20full.pdf Accessed 3 December 2018.

^{65.} Ibio

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Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
WR:11 Groundwater quality					\rightarrow	
Data Custodian DELWP			n Victoria ia and Fai			DATA QUALITY Fair (no trends can be determined from private bores)

Salinity is the primary groundwater quality parameter measured across the state, with data collected from private and state observation bores. While this indicator focuses on salinity, other pollutants can be found in groundwater, particularly in urban and industrial areas. Groundwater salinity is influenced by current and past climates, landscape and human activities. Under natural conditions, changes in groundwater salinity occur very slowly due to processes such as changing sea-water levels and evapotranspiration (evaporation from the soil and other surfaces and transpiration from plants). However, more rapid changes may occur due to human activities such as groundwater extraction and irrigation.

Across Victoria, groundwater salinity generally reduces from west to east, with a peak in the north-west of the state and minimums in the alpine region and far-east of the state (Figure WR.20).

The watertable in the north-west of the state has high natural salinity. Groundwater in this part of the state typically resides in the aquifer for long periods, providing more opportunity for salts to become concentrated. In addition, there are fewer sources of fresh water to recharge the aquifer due to lower rainfall.

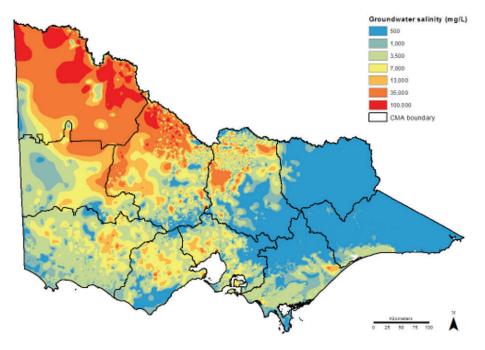


Figure WR.20 Baseline watertable salinity in Victoria (Data source: DELWP, 2018)

The Great Dividing Range of central and eastern Victoria has fresh groundwater. There is typically more rainfall in these areas, providing more recharge to the aquifers. Groundwater is stored in the aquifer for short periods before discharging to streams and wetlands.

In other parts of the state, local climate and landscape conditions influence variable watertable salinity.

There are 12 Groundwater Management Units (GMUs) where salinity is actively monitored through the state observation bore network. The salinity trend for bores with data for groundwater quality is mapped in Figure WR.21. The long-term trends in groundwater salinity are stable in most observation bores, meaning groundwater salinity has remained relatively consistent during the reporting period. In some of the observation bores, the trend is 'stable with fluctuations', which means groundwater quality has risen or fallen during

the monitoring period, but remains stable overall. Sharp changes in quality may be the result of human activities (such as extraction or land-use change) influencing water in the aquifer. However, in some coastal aquifers, natural variation in salinity may occur due to ocean tides.

In addition to this monitoring, Rural Water
Corporations collect groundwater samples from
private bores in other groundwater-use areas. This
data can identify high levels of salinity. However,
it is difficult to identify significant trends due
to the spatial and temporal variation of these
measurements.

Groundwater Quality Restricted Use Zones are areas where there has been historical groundwater pollution from industrial or other activities. EPA Victoria has made this information available via an interactive web tool.⁶⁶

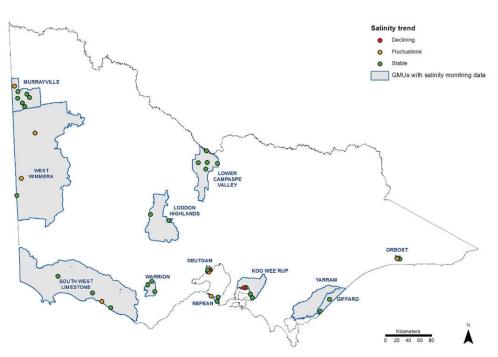


Figure WR.21 Groundwater salinity trend in GMUs (Data source: DELWP, 2018)

EPA, 'Map of groundwater quality restricted use zones in Victoria', Carlton, Melbourne https://www.epa.vic.gov.au/your-environment/land-and-groundwater/groundwater-pollution/ggruz-map Accessed 3 December 2018.

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Indicator	Status				Trend	Dat	a Quality
	UNKNOWN	POOR	FAIR	GOOD			
WR:12 Groundwater levels					\rightarrow		
					allow aquifers.		QUALITY
Data Custodian DELWP	В	asin and no	ting (lower o rthern regio Western Por	(data not available across the state)			

Groundwater levels are an indicator of groundwater condition, as they reflect overall changes in the water balance. Trends in groundwater levels can be used to monitor the impact of climate, and human activities such as groundwater extraction and land-use change. Groundwater levels respond to changes in climate, rising or falling during periods of high or low rainfall. When groundwater is extracted, water levels decline around the area of pumping.

In GMUs, licensed extractions can be restricted if water levels decline below the management limits in accordance with the management plan. Table WR.4 shows the seasonal allocations for the four GMUs where allocations were restricted during the reporting period.

Shallow aquifers respond more rapidly to climate and are expected to recover quickly after rainfall events. Declines in shallow watertables can impact environmental features such as waterways and vegetation. Groundwater levels in shallow GMUs have mostly remained stable in the reporting period, except for a small number of areas where declines were observed. Two of these areas, Loddon Highlands and Duetgam Water Supply Protection Areas (WSPAs), have restrictions on allocations.

Table WR.4 Restrictions on allocations in GMUs

	Seasonal allocations (%)							
GMU	2012-13	2013-14	2014-15	2015-16				
Katunga WSPA	70	70	70	70				
Loddon Highlands WSPA (Newlyn zone)	100	100	75	75				
West Wimmera GMA – Neuarpur (Subzone 1)	92	88	84	80				
Deutgam WSPA	100	100	100	50				

Note: WSPA denotes a Water Supply Protection Area

(Data source: DELWP, 2018)

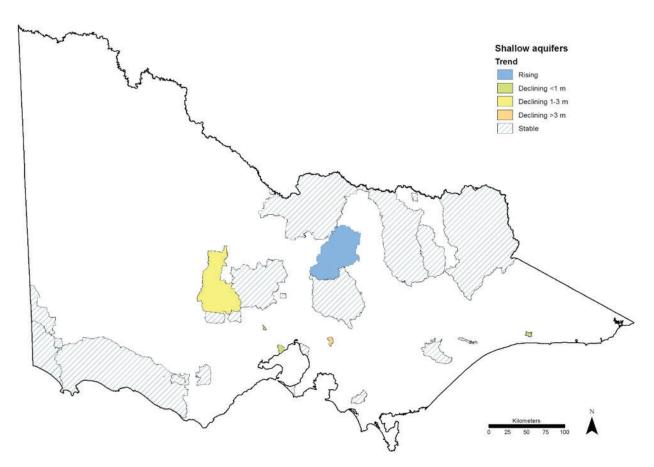


Figure WR.22 Groundwater-level trends in shallow-aquifer GMUs (Data source: DELWP, 2018)

Deep aquifers have a slower response time to changes in climate and are often disconnected from shallow groundwater and waterways.

Groundwater in deep aquifers is under pressure and experiences a greater water-level decline due to extractions. Declines in deep-groundwater levels generally have little or no impact on environmental features at the surface.

In southern Victoria, declines in lower aquifers related to mining activities are occurring in the Gippsland Basin. Smaller declines have also been observed in confined aquifers around Western Port and the Otway Ranges.

In northern Victoria, groundwater levels have declined in recent years due to periods of low rainfall and groundwater extractions.

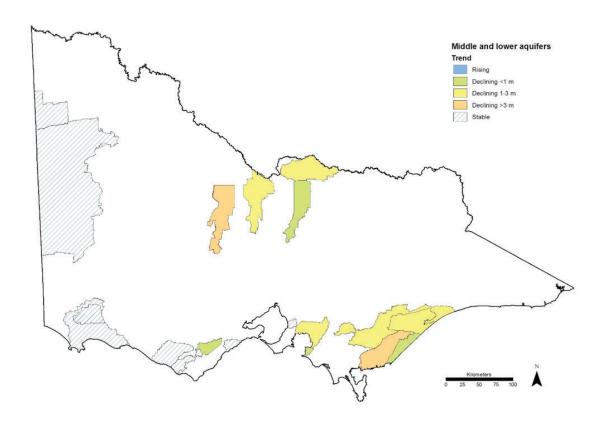


Figure WR.23 Groundwater-level trends in middle and lower aquifer GMUs (Data source: DELWP, 2018)

DELWP monitors water levels in more than 1,500 observation bores across the state. Approximately 200 sites are now fitted with telemetry equipment to collect hourly water-level data. Telemetered data enables real-time data access and will

provide greater insight to groundwater-level condition and trends, which can be reported in future SoEs. An example of hourly telemetered water-level data is provided in Figure WR.24, which compares the new dataset with manual readings that are collected quarterly.

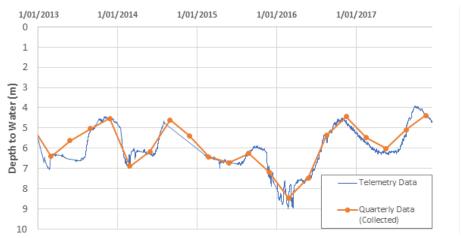


Figure WR.24 Example of telemetered hourly groundwater-level data and quarterly (manual) data for a bore (bore ID 62085)

(Data source: DELWP, 2018)

SCIENTIFIC ASSESSMENTS PART III Water Resources

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
WR:13 Groundwater harvested for consumptive use					\rightarrow	
Data Custodian DELWP						data quality Good

Groundwater extractions can influence groundwater quality and levels. Therefore, data about licensed groundwater use is a good indicator of where overall groundwater condition is under pressure. However, licensed extraction can also be greatest where groundwater quality and accessibility are good, so extraction can only partially explain groundwater quality. For further discussion about groundwater consumption, see indicator WR:07 (Percentage of waterways and groundwater areas, subject to water extraction, with a limit on extraction).

Average licensed groundwater use is 30% of the total entitlement in GMUs. During prolonged dry periods such as the millennium drought, average groundwater use increased to approximately 50% of entitlement.

Nearly half of the state's licensed groundwater use occurs in northern Victoria (Table WR.5). The other regions with large extraction volumes are Gippsland, and the south-west of the state. Licensed groundwater use in the Wimmera-Mallee is relatively low; however, extraction can be significant in localised extraction areas.

Table WR.5 Licensed groundwater use across Victoria

Region of Victoria	Percentage of Victoria's licensed use (%)
Northern	44
South-east	27
South-west	21
North-west	8

(Data source: DELWP)

Ongoing research and analysis is required to determine appropriate extraction limits.

Future Focus

Improve future water-resource assessments and decision-making

Two significant issues that emerge from the Water Resources chapter are: water-supply shortfalls for Victoria are expected to occur due to a drying climate and population growth: that there is an absence of detailed knowledge on how the environmental water reserve and the allocation of water for consumptive purposes is affecting waterway health.

The Water Act 1989 was amended in 2005 with a requirement for Victoria to complete a Long-Term Water Resource Assessment (LTWRA) every 15 years.⁶⁷ The LTWRA is action 8.6 of the Water for Victoria plan, and the first LTWRA was undertaken in 2018.68, 69, 70 It is anticipated that it will be

A LTWRA must identify whether either or both of the following has occurred:

- there has been any decline in the long-term availability of surface water or groundwater (and whether the burden of decline has fallen disproportionately on the environmental water reserve or on the allocation of water for consumptive purposes)71
- 2. there has been any deterioration in waterway health for reasons related to flow.72,73

There is an opportunity to improve future water-resource decision-making if the evidence base established by the current LTWRA is used to develop metrics for water availability and ecosystem health. These metrics would include corresponding thresholds that would determine actions required when thresholds are crossed.

Given the significant changes to water resources, water quality, climate and population that can occur in a 15-year period, more frequent LTWRAs are likely to be required to report on these metrics and thresholds, to ensure environmental values and the health of aquatic ecosystems are being preserved.

Recommendation 11: That DELWP use the current LTWRA to identify metrics for monitoring the condition of, and risks to, Victoria's water resources and waterway health for reasons related to flow, and commit to long-term monitoring. Complementary thresholds would also be established for these metrics, and actions determined for circumstances when thresholds are crossed. Further, in a changing climate, it is recommended that DELWP review the 15year period between LTWRAs, as more frequent assessments may be required to maintain ecosystem health and function.

Office of the Chief Parliamentary Counsel Victoria 1989, 'Water Act 1989', Melbourne, Victoria, http://www.legisla DDE300B846FED9C7CA257616000A3571/F8DBB7F6417A03EDCA257

DELWP 2016, 'Water for Victoria Water Plan', Melbourne, Victoria 68.

DELWP, 'Assessment process: Long-Term Water Resource Assessment', Melbourne, Victoria https

DELWP, 'Long-Term Water Resource Assessment', Melbourne, Victoria

DELWP, 'Long-Term Water Resource Assessment', Melbourne, Victoria

Office of the Chief Parliamentary Counsel Victoria 1989, 'Water Act 1989', Melbourne, Victoria, http://www.legisle

DELWP, 'Long-Term Water Resource Assessment', Melbourne, Victoria LTWRA-General-Fact-Sheet.docx.

Accounting for the Environment

Under the System of Environmental-Economic Accounting, there are water resources accounts, along with water quality accounts and water emissions accounts (discussed in the Water Quality chapter).

Water resources accounts provide a framework to make explicit the links between the use of water and economic activity – both the contribution of water to the economy and the impact of the economy on water resources.

Water resources accounts typically include physical supply and use tables for water, and a water asset account. The physical supply and use tables show the amount of water extracted from the environment, how this flows through the economy, and the volumes that are returned to the environment (such as the discharges of treated sewage water). The water asset account shows the amount of water occurring in the environment, including artificial reservoirs, inflows from rainfall and upstream sources, and the amount extracted from the environment for use.

Water accounting is one of the most developed and applied areas of environmental-economic accounting. There are two existing Australian water resources accounts – the Australian Bureau of Statistics (ABS) Water Account and the BoM National Water Account.

The ABS Water Account is produced annually and presents information on the physical and monetary supply and use of water in the economy – nationally, and at a state and territory level. The water resource that is accounted for is the volume of fresh water extracted from the environment for consumption and production, and the water returned to the environment or discharged to sewage treatments. The accounts also outline who uses the water (such as households or industries) at a state level.

BoM's annual National Water Account reports available water resources at a national and regional level in megalitres, but not in monetary terms. This complements the ABS accounts, which report on water supply and use within the economy.

Victorian Water Accounts are published by DELWP each year and focus on water availability and use across Victoria at bulk-supply level.

Water supply and use accounts that show water use by different industries and sectors can be compared with economic activity to track patterns of use and efficiency over time. They could also be used to evaluate the success of government or community initiatives to improve the efficiency and productivity of water use in different industries and sectors.

Water resources accounts could be linked to ecosystem service accounts for water supply and water filtration (for example, by forest ecosystem assets) to give an integrated picture of the linkages between ecosystems and the water resources available for use in the economy. Linking water and ecosystem accounts can also help to track the impact of the economy on the environment due to water extraction. Extraction of water can affect the condition of ecosystem assets (such as wetlands), which impacts on their ability to produce ecosystem services that support economic activity and wellbeing (such as recreation and tourism).



Water Quality

This chapter includes assessments of Victoria's surface-water quality, occurrence of algal blooms, reported inland water-pollution incidents and volume of sewage discharged to surface waters. Indicators for groundwater quality are included in the Water Resources chapter, and indicators associated with marine-water quality are included in the Marine and Coastal Environments chapter.

Background

Water quality is fundamental to the ecosystem services that inland waters provide, such as drinking water, cycling of nutrients, maintenance of biodiversity, and recreational and cultural opportunities. Poor water quality has serious implications for the ecological health of inland waters, biodiversity, and human and livestock health.

Water-quality pollution generally arises from point-source discharges (directly from industry and treatment plants) or diffuse sources (runoff from catchments). Regulatory improvements have reduced point-source water pollution. Diffuse sources, such as urban stormwater, are now the most significant contributor to pollution of Melbourne's rivers, creeks and wetlands. The projected increase in extreme rainfall events in Victoria is highly likely to amplify the effects of urban stormwater pollution unless practical solutions are implemented.

The main water-quality issues for Victoria have traditionally been salinity, turbidity, nitrogen and phosphorus. At a state and national level, these variables are considered the most significant river contaminants. However, there are numerous other variables that contribute to water quality, such as pH, pesticides, heavy metals and temperature, which may have local or regional significance. Water quality is also affected by interactions between these components. For example, salinity and temperature both affect the saturation concentration of dissolved oxygen.

When SoE 2013 was issued, the Department of Environment, Land, Water and Planning (DELWP) had not analysed the raw monitoring data that had been collected, and was unable to provide a statewide assessment of water quality. Consequently, SoE 2013 contained only a limited update of water quality from SoE 2008. The 2008 assessment showed that water quality was generally poor in much of Victoria, particularly in Victoria's lowlands and in the west of the state.

There has been an increased focus on the water quality sector since 2013. DELWP conducted an internal audit of its water-quality monitoring programs in January 2015, prior to a Victorian Auditor-General's Office (VAGO) audit into Victorian water-resource monitoring, completed in May 2016.

The VAGO audit made three recommendations in response to a central finding that, although some individual programs are coordinated and governed well, oversight of the individual long-term waterquality monitoring programs in the Port Phillip Bay and Western Port region is deficient. The deficiency was due to inadequate coordination across all programs among the three relevant agencies: DELWP, Melbourne Water and Environment Protection Authority Victoria (EPA Victoria). The issue is less prevalent in the nine other catchments where DELWP has the clear coordination role. Specific findings from the VAGO audit included agencies not having a formal cooperative approach to monitoring, reporting and evaluating the individual monitoring programs in the region, and agencies not sharing and using data efficiently to meet reporting needs.1 The DELWP and VAGO audits informed the Victorian Government's water plan, Water for Victoria, released in October 2016.2

VAGO 2016, 'Monitoring Victoria's Water Resources', Melbourne, es.pdf Accessed 3 December 2018.

DELWP 2018, 'Water for Victoria', East Melbourne, Victoria https:// strategy2.pdf Accessed 3 December 2018.

Other organisations that help to manage water quality are Catchment Management Authorities (CMAs), which develop and implement waterway management strategies, and EPA Victoria, which implements the State Environment Protection Policy (Waters) (SEPP (Waters)) and regulates water quality.

Victoria also contributed to the development of the Basin Salinity Management 2030 strategy, which is responding to the environmental, social and economic risks posed by salinity in the Murray-Darling Basin.3

Water-quality monitoring has been a greater focus of state and departmental strategies since SoE 2013. Consequently, SoE 2018 is a significant update to water-quality information, due to the trend data that has been supplied by DELWP on a range of quality indicators measured at approximately 80 sites.

A warmer climate will lead to higher water temperatures, affecting the distribution of many aquatic species. Increased temperatures also have water-quality implications, including reduced concentrations of dissolved oxygen and therefore a potential increase in algal blooms. Increased bushfires will also impact on water quality and riparian vegetation.

Critical challenges facing Victoria's management of water-quality impacts now and in the future include:

- balancing the needs of catchment and waterway health with human and agricultural water consumption needs
- managing urban growth and its impact on urban waterway health
- ensuring that long-term water-quality monitoring is coordinated and shared among the lead agencies (a key recommendation of the 2016 VAGO audit)

- maintaining long-term water-quality monitoring data so that it is easily accessible and suitable for informing policy and strategy development
- ensuring a coordinated approach to 'citizen science' (which incorporates public participation in research) in the water-quality sector. Citizen science programs are more prevalent in water-quality than in other sectors. Ensuring that lead agencies design and target programs with a similar level of rigour will help to maximise the value of community participation.
- identifying strategies to tackle the likely increase in stormwater pollution incidents associated with more frequent and intense rainfall events.
- mitigating against:
 - 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 individual waterquality stressors, including nutrients, sediments, toxicants and pathogens, exceed objectives.

Note that this chapter refers to surface water only: groundwater quality is covered in the Water Resources chapter.

Murray-Darling Basin Ministerial Council 2015, 'Basin Salinity Management 2030 (BSM2030)', Canberra, Australia https://mdba.gov.au/sites/default/files/pubs/D16-34851-basin_s management strategy BSM2030.pdf Accessed 3 December 2018.

Current Victorian Government Settings: Legislation, Policy, Programs

In October 2016, the Victorian Government released *Water for Victoria*, a plan for the management of Victoria's water resources, now and in the future.⁴

The plan includes commitments to improve Victoria's existing waterway monitoring programs, invest in community partnerships and citizenscience initiatives, strengthen integrated catchment management, and deliver a new SEPP to protect water quality.

The plan invests \$222 million for catchment and waterway health, to better balance the needs of the environment with water consumption needs. This investment includes water for the environment, riparian restoration and other programs.

The government has also established a series of Integrated Water Management Forums across the state. In these forums, the water sector and the community work together to plan, manage and deliver water in towns and cities.

To help manage urban growth and its impact on urban waterway health, the government has developed a range of water policies, including Water for Victoria, the Yarra River Action Plan, the Plan Melbourne Implementation Plan and the Port Phillip Bay Environmental Management Plan.

Melbourne Water's responsibility is to create longterm plans that ensure the region's waterways are healthy, liveable and accessible. Melbourne Water's *Healthy Waterways Strategy 2018* is intended to address future urban waterway management needs.⁵ As part of the Melbourne Urban Stormwater Institutional Arrangements Review, DELWP is reviewing the arrangements between Melbourne Water and local government authorities to clarify responsibilities for urban stormwater risk management, related assets and services in the Melbourne metropolitan area. The government has also established the Improving Stormwater Management Advisory Committee to provide independent advice on planning and development controls for improving stormwater management and strengthening the links between water management and urban planning.

The 2003 SEPP (WoV) was the government's primary water-quality policy. However, it did not provide clarity on the roles and responsibilities of the lead agencies involved in long-term water-quality monitoring. The government committed to ensuring that the water-quality standards and objectives that are the basis of policies reflect best-available science, and provide clear and relevant standards and obligations to protect and improve the health of Victoria's water environments. To do this, the government has updated and merged the Waters of Victoria SEPP and the Groundwaters of Victoria SEPP, to create the new SEPP (Waters).

DELWP 2018, 'Water for Victoria', East Melbourne, Victoria https://www.watervic.gov.au/ data/assets/pdf file/0030/58827/Water-Plan strategy2.pdf Accessed 3 December 2018.

Melbourne Water Corporation 2018, 'Healthy Waterways Strategy 2018', Melbourne, Victoria https://www.melbournewater.com.au/media/6361/download Accessed 3 December 2018.

DELWP, 'Melbourne Urban Stormwater Institutional Arrangements Review', East Melbourne, Victoria https://www.water.vic.gov.au/managing-floodplains/stormwater-review Accessed 3 December 2018.

EPA, 'State Environment Protection Policy (Waters) review', Melbourne, Victoria https://www.epa.vic.gov.au/our-work/settingstandards/environmental-standards-reform/water Accessed 3 December 2018

EPA, 'Water-related policies', Melbourne, Victoria https://www.epa.vic.gov.au/about-us/legislation/water-legislation/water-related-policies
Accessed 3 December 2018.

Indicator Assessment

Legend

Status

N/A Not Applicable

The indicator assessment is based on future projections or the change in environmental condition and providing a status assessment is not applicable. Only a trend assessment is provided.



Unknown

Data is insufficient to make an assessment of status and trends.



condition is under significant stress, OR pressure is likely to have significant impact on environmental condition/ human health, OR inadequate protection of natural ecosystems and biodiversity is

Environmental



Environmental condition is neither positive or negative and may be variable across Victoria, OR pressure is likely to have limited impact on environmental condition/human health, OR moderate protection of natural ecosystems and biodiversity is evident.

Environmental condition is healthy across Victoria, OR pressure is likely to have negligible impact on environmental condition/ human health, OR comprehensive protection of natural ecosystems and biodiversity is evident.

Trend

N/A Not applicable

This indicator assessment is based on current environmental condition only and it is not applicable to provide a trend assessment. Only a status assessment is provided



Unclear



Deteriorating



Stable



Improving

Data quality



Evidence and consensus too low to make an assessment



Fair

Limited evidence or limited consensus



Adequate high-quality evidence and high level of consensus

WATER QUALITY

Summary

WQ:01 Occurrence of algal blooms

Region

Indicator

Victoria

Measures

Number of algal blooms (trigger level for reporting is when cyanobacteria in any water body exceed $0.2 \, \text{mm}^3/\text{L})$

Data custodian

DELWP

More than 100 algal blooms were reported in Victorian water bodies during 2017-18 and these blooms occurred throughout all Victorian regions. No data is available to report on trends in algal bloom occurrence.



Status









Trend

DATA QUALITY

Fair (due to the absence of suitable trend data)

Status Summary Trend UNKNOWN POOR FAIR GOOD Dissolved oxygen in Victorian rivers and Indicator streams for 2010-17 was rated as excellent in **WQ:02** Dissolved the east and central regions of the state, and oxygen good in the western Catchment Management concentration in Authority regions. rivers DATA QUALITY Region Good Victoria Measures % of sites that attained SEPP (WoV) water quality objectives Data custodian DELWP, Melbourne Water Indicator Salinity in Victorian rivers and streams for 2010-17 was rated as good or excellent in seven **WQ:03** Salinity catchments, fair in a further two and poor in concentrations in Poor in the Glenelg Hopkins Glenelg Hopkins. rivers catchment, Fair in the Wimmera and Port Phillip and Westernport Region catchments, Good in the other Victoria catchments Measures % of sites that attained SEPP DATA QUALITY (WoV) water quality Good objectives Data custodian DELWP, Melbourne Water Indicator There was a gradient for total nitrogen (2010-17) from excellent water quality in the WQ:04 Total nitrogen east deteriorating to poor and very poor water Good in the North East and East concentration in quality in Victoria's west and the urbanised rivers Gippsland catchments, Fair in catchment of the Port Phillip and Western Port. the Goulburn Broken and West Region Gippsland catchments, and Poor Victoria in other catchments. Unknown in Measures the Mallee catchment. % of sites that attained SEPP DATA QUALITY (WoV) water quality objectives Good

Data custodian DELWP, Melbourne

Water

Status Trend Summary GOOD POOR FAIR UNKNOWN Indicator There was a gradient for total phosphorus (2010-17) from excellent water quality in the far WQ:05 Total east of Victoria to very poor water quality in phosphorus Good in the East Gippsland the west of the state concentrations in catchment, Fair in the North East rivers and West Gippsland catchments, Region and Poor in other catchments. Unknown in the Mallee catchment. Victoria Measures % of sites that DATA QUALITY attained SEPP Good (WoV) water quality objectives Data custodian DELWP, Melbourne Water Indicator Turbidity in Victorian rivers and streams from 2010-17 was rated as moderate to very **WQ:06** Turbidity poor. The Mallee and Wimmera catchments levels in rivers Fair in the East Gippsland, were both ranked as very poor. Turbidity Region North East and Glenelg Hopkins has increased in recent times compared to Victoria historical data. catchments, and Poor in other catchments. Measures % of sites that attained SEPP (WoV) water quality DATA QUALITY objectives Good Data custodian DELWP, Melbourne Water Indicator Water quality with respect to pH in Victorian rivers and streams for 2010-17 was rated as **WQ:07** pH excellent across all catchment regions and Region river basins. Victoria DATA QUALITY Measures Good % of sites that attained SEPP (WoV) water quality objectives Data custodian DELWP, Melbourne Water

Summary **Status** Trend UNKNOWN POOR FAIR GOOD Indicator The current assessment suggests that water quality is generally better in the east of the **WQ:08** Proportion of state than in the central and western regions. bodies of water with 26% of all sites rated as having good or better good ambient water water quality for 2010-17, a reduction from 37% quality of sites for 2004-09. DATA QUALITY Region Good Victoria Measures % of river basins rated as having good or better water quality (as per the water quality component of the Index of Stream Condition calculations) Data custodian DELWP, Melbourne Water Indicator Data on water pollutants that are discharged from EPA Victoria's licensed sites was WQ:09 Volume of unavailable at a statewide level. Therefore, the sewage discharge status and trend assessments for this indicator to surface waters have been provided as unknown and unclear Region DATA QUALITY respectively. Victoria Poor (No data available to make Measures

Volumes of discharged pollutants

Data custodian

EPA Victoria

an assessment)

Indicator

WQ:10 Reported inland water pollution incidents

Region

Victoria Measures

Number of pollution reports

Data custodian

EPA Victoria

The number of water pollution reports received by EPA Victoria was stable from 2013-15 and then increased in 2016. From 2013-17 there was a 37% increase in water pollution reports.





DATA QUALITY

Fair (Data provided not linked to water bodies)

Algal Blooms

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
WQ:01 Occurrence of algal blooms					?	
						DATA QUALITY
Data Custodian DELWP						Fair (no suitable trend data)

An algal bloom is a rapid increase in the population of algae, often resulting in the discolouration of water from their pigments. In freshwater, the algae of greatest concern are cyanobacteria (blue-green algae).

Cyanobacteria are naturally present in Victoria's inland waters. Under certain conditions, cyanobacteria populations can increase, causing potentially toxic blooms. Low flows, combined with the availability of nutrients and higher water temperatures, have been identified as likely causes of algal blooms. SoE 2013 found high variability in algal bloom number and extent, to the point that it was not possible to determine any trends.⁹

Some species of blue-green algae can produce chemical compounds that can taint drinking water, often giving it a musty odour and taste. More significantly, some species can produce toxins that have serious health implications for humans and animals, including livestock, if they are consumed, inhaled or come into contact with skin. Even high levels of non-toxic algae can affect water quality and treatment through filter-clogging.

During the late 1980s and early 1990s there were widespread cyanobacteria blooms in several rivers in south-eastern Australia, most notably

a 1,000 km bloom along the Darling River. This prompted research that led to the conclusion that algal blooms, particularly of blue-green algae, were stimulated by high nutrient availability, and that phosphorus was the limiting nutrient. ¹² More recent studies have indicated that the conditions that stimulate algal growth to bloom proportion are more complex, and involve many site-based factors. Furthermore, nitrogen seems to play an equally important role as phosphorus in controlling the biomass of these freshwater blooms. ¹³

Once algal blooms exceed a certain level, they are reported in a coordinated database. The trigger level for reporting a cyanobacteria bloom is when cyanobacteria in any water body exceed 0.2 mm³/L. In 2017–18, 113 cyanobacteria blooms were reported, in water bodies throughout all Victorian regions. While algal blooms are more prevalent in the warmer months, they can occur in any season, and without warning. No data is available to report on trends in algal bloom occurrence.

Commissioner for Environmental Sustainability 2013, 'State of the Environment report 2013', Melbourne, Victoria https://www.ces.vic.gov.au/sites/default/files/publication-documents/2013%20SoE%20 report%20full.pdf Accessed 3 December 2018
 DELWP 2015, 'Blue-Green Algae Circular 2016-17', East Melbourne,

DELWP 2015, 'Blue-Green Algae Circular 2016-17', East Melbourne, Victoria https://www.watervic.gov.au/_dota/assets/word_doc/0033/65589/BGA-Circular-2016-17final_-docx_Accessed 3 December 2018

^{11.} Ibid

Oliver R, Hart B, Olley J, Grace M, Rees C, Caitcheon G 1999, 'The Darling River: Algal growth and the cycling and sources of nutrients', Murray-Darling Freshwater Research Centre.

Davis JR, Koop K 2006, 'Eutrophication in Australian rivers, reservoirs and estuaries—a southern hemisphere perspective on the science and its implications', *Hydrobiologia*, 559(1) pp. 23–76.

Aquatic Ecosystem Health

Healthy aquatic ecosystems depend on the quality of water for critical processes such as nutrient cycling, primary production and the creation of suitable habitats to support diverse communities of aquatic animals and plants.

Water quality is influenced by a range of factors, including:

- climate (patterns of rainfall and drought)
- land use (adjacent to waterways, but also in the catchment)
- water-resource use (extraction of water for drinking and agriculture, and discharge of stormwater and wastewater)
- ecosystem processes (such as water-sediment interactions and nutrient cycling)
- extreme events such as bushfires.

There are many aspects to water quality, including physical properties such as temperature and water clarity, concentrations of chemical components (such as salinity and dissolved oxygen) and biological processes such as algal growth.

The assessment of water quality in this report focuses on five water-quality indicators: dissolved oxygen, salinity (electrical conductivity), nutrients (total nitrogen and total phosphorus), water clarity (turbidity) and alkalinity (pH).

No statewide data was available for suspended solid concentrations in rivers, or for water temperature and chlorophyll-a concentrations in rivers. These indicators are generally less relevant for Victoria's water quality, although they can inform specific water-quality issues on localised scales. For example, suspended solids can indicate impacts, such as erosion, from localised to catchment scale. Chlorophyll-a can indicate the potential for algal blooms and fish kills.

Data collected from 2010 to 2017 was used to inform the water-quality assessment for indicators in this theme. This period spans a range of climatic conditions, from the wet years of 2010 and 2011, to the dry years of 2014 and 2015. This enables an assessment of water quality over a period that resembles the projected climate for Victoria: generally hotter and drier, but interspersed with more extreme rainfall events. Data was sourced from the Water Measurement Information System and Melbourne Water. 14,15,16 Most of the waterquality measurements were made on a monthly basis.

SEPP (WoV) provides water-quality objectives for Victorian surface waters. Measurements attain the objective are indicative of good conditions; measurements that do not attain the objective are a warning of potentially poor conditions. In this report, attainment of SEPP (WoV) objectives has been used as an indicator of the state of water quality across Victoria. The number of sites in a region attaining SEPP (WoV) objectives was used to complete the SoE status assessment (Figure WQ.1).17

Many of the figures in the Aquatic Ecosystem Health theme display the average number of monitoring sites per region over an assessment period from 2010 to 2017. An average has been used because the number of monitored sites in a region can change each year.

^{14.} DELWP, 'Water Measurement Information System', East Melbourne, Victoria http December 2018

Melbourne Water Corporation, 'Waterway water quality data', Melbourne, Victoria https vater-quality-data Accessed 3 December 2018.

Note that data from Melbourne Water sites was provided only as summary statistics for 2010 to 2015. Total 75th percentiles (2010 – 2017) were calculated by averaging the 75th percentiles of individual

Note that the SEPP (WoV) was the subject of a recent review and a new 2018 SEPP (Waters) has been released (https://engage.vic.gov.oseppwaters Accessed 3 December 2018). This SoE 2018 assessment of water quality, however, was completed before the new SEPP was approved and has used the previous (2003) policy. It should be noted that the water quality objectives for rivers and streams have not changed substantially between the old policy and the new policy.

SEPP (WoV) rating	SEPP (WoV) criteria	SoE status
Excellent	> 70 $\%$ of sites attained SEPP (WoV) water-quality objectives	Good
Good	51–70% of sites attained SEPP (WoV) water-quality objectives	Good
Moderate	31–50% of sites attained SEPP (WoV) water-quality objectives	Fair
Poor	11–30% of sites attained SEPP (WoV) water-quality objectives	Poor
Very Poor	< 10% of sites attained SEPP (WoV) water-quality objectives	Poor

Figure WQ.1 Matching the SEPP (WoV) ratings to the SoE status

SEPP (WoV) attainment across all catchments and years of monitoring from 2010 to 2017 shows that inland water quality for pH and dissolved oxygen is generally rated as excellent, and salinity is rated as good. However, nutrients (total nitrogen and phosphorus) and water clarity (turbidity) are generally rated as poor in Victoria's inland waters. (These important assessments are possible due to improved data availability since SoE 2013, and illustrate the value of DELWP investments to align data availability with SoE reporting.)

In addition to this analysis, water-quality report cards for the catchment waterways of Port Phillip Bay, Western Port and Gippsland Lakes are available online at the Yarra and Bay website.18

State Government of Victoria, 'Report Card 2016–2017', Melbourne, Accessed 3 December 2018.

Indicator	Status				Trend	Data Quality		
	UNKNOWN	POOR	FAIR	GOOD				
WQ:02 Dissolved oxygen concentration in rivers					\rightarrow			
						DATA QUALITY		
Data Custodian DELWP, Melbourne Water						Good		
Data Custodian DELWP, Melbourne Water						Good		

Biota that access oxygen from the water column, such as fish, tadpoles and macroinvertebrates, are highly susceptible to decreases in dissolved oxygen. Dissolved oxygen vary considerably over short periods and is influenced by temperature, salinity and biological activity. In most aquatic systems, dissolved oxygen follows a diurnal (daily) cycle, with a longer-term pattern that is balanced by diffusion of oxygen from the atmosphere and consumption of oxygen by biota. While the dissolved-oxygen requirements of fish species and different life-stages can vary significantly, mortality can occur at concentrations lower than 3 mg/L, which is only fractionally lower than the SEPP attainment value of greater than or equal to 3.5 mg/L.19

Dissolved oxygen in Victorian rivers and streams for 2010 to 2017 was rated as excellent in the east and central regions of the state, and good in the western CMA regions (Figure WQ.2). The only river basin that ranked lower than good was the Murray-Riverina, which includes the main stem of the Murray River, and reflects water quality not only in Victorian rivers, but that flowing in from New South Wales systems into the mid-Murray.

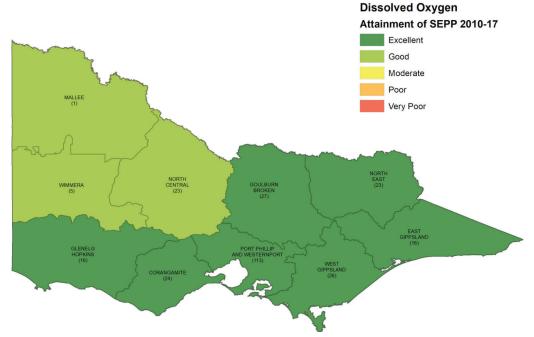


Figure WQ.2 SEPP (WoV) attainment of the dissolved oxygen threshold of ≥ 3.5 mg/L by CMA regions

Note: Numbers represent the average number of monitoring locations in each region used in the assessment. (Data source: DELWP, Melbourne Water, 2018)

Small K, Kopf RK, Watts RJ, Howitt J 2014, 'Hypoxia, blackwater and fish kills: experimental lethal oxygen thresholds in juvenile predatory lowland river fishes', PLoS One, 9(4).

Table WQ.1 Per cent attainment of SEPP (WoV) water-quality objectives for dissolved oxygen

CMA region (average number of sites)	2010	2011	2012	2013	2014	2015	2016	2017	All years
West Gippsland (27)	96	96	100	100	100	100	100	100	99
East Gippsland (17)	100	88	100	100	100	100	94	100	98
North East (24)	92	96	96	100	100	100	91	100	97
Glenelg Hopkins (16)	69	88	94	88	88	94	100	100	90
Corangamite (24)	67	75	88	83	83	83	79	75	79
Port Phillip & Western Port (114)	62	85	84	80	81	77	72	68	77
Goulburn Broken (27)	45	81	80	84	86	68	63	59	71
Mallee (1)	50	0	100	100	100				67
North Central (23)	38	55	77	87	75	71	64	71	67
Wimmera (5)	40	0	80	100	80	80	80	60	65

Note: Blank cells indicate no data available. The following cell colours in the table represent specific water quality ratings: dark green (excellent water quality), light green (good water quality), yellow (fair water quality), orange (poor water quality) and red (very poor water quality). (Data source: DELWP, Melbourne Water, 2018)

Dissolved oxygen was generally worse in 2010 and 2011 than in subsequent years (Table WQ.1). This is most likely the result of large floods in late 2010 and early 2011, which inundated large parts of dry floodplains where organic matter had accumulated during the millennium drought. Floodplain inundation mobilised the carbon stored on the floodplain, and secondary productivity was stimulated in the rivers, depleting the water column of oxygen and leading to 'blackwater' events and low dissolved-oxygen concentrations.²⁰ Fish kills were reported in several major rivers.²¹ More recently, heavy rainfall in the Wangaratta region in January 2018 caused a blackwater event in One Mile Creek. The rainfall increased catchment runoff into the creek; however, this runoff, which included leaf litter and other debris, was not flushed through due to dry conditions upstream. The organic material decayed, giving the water a black appearance, lowering the concentration of dissolved oxygen and causing stress to fish and other aquatic animals.22

Longer trends in dissolved oxygen show decreased dissolved oxygen in many river systems during drought years when water receded to residual pools and there was a lack of mixing. Data at longer-term monitoring sites is available from 1991, and shows variable trends in dissolved oxygen. This variability reflects both site-based factors, and the inherent difficulty in evaluating dissolved oxygen with spot measures. The diurnal variation in dissolved-oxygen concentrations is naturally large, so simple factors such as time of day, depth of sampling and fine-scale site attributes can obscure actual trends.

King AJ, Tonkin Z, Lieshcke J 2012, 'Short-term effects of a prolonged considerations for future events', Marine and Freshwater Research, 63(7), pp. 576-586

Small K, Kopf RK, Watts RJ, Howitt J 2014, 'Hypoxia, blackwater and fish kills: experimental lethal oxygen thresholds in juvenile predatory lowland river fishes', PLoS one, 9(4).

EPA. 'Blackwater event at One Mile Creek, Wangaratta', Carlton, Accessed 3 December 2018

Indicator	Status				Trend	Data Quality		
	UNKNOWN	POOR	FAIR	GOOD				
WQ:03 Salinity concentrations in rivers					\rightarrow			
	Poor	in the Glen	elg Hopkins	catchmen	t, Fair in	DATA QUALITY		
Data Custodian DELWP, Melbourne Water			nd Port Phill od in the ot	Good				

Salinity is a measure of the total concentration of inorganic salts in the water column. Electrical conductivity (the ability of water to conduct an electrical current) is typically used to measure salinity in waters where the concentration of salts is relatively low. Salinity is an important aspect of water quality and can have a profound effect on aquatic biota, either through direct toxicity or disruptions to ecosystem processes and functions.^{23,24} Animals and plants generally have a narrow salinity range they can tolerate for optimum growth and reproduction. Increased salinity in Australian freshwater systems can lead

- a reduction in the diversity of native fish, with eggs and larval stages more susceptible than adults in many instances
- decreased diversity and growth of freshwater aquatic and riparian vegetation
- reduced diversity of macroinvertebrate communities and negative impacts to frogs, particularly to eggs and tadpoles.25

Salinity in Victorian rivers and streams for the period 2010 to 2017 was rated as excellent in four catchments and good in a further three (Figure WQ.3). The urbanised rivers of the Port Phillip and Western Port catchment were ranked as moderate, with poorer salinity found in the Maribyrnong and Moorabool river basins. The far west of the state also had lower ratings for salinity, although in the case of the Wimmera catchment, this was based on data from only four sites. Salinity was rated as poor for the Glenelg Hopkins catchment, with most sites in its river basins not meeting the SEPP (WoV) salinity objectives.

Kefford BJ, Schäfer RB, Liess M, Goonan P, Metzeling L, Nugegoda D 2010, 'A similarity-index based method to estimate chemica concentration limits protective for ecological communities',

SEPP (WoV) attainment for salinity from 2010 to 2017 was generally consistent (Figure WQ.3). An assessment of longer-term trends in water quality indicated that while there had been increased salinity during the millennium drought of 1996 to 2010, increasing rainfall in recent years has led to decreased salinity in most river systems across the state.26

With respect to the six long-term indicator sites, salinity has decreased in the Broken, Barwon, Ovens, Latrobe and Yarra rivers from the historical period, 1991 to 2010, to the current period, 2011 to 2016, but increased in the Wimmera River. It is likely that the reduced salinity levels at most sites in recent years will have beneficial environmental outcomes in the river systems.27

The dominant factor influencing salinity at all sites was flow (water volume), with low flows in the Wimmera River in summer and during drought leading to increased salinity.²⁸ Rising groundwater levels can also affect salinity.

Some waterways are naturally more saline due to their geology. The new SEPP (Waters) guidelines, discussed earlier, have increased the target value of electrical conductivity in much of the Port Phillip and Western Port area, so waterways in that catchment will be more likely to meet the new SEPP (Waters) targets than the targets under the previous SEPP (WoV).

Environmental Toxicology and Chemistry, 29(9), pp. 2123-31. Schäfer RB, Bundschuh M, Rouch DA, Szöcs E, Peter C, Pettigrove V, Schulz R, Nugegoda D, Kefford BJ 2012, 'Effects of pesticide toxicity, salinity and other environmental variables on selected ecosystem functions in streams and the relevance for ecosystem services', Science of the Total Environment, 415, pp. 69–78.

Hart BT, Lake PS, Webb JA, Grace MR 2003, 'Ecological risk to aquatic systems from salinity increases', Australian Journal of Botany, 51(6), pp. 689-702

entia 2018, 'Victorian Water Quality Trends 1991-2016'

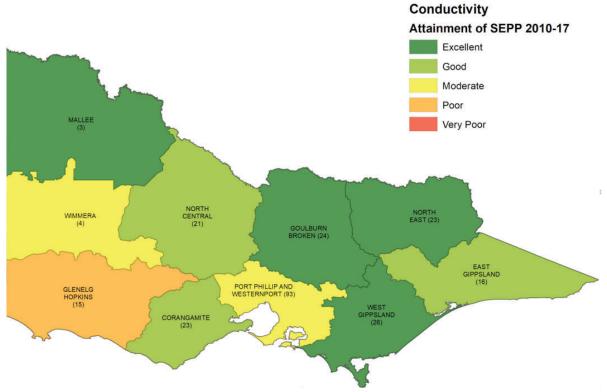


Figure WQ.3 SEPP (WoV) attainment of water-quality objectives for electrical conductivity (as an indicator of salinity) by CMA regions

Note: Numbers represent the average number of monitoring locations in each region used in the assessment.

(Data source: DELWP, Melbourne Water, 2018)

Table WQ.2 Per cent attainment of SEPP (WoV) water-quality objectives for electrical conductivity (as an indicator for salinity)

CMA region (average number of sites)	2010	2011	2012	2013	2014	2015	2016	2017	All years
Mallee (3)	100	100	100	100	100	100	100	100	100
North East (23)	92	96	100	96	96	91	96	96	95
Goulburn Broken (24)	93	95	95	90	92	91	73	76	88
West Gippsland (26)	81	78	85	74	81	72	72	72	77
North Central (21)	67	55	55	55	63	60	58	63	59
East Gippsland (17)	71	65	59	53	47	59	53	47	57
Corangamite (23)	57	50	63	55	59	63	55	50	56
Wimmera (4)	33	60	25		40	50		80	38
Port Phillip & Western Port (93)	35	41	37	33	20	26	28	26	33
Glenelg Hopkins (15)	21	19	25	20	20	21	21	19	21

Note: The following cell colours in the table represent specific water quality ratings: dark green (excellent water quality), light green (good water quality), yellow (fair water quality), orange (poor water quality) and red (very poor water quality).

(Data source: DELWP, Melbourne Water, 2018)

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
WQ:04 Total nitrogen concentration in rivers					\rightarrow	
	catchme	he North Eants, Fair in t	he Goulbu	rn Broken		DATA QUALITY Good
Data Custodian DELWP, Melbourne Water	in other c catchme	atchments nt.	. Unknown	in the Mall	ee	

Nutrients in aquatic ecosystems play a significant role in primary production, with nitrogen and phosphorus being two key nutrients in freshwater systems. Aquatic plants and phytoplankton take up nutrients in dissolved inorganic and organic forms. Measures of total nitrogen and total phosphorus include dissolved organic and inorganic particulate forms, as well as nutrients within the cells of phytoplankton and zooplankton. In the sediment, particulate forms of nitrogen and phosphorus can be broken down by microorganisms. The processes of deamination, nitrification and denitrification can result in the release of ammonium into the water column, or the loss of nitrogen gas to the atmosphere. Phosphorus in the sediment can be released as bioavailable phosphate that allows algal growth. Sedimentary nutrient cycling is strongly influenced by the oxygen regime at the sediment water interface,²⁹ with a breakdown in the nutrient cycle likely to be associated with a lack of oxygen, causing fish kills or an overabundance of nutrients that can lead to algal bloom.

Attainment of SEPP (WoV) objectives for total nitrogen deteriorated from east to west – from excellent in Victoria's east, to poor and very poor in the state's west (Figure WQ.4). Attainment of SEPP (WoV) objectives for total nitrogen was achieved in fewer than 10% of sites in the urbanised catchment of Port Phillip and Western Port, as well as the Corangamite and Wimmera catchments in the west to south-west of the state. Conversely, SEPP (WoV) attainment was greater than 90% in the East Gippsland CMA region river basins of the Mitchell River and far-east Gippsland.

There was little evidence of a consistent temporal pattern across the 2010 to 2017 monitoring period, with ratings fluctuating from year to year. However, the spatial pattern of better nitrogen levels in the east, and poorer levels in the west, remained consistent (Figure WQ.4 and Table WQ.3). Longerterm trends in total nitrogen were influenced by rainfall and flow, with generally increased nutrient loads washing into streams during periods of heavy rainfall and floods.³⁰ Trends are also influenced by site factors, including surrounding land use, slope, soil types and stream-bank and bed stability. There was no significant trend in total nitrogen from historical (1991 to 2010) to current (2011 to 2016) conditions, although nitrogen levels at most sites were slightly higher after 2011.31 It is likely that this increase in nutrients at most sites is due to higher catchment runoff since the end of the millennium drought.³² Because there has been no discernible trend in temporal variations, the overall trend for this indicator has been classified as stable.

Harris GP 2001, 'Biogeochemistry of nitrogen and phosphorus in Australian catchments, rivers and estuaries: effects of land use and flow regulation and comparisons with alobal patterns', Marine and Freshwater Research, 52(1), pp. 139-149

Ventia 2018, 'Victorian Water Quality Trends 1991-2016'

Ibid

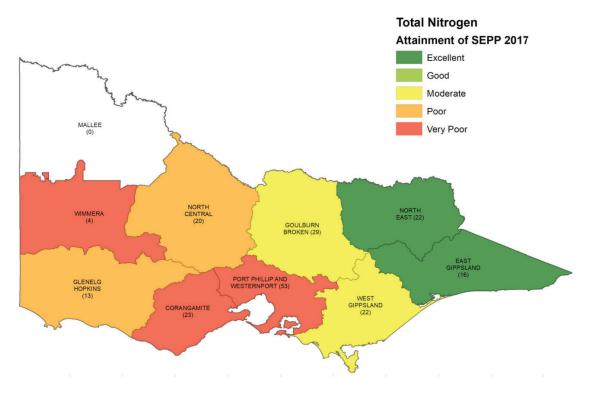


Figure WQ.4 SEPP (WoV) attainment of water-quality objectives for total nitrogen by CMA regions

Note: Numbers represent the average number of monitoring locations in each region used in the assessment.

(Data source: DELWP, Melbourne Water, 2018)

Table WQ.3 Per cent attainment of SEPP (WoV) water-quality objectives for total nitrogen

able wa.s Fer cent attainment of SEFF (wov) water-quality objectives for total nitrogen											
CMA region (average number of sites)	2010	2011	2012	2013	2014	2015	2016	2017	All years		
East Gippsland (17)	82	59	59	88	59	76	69	94	73		
North East (22)	55	55	59	68	64	82	50	77	64		
West Gippsland (26)	44	26	30	37	41	52	41	41	39		
Goulburn Broken (29)	14	28	38	41	44	50	27	45	36		
Glenelg Hopkins (13)	15		23	15	15	38	23	23	20		
North Central (22)	5			14	19	24		25	11		
Port Phillip & Western Port (115)	4				9	9	2	4	6		
Corangamite (23)	4	4	4					4			
Wimmera (4)	0	0	0	0	0	0	0	0	0		
Mallee (0)	No data										

Note: The following cell colours in the table represent specific water quality ratings: dark green (excellent water quality), light green (good water quality), yellow (fair water quality), orange (poor water quality) and red (very poor water quality).

(Data source: DELWP, Melbourne Water, 2018)

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
WQ:05 Total phosphorus concentrations in rivers					\rightarrow	
Data Custodian DELWP, Melbourne Water	East and V		and catchr	nents, and	ir in the North Poor in other nent.	

Phosphorus plays an important role in freshwater systems. As for total nitrogen, attainment of SEPP (WoV) objectives for total phosphorus deteriorated from east to west – from excellent in the far-east of Victoria to very poor in the west of the state (Figure WQ.5). There were 10 river basins with less than 10% attainment of SEPP (WoV) water-quality objectives for total phosphorus. More than half of the river basins were considered poor or very poor (Table WQ.4).

There was little evidence of a consistent temporal pattern in the 2010 to 2017 monitoring period, with ratings fluctuating from year to year. However, the spatial pattern of better phosphorus levels in the east and poorer levels in the west remained consistent (Figure WQ.5 and Table WQ.4). Longerterm trends in total phosphorus were influenced by rainfall and flow, with generally increased nutrient loads washing into streams during periods of heavy rainfall and floods.³³ Trends are also influenced by site factors, including surrounding land use, slope, soil types and stream-bank and bed stability.

The majority of sites showed an increase in phosphorus levels after 2011, compared to the levels between 1991 and 2010.34 The majority of sites in the east of the state showed increases in phosphorus that may be due to increased runoff since the end of the millennium drought.35 As there is no trend in temporal variation, the overall trend for this indicator has been classified as stable

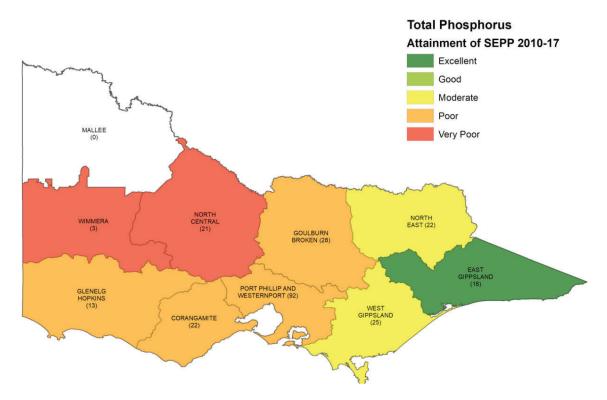


Figure WQ.5 SEPP (WoV) attainment of water-quality objectives for total phosphorus by CMA regions

Note: Numbers represent the average number of monitoring locations in each region used in the assessment. (Data source: DELWP, Melbourne Water, 2018)

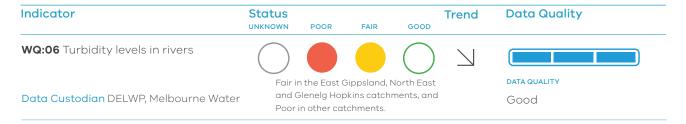
Table WQ.4 Per cent attainment of SEPP (WoV) water-quality objectives for total phosphorus

CMA region (average number of sites)	2010	2011	2012	2013	2014	2015	2016	2017	All years	
East Gippsland (17)	71	82	88	88	65	76	88	94	81	
North East (22)	32	41	50	41	59	50	59	64	49	
West Gippsland (26)	44	41	44	44	48	48	45	45	45	
Goulburn Broken (29)	14	24	28	33	26	32	27	31	27	
Glenelg Hopkins (13)	15		23	23	46	46		15	23	
Corangamite (23)	17	4	17	14	14	32	10	26	17	
Port Phillip & Western Port (115)	8	11	10	18	9	14	4	9	11	
North Central (22)	0		4	10	10	14	11	14		
Wimmera (4)	0									
Mallee (0)	No data									

Table WQ.4 Per cent attainment of SEPP (WoV) water-quality objectives for total phosphorus

Note: The following cell colours in the table represent specific water quality ratings: dark green (excellent water quality), light green (good water quality), yellow (fair water quality), orange (poor water quality) and red (very poor water quality).

(Data source: DELWP, Melbourne Water, 2018)



Turbidity is a measure of the particulate matter (sediment particles, organic matter and phytoplankton) suspended within the water column. (In simple terms, turbidity is a measure of cloudiness.) Turbidity is not only influenced by the amount of suspended matter in the water column, but the size, shape and composition of the particles. For example, small amounts of fine particles such as clay will result in much higher turbidity (lower water clarity) than an equivalent amount of sand particles. Turbidity can affect aquatic ecosystems by:36

decreasing light penetration through the water column, which inhibits photosynthesis and reduces submerged plant growth

- reducing underwater visibility, which affects visual feeders, including some species of fish, turtle and waterbird
- physically impacting on the gills of fish and macroinvertebrates (in the case of very high levels of suspended matter in the water column).

Turbidity in Victorian rivers and streams from 2010 to 2017 was rated as moderate to very poor (Figure WQ.6). The Mallee and Wimmera catchments were both ranked as very poor, but this was based on a very small number of sites in each region, and may not reflect overall water turbidity across all rivers and streams in those catchments.

Turbidity

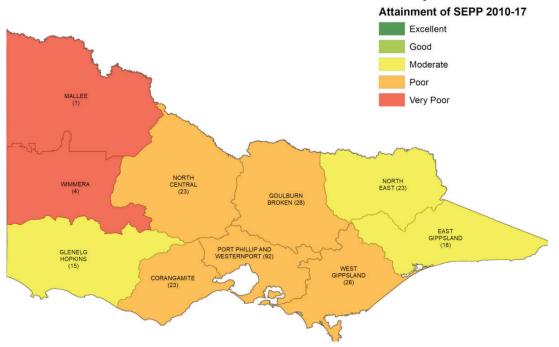


Figure WQ.6 SEPP (WoV) attainment of water-quality objectives for turbidity (as an indicator of water clarity) by CMA regions

Note: Numbers represent the average number of monitoring locations in each region used in the assessment.

(Data source: DELWP, Melbourne Water, 2018)

Davies-Colley RJ, Smith DG 2001, 'Turbidity, suspended sediment and water clarity: A review', *Journal of the American Water Resources Association*, 37(5), pp. 1085–1101.

Turbidity was excellent or good in a small number of river basins, including the Hopkins River and Portland coast basins in Glenelg Hopkins, the Mitchell River in East Gippsland, and the Moorabool River in Port Phillip and Western Port. There was little evidence of a temporal pattern across the eight years, although the drier years of 2014, 2015 and 2017 generally had lower turbidity than the wet years of 2010 and 2011 (Table WQ.5).

Longer-term trends in turbidity were influenced by rainfall and flow. Turbidity generally decreased in the drought years and increased during wet periods when run-off washed sediment from the surrounding landscape into the rivers.37

Turbidity has increased in recent times (since 2011) compared to historical data (1991 to 2010) across most streams in Victoria, and the six longterm trend sites all exhibited increasing trends in turbidity related to increased streamflow and rainfall runoff.³⁸ Because of this, the overall trend for this indicator has been classified as deteriorating. In addition to climate, land use plays an important role in turbidity, with increased landclearing, agricultural activities that lead to bank erosion (for example, livestock access to streams) and water-resource use all linked to increasing turbidity in Australian streams.39

Table WQ.5 Per cent attainment of SEPP (WoV) water-quality objectives for turbidity (as an indicator of water clarity)

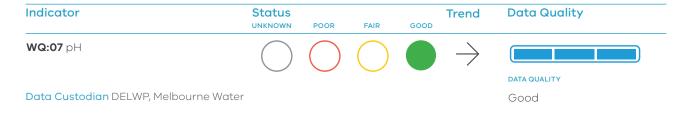
CMA region (average number of sites)	2010	2011	2012	2013	2014	2015	2016	2017	All years
Glenelg Hopkins (15)	36	38	50	40	60	93	36	44	49
East Gippsland (17)	35	24	35	59	35	35	33	93	43
North East (23)	29	29	29	39	52	52	35	61	41
North Central (24)		23	42	25	35	30	16	46	29
Corangamite (23)	17		17	23	23	54	23	33	24
West Gippsland (26)	22	19	15	19	30	28	20	36	23
Goulburn Broken (28)			10	15	24	41		34	17
Port Phillip & Western Port (92)	18	6		14	31	24	6	19	14
Wimmera (4)			25						
Mallee (2)	0	0	0	0	0	0	0	0	0

Note: The following cell colours in the table represent specific water quality ratings: dark green (excellent water quality), light green (good water quality), yellow (fair water quality), orange (poor water quality) and red (very poor water quality).

(Data source: DELWP, Melbourne Water, 2018)

Ventia 2018, 'Victorian Water Quality Trends 1991-2016'.

Davis J, O'Grady AP, Dale A, Arthington AH, Gell PA, Driver PD, Bond N, Casanova M, Finlayson M, Watts RJ 2015, 'When trends intersect: The challenge of protecting freshwater ecosystems under multiple land use and hydrological intensification scenarios', *Science of the Total* Environment, 534, pp. 65-78.



pH is a measure of the acidity or alkalinity of water. It is measured on a logarithmic scale from O (acidic) to 14 (alkaline), with a pH of 7 indicating neutral conditions.

Most natural freshwaters have a pH in the range of 6.5 to 8.0, depending on the soil and underlying geology of the catchment. Factors that influence the pH of river systems are land-use intensification, point-source pollution, exposure of acid sulfate soils via surface and groundwater flows, and the balance of buffering carbonates in the water column (a water body's pH can change as its carbonate concentrations keep an equilibrium with atmospheric concentrations).40

Increases and decreases in pH can have ecological effects: water can be neither too alkaline nor too acidic. Altered pH disrupts physiological processes at a cellular level, with species that are confined to aquatic environments, such as fish, more exposed to pH changes. Juvenile stages of fish and frogs are highly susceptible to altered pH. In addition, increased acidity (lower pH) can affect the release of heavy metals from sediments and influence the toxicity of other chemicals such as ammonia.41,42

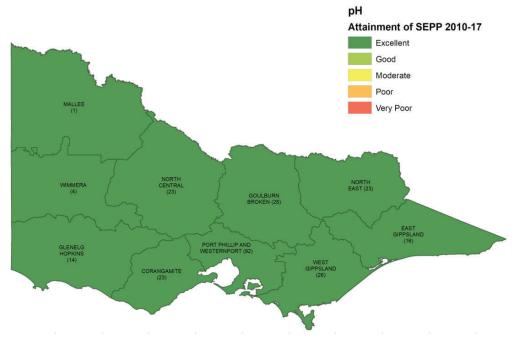


Figure WQ.7 SEPP (WoV) attainment of water-quality objectives for pH by CMA regions

Note: Numbers represent the average number of monitoring locations in each region used in the assessment. (Data source: DELWP, Melbourne Water, 2018)

Apte, S. and Batley, G. 2011, 'Water: Science and solutions for Australia', CSIRO Publishing, Collingwood. Victoria

Emerson K, Russo RC, Lund RE, Thurston RV 1975, 'Aqueous ammonia equilibrium calculations: effect of pH and temperature', Journal of the Fisheries Board of Canada, 32(12), pp. 2379–2383

Randall DJ, Tsui TKN 2002, 'Ammonia toxicity in fish', Marine pollution bulletin, 45(1-12), pp. 17-23.

Water quality with respect to pH in Victorian rivers and streams for 2010 to 2017 was rated as excellent across all catchment regions (Figure WQ.7) and river basins. SEPP (WoV) water-quality objectives for pH were attained at more than 80% of sites in all catchment regions, except the Port Phillip and Western Port catchment, where 72% of sites recorded attainment.

No temporal trends in pH were evident from 2010 to 2017 (Table WQ.6). There has been very little change in pH between current (since 2011) and historical periods (1991 to 2010).43

Table WQ.6 Per cent attainment of SEPP (WoV) water-quality objectives for pH (as an indicator of alkalinity/acidity)

CMA region	2010	2011	2012	2013	2014	2015	2016	2017	All years
(average number of sites)	2010	2011	2012	2013	2014	2015	2010	2017	All years
Mallee (2)	100	100	100	100	100	100	100	100	100
West Gippsland (26)	96	100	100	89	100	100	92	100	97
North East (23)	88	100	88	100	100	96	100	100	96
North Central (24)	100	96	96	96	91	87	95	96	95
East Gippsland (17)	94	94	94	94	94	94	81	88	92
Corangamite (24)	96	92	88	96	91	88	95	79	90
Wimmera (4)	100	100	75	75	80	100	100	80	88
Glenelg Hopkins (14)	79	86	86	86	79	93	86	79	84
Goulburn Broken (28)	86	79	90	81	71	85	85	79	82
Port Phillip & Western Port (93)	65	74	84	84	68	62	60	58	72

Note: The following cell colours in the table represent specific water quality ratings: dark green (excellent water quality), light green (good water quality), yellow (fair water quality), orange (poor water quality) and red (very poor water quality).

(Data source: DELWP, Melbourne Water, 2018)

^{43.} Ventia 2018, 'Victorian Water Quality Trends 1991-2016'.

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
WQ:08 Proportion of bodies of water with good ambient water quality					\supset	
Data Custodian DELWP, Melbourne Water						Good

Victoria is moving to align its SoE reporting with the United Nations Sustainable Development Goals. As such, this indicator represents a way to use existing water-quality data to provide a statewide method of reporting on water quality in Victoria that is also applicable in a global context. The United Nations defines 'good' ambient water quality as water quality that does not damage ecosystem function and human health, according to core ambient water-quality parameters.44

While the attainment of SEPP (WoV) water-quality objectives has been used to evaluate water-quality variables in the previous water-quality indicators, the methodology developed for calculating the water-quality component of the Index of Stream Condition (ISC) can be used to determine the overall water quality in Victoria for this indicator.

The primary aim of the ISC is to assess the environmental condition of Victoria's major rivers and streams, and to provide statewide data for CMA regional waterway action-planning and priority-setting. Three statewide benchmark analyses have been undertaken, in 1999, 2004 and 2010.45 The ISC method assigns scores that are integrated across water-quality indicators and ranked in five categories: very poor, poor, moderate, good and excellent. The good and excellent ISC categories are equivalent to the 'good' ambient water-quality assessed by this indicator.

The current assessment suggests that water quality is generally better in the east of the state than in the central and western regions (Figure WQ.8). The East Gippsland river basins of far-east Gippsland and the Snowy and Mitchell rivers all had good or excellent water quality, as did the North East catchment river basins of the Ovens, Kiewa and Upper Murray Regions (Figure WQ.9). The rest of the state was ranked as moderate or poor, with lower water quality in the urbanised river basins of the Port Phillip and Western Port

The general trend of better water quality in the east of the state and moderate to poor water quality in central and western regions has not changed from the previous ISC assessment from 2004-2009. Not enough data was collected in the Mallee catchment to provide a water-quality score and ranking for 2010 to 2017.

United Nations, 'Indicator 6.3.2 – Water quality', New York City, New York http:// 2/ Accessed 3 December 2018

DELWP, 'Third Index of Stream Condition report', East Melbourne, stream-condition-report Accessed 3 December 2018.

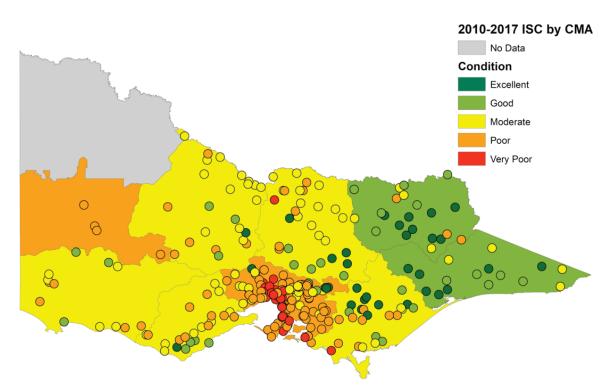


Figure WQ.8 Water-quality scores and rankings for Victoria (2010–17), based on the methodology developed to calculate the ISC

(Data source: DELWP, Melbourne Water, 2018)

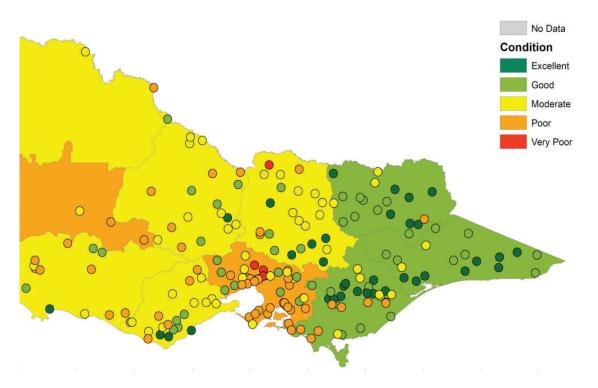


Figure WQ.9 ISC integrated water-quality scores for CMA regions, 2004–09, showing scores for individual sites

(Data source: DELWP, Melbourne Water, 2018)

Of the 27 river basins assessed from 2010 to 2017, seven (26%) rated as having good or better water quality. This represents a slight deterioration in water quality from the most recent ISC assessment (2004 to 2009) when 10 of the 27 river basins (37%) were rated as having good or better water quality.

Data for the 2010-17 reporting period shows a gradual deterioration of water quality at most sites (22 of 27), by an average score of 0.42, compared to the 2004-09 data. The most common ranking for river basins in both the current and previous period was moderate. The status assessment of poor for this indicator is based on fewer than one-third of all sites being rated as having good or better water quality for the current water-quality assessment period.

When assessing water-quality results over different periods, consideration must be given to changes in weather, particularly rainfall. Statewide rainfall maps covering some of the reported water-quality periods (2004 to 2009, and 2010 to 2017) have been included and are discussed below. However, most of the water-quality measurements are made monthly. Therefore, the data is not available at a sufficiently fine temporal resolution to properly compare individual samples with local rainfall at the specific time of the sampling. This means the impact of rainfall on water quality during the reporting periods is not well understood.

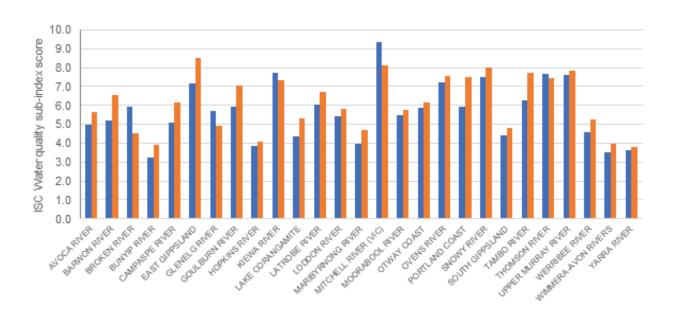


Figure WQ.10 ISC water-quality sub-index scores from the 2010 assessment (data from 2004–09) and the current assessment (data from 2010–17) for river basins

Note: ISC rankings are: excellent \geq 9; good 8–9; moderate 6–7; poor 4–5; very poor \leq 3.

(Data source: DELWP, Melbourne Water, 2018)

The 2010 ISC assessment spans six years of drought conditions in Victoria, while the current period represents both dry years (2014 and 2015) and wet years (2011) (see Figure WQ.12 and Figure WQ.13). The current period certainly experienced greater rainfall and runoff. The impacts of drought on water quality include increased salinity (as water evaporates in streams and in channel pools) and decreased dissolved oxygen in residual pools.46 Decreases in overland flow and runoff are also associated with drought, and decrease sediment and nutrient loads, leading to increased water clarity and lower nutrient conditions. 47 Conversely, heavy rainfall and flooding following a dry period can mobilise large loads of sediments and nutrients into the system, leading to higher turbidity and nutrient concentrations, particularly in lowland river sites. 48,49

The climatic conditions during the 2010 to 2017 assessment closely align with Victoria's projected climate in the coming decades. That is, generally drier, but interspersed with more extreme rainfall events. Therefore, the assessment made in this indicator, that only 26% of Victoria's monitored inland waterways have good or better water quality, is representative of what water quality will be expected to be like between now and 2030, without policy or management interventions.

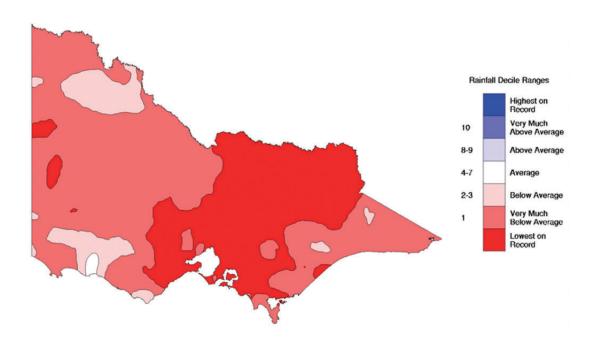


Figure WQ.11 Rainfall, 2006–09 (as an indicator of conditions during the current ISC assessment) compared to long-term averages

(Data source: BoM, 2018)

Bond NR, Lake PS, Arthington AH 2008, 'The impacts of drought on freshwater ecosystems: an Australian perspective', *Hydrobiologia*, 600(1), pp. 3–16.

Baldwin DS, Mitchell AM 2000, 'The effects of drying and re-flooding on the sediment and soil nutrient dynamics of lowland river– floodplain systems: a synthesis', *River research and applications*, 16(5), pp. 457–467.

^{48.} Ibid.

Cook PL, Holland DP, Longmore AR 2010, 'Effect of a flood event on the dynamics of phytoplankton and biogeochemistry in a large temperate Australian lagoon', *Limnology and Oceanography*, 55(3), pp, 1123–1133.

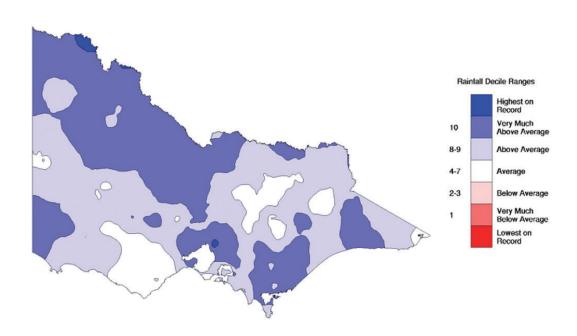


Figure WQ.12 Rainfall in 2011 (as an indicator of conditions during the current ISC assessment) compared to long-term averages

(Data source: BoM, 2018)

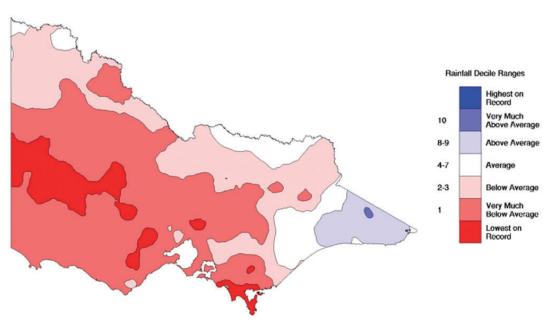


Figure WQ.13 Rainfall, 2014–15 (as an indicator of conditions during the current ISC assessment) compared to long-term averages

(Data source: BoM, 2018)

Discharges

Indicator	Status	POOR	FAIR	GOOD	Trend	Data Quality
WQ:09 Volume of sewage discharge to surface waters					?	
Data Custodian EPA Victoria						Poor (no data available to make an assessment)

Point-source pollution is contamination that enters the environment through a single, identifiable emission source, such as a pipe or a drain. Point-source discharges to waterways are dominated by effluents from sewage treatment. These effluents tend to be the major source of contaminants that are potentially harmful to waterways and our use of them. These contaminants and their associated impacts include:

- pathogenic micro-organisms (such as bacteria and viruses) that may affect the health of instream fauna, animals drinking the water and people (through direct contact or piped watersupply systems)
- oxygen-demand substances (that is, substances that consume oxygen during decomposition) that may result in low oxygen levels in the water column. Low oxygen levels can damage the biota of receiving waters
- nutrients (especially nitrogen and phosphorus) that may result in a proliferation of algal and weed growth, change of species type and diversity, and a reduction in dissolved-oxygen levels. Some algal blooms may also be toxic.
- toxic substances (including ammonia, surfactants, heavy metals and biocides) that can be harmful to both in-stream life and users of the water. The greatest concern is persistent toxicants that bio-accumulate in the food chain.

In Victoria, high-risk point-source discharges are regulated by EPA Victoria, which specifies minimum acceptable environmental standards for treated effluent discharges to rivers and streams. Regulation of point-source sewage discharges has helped improve the quality of Victoria's water environment over the past 40 years. Focus and effort is still needed to maintain and further improve these, particularly given the likelihood of significant climate changes.

Indeed, climate change will be one of the main challenges to sewage treatment systems in the future. ^{50,51} Climate change projections indicate that Victoria's average temperatures will increase, and rainfall and runoff will decline. Modelling also indicates that there will be an increase in the intensity of heavy rainfall events. ^{52,53} These changes in climate will have multiple implications for sewage treatment plants and will accentuate existing discharge problems.

EPA Victoria holds data on all water pollutants that are discharged from its licensed sites; however, this information was not available to be extracted and analysed at a statewide level. Therefore, the status and trend assessments for this indicator are listed as unknown and unclear.

Tolkou A, Zouboulis A, 2015, 'Effect of Climate Change in Wastewater Treatment Plants: Reviewing the Problems and Solutions', in Managing Water Resources under Climate Uncertainty, Springer International Publishing, pp.197-220.
 Tolkou A and Zouboulis A, 2016, 'Effect of Climate Change in

Iolkou A and Zouboulis A, 20 lo, 'Effect of Climate Change in WWTPs with a focus on MBR infrastructure', Desalination and Water Treatment, 57(5): pp. 2344-2354.

Hobday AJ, Lough JM 2011, 'Projected climate change in Australian marine and freshwater environments', *Marine and Freshwater* Research, 62, pp. 1000-1014.

Timbal B, Ekström B, Fiddes S, Grose M, Kirono D, Lim E-P, Lucas C and Wilson L 2016, 'Climate change science and Victoria: Bureau Research Report No.14', Report issued by the Bureau of Meteorology.

Pollution Incidents

Indicator	Status	POOR	FAIR	GOOD	Trend	Date	Quality
WQ:10 Reported inland water pollution incidents					\supset		
						DATA G	UALITY
Data Custodian EPA Victoria						Fair	(data provided not linked to water bodies)

EPA Victoria received 7,481 water-pollution reports for the five years from 2013 to 2017. Seventy-three per cent of the water-pollution reports were made in the Port Phillip and Westernport catchment, where a significant proportion of Victorians live.

Pollution reports can be categorised by the type of pollution; however, only 25% of reports contained some level of classification. Of the reports that were classified, industry, sewer overflow, fish death and residential construction were the main classifiers of pollution.

As well as reports for pollution in waterways, many reports are made for pollution before it reaches a waterway (such as pollution entering a stormwater drain). In EPA Victoria's database, a single pollution event can be duplicated if more than one reporter makes a report.

The data for this indicator captures water-pollution reports from across the state, including coastal areas and estuaries. Most of the reports were for inland waters, with just 9% of pollution reports made for pollution within 200 m of the coast.

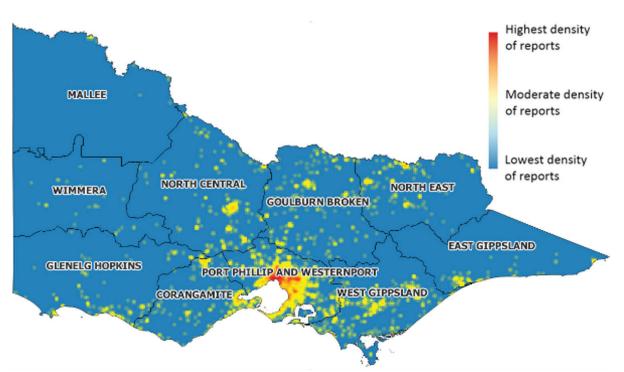


Figure WQ.14 Heat map of water pollution reports received by EPA Victoria, 2013-17

(Data source: EPA Victoria, 2018)

Table WQ.7 Water pollution reports received by EPA Victoria for each local government area (LGA) and locality, 2013–17

LGA	Total no.	Locality	Total no.
Melbourne	381	Yarraville	202
Darebin	363	Melbourne	118
Maribyrnong	321	Alphington	107
Moreland	307	Coburg North	101
Whitehorse	263	Dandenong South	97

(Data source: EPA Victoria, 2018)

The number of water-pollution reports to EPA Victoria was very stable between 2013 and 2015, then increased by 32% to 1,766 in 2016, and stabilised again in 2017. The increase in 2016 is likely to be associated with above-average annual rainfall. High rainfall increases runoff, which affects streams by decreasing water clarity and increasing the amount of pollutants that enter waterways. This, coupled with greater community awareness of the option to report water pollution to EPA Victoria, may explain pollution report numbers in 2016. In 2017, annual rainfall was below average: the number of reports in this year may be due primarily to increased public awareness of pollution reporting.

Water-pollution reporting is reasonably consistent within a given year, peaking slightly in late winter and early spring, when increased rainfall and runoff can exacerbate water-quality impacts.⁵⁴ Another slight peak occurs in late summer and early autumn, which is likely to be caused by heavy rainfall events and algal blooms.

Fish Deaths

As part of its pollution reporting database, EPA Victoria keeps records of pollution reports relating to fish deaths. For the five years from 2013 to 2017, EPA Victoria received 306 reports of fish deaths. There was no obvious trend in fishdeath reports over the relatively short period, although the fewest fish-death reports were in the very dry years of 2014 and 2015 (Figure WQ.13). The location of fish-death reports was not as concentrated on Melbourne (as were reports for other water-pollution categories), with 39% of fish-death reports originating in the Port Phillip and Westernport catchment, compared to 73% for all water reports. The Corangamite catchment was responsible for the second-most fish-death reports (19% of all fish-death reports). Figure WQ.15 shows the locations of fish-death pollution reports received by EPA Victoria for 2013 to 2017.

Fish deaths in Victoria have a wide range of likely causes, and the exact cause of a fish death is often difficult to determine.⁵⁵ Some of the likely causes are:

- pollution from a contaminant entering a waterway (or as a result of a water intake or outfall)
- environmental stress, such as warmer waters, lower flows or water levels, and reduced dissolved oxygen
- changes in estuarine salinity due to high freshwater river flows or high tidal movements.
 These processes can rapidly change the salinity of the water, making it fresher or more saline, which can result in the death of freshwater, estuarine or marine fish.
- disease, most commonly associated with viruses, bacteria or parasites.

Agriculture Victoria, 'Rainfall', http://vro.agriculture.vic.gov.au/dpi/vro.vrosite.nsf/pages/rainfall Accessed 3 December 2018.

EPA 2007, 'Fish deaths reported to EPA Victoria, 1998–2007', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1175.pdf Accessed 3 December 2018.

- algal blooms, including blue-green algae, which can grow prolifically in freshwater conditions, particularly when water temperatures and nutrient levels are high. The growth or the decomposition of algae can significantly deplete dissolved-oxygen levels in the water, which may cause fish death through suffocation.
- blackwater events, which occur when a high runoff event carries organic matter from the land into a waterway, or when highly organic water in billabongs or backwaters is flushed into another waterway. The organic matter stains the water black and decomposes, resulting in low dissolved-oxygen levels, which may cause fish death through suffocation. Black water events occur most often following rainfall after a dry period, when infiltration into the soil is low (that is, the soil absorbs rainfall at a slow rate) and waterway flows are also low.

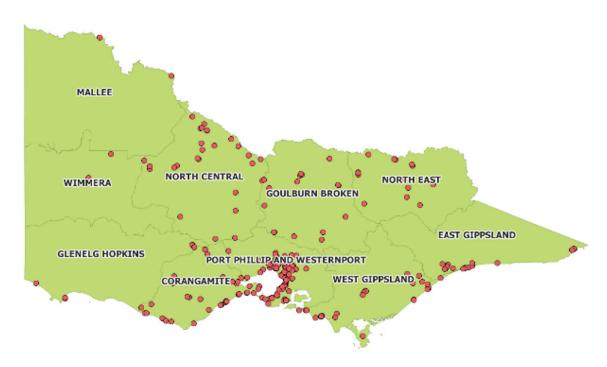


Figure WQ.15 The locations of fish death pollution reports in Victoria, 2013–17

(Data source: EPA Victoria, 2018)

Future Focus

Improvements in the availability of statewide water-quality data have meant a much more robust assessment of water-quality indicators in this report than in SoE 2013. This reflects steps undertaken since SoE 2013 to increase data availability, in line with that report's recommendations and subsequent VAGO and DELWP audits that identified a deficiency in data-usage and sharing. There are still considerable improvements to be achieved by coordinating monitoring programs and data between government agencies, industry and the community. Advances in monitoring will also need to be complemented by improvements to data, trend analysis and modelling.

Implement an agile Water-Quality Monitoring Framework

Future water-quality monitoring needs to include a network of long-term sites, complemented by targeted monitoring of water-pollution hotspots. Where and how this monitoring is completed, and who does it, needs to be determined in a transparent process, guided by evidence, and ultimately recommending clearly defined roles and responsibilities. The water-quality monitoring framework would be developed by DELWP with support from other agencies and the community. The framework would be a risk-based approach that uses threats and pressures on water quality to guide where and how monitoring is undertaken.

These reforms will support Victoria's progress in becoming a modern regulatory environment for water-quality protection. They align with recommendations 6.3 and 7.2 of the 2016 Ministerial Advisory Committee Inquiry into EPA Victoria to 'assess the adequacy of its air and water-monitoring networks, particularly in relation to air quality, and consider options to improve data-sharing and accessibility, and community communication' (recommendation 6.3) and to implement, through DELWP, statewide environmental monitoring, a spatial data system and reporting on outcomes (recommendation 7.2).56 The reforms will be essential for monitoring delivery of the State Environment Protection Policy (Waters) and the Environment Protection Amendment Act 2018.

Combining targeted monitoring of pollution hotspots with monitoring at priority long-term sites will help inform pollution-prevention interventions in hotspots and enable quantitative evaluations of those actions. Enhancements to EPA's pollutionreporting database would assist the determination of potential hotspot areas for monitoring.

Recommendation 12: That DELWP, working with its portfolio agencies, implement an agile waterquality 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.

Ministerial Advisory Committee 2016, 'Independent inquiry into the Environment Protection Authority', htt

Accounting for the Environment

Under the System of Environmental-Economic Accounting (SEEA), there are water-quality accounts and water-emissions accounts, along with water-resources accounts (discussed in the Water Resources chapter).

Water-quality accounts are linked to waterresources accounts and describe the stocks of water at the beginning and end of an accounting period, according to their quality. Water quality is a key determinant of what water can be used for, and consequently is a key factor in determining the benefit of water resources to the economy.

In environmental-economic accounting, water pollution is categorised as a residual flow from the economy to the environment. A water-emissions account records this connection, recording both pollutants that enter the environment directly (either point-source emissions or non-point-source emissions such as urban and agricultural runoff) or through a treatment plant. Water-emissions accounts present information on the sectors (such as industry, government and households) responsible for emissions, the type and amounts of pollutants, and the destination of the emissions (for example, water resources or the sea). Wateremissions accounts should report emissions in line with industry classifications used by the Australian Bureau of Statistics.

Tracking water-pollution emissions over time, along with economic activity, can help highlight trends in the relative contributions of different sectors, including future levels expected with growth in economic activity. This type of account can also be used to assess efforts by government, industry and households to reduce water-pollution emissions.

Emissions to water resources can constitute a major environmental problem and cause the quality of water resources to deteriorate. Some substances are highly toxic (such as heavy metals); others, such as nitrogen and phosphorus, can lead to eutrophication. Organic substances can have effects on the oxygen balance, impacting the ecological status of a resource.

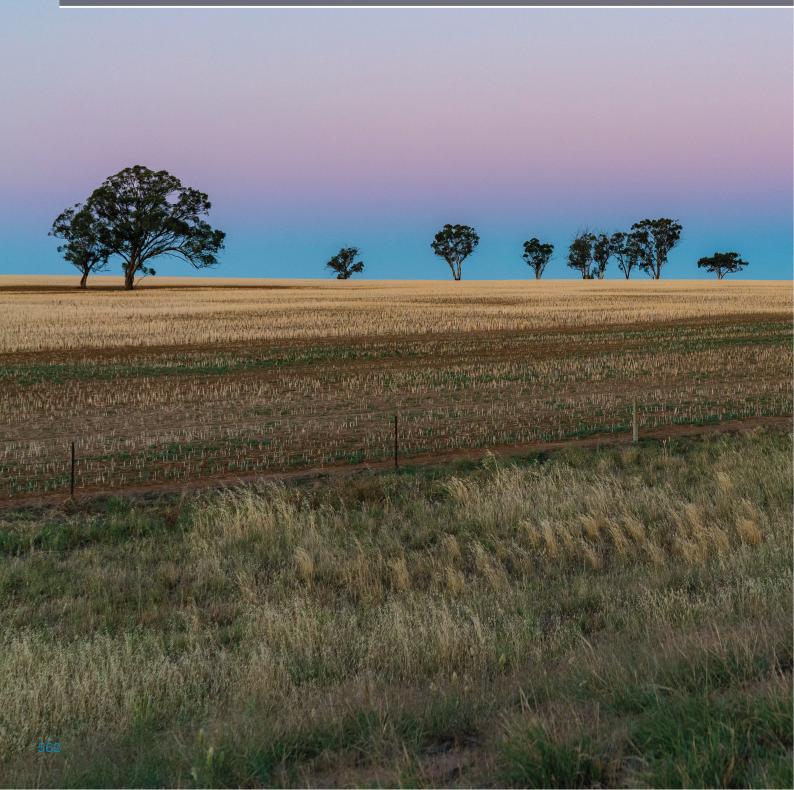
The impact of residual flows of water pollution on people and the environment already appears to some extent in Victoria's traditional economic accounts (the System of National Accounts). For example, these impacts would be included as expenditure in the health system from doctor visits and hospital admissions, or reductions in property values due to decreased amenity near water bodies. However, the amounts attributable to water pollution are not identified in the traditional accounts. Expenditure to prevent and manage the impacts of water pollution currently count towards Victoria's gross state product, rather than being recorded as a cost to the Victorian community.

Water-pollution emissions can affect the condition of assets, including water resources and freshwater and marine ecosystems. Emissions can impact on ecosystem functioning and the capacity of assets to support ecosystem services. Examples include provisioning services such as water supply; regulating services such as dilution/filtration of pollutants and water-cycle regulation; and cultural services such as recreation and tourism, and ecosystem capital for future generations.

The SEEA framework also recognises the benefit to the ecosystem of water purification by natural assets. An ecosystem account would record this connection by showing the quantity of waterpollutant emissions absorbed or diluted by natural assets, the impact of this on water quality and the corresponding benefit to the Victorian community in terms of avoided impacts.

WASTE AND RESOURCE RECOVERY (W) SCIENTIFIC ASSESSMENTS Part III





Waste and Resource Recovery Background

Waste is produced at all stages of extraction, consumption and creation of products and services, as well as at the end of a product's lifecycle. Within a traditionally linear model of economy, the 'take-make-waste' process results in a range of negative impacts on Victoria's environment: depletion of natural resources, environmental pollution and a compounding of the risks and effects of climate change.

Depending upon the way it is managed, waste can have multiple environmental impacts, including:

- greenhouse gas (GHG) emissions
- amenity impacts and pollution of water from landfill (particularly groundwater)
- impacts on amenity, ecosystems and human health from hazardous wastes
- increased energy and water use, and accompanying GHG emissions, through utilisation of virgin materials rather than recycled products1
- impacts of unmanaged outputs such as litter and dumped wastes.

Reducing these impacts requires prioritising avoiding waste in the first place, minimising externalities through avoiding unnecessary wastes, and focusing on resource efficiency and productivity.

When resources are not re-used, recycled or used efficiently, waste is created and there is an opportunity lost as the material can no longer be used to contribute to the economy. Victoria produced approximately 12.9 million tonnes of solid waste in 2016–17, a figure which has been relatively steady over the past five years.2

Figure W.1 illustrates the trend over the previous 10 years. Note that a further 1.4 million tonnes of hazardous waste is estimated to be managed in Victoria.3,4

Recycling waste not only returns materials to the economy but also reduces the demand for resource extraction. In most instances, creating products from recycled waste materials uses less energy and water than manufacturing products from virgin materials. In 2016–17, of the 12.9 million tonnes of solid waste produced, approximately 67% or 8.6 million tonnes was recovered for reprocessing. However, 4.2 million tonnes still went

Sustainability Victoria 2018, 'Lifecycle Kerbside Recycling Calculator', http://www.sustainability.vic.gov.au/Government/\data-portal/Lifecycle-assessment-of-kerbside-re ctoria/LCA-kerbside-recycling-calculator Accessed 3 December

Sustainability Victoria 2018, 'Victorian Recycling Industry Annual Report 2016-17', Melbourne, Victoria.

Ascend Waste and Environment and Blue Environment 2017,
'Hazardous Waste in Australia 2017', a report for the Department of
the Environment and Energy, p30. http://www.environment.gov.au/ 2017.pdf Accessed 3 December 2018.

hazardous-waste-australia-2017.pdf Accessed 3 December 2018. Sustainability Victoria 2018, 'Statewide Waste and Resource Recovery Infrastructure Plan', Melbourne, Victoria.

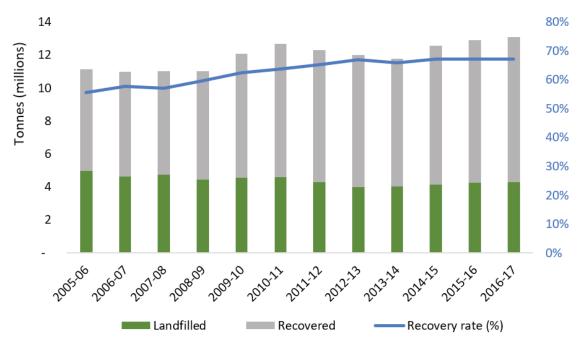


Figure W.1 Total waste generated, landfilled and recovered 2005-06 to 2016-172

Note: Data excludes hazardous waste.

The concepts of waste minimisation and recycling of materials are central to the development of a circular economy, where material that would previously have been classified as 'waste' is retained in the system and repurposed. A circular economy aims to redefine growth by decoupling economic activity from the consumption of finite resources, and designing waste out of the system.

Circular economic thinking requires a whole-ofsystem approach. It is a critical component in climate change mitigation, and it underpins the United Nations Sustainable Development Goals (SDGs). Sustainable consumption and production - critical elements in the circular economy - are incorporated into Goal 12 of the SDGs ('Ensure sustainable consumption and production patterns'). Having a full understanding of their interactions, both positive and negative, is key to unlocking their full potential.

Since a significant amount of global GHG emissions are a result of the management of materials, there are emissions reduction benefits in implementing the circular economy.

While Victoria has continued to increase its waste recovery rate, waste volumes continue to grow. The waste and resource recovery sector in Victoria is facing the following challenges:

- Increasing volumes of material are entering the waste and resource recovery sector. As Victoria's population grows, so too is the amount of materials that are used and discarded. By 2046, this figure is projected to reach 20 million tonnes – an increase of 57% on the 2015-16 amount.5
- The existing system is struggling to manage waste materials and composites that are created in the design of new products (for example composite plastics or emerging battery technologies (lithium-ion)). Also problematic are high volumes of legacy wastes that exist due to a lack of recovery methods (for example 7.5 million tonnes of dewatered contaminated biosolids at Melbourne's Western Treatment Plant).

Sustainability Victoria 2018, 'Statewide Waste and Resource Recovery Infrastructure Plan', Melbourne, Victoria.

- Victoria's recycling system household collections in particular - has been impacted by major disruptions and restrictions in global commodity markets, particularly from China and other south-east Asian export destinations. This has highlighted vulnerabilities in resource recovery including heavy reliance on the exporting of unsorted comingled recycling (baled plastic, paper and cardboard) for processing and a lack of diversification in local markets. While exports and commodity prices of high-value paper, cardboard and metals continue, market disruptions have highlighted the need to develop a stronger and more resilient recycling system and to ensure that recovered materials are used for productive purposes such as remanufacturing, domestically.
- Managing increasing diffuse sources of pollution (litter and illegal dumping) presents management and monitoring issues for waste that does not enter the formal collection system. While there has been a long-term trend of reduction in litter in Victoria as measured by the annual National Litter Index⁶, problematic materials such as plastics accumulate in the environment for many years because they do not biodegrade.
- Food waste is estimated to be nearly 1,000,000 tonnes annually⁷ and at least 20% of all food produced, contributing to undue pressure on finite natural resources, the environment and climate change.8

Keep Australia Beautiful 2017, 'National Litter Index', Newtown, New South Wales http://kab Accessed 3 December 2018

Sustainability Victoria 2018, 'Statewide Waste and Resource Recovery Infrastructure Plan', Melbourne, Victoria.
Institution of Mechanical Engineers 2013, 'Global Food: Waste Not,

Want Not', Westminster, London https://www.ime want-not.pdf?sfvrsn=0 Accessed 4 December 2018.

Current Victorian Government Settings: Legislation, Policy, **Programs**

Materials and wastes can be harmful to human health, damage the natural environment and impact on amenity. Therefore, the system, which is regulated by EPA Victoria, must operate to minimise these risks. Under the *Environment* Protection Act 1970, EPA Victoria can develop waste management policies (WMPs) to improve management of waste and material streams. WMPs provide enforceable statewide objectives and directions. Currently, a series of WMPs address movement of controlled waste, landfills, used packaging materials and other waste-related operations.

Sustainability Victoria has a legislated responsibility for long-term planning for waste and recycling infrastructure in the state. It released the first Statewide Waste and Resource Recovery Infrastructure Plan (SWRRIP) in 2015, with an update in April 2018 to reflect the priorities identified in the seven regional implementation plans. The SWRRIP provides a blueprint for investment and highlights the gap between current capacity and future needs.

The SWRRIP is premised on a circular economy model. It sets goals and strategic directions to ensure that the system continues not only to provide an efficient and well-operated service, but also to maximise the recovery of materials and reduce reliance on landfill. It draws on data and information from a range of sources and identifies opportunities – both local and statewide – to increase infrastructure and the recovery of materials. The strategic directions underpin government interventions, but also play a critical role in informing industry investment and government decisions, such as strategic land-use planning and approvals. The SWRRIP

critically notes the importance of viable markets for recycled materials and has led to an increased focus on the recovery of organic materials, which is building momentum for a significant increase in recovery. Monitoring and evaluation will measure progress and inform future iterations and action.

Since the SWRRIP's publication, Victorian Government investments from the Sustainability Fund⁹ have been aligned to priorities identified in the Plan. Sustainability Victoria has also worked to promote opportunities for investment and growth in Victoria's resource recovery sector through its Investment Facilitation Service.

While the primary role of the SWRRIP is to plan for the infrastructure needed to manage the waste and materials entering the waste and resource recovery system, the Victorian Government's supporting initiatives provide a broader framework that include:

- Victorian Organics Resource Recovery Strategy
- Victorian Market Development Strategy for Recovered Resources
- Victorian Waste Education Strategy
- Victoria's Waste and Resource Recovery Infrastructure Investment Prospectus
- Waste Data Service.

The Victorian Government has also provided funding in 2018–19 to build a better evidence base for hazardous waste management. This will deliver a research program for new and emerging hazardous wastes, better data management and collection, and an agreed process to include hazardous waste in the SWRRIP.

DELWP 2018, 'Sustainability fund', Melbourne, Victoria https://w December 2018.

Recycling Industry Strategic Plan

On 3 July 2018 the Victorian Government released Victoria's Recycling Industry Strategic Plan which sets out a vision for a more sustainable. resilient and efficient recycling sector. The suite of complementary actions included in the plan aims to support industry in the medium to longterm, minimise costs for Victorian households, and improve the resilience of Victoria's recycling sector.

The implementation of this plan will be supported by a \$37 million package of initiatives that includes:

- leveraging private investment in recycling infrastructure
- ensuring Victorians clearly understand what they should place in their recycling bin
- supporting research institutions and industry to identify new uses for priority waste materials
- leveraging government procurement to drive demand for recycled materials
- developing a whole-of-government circular economy policy and action plan by 2020.

It is an important step for Victoria and reaffirms the state's intention to work towards a circular economy.

Greater efficiency and resilience in the recycling sector will be important in anticipating and reducing costs in the longer term.

E-waste Management

Electronic waste (or 'e-waste') volumes are growing three times faster than general municipal waste. E-waste contains hazardous components that pose risks to the environment and human health, and valuable materials that can be recovered. To manage this growing waste stream, the Victorian Government has new regulatory measures that will ban e-waste from landfill and specify how e-waste must be managed. These will take effect on 1 July 2019. To support these regulatory measures, the government has committed to upgrading Victoria's e-waste collection network, which will increase community access to safe e-waste disposal points. The government also recently launched an education and communication campaign that will increase community and industry awareness of e-waste and what to do with it.

To support these regulatory measures, the government has committed to upgrading Victoria's e-waste collection network, which will increase community access to safe e-waste disposal points. The government also recently launched an education and communication campaign that will increase community and industry awareness of e-waste and what to do with it.

Managing the Risks from Stockpiled Combustible Materials

The Victorian Government is committed to reducing the risk of fire at waste and resource recovery facilities. In August 2017, the interim Waste Management Policy (Resource Recovery Facilities) placed requirements on sites that store combustible and recyclable waste materials to minimise their fire risk. The interim policy was replaced by a longer-term Waste Management Policy (Combustible Recyclable and Waste Materials) in August 2018.

The Resource Recovery Facilities Audit Taskforce was also established in 2017. It has conducted 295 on-site inspections across 114 sites, issued 70 remedial notices and 10 sanctions (as at 3 July 2018). Compliance has been achieved by about 50% of notice recipients. The Taskforce has been actively working with facilities through those inspections to minimise their fire risk and improve their understanding of obligations.

Addressing Plastic Pollution

The Victorian Government recently announced that a ban on lightweight plastic shopping bags will come into effect in Victoria by the end of 2019. The ban will include degradable, biodegradable and compostable plastic shopping bags. Victoria is also working with other states, the Commonwealth, and retail associations on a national voluntary phaseout of thick plastic bags. The government will consider designing the ban so that thicker plastic bags can be included in the future if voluntary action is not effective.

In 2019, the Victorian Government will develop a plastic pollution reduction plan to prioritise the most effective actions to reduce other types of plastic pollution, such as beverage containers, balloons and cigarette butts. The government is establishing a reference group of government, industry, community and environmental representatives to help guide this plan.

The SoE 2018 indicators and analysis can be understood in terms of the circular economy - all aspects of which need to function to maximise the sustainable use of resources. Stakeholders need to think and act operationally

Resource flows in Victoria's circular economy

2016-17 total waste 12.87 million



4.2m tonnes (49%) from Construction and Demolition 1.3m tonnes (15%) from Municipal

3.1m tonnes (36%) from Commercial and Industry

Landfill 4.23m tonnes

Diversion from landfill - 67%

Reprocessing, in Victoria 7.4m tonnes 2016-17





PET plastic (26,000 tonnes)

recycled into plastic bottles

Glass (137,000 tonnes)

recycled into glass packaging or used as sand replacement

Organics (1.1m tonnes)

processed into compost and soil conditioners for dairy farms

Paper/cardboard (1.4m tonnes)

pulped for cardboard products

Metals (1.7m tonnes)

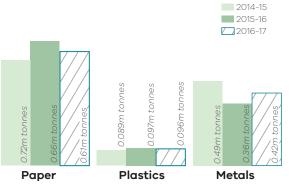
recycled into new product

Export

1.22m tonnes 2016-17 exported for recycling



~50% to China / ~50% to other destinations



Source Victorian Recycling Industry Annual Report 2016-17 (2018)

^{*}not including hazardous waste

Indicator Assessment

Legend

Status

N/A Not Applicable

The indicator assessment is based on future projections or the change in environmental condition and providing a status assessment is not applicable. Only a trend assessment is provided.



Unknown

Data is insufficient to make an assessment of status and trends.



Fair

Environmental condition is neither positive or negative and may be variable across Victoria, OR pressure is likely to have limited impact on environmental condition/human health, OR moderate protection of natural ecosystems and biodiversity is evident



Environmental condition is healthy across Victoria, OR pressure is likely to have negligible impact on environmental condition/ human health, OR comprehensive protection of natural ecosystems and biodiversity is evident.

Trend

N/A Not applicable

This indicator assessment is based on current environmental condition only and it is not applicable to provide a trend assessment. Only a status assessment is provided.



Unclear



Deteriorating

Environmental

OR pressure is

human health,

likely to have

condition/

condition is under

significant stress,

significant impact

on environmental

OR inadequate protection of natural

ecosystems and biodiversity is



Stable



Improving

Data quality



Evidence and consensus too low to make an assessment



Limited evidence or limited consensus



Good

Adequate high-quality evidence and high level of consensus

WASTE AND RESOURCE RECOVERY

Indicator Reported waste to landfill plus reported W:01 Total Waste Generation

Summary



Status

UNKNOWN



POOR



FAIR





GOOD

Trend

Region

Victoria

Measures

Tonne/yr

Data custodian

Landfill data (EPA) and Victorian Recycling Industry Annual (SV)

material recovered (recyclables and organics), not including hazardous waste.

DATA QUALITY

Good

SCIENTIFIC ASSESSMENTS Part III Waste

	Summary	Status Trend UNKNOWN POOR FAIR GOOD
Indicator W:02 Generation of municipal waste per capita Region Victoria Measures Kg/capita Data custodian Victorian Local Government Annual	Kerbside waste and recycling collections by weight divided by population.	
Survey (SV) and ABS population figure		
Indicator W:03 Total food waste Generated Region Victoria Measures Tonne/yr Data custodian SV 2009 landfill audit data modelling of kerbside collections.	Estimates of the total food waste generated.	DATA QUALITY Good
Indicator W:04 Diverson Rate Region Victoria Measures % Data custodian Landfill data (EPA Victoria) and Victorian Recycling Industry Annual Survey (SV)	Reported material recovered as a percentage of total non hazardous waste generation.	DATA QUALITY Good

SCIENTIFIC ASSESSMENTS Part III Waste

	Summary	Status Trend UNKNOWN POOR FAIR GOOD
Indicator W:05 Litter and Illegal Dumping Region Victoria Measures Counts of litter by type Data custodian National Litter Index (Keep Australia Beautiful) SV	Annual survey of 151 sites across Victoria, with an area surveyed of 239,403 square metres.	DATA QUALITY Poor
Indicator W:06 Total hazardous waste managed Region Victoria Measures Tonne/yr Data custodian Derived from Hazardous Waste in Australia 2017 (Dept. Environment and Energy 2017) from EPA source data. EPA	Hazardous waste (excluding biosolids) are recorded as arising when it is delivered to processing, storage, treatment or disposal infrastructure.	DATA QUALITY Fair



Some waste materials may be generated but not managed and therefore not measured in Victoria's waste data system. Waste managed refers to materials or wastes that have passed through or been managed at a waste and resource recovery facility and the figures in this report reflect waste managed.10

In 2016–17, the amount of waste managed in Victoria was 12.87 million tonnes, with approximately 4.25 million tonnes (33%) of waste sent to landfill and 8.62 million tonnes (67%) of material diverted from landfill for reprocessing (see Figure W.2).11

The total amount of waste managed has trended upward over the past 10 years (see Figure W.2), increasing by 16% – a slower trend than the 40% increase measured in the 10 years leading up to 2011, as reported in SoE 2013. The data suggests a correlation between waste managed and population growth, which has increased by around 23% over the same period.12 Although the amount of waste managed has risen overall, the amount going to landfill has declined from 4.75 million tonnes in 2007-08 to 4.28 million tonnes in 2016-17; this is due to an increase in the proportion of materials recovered for recycling.

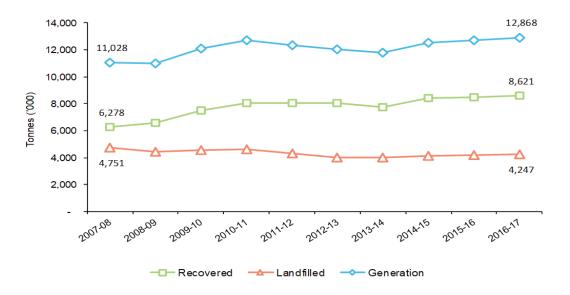


Figure W.2 Waste managed, Victoria, 2007-08 to 2016-17 (tonnes)¹³

^{10.} Sustainability Victoria 2018, 'Statewide Waste and Resource Recovery

Sustainability Victoria 2018, Sustewale Waste and Resource Rec Infrastructure Plan', Melbourne, Victoria, p170. Sustainability Victoria 2018, 'Victorian Recycling Annual Survey Report 2016–17', Melbourne, Victoria. 11.

ABS 2018, 'Australian Demographic Statistics, Estimated Resident

Population, Persons, 3101.0 – Victoria.'
Sustainability Victoria 2018, 'Victorian Recycling Annual Survey Report 2016–17', Melbourne, Victoria. 13

In 2016–17, total waste managed per capita was 2.1 tonnes, an amount that has been relatively consistent since 2006-07.14 Total waste per capita has stabilised at around 2.1 tonnes per year with a high of 2.29 and a low of 2.09 tonnes per capita in 2010–11 and 2013–14 respectively. The variability is mainly due to changes in the amount of waste generated by the construction and demolition sector. Note that this has shifted since the State of the Environment Report 2013, which noted an increase over the previous 10 years from 1.7 to 2.1 tonnes per capita.

Waste managed relative to Gross State Product (GSP) (a proxy for resource productivity) has decreased from 38.7 tonnes in 2007-08 to 29.8 tonnes of waste managed for every million dollars of GSP in 2016-17 (Figure W.3), a 23 % reduction. Noting that the rate of population growth exceeds the rate of waste managed, this per GSP unit decline is possibly due to the changing nature of business in Victoria (including the closure of some large manufacturing sites, and trends of recovering materials in construction and infrastructure) but could also be due to efficiency improvements in material use. These assumptions need to be tested.

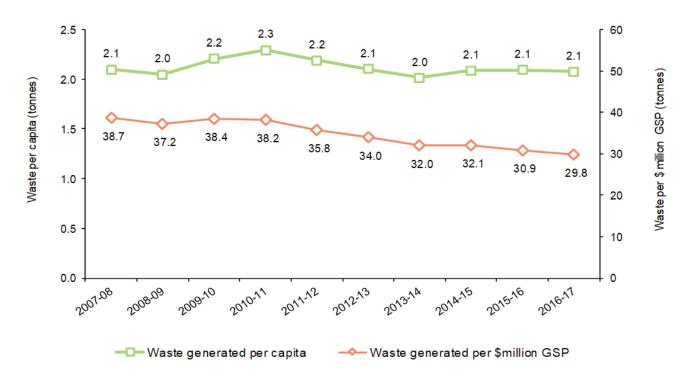


Figure W.3 Total waste managed relative to economic and population trends, Victoria, 2007-08 to 2016-17 (tonnes)15

Sustainability Victoria 2018, 'Victorian Recycling Annual Survey 14

Report 2016–17', Melbourne, Victoria 15.

Figure W.4 demonstrates the changes in the amount of recovered materials over a nine-year period from 2007-08 to 2016-17. Aggregates, masonry and soils (predominately derived from the construction and demolition sector) comprise 40% of total managed materials in 2016–17 and had a 34% increase in recovery during the nine years to 2016-17. Similarly, paper and cardboard (approximately 16% of the total waste managed), has seen recovery increase by 51%, with 78% of the total being derived from the commercial and industrial sector. Organics recovery has increased significantly, although notably linked to the introduction of garden organics collections by local governments, whereby much had previously been managed by households.

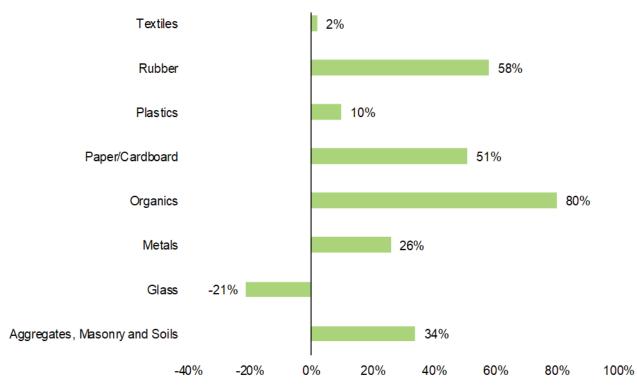


Figure W.4 Percentage change of tonnes of material types recovered for reprocessing, Victoria, 2007-08 to 2016-17

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
W:02 Generation of municipal waste per capita					\rightarrow	
Data Custodian Victorian Local Governm Annual Survey (SV) and ABS Population F		DATA QUALITY Good				

Municipal solid waste (MSW) comprises primarily household waste, which is collected through kerbside bin services and at resource recovery centres (often referred to as transfer stations). Service levels are high across the state, with over 96% of households having a kerbside collection service. The total per capita MSW in 2016–17 was 353 kg. Figure W.5 demonstrates the trend of household waste generated per capita since 2001-2002.

Figure W.5 shows that municipal waste per capita has increased slightly from 326 kg in 2001–02 to 362 kg in 2016–17. The largest increase is in organic wastes (garden organics and food organics), which have risen from 25 kg in 2001-02 to 73 kg in 2016-17. This increase was driven by the introduction, or expansion, of kerbside services for organic waste, including combined food and garden organics, in several council areas. Some of the organics would have been taken out of the residual waste service: hence, residual waste per capita fell steadily from 228 kg to 186 kg (although since 2012–13 this has been relatively stable). However, it is likely some of this material was managed outside of the kerbside system through services like hard rubbish collections, self-haul to transfer stations and on site compost bins.

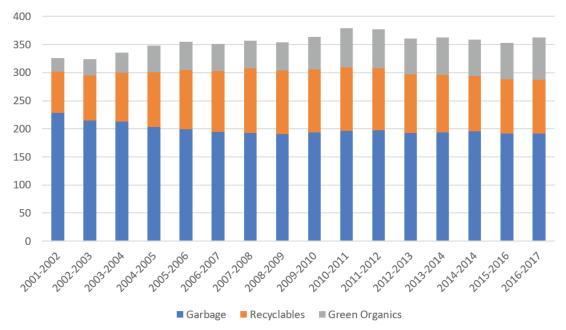


Figure W.5 Municipal solid waste per capita, 2001-02 to 2016-17 (kg) 16

Sustainability Victoria 2018, 'Victorian Local Government Annual Waste Services Report 2016-17', Melbourne, Victoria

The quantity of commingled recyclables showed a steady increase from 2001–02 (74 kg) through to 2007–08 (115 kg) and then a decline to 93 kg in 2016-17. This is most likely due to the lightweighting of packaging materials (these have moved from glass to plastics and then to lighter, flexible plastics) and a decline in the amount of paper/cardboard being managed and recycled. The commingled service offering by councils has been largely consistent in terms of materials collected, and the relatively small changes are likely a function of household consumption and

The relationship between municipal waste generation and GSP reflects the total decline in waste per GSP (refer Figure W.6).

The direct environmental benefits of Victoria's kerbside commingled recyclables collection service are significant. In 2016–17, of the 591,103 tonnes of recyclables collected by local government household kerbside services, 552,704 tonnes (94%) was recycled. Applying this figure, along with 462,599 tonnes of recycled organics, to the Life

Cycle Assessment Calculator,18 the environmental benefits of the combined 1,015,303 tonnes are estimated to include savings of:

- 8,726 megalitres of water equivalent to filling 3,491 Olympic-sized swimming pools
- 477,884 tonnes of greenhouse gases (CO₂-e) in a year, or equivalent to taking 125,759 cars off the road¹⁹ for an entire year
- saving 3,747,243 gigajoules of energy enough to provide power to almost a million Victorian households for a month

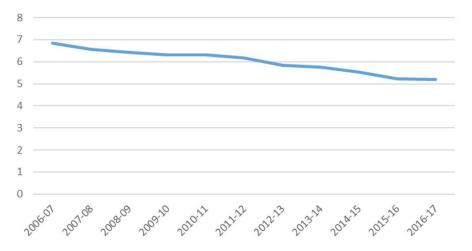


Figure W.6 The amount in tonnes (y-axis) of municipal solid waste generation per capita from 2006-07 to 2016-17 17

¹⁸ Sustainability Victoria 2018, 'Lifecycle assessment of kerbside recycling', Melbourne, Victoria https://www.sustainability.vic.gov.au

kerbside-recyclables-in-Victoria Accessed 3 December 2018. Australian Bureau of Statistics 2018, '9208.0 - Survey of motor vehicle use, Australia, 12 months ended 30 June 2016', http:// o.nsf/mf/9208.0/ Accessed 4 December 2018. Department of the Environment and Energy 2016, 'National greenhouse accounts factors, Australian national greenhouse accounts', Canberra, Australian Capital Territory http://www. environment.gov.gu/system/files/resources/e30b1895-4870-4g1faugust-2016.pdf Accessed 4 December 2018.

Sustainability Victoria 2018, 'Victorian Local Government Annual Waste Services Report 2016-17', Melbourne, Victoria



Food is a significant component of the waste generated in Victoria. It is estimated that, for 2016-17, 990,000 tonnes of food waste were generated in the state²⁰ – approximately two-thirds from households and a third from commercial and industrial activities (restaurants, hotels, food manufacturers, retailers etcetera). Audits undertaken by local governments and Sustainability Victoria show that food is about 40% of the waste thrown out by households of which half was avoidable.

The data presented in Figure W.7 shows that food waste generation decreased from 2005-06 to 2010–11, and has been relatively consistent since 2011–12. The causes of the decline in food waste generation prior to 2011 is not known.

From 2009 to 2017, estimates of the total food waste generated have been made through modelling of food waste in kerbside collections and the amount of food waste sent to landfill. New landfill and commercial and industry audit data from work being carried out in 2018 will provide more current estimates of food waste generated.

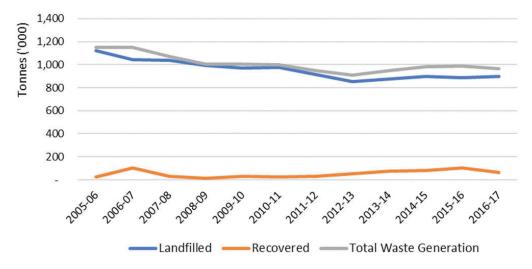


Figure W.7 Food organics, recovered and landfilled, Victoria, 2005–06 to 2016–1721

Sustainability Victoria 2018, 'Statewide Waste and Resource Recovery Infrastructure Plan', Melbourne, Australia.

Sustainability Victoria 2018, 'Waste projection model', Melbourne, projection-model# Accessed 3 December 2018.



The diversion of waste from landfill (that is, the movement of waste into recycling, recovery and reuse options as alternatives to landfill) increased steadily from 2005-06 until 2011-12 but has largely plateaued since 2012–13. Figure W.8 shows the increase in diversion rate of solid waste since 2007–08 and Figure W.9 demonstrates the trends in diversion rate by source sector.

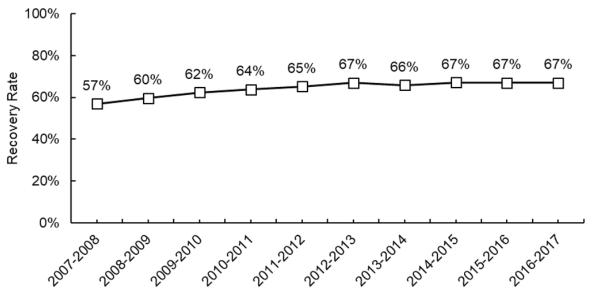


Figure W.8 Resource Recovery; Diversion rate of solid waste, Victoria, 2007–08 to 2016–17 ²²

Sustainability Victoria 2018, 'Victorian Recycling Annual Survey Report 2016–17', Melbourne, Australia.



Figure W.9 Annual diversion rate by source sector, Victoria, 2005-06 to 2015-162 23

The increase in construction and demolition recovery has been mainly in aggregates, masonry and soils from large new construction projects; these materials are readily able to be recycled into products that can be used in construction. Crushed concrete and masonry (bricks) are readily used as a replacement for gravel products, particularly for roads. The construction and demolition recycling industry is well-established, with financially viable models in current policy settings and markets for end-products, and contributes significantly to the overall diversion from landfill.

Glass recycling is an exception to the overall trend. Glass can be melted and recycled, but requires colour sorting. An alternative is for mixed, broken glass to be further crushed for use as a fitforpurpose sand replacement in some settings. Specifications and changes in procurement practices have not yet developed sufficiently and the overall recovery rate for glass has fallen.

Contamination is an ongoing challenge, with some forms of contamination rendering the recycling of materials less viable. For example, glass and oily liquids readily contaminate paper and cardboard.

Municipal diversion significantly increased from 2005 to 2008 when new collection systems were implemented. However, it has slightly declined since 2011–12, most likely due to the light-weighting of packaging materials (that is, replacing heavier recycled materials with lightweight materials that are added to garbage) and reduced amounts of paper and cardboard being recycled. An increased number of local government authorities offered organics collections, which contributed to the contributed to the increase recovery rate for organics (refer Figure W.10), but not yet at a sufficient level to substantially increase the municipal diversion rate. Variations in total organics collections due to local weather conditions (households generate more garden organics in wetter years) also impacts on the overall diversion rates.

Ibid

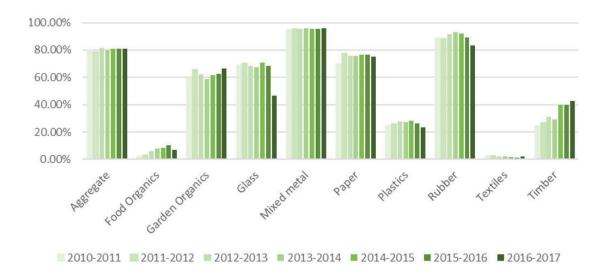


Figure W.10 Recovery rate by material type in Victoria from 2010-11 to 2016-17 27

Reprocessing and Recovery

Figure W.10 shows the recovery rates for major material categories from 2010–11 to 2016–17. These material categories include: aggregate, food organics, garden organics, glass, mixed metal, paper, plastics, rubber, textiles and timbers. Note, not all materials can be diverted from landfill and recovery rates apply to specific materials which can be recycled.

Aggregates²⁴ (mainly from the construction and demolition sector) had a recovery rate of 81%, a rate which has been relatively stable over the past seven years; similarly, mixed metals had a recovery rate of 96%. These materials have strong markets, and in the case of metals, benefit from international demand. The material that shows the greatest need for recovery (and reduction) is food organics which, despite recovery rates increased from 2% to 10% in 2015–16,²⁵ still requires substantial improvement. Food and garden organics comprise nearly 2.5 million tonnes of the waste managed. Food waste is nearly 1 million

tonnes of this. It contributes close to 25% of total waste to landfill, and generates methane in landfill, contributing odour and GHG emissions.

The recovery of plastics is also problematic, with recovery rates consistently around 25% – noting that there are many types of plastics, with varying properties that can influence recovery rates.²⁶

Excluding contaminated soils, which are considered hazardous
 Sustainability Victoria 2018, Victorian Recycling Annual Survey Report 2016–17', Melbourne, Victoria.

The changes in China's policy restricting the import of recovered materials, including plastics, came into effect in 2017-18 and is not evident in this data set.

Sustainability Victoria 2018, 'Victorian Recycling Annual Survey Report 2016–17', Melbourne, Australia.

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
W:05 Litter and Illegal Dumping					\nearrow	
Data Custodian National Litter Index (Keep Australia Beautiful) SV						Poor

Litter and Illegal dumping can have significant impacts on the environment: they threaten wildlife and can lead to long-term contamination of land and waterways. Collecting data on litter and illegal dumping is problematic because of the diffuse nature of the issue. The National Litter Index has provided a consistent measure of litter over the past nine years and while there are methodological shortcomings in the approach it does provide some comparative insights.

National Litter Index

The National Litter Index surveys 151 sites across Victoria, with an area surveyed of 239,403 square metres. While the primary focus of the monitoring is across Melbourne suburban areas, several regional and rural sites are also surveyed. A further 15 rural highway and road sites are also surveyed.

As shown in Figure W.11, with the exception of 2009–10, there has been a steady reduction of litter in Victoria. It also shows that while there are year-on-year changes, the overall shape of the litter stream has not significantly changed. In Victoria in 2016–17, cigarette butts represents approximately 53% of items counted, while takeaway food packaging is 15%.

The sites with the highest number of the littered items found in Victoria are parks and industrial and retail precincts.

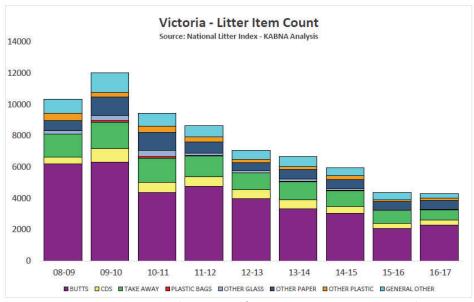


Figure W.11 Litter item count trends in Victoria from 2008-09 to 2016-17. Note: The numbers on the y-axis refer to the number of items counted ²⁸

Keep Australia Beautiful 2017, 'National Litter Index, 2016-17, Victoria Results', Newtown, New South Wales http://kab.org.au/wp-content/ report v2 2016-17.pdf Accessed 4

Victorian Litter Report Card

In 2016 the Victorian Litter Report Card was developed to research, collate and analyse current litter and illegal dumping data from across Victoria. The Litter Report Card identifies Victoria's top five litter issues, providing evidence for future investment.

In developing the Litter Report Card, the purpose, activities and available datasets in relation to litter of 25 organisations that deliver litter prevention and/or management programs were examined. The organisations reviewed included localised and specialised groups, regional bodies, statewide authorities and national organisations. Following the collation of evidence, a multi-criteria analysis (MCA) was undertaken to enable an efficient and objective analysis, considering both the qualitative and quantitative data. The MCA rating framework was designed to weight litter themes and score litter issues, to determine rankings for prioritisation based on environmental, social, economic and health and safety impacts.

The top five litter issues identified by this project were:

- litter in coastal areas and waterways
- illegal dumping of waste
- roadside litter
- cigarette butt litter
- plastic and micro-plastic litter.

Illegal Dumping

Illegal dumping is a cost that is difficult for councils to plan for, because dumping is an unknown until after it happens.

Research conducted by EPA Victoria's Illegal Dumping Strike Force program in 2016 has shown that, on average, each council is paying around \$76,000 a year to clean up 38,697 incidents of dumping, totalling more than 33,000 tonnes of illegally dumped waste.



Hazardous wastes are those that pose a substantial present or potential threat to human health and the environment. In Victoria, they are also known as Prescribed Industrial Waste and are regulated by the EPA Victoria.

In 2014–15, 920,000 tonnes of hazardous waste (excluding biosolids) were recorded as arising in Victoria (see Figure W.12). Hazardous waste is said to 'arise' when it is delivered to processing, storage, treatment or disposal infrastructure.29 It reflects how much waste is required to be managed by the various types of infrastructure, often at several locations, rather than the non-hazardous waste data which enables a calculation of the amount of material being managed by the system overall.

From 2003-04 to 2014-15, hazardous waste arising in Victoria ranged between approximately 800,000 and 1.1 million tonnes. The decline in hazardous waste from 2007 to 2009 is found across a range of types of hazardous materials³⁰ and could be related to a decline in manufacturing in Victoria during this period.

All hazardous wastes

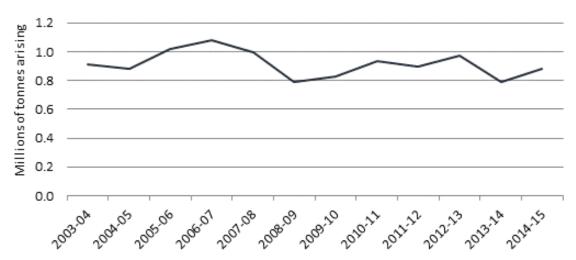


Figure W.12 Hazardous waste arising in Victoria

(Data source: Derived from Hazardous Waste in Australia 2017 (Dept. Environment and Energy 2017))

The term 'arise' 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 distinct from 'generation', a term commonly used in waste reporting, in that if waste is transported to more than one site it may 'arise' more than once in the tracking system data.

Department of the Environment and Energy 2017, 'Hazardous Waste

in Australia', Canberra, Australian Capital Territory.

There are two main waste types that are not immediately apparent in the trend data – those of legacy and emerging wastes. Legacy wastes are those wastes that are missing from the tracking data and can be present (usually stockpiled) in large volumes. In Victoria, this includes fly ash, a residue generated from combustion (of coal at coal-fired power stations), that is captured by filtration equipment. Emerging hazardous wastes include lithium-ion batteries and various flame retardants (such as per- and poly-fluoroalky) substances). The risks posed by hazardous wastes do not always correlate to volume, with some materials posing a much greater risk to human health and the environment than others.

EPA Victoria, under the Environment Protection (Industrial Waste Resource) Regulations 2009, classifies hazardous waste into more than 70 waste types. Hazardous wastes are generally a result of manufacturing or industry processes, or construction and demolition. They include contaminated soils, asbestos from construction projects, wastes from the chemicals and heavy manufacturing industry, spent industrial catalysts and other residual wastes contaminated with heavy metals. Hazardous wastes are also produced through everyday sources such as tyres, oils and oily water, grease-trap waste (commercial cooking) and lead-containing wastes such as lead acid batteries and leaded glass from used televisions and computers.

The top 10 hazardous wastes produced in Victoria in 2014-15 by weight (approx. tonnes) were:

- 1. biosolids (429,000)
- 2. contaminated soils (359,000)
- 3. grease-trap wastes (119,000)
- 4. tyres (93,000)
- 5. asbestos (80,000)
- 6. oil/water mixtures (59,000)
- 7. other putrescible/organic wastes (42,000)
- 8. other soil and sludges (28,000)
- 9. oils (26,194)

10.paints, resins, inks, organic sludges (16,000).31

Recent research undertaken at the national level 32 identified weaknesses in the hazardous waste data available in Victoria. It found:

The data quality issues arise through a mix of systemic weaknesses, poor quality assurance (QA), system-user knowledge gaps and ambiguity in coding and definitional conventions. In summary:

- source industry identification coding is absent or unreliable in all five state tracking systems
- user choices of waste codes and management codes are sometimes incorrect and often inconsistent
- incorrect use of units (e.g. m³ instead of kg) has a major impact on annual estimates
- management type data is missing from Victorian data for wastes sent interstate.

Total Hazardous Waste Per Capita

The hazardous waste dataset does not enable this calculation, as data relating to wastes arising means that materials may be measured a number of times as they move through the system. Similarly, hazardous waste is generated largely by the industrial sector, and a per capita measure is not meaningful. Furthermore, the potential or current impacts of hazardous waste relate to the risks posed and not necessarily by volume. A more nuanced indicator, relating to the SDGs, may be required to be developed.

Department of the Environment and Energy 2017, 'Hazardous Waste in Australia', Canberra, Australian Capital Territory.

³² Ibid

Future Focus

Develop indicators and reporting for the circular economy

Waste is produced at all stages of extraction, consumption and production, as well as at the end of a product's lifecycle. Victoria produced approximately 12.9 million tonnes of solid waste in 2016-17 - about as much as has been produced over the past five years.³³ The Victorian Government has committed to developing a circular economy strategy for Victoria by June 2020. This commitment is consistent with, and builds on, the current Victorian Statewide Waste and Resource Recovery Infrastructure Plan (SWRRIP) released in 2015 and amended in 2018.

The SWRRIP, and the regional plans (WRRIPs), are developed on the principles of a circular economy. A circular economy aims to:

- re-define growth by decoupling economic activity from the consumption of finite resources and design waste out of the system
- keep resources in use for as long as possible
- extract maximum value from resources while in use
- recover and regenerate products and materials at the end of each service-life so that material is not lost from the system as a waste, but becomes a resource for another use.

The concepts of waste minimisation and recycling of materials are central to the current model of waste management and resource recovery in Victoria, but transitioning our current linear economy (a 'take-make-dispose' supply-chain approach) to a circular economy model will require a paradigm shift.

Designing and implementing the transition pathway will require deep community and business engagement, and whole-of-government buy-in. It will also require more comprehensive and intensive monitoring, and a deeper understanding of system operation, than government has currently, and a shared understanding of the roles and responsibilities of all partners. A circular economy cannot focus only on waste and recycling if it is to drive change in the way people consume resources. It needs to encompass all aspects of the resources cycle, including resource extraction, imports, consumer behaviour and procurement by government. It also needs to consider approaches by, and impacts on, all sectors and markets.

To achieve this, the circular economy strategy in preparation must be supported by evidence that sets a baseline and includes performance measures to enable government and businesses to demonstrate progress and foster transparency and accountability in delivery. This will require a review of the adequacy of the planning and procurement practices of the Victorian waste management and resource recovery groups, and the Victorian Government more broadly. The Victorian Government Procurement Board could provide advice on mechanisms for executing circular economy outcomes, particularly with a focus on leveraging government procurement to create and develop markets. Changes to Financial Reporting Directions (prepared by the Department of Treasury of Finance in accordance with Australian Accounting Standards) may be a useful mechanism.

This recommendation aims to shift reporting on waste and resource recovery from transactional, ad hoc accounting to a strategic evidence base that better tracks and reports on the operation of Victoria's waste and resource recovery system - now, and as it transitions to a circular economy model over the next decade. The reporting needs to clarify the roles and responsibilities of the agencies and partners in the system and what data they are responsible for collecting, interpreting and/or maintaining.

Victorian Recycling Industry Annual Report 2016-17, Sustainability Victoria 2018

Recommendation 13: That Sustainability Victoria, in 2019, develop indicators and implement a comprehensive monitoring and reporting framework to measure delivery of the current SWRRIP and WRRIPs against their circulareconomy design principles. From July 2020, that Sustainability Victoria 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.

Align the Institutional Framework for Waste and Resources Recovery to Support a Circular Economy

One of the key priorities of the SWRRIP is the consolidation of infrastructure to collect and process recovered resources. Household and municipal waste from across local government areas is an anchor for investment in infrastructure by providing reliable, base-load volumes and creating the opportunity for potentially longer contract terms which are conducive to investment in best-practice technologies for resource reuse and recovery. Victoria has seven regional Waste and Resource Recovery Groups (WRRGs), the largest of which is the Metropolitan WRRG, servicing the majority of Victoria's population. The WRRGs share an important purpose: to undertake collective, strategic procurements for local government. Given the importance of collaborative procurement in making large volumes of recovered materials available to the market, it would be timely to evaluate success against desired objectives, and what changes may be required to achieve the delivery of a circular economy. There is scope to accelerate the pace and scale of joint procurements; however, evidence is required to identify where barriers exist and how best to remove them.

Resource recovery infrastructure needs to be established and upgraded so that recovered materials are sorted and processed to a higher standard. These recycled materials need strong domestic markets – so that various types of wastes are 'pulled' through into other material uses and products by stimulating market demand.

Recommendation 14: That the Victorian Government, commencing within the metropolitan region as a minimum, align the institutional planning and procurement processes (including leveraging Victorian Government procurement) to support the delivery of the circular economy strategy from July 2020. Ultimately, this alignment would be adopted statewide and enable an orderly transition to a circular economy in Victoria by 2030. In developing the action plan to deliver the circular-economy strategy, the roles and responsibilities of all agencies should be clarified to nominate those agencies responsible for delivering policy, procurement, program, reporting and regulatory roles. Further, that the Victorian Government commit to long-term, systemic, statewide community education to support this transition and assist the change in behaviours that will be required to improve long-term system outcomes. Reducing consumption and contamination levels in kerbside recycling would be the initial focus.

Accounting for the Environment

Environmental-economic accounting provides a framework for measuring flows of waste within the economy and from the economy to the environment. In the System of Environmental-Economic Accounting (SEEA), waste is categorised as a product flow or residual flow within the economy, or a residual flow from the economy to the environment (see Figure W.13).

Waste accounts record these connections, showing the generation (supply) and use of waste by different economic units (such as industry, government and households). Over time, accounts can be used to identify trends in waste generation and use by different sectors, including the relationship between waste generation or use and economic activity. Waste accounts provide a useful set of information for evaluating government, industry and household waste management activity.

In 2013, the Australian Bureau of Statistics (ABS) produced Australia's first and only waste accounts, which valued the supply of waste management in 2009–10 at just over \$9.5 billion. These accounts report supply and use of waste in physical (tonnes) and monetary (purchasers' prices) terms, and they align with industry classifications used by the ABS.

Unlike some residual flows, such as air emissions, solid waste often remains within the economy as it is recycled or disposed of in controlled landfills. However, there can be residual flows of liquids and gaseous materials (such as leachate and methane) from landfills to the environment. Solid waste also enters the environment as litter or dumping.

Ecosystems can be a sink for waste, providing important waste assimilation services through processing and absorption of residuals. In the case of solid waste, assimilation services are limited, as waste materials such as plastic and metal take a long time to break down. This is different to other residual flows from the economy to the environment, such as air emissions or nutrients, which are more readily assimilated.

SEEA definition	Example
Product flow within the economy	Waste that is recovered and re-used
Residual flow within the economy	Waste collected in landfill sites
Residual flow from the economy to the environment	Litter, illegal dumping Leachate or methane emissions from landfills

Figure W.13 Types of waste flows in the SEEA



Transport

This chapter includes assessments of Victoria's travel demand, greenhouse gas emissions (and emissions intensities) from transport, and air pollution from transport.

Themes relevant to this chapter are covered in other chapters, specifically the Air chapter, which incorporates air pollution from transport as part of an overall assessment of ambient air quality, and the Energy and Climate Change Impacts chapters, which also report on greenhouse gas (GHG) emissions from transport.

Background

An integrated transport network across all modes of travel is essential for a sustainable, liveable and prosperous Victoria, with the mode and efficiency of travel having a significant effect on the local economy and environment. Pollution from motor vehicles, aircraft, trains and boats increases Victoria's GHG emissions and impacts on Victoria's ambient air quality. Associated noise impacts can also affect human health and wellbeing.

The transport sector is the second-biggest contributor to GHG emissions in Victoria, accounting for 20% of the state's total in 2016. Within the transport sector, passenger cars account for the most GHG emissions, followed by trucks and light commercial vehicles.1

Victoria's population has increased from 4.8 million in 2001 to 5.9 million in 2016.2,3 This population expansion has been reflected in increased motorvehicle use, with the total kilometres travelled by motor vehicles registered in Victoria increasing by 15% from 2007 to 2016.4 The population is projected

to nearly double in the next three decades, to reach 10.1 million in 2051. Without major changes, this would significantly strain Melbourne's motor vehicle and public transport networks, which are already experiencing congestion and overcrowding.5,6,7

A greater amount of road travel increases vehicle emissions and is likely to increase population exposure to degraded ambient air quality. A Tasmanian study published in 2018 found that living within 200 m of a major road influences both the development and persistence of asthma in middle-aged adults.8

A denser population, more large-scale transport construction projects, and increased motor-vehicle use mean it is likely that more Victorians will be impacted by noise, and that impacts will be felt more often.

A current example of extended noise impacts associated with motor vehicles is the noise from trucks travelling on major residential streets in Melbourne's inner-western suburbs. Environment Protection Authority Victoria (EPA Victoria) noise-monitoring has shown elevated noise levels associated with truck movements in the region during 2001, and again during 2012. VicRoads has gradually introduced and increased truck curfew timings and locations in Melbourne's inner-west over the past two decades.9,10,11

Australian Department of the Energy and Environment, 'Australian Greenhouse Emissions Information System', Canberra, Australia

^{&#}x27;Australian Bureau of Statistics, 'Population by Age and Sex, Victoria

June 2002 Canberra, Australia. Australian Bureau of Statistics, '2016 Census QuickStats', Canberra, 3. Australia Accessed 3 December 2018

Australian Bureau of Statistics 2017, 'Survey of Motor Vehicle Use, Australia, 12 months ended 30 June 2016', Canberra, Australia http:// Accessed 3 December 2018

DELWP 2016, 'Victoria in Future 2016', East Melbourne, Victoria b pdf Accessed 3 December 2018

Infrastructure Victoria 2016, 'The Road Ahead: How an efficient, fair and sustainable pricing regime can help tackle congestion', Melbourne, Victoria http://www.infrastructurevictoria Accessed 3 December 2018

Transport for Victoria 2018, 'Metropolitan Train Load Standards Survey Report May 2018', Melbourne, Victoria http

Bowatte, G. et al 2018, 'Traffic related air pollution and development 8. and persistence of asthma and low lung function', Environment International, 113, pp. 170-176.

EPA 2001, 'Traffic Noise Measurement – Francis Street, Yarraville, 2001', Carlton, Victoria https://www.epa.vic.gov.ar Publications/820.pdf Accessed 3 December 2018

EPA 2013, 'Francis Street monitoring program - Final report', Carlton, Victoria <u>https</u> of Accessed 3 December 2018.

VicRoads, 'Truck curfews and the Inner West', Melbourne, Victoria ws/truck-curfews-in-the-inner-west Accessed 3

The critical environmental and sustainability challenges facing Victoria's transport management now and in the future include:

- reducing GHG emissions and other major pollutants in the transport sector
- reducing travel demand
- limiting noise impacts associated with travel and transport infrastructure construction.

Current Victorian Government Settings: Legislation, Policy, Programs

Transport for Victoria (TfV), part of the Department of Economic Development, Jobs, Transport and Resources, was established in April 2017. Its function is to plan, coordinate and manage the state's transport system. TfV provides leadership to Victoria's transport agencies, including VicRoads, Public Transport Victoria and V/Line, and is the customer of major project construction authorities, such as the Level Crossings Removal Authority, Rail Projects Victoria (formerly Melbourne Metro Rail Authority) and Major Road Projects Authority. TfV also works closely with VicTrack.

The objectives of Victoria's transport system are defined in the Transport Integration Act 2010.12 Section 10 of the Act states that: 'The transport system should actively contribute to environmental sustainability by -

- (a) protecting, conserving and improving the natural environment;
- (b) avoiding, minimising and offsetting harm to the local and global environment, including through transport-related emissions and pollutants and the loss of biodiversity;
- (c) promoting forms of transport and the use of forms of energy and transport technologies which have the least impact on the natural environment;
- (d) improving the environmental performance of all forms of transport and the forms of energy used in transport.'

TfV published Delivering the Goods - Victorian Freight Plan in July 2018.13 The plan sets out short, medium and long-term priorities to support Victoria's freight and logistics system through a period of unprecedented growth in freight volumes.

Transport for Victoria, 'Transport Integration Act', Melbourne, <u>-act</u> Accessed 3 December 2018

Transport for Victoria 2018, 'Delivering the Goods', Melbourne, Victoria https://transport.vic.gov.au/-/media/ tfv-documents/ports-and-freight/delivering-the-goods. pdf?la=en&hash=3AE9573B325C4886DD60408E190F55E8 Accessed

Infrastructure Victoria released a five-year focus report in April 2018 that identified immediate actions to tackle congestion.14 The Infrastructure Victoria report found that, by 2030, the time spent on congested roads across Melbourne will increase by 20%.15

In August 2018, Infrastructure Victoria published a report advising on automated and zero-emissions vehicles infrastructure.16 The report found zeroemissions vehicles would eliminate all vehicle tailpipe emissions, with a potential reduction in GHG emissions of up to 27 million tonnes by 2046 - the equivalent of about 25% of Victoria's total GHG emissions in 2015. The report also found that eliminating vehicle exhaust emissions could deliver an annual health dividend to Victorians worth between \$270 million and \$735 million.

^{14.} Infrastructure Victoria 2018, 'Five-year focus – Immediate actions to tackle congestion', Melbourne, Victoria http://infrastructurevictor April%202018.pdf Accessed 3 December 2018.

Infrastructure Victoria 2018, 'Advice On Automated and Zero Emissions Vehicles Infrastructure', Melbourne, Victoria http:// www.infrastructurevictoria.com.au/sites/default/files/files/AVZEV/Infrastructure%20Victoria%20-%20Vehicles%20Infrastructure%20 pdf Accessed 3 December 2018.

Indicator Assessment

Legend

Status

N/A Not Applicable

The indicator assessment is based on future projections or the change in environmental condition and providing a status assessment is not applicable. Only a trend assessment is provided.



Unknown

Data is insufficient to make an assessment of status and trends.



Environmental condition is under significant stress,

OR pressure is likely to have significant impact on environmental condition/ human health, OR inadequate protection of natural ecosystems and biodiversity is evident.



Environmental condition is neither positive or negative and may be variable across Victoria, OR pressure is likely to have limited impact on environmental condition/human health, OR moderate protection of natural ecosystems and biodiversity is evident.

Good

Environmental condition is healthy across Victoria, OR pressure is likely to have negligible impact on environmental condition/ human health, OR comprehensive protection of natural ecosystems and biodiversity is evident.

Trend

N/A Not applicable

This indicator assessment is based on current environmental condition only and it is not applicable to provide a trend assessment. Only a status assessment is provided.



Summary

Unclear



Deteriorating



Stable



Improving

Trend

Data quality



Evidence and consensus too low to make an assessment



Limited evidence or limited consensus



Adequate high-quality evidence and high level of consensus

Indicator

T:01 Travel demand Region

Victoria

Measures

Percentage and total number of journeys to work across Victoria made by each transport mode

Data custodian

ABS, TfV

There is a heavy reliance on motor vehicles as a commuting option in Victoria. Population growth is outpacing the mode shift away from motor vehicles to public transport, cycling or walking - more than 400,000 additional Victorians are driving to work than at the start at the 21st century.



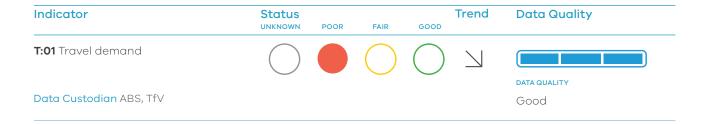
ΠΑΤΑ ΟΠΑΓΙΤΥ

Good

Status

Status Trend Summary POOR FAIR GOOD Indicator Transport GHG emissions have grown by 39% from 1990 to 2016, making it the sector with T:02 Greenhouse the highest increase in emissions in Victoria gas emission and over this period. Transport emissions have emission intensities increased in line with population growth since from transport 2009 DATA QUALITY Region Good Victoria Measures Greenhouse gas emissions from the transport sector as a proportion of total greenhouse gas emissions Greenhouse gas emission intensity (emissions per kilometre travelled) for various transport modes Data custodian TfV Indicator Air pollution is being measured in association with motor vehicle traffic in Melbourne T:03 Air pollution at only one roadside station. Decreasing from transport Fair for motor vehicles Improving for motor vehicle pollution has been linked to improved Region and Unknown for rail and vehicles and Unclear for air-quality. shipping rail and shipping Victoria Measures Air-quality DATA QUALITY concentrations Poor (Only one major roadside measured near air monitoring station and no airmajor roads and quality monitoring data available other transport for rail and shipping) activity centres Data custodian

EPA Victoria



The way Victorians travel to work can have a significant effect on the quality of the surrounding environment. Areas immediately near busy roads often have considerable air pollution. At a broader level, all vehicles with internal combustion engines emit GHGs that contribute to climate change.

The commuting habits of Victorians are slowly changing. Trend data for the period 2001 to 2016 shows that the percentage of Victorians using public transport to commute to work has increased from 11% to 16%. In the same period, there has been a drop in the percentage of people driving to work, from 84% to 79% (Figure T.1).

In Melbourne, commuting to work by bike has increased slightly (1.0% to 1.6%), as has walking to work (2.9% to 3.5%). There have been modest decreases for these transport modes in regional Victoria (1.5% to 0.8% for cycling, and 6.6% to 4.9% for walking).

Despite the decreasing proportion of Victorians driving to work since 2001, the dramatic increase in workforce population means 408,548 more Victorians were driving to work in 2016, compared to 2001. This encapsulates the challenge Victoria is facing to limit the growth in vehicle-use and alleviate congestion on the state's roads as the Victorian and Melbourne populations grow rapidly (Figure T.2).

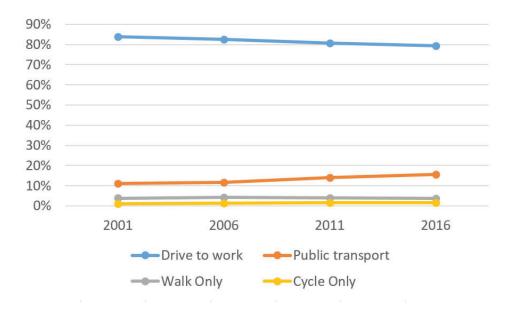


Figure T.1 Percentage of journeys to work by transport mode (Victoria) (Data source: TfV)

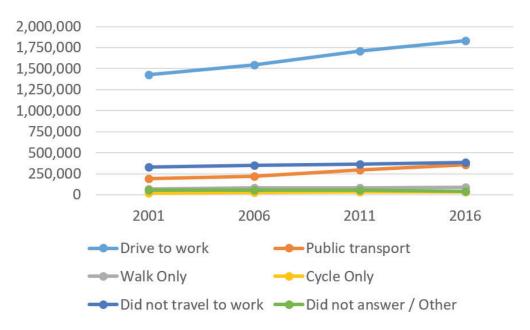


Figure T.2 Number of journeys to work, by transport mode (Victoria) (Data source: TfV, 2018)

Victoria's population expansion has led to an increase in motor-vehicle use. Total kilometres travelled by motor vehicles registered in Victoria has increased by 15% from 2007 to 2016. 17 This means the growth in vehicle use across Victoria has slightly lagged behind population growth, which increased by 20% throughout the state from 2007 to 2016.18,19

That balance is expected to flip, with Melbourne's motor-vehicle use projected to increase by 41% from 2015 to 2030,20 outpacing population growth, which is expected to be 31% over a similar period (2016 to 2031).²¹ However, there is limited scope in the current road network to accommodate the

projected growth in motor-vehicle use, so a 41% increase in vehicle use from 2015 to 2030 could be an overestimate and motor vehicle growth might only increase in-line with, or lag slightly behind, population growth.

The overall status for this indicator has been rated as poor, due to the state's reliance on motor vehicles for commuting. The trend is listed as deteriorating, because population growth is outpacing the mode-shift away from motor vehicles to public transport, cycling or walking. More than 400,000 additional Victorians are driving to work than at the start of the century.

^{17.} Australian Bureau of Statistics 2017, 'Survey of Motor Vehicle Use. Australia, 12 months ended 30 June 2016', Canberra, Australia http:// Accessed 3 December 2018.

Australian Bureau of Statistics 2008, '3235.0 - Population by Age and Sex, Regions of Australia, 2007', Canberra, Australia http://www.abs.gov.au/ Accessed 3 December 2018. Australian Bureau of Statistics 2017, '2016 Census:

^{19.} Victoria', Canberra, Australia http://www.a 3 December 2018.

Australian Department of Infrastructure and Regional Development 2015, 'Traffic congestion and cost trends for Australian capital cities'. Canberra, Australia https://bitre.gov.ai is 074.pdf Accessed 3 December 2018.

Transport and Energy

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
T:02 Greenhouse gas emission and emission intensities from transport					\rightarrow	
Data Custodian TfV						data quality Good

As noted in the Climate Change Impacts chapter and Energy chapter, the transport sector contributed 20% of Victoria's GHG emissions in 2016, with transport emissions increasing in-line with population growth since 2009. Transport emissions have grown by 39% since 1990, and the sector has had the highest proportional increase in emissions in Victoria over the period.

Road transportation is the major source of emissions from this sector, accounting for 90% of transport emissions in 2016. This is a result of the use of motor vehicles as the main mode of transport for passengers and freight.

Figure T.3 compares the GHG emissions intensity (emissions per kilometre travelled) estimated for various transport modes for 2008 and 2017. There has been a range of increases and decreases in the emissions intensity of various transport modes.

In terms of passenger travel, light vehicles contribute 91% of passenger travel kilometres in Victoria, and 94% of the transport GHG emissions. While cars increasingly emit fewer GHGs due to technological improvements, lower emissions are not reflected in average occupancy emissions, which may be attributable to reduced average car occupancy (that is, each car is carrying fewer people per trip, on average).

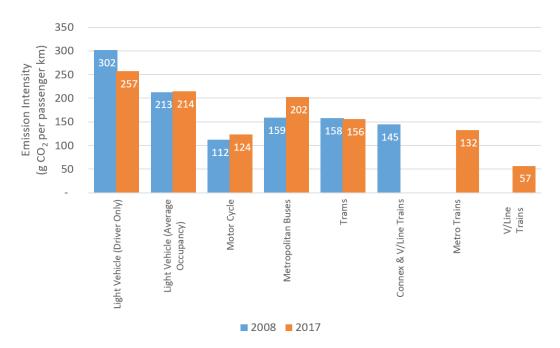


Figure T.3 Estimated GHG emissions intensity (grams CO,-e per passenger kilometre) for 2008 and 2017 (Data source: TfV, 2018)

Low or net-zero carbon-energy vehicles are emerging as a viable alternative to internal combustion engines. However, transitioning the vehicle fleet away from internal combustion engines is likely to take decades.

A notable reduction in GHG emissions per passenger kilometre has been observed on the rail network. This reduction can be attributed to greater passenger loadings associated with the increased popularity of rural rail travel following upgrades to the V/Line system. System improvements, including the Rural Fast Rail Project, Regional Rail Link and investment in VLocity trains, have driven these emissions reductions per passenger. However, total GHG emissions have increased from V/Line trains, due to significant increases in the number of services. This also means an increase in diesel pollutants and noise.

Emissions from buses per passenger kilometre have increased since 2008, which is likely due to bus services increasing faster than patronage in the intervening period. GHG emissions from trams remain unchanged, but are expected to fall to nearly zero with the launch of solar-powered trams late in 2018, when all tram energy began being purchased from renewable energy. As renewable energy increases its contribution to the energy grid, GHG emissions per passenger kilometre for metro trains will also reduce.

Freight will heavily influence future transport emissions trends. In association with population growth, freight volumes are predicted to increase from about 360 million tonnes in 2014 to nearly 900 million tonnes in 2051.22 Most of the growth in freight volumes will take place in metropolitan Melbourne.

The status assessment for this indicator has been listed as poor, due to the transport sector having the biggest proportional increase in GHG emissions from 1990 to 2016, as well as not having a reduction in emissions that other sectors (for example, stationary energy) have recorded in recent years. The trend assessment has been listed as stable, representing no significant change in total transport GHG emissions for the most recent five-year period.

DELWP, 'Victoria In Future one page profiles', East Melbourne, Victoria https://www.planning. s Accessed 3 December 2018

Transport for Victoria 2018, 'Delivering the Goods', Melbourne, Victoria https://transport.vic.gov.au/-/media/ orts-and-freight/delivering-the-goods. 3AE9573B325C4886DD60408E190F55E8 Accessed 3 December 2018

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
T:03 Air pollution from transport					⊿?	
		notor vehicle			rend: Improving	
	Unknowr	for rail and	l shipping		(motor vehicles); Unclear (rail and	Poor
					hipping)	(only one major roadside air-monitoring station; no
Data Custodian EPA Victoria						air-quality monitoring data available for rail and shipping)

Victoria has only one air-monitoring station near a busy road – the Melbourne CBD station on the northern side of the city centre. Initial results recorded at this monitoring station indicate that air-pollution ($PM_{2.5}$ – particles less than 2.5 micrometres in diameter) levels are not much different to inner-city monitoring stations at Alphington and Footscray. Decreasing motorvehicle pollution has been linked to improved air quality (see indicator AQ:02 Carbon monoxide and nitrogen dioxide), which has been reflected in the trend assessment of improving for motor vehicles.

Twelve-months of air-monitoring and noisemonitoring was completed in a residential area immediately next to Francis Street in Yarraville (in Melbourne's inner-west) in 2012 and 2013.23 This followed monitoring conducted in the region during 2001 and 2002.^{24,25,26,27} The monitoring was designed to assess air-quality and noise-quality associated with the large number of trucks using the road each day. Air-pollution levels in 2012 and 2013 breached the annual standard for PM₂₅ and the pollution was measured at greater concentrations compared with EPA Victoria's other fixed air-monitoring stations in Melbourne's inner-city. ^{28,29} Noise levels were measured at levels high enough to impact residents.30 Based on World Health Organization Guidelines for community noise, road-traffic noise-levels measured in Francis Street were high enough to cause annoyance and disturb speech and sleep.31 VicRoads has gradually introduced, and increased, truck curfew timings and locations in Melbourne's inner-west during the past two decades to ease pollution levels.32

Particle pollution associated with traffic along unsealed roads near the Brooklyn Industrial Precinct was a major contributor to one of Victoria's most significant air-pollution hotspots.33 Road-sealing works have reduced the magnitude and frequency of poor air quality in Brooklyn; however, it still remains Victoria's biggest airpollution hotspot in terms of the number of days exceeding air-quality standards (see indicator AQ:03 Particle pollution (PM₁₀ and PM₂₅)). As unsealed roads are progressively being sealed, particularly in built-up areas, re-suspended dust and its health impacts are more likely to decrease than increase.

EPA 2013, 'Francis Street monitoring program – Final report', Carlton, 23. Victoria http sed 3 December 2018

^{24.} EPA 2001, 'Air Monitoring at Francis Street, Yarraville', Carlton,

^{25.} EPA 2001, 'Traffic Noise Measurement – Francis Street, Yarraville, 2001', Carlton, Victoria https://www.epa.vic.gov.gi Publications/820.pdf Accessed 3 December 2018

^{26.} EPA 2003, 'Air monitoring at Francis Street, Yarraville during 2002', Carlton, Victoria.

^{27.} EPA 2003, 'Traffic noise measurements, Francis Street, Yarraville, 2002', Carlton, Victoria http f Accessed 3 December 2018

^{28.} EPA 2013, 'Francis Street monitoring program – Final report', Carlton, pdf Accessed 3 December 2018.

²⁹ Ibid

VicRoads, 'Truck curfews and the Inner West', Melbourne, Victoria, https://www.vicroads.vic.gov.au/business-and-industry/heav truck-curfews/truck-curfews-in-the-inner-west Accessed 3

EPA 2016, 'Brooklyn air quality update: effectiveness of road sealing', Carlton, Victoria ht 1627.pdf Accessed 3 December 2018.

EPA Victoria previously released projections for the state's air-quality,34 reported in SoE 2013. The key findings for motor vehicles were:

- total vehicle exhaust emissions are decreasing because of the introduction of better vehicle exhaust controls
- the trend towards improved exhausts is happening faster than the growth in vehicle traffic, resulting in a net reduction in total exhaust emissions from cars and trucks over time
- road dust, caused by the movement of vehicles on roads during dry weather, is expected to increase in-line with traffic growth.

No air-monitoring studies have been conducted to specifically monitor air pollution from rail emissions, although the air-monitoring station at Geelong South is located near the railway line that V/Line trains use to travel through Geelong. No adverse air-quality results associated with train travel have been recorded at Geelong South.

The status assessment for motor vehicles has been listed as fair to reflect the air pollution being measured in association with motor vehicle traffic in Melbourne's inner-west.

^{34.} EPA 2013, 'Future Air Quality in Victoria: Final Report, 2013', Carlton, Accessed 3 December 2018.

Future Focus

Monitor noise and air for thorough, timely information

Additional research must be undertaken to acquire data and understand the impacts of transport noise on Victorians. A logical starting point would be a real-time noise-monitoring network across Victoria, with a strong focus on monitoring near major transport hotspots, including busy roads, under flight-paths and along public transport routes. The noise-monitoring network would need to be established in conjunction with regular strategic noise-mapping that provides the spatial distribution of noise levels, allows for the identification of hotspots and estimates the population exposure and resulting health burden.

The other significant issue associated with transport is ambient air quality. This is closely related to population exposure, which is set to dramatically increase in line with population growth and planning strategies that aim to locate medium and high-density housing developments near metropolitan activity centres. This means that many more people are likely to be living near major roads, which might reduce travel times, but could increase exposure to air pollution from motor vehicles and the risk of respiratory illness. The risk of asthma increases by 50% for Australians that live within 200 m of a major road.35 EPA Victoria currently monitors air quality alongside only one major roadway in Victoria (in Melbourne's CBD), which is insufficient to understand the impact of air pollution in Victoria associated with motor vehicles.

Recommendation 17: That EPA Victoria. in coordination with other Victorian Government agencies, improve transport-related air and noise monitoring, including:

- developing a real-time noise-monitoring network across Melbourne (with a view to expansion across larger cities in regional Victoria), focusing on monitoring near major transport hotspots that include busy roads, flight paths and along public transport routes
- increasing the number of roadside airmonitoring stations
- publishing the noise and air data on the internet in real-time.

Note: this recommendation complements recommendation 3: Improve air-quality assessment capability.

^{35.} Bowatte G et al. 2017, 'Traffic-related air pollution exposure is associated with allergic sensitization, asthma, and poor lung function in middle age', Journal of Allergy and Clinical Immunology, 139(1), pp. 122-129 e1

Accounting for the Environment

Transport is a source of pollution and a user of energy. Under the System of Environmental-Economic Accounting (SEEA), pollution is categorised as a residual flow from the economy to the environment. Transport pollution includes noise, odour, GHGs and other air emissions.

In environmental-economic accounting, air emissions from transport can be reported in airemissions accounts where they are attributed to households, government, the transport industry or other industries. This allows consistency with the sector classifications used in the traditional System of National Accounts (SNA). Over time, air emissions accounts can be compared with economic activity reported in the SNA to track the emissions intensity of sectors and industries. Accounts information can also be used to evaluate efforts by government, industry and households to reduce emissions. (Air-emissions accounts are discussed further in the Air Quality chapter.)

The transport sector is also a user of energy. Under the SEEA, energy-use accounts report the use of different energy products (such as oil or electricity) by different sectors and industries consistent with the SNA, including the transport industry. Over time, energy accounts can be used to track how the energy-use profile of the transport industry is changing – for example, with the increased uptake of electric vehicles or improvements in the efficiency of energy-use by the transport industry.



Energy

Background

Victoria has a high-energy, high-carbon economy. The state's modern economy and society depends on a continuous flow of affordable and reliable energy. Energy powers the state's businesses, homes and transportation systems. It lights, heats and cools Victorians' buildings; powers their appliances and information and communications systems; cooks and cools their food; and pumps their water and sewerage. It is an essential factor of production, producing and transforming materials for the state's manufacturing and industrial sectors.^{1,2} The history of energy production and consumption in Victoria has shaped its cities, industries and broader economy.

An abundance of cheap energy fuelled Victoria's 20th-century economic development. Low-cost electricity allowed the state to develop heavy industries like aluminium smelting and steel production from the 1960s and become one of Australia's pre-eminent manufacturing centres.3,4 Long periods of cheap energy during the 20th century - combined with policy choices on building standards, urban planning and transport - helped to keep Victoria's energy-use efficiency at a comparatively low level compared to citizens of other Organisation for Economic Co-operation and Development (OECD) nations. 5,6 For7 example, the energy efficiency of Victoria's building stock is low when compared to world best practice8,9 and Victoria's low urban population density ensures

Victorians use considerably more energy for transport per capita than citizens of most other OECD nations.¹⁰ Overall, Victoria's per capita energy consumption in 2015 was higher than the Australian national average and higher than that of most other OECD nations, particularly when Victoria's relatively mild climate and low heating loads are taken into account (see Table E.1).

Grubb M 2014, 'Planetary Economics', Routledge, London, United

Ayers RU, Ayers EH 2009, 'Crossing the energy divide', Pearson FT Press, London United Kinadom

^{3.} Productivity Commission 2003, 'Trends in Australian Manufacturing', Canberra, Australia https turing/tiam.pdf Accessed 4 December 2018.

The McKell Institute Victoria, 'The Place to Make: The Future of Manufacturing in Victoria', Melbourne, Victoria https://mckellinstitute 4. Accessed 4 December 2018.

IEA 2017, 'Energy Efficiency 2017', Paris, France. American Council for an Energy-Efficient Economy 2018, 'The 2018 6. International Energy Efficiency Scorecard'.

IEA 2017, 'Energy efficiency indicators', Paris, France.

Sustainability Victoria 2015, 'Energy Efficiency Upgrade Potential of Existing Victorian Houses', Melbourne, Victoria https://www.sustaina-totoria cy-Upgrade-Potential Accessed 4 December 2018

Demographia 2018, 'World Urban Areas 14th Annual Edition: 201804'

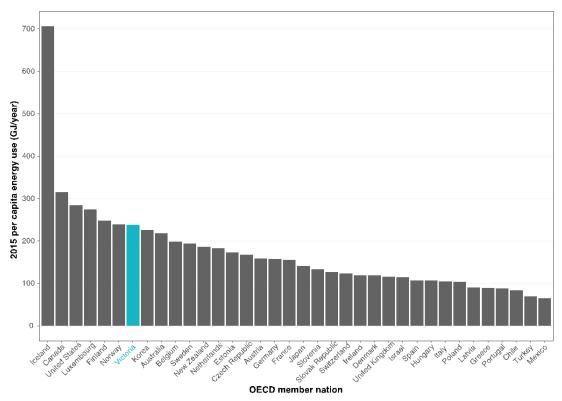


Figure E.1 Per capita energy use in Victoria, compared to OECD nations, 2015^{11,12,13}

Victoria's energy is primarily sourced from the combustion of fossil fuels, with which the state is richly endowed. Victoria has some of the world's largest deposits of brown coal, in the Gippsland Basin,14 alongside oil and gas reserves in the Gippsland, Bass and Otway Basins. 15,16,17 Access to these fossil fuel reserves helped keep Victorian energy prices low during the latter half of the 20th century. However, low-cost brown coal has also left Victoria with a legacy of dependence on high-emissions brown coal-fired generators and a much higher carbon intensity of electricity than other developed nations whose past investments in electricity generation focused on nuclear and/or hydroelectricity.

- IEA 2017, 'CO $_2$ Emissions from Fuel Combustion', Paris, France. Australian Bureau of Statistics 2018, '3101.0 Australian Demographic
- Statistics, Dec 2017 issue', Canberra, Australia. Australia Department of the Environment and Energy 2017, 'Australian 13.
- Energy Updated 2017', Canberra, Australia.
- 14 Geoscience Australia, 'Brown Coal', Canberra, Australia http://www aimr/brown-coal Accessed 4 December 2018.
- cience Australia 2012, 'Shaping a Nation: A Geology of Australia', 15. ANU Press.
- 16. Geoscience Australia, 'Australian Energy Resource Assessment', Canberra, Australia http://gera.ga.gov.gu/ Accessed 4 December 2018.
- 17. DEDJTR, 'Petroleum', Melbourne, Victoria http://eart
- Hughes L, McMichael T 2011, 'The Critical Decade: Climate Chanae 18. and Health', Climate Commission Secretariat (Department of Climate Change, Canberra, Australia.

Victoria's continued dependence on energy from fossil fuels has significant human health and environmental impacts including local air pollution (see Air chapter) and diversion of water flows for electricity generation. However, the most significant long-term environmental and human health issue arising from the state's dependence on energy from fossil fuels is the impact on Victoria's greenhouse gas emissions and their contribution to climate change (see Climate Change Impacts chapter). 18,19,20,21,22 In 2016, Victoria's net greenhouse gas emissions were around 115 Mt CO₂-e (carbon dioxide equivalent). Emissions from energy, including fuel combustion and fugitive emissions, contributed around 103 Mt of CO₂-e, or 90% of this total (Figure E.2), representing almost one-quarter of Australia's total emissions from energy.23

- Climate Council and Climate and Health Alliance 2014, 'Climate Council: Joint Statement on the Health Effects of Coal in Austral-554179635d9f4070.pdf Accessed 4 December 2018
- Preston BL, Jones RN 2006, 'Climate change impacts on Australia and the benefits of early action to reduce global greenhouse gas emissions', CSIRO, Aspendale, Victoria. Garnaut R, 2008, 'The Garnaut climate change review', Cambridge
- 21.
- University Press, Cambridge, United Kingdom. Garnaut R, 2011, 'The Garnaut review 2011: Australia in the global response to climate change', Cambridge University Press, Cambridge, United Kingdom.

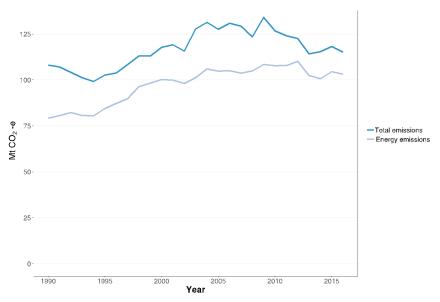


Figure E.2 Victorian energy GHG emissions compared to Victorian total GHG emissions²⁴

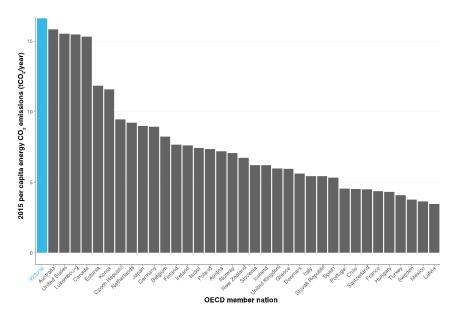


Figure E.3 Per capita energy emissions in Victoria, compared to OECD nations, 2015^{25,26,27}

In 2015, Victoria's per capita greenhouse gas emissions from energy were higher than the Australian average, which was itself the highest in the OECD (Figure E.3).

Australian Department of the Environment and Energy, 'Australian Greenhouse Emissions Information System', Canberra, Australia http://ageis.climatechange.gov.au Accessed 4 December 2018. 23.

^{24.} 25.

^{26.}

imatechange.gov.au Accessed 4 December 2018.

Challenges

Greenhouse Gas Emissions from Energy

Meeting Victoria's climate change mitigation goals requires a large-scale energy transition. Victoria's energy system is by far the most significant source of the state's greenhouse gas emissions, producing around 90% of the total in 2016. Consequently, reducing greenhouse gas emissions from energy is Victoria's principal challenge to meeting its greenhouse gas emissions reduction goals.

The Victorian *Climate Change Act 2017* (the Act) explicitly acknowledges the Paris Agreement's 2015 goal of:

... holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels recognizing that this would significantly reduce the risks and impacts of climate change.²⁸

In recognition of the responsibility of signatory nations to take strong mitigation action, the Act commits Victoria to a long-term emissions reduction target of net-zero greenhouse gas emissions by 2050. With this Act, the Victorian Government seeks to begin 'decisive, long-term action' that helps Victoria 'achieve an orderly and just transition to a net-zero greenhouse gas emissions economy and remain prosperous and liveable'.²⁹

Victoria will require an almost complete transformation of its energy system away from the current dominance of fossil fuels to low- and zeroemissions energy resources if it is to transition to a net-zero greenhouse gas emissions economy by 2050. At present, this energy transition remains in its early stages. As Figure E.4 shows, Victoria's emissions intensity of energy has remained reasonably stable since 1990 with small rises during the mid-2000s declining to just above 1990 levels by 2016. Victoria's per capita energy use and per capita CO₂-e emissions from energy have declined from their mid-2000s high to around 90% of their 1990 level. However, total energy use and total CO₂-e emissions from energy remained around 30% higher in 2016 than they were in 1990, although there have been recent small declines in both these measures despite population growth. The closure of Hazelwood power station's 1.6 GW of brown-coal-fired power generation in 2017 will likely have further reduced Victoria's overall energy emissions.

Breaking Victoria's energy emissions into sectors presents a more complex picture (see Figure E.5), but one that confirms Victoria's energy transition remains in its early stages. Electricity emissions, which represented over 50% of Victoria's total emissions in 2016, have dropped from their 2012 peak but remain close to 35% above their 1990 levels. Transport emissions, which represented around 20% of Victoria's total emissions in 2016, continue to climb at a faster rate than population growth as do those from the grouping of other energy emissions (including commercial, industrial and residential), which represent around 8% of Victoria's total. Only energy sector fugitive emissions and emissions from manufacturing and construction are lower than their 1990 levels. Together these two groups make up around 8% of Victoria's total emissions.

^{28.} United Nations 2015, 'Paris Agreement', https://unfccc.int/sites/default/files/english_paris_agreement.pdf Accessed 4 December 2018.

Office of the Chief Parliamentary Counsel Victoria 2017, 'Climate Change Act 2017', Melbourne, Victoria http://www.legislation.vic.gov.gu/Domino/Web Notes/LDMS/PubStatbook.nsf/f932b6624lecf1b-7ca256e92000e23be/05736C89E588C7C0CA2580D50006FF95/\$-FILE/17-005aa%20authorised.pdf Accessed 4 December 2018.

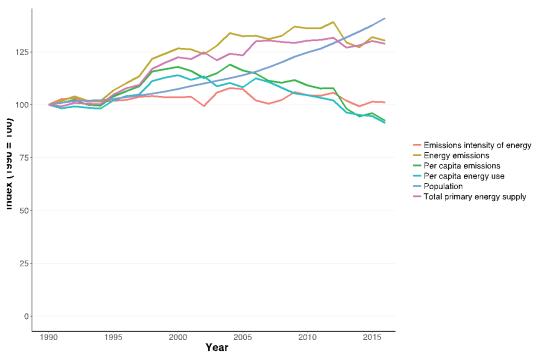


Figure E.4 Victorian population, energy use and energy emissions, changes 1990 to 2016^{30,31,32}

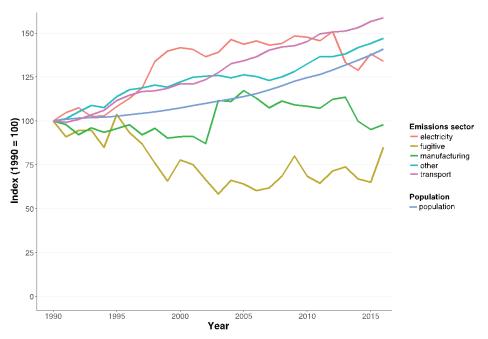


Figure E.5 Energy emissions by sector 1990 to 2016 with population growth³³

^{30.}

Australian Bureau of Statistics 2018, '3101.0 - Australian Demographic Statistics, Dec 2017 issue', Canberra, Australia.

Australian Department of the Environment and Energy, 'Australian Greenhouse Emissions Information System', Canberra, Australia http://ageis.climatechange.gov.au Accessed 4 December 2018.

Australia Department of the Environment and Energy 2017, 'Australian Energy Updated 2017', Canberra, Australia.

Australian Department of the Environment and Energy, 'Australian Greenhouse Emissions Information System', Canberra, Australia http://ageis.climatechange.gov.au Accessed 4 December 2018.

The Scale of Victoria's Energy Transition in an International Context

Like the energy systems of most Australian states and many other countries, the majority of Victoria's energy system was built over the past century on the premise of ongoing, cheap energy from fossil fuel combustion. The task of shifting a large, complex energy system from a deep reliance on fossil fuels to a net-zero-emissions future over the next 30 years has no historical precedent.34 Challenges exist across the technological, institutional, market, social and policy domains of Victoria's energy system because settings that work well for a fossil fuel system tend not to be well-suited for a low- or net-zero-carbon energy future.35 Figure 6 illustrates the magnitude of Victoria's energy transition challenge in an international context.

Attaining a Net-zero Electricity System Before 2050

Victoria's electricity system produced over 50% of Victoria's total emissions in 2016. Given the size of its contribution to state emissions and the challenges in decarbonising other sectors, particularly transport (~20% of total), the electricity system will need to lead Victoria's economy-wide emissions reductions. Decarbonisation of the electricity system also provides a platform for the future decarbonisation, through electrification from a low- or net-zero-carbon grid, of many currently non-electric, end-use energy services in transport, heating, industry and manufacturing. 40,41

Victoria has a wealth of resources for renewable electricity generation, with a number of renewable energy zones (REZs) identified by the Australian Energy Market Operator as suitable for future development because they are locations where high-quality renewable resources overlap with

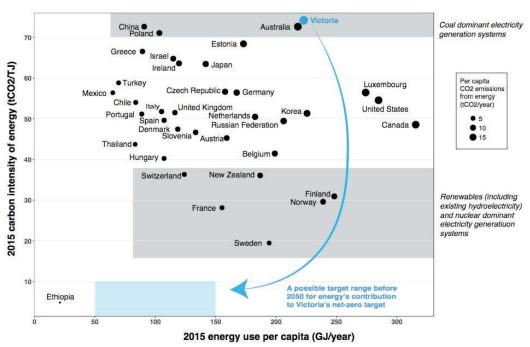


Figure E.6 Victoria's energy transition challenge to 2050^{36,37,38,39}

- Millar RJ, Fualestvedt JS, Friedlingstein P, Rogeli J, Grubb MJ, Mat-34. thews HD, Skeie RB, Forster PM, Frame DJ, Allen MR 2017, 'Emission budgets and pathways consistent with limiting warming to 1.5 C Nature Geoscience, 10, pp. 741-747.
- 35. Seto KC, Davis SJ, Mitchell RB, Stokes EC, Unruh G, Ürge-Vorsatz D 2016, 'Carbon lock-in: types, causes, and policy implications', Annual Review of Environment and Resources, 41, pp. 425-452.
- IEA, 'CO, Emissions from Fuel Combustion', Paris, France 36. Australian Bureau of Statistics 2018, '3101.0 - Australian Demographic Statistics, Dec 2017 issue', Canberra, Australia.
- Australian Department of the Environment and Energy, 'Australian Greenhouse Emissions Information System', Canberra, Australia limatechange.gov.au Accessed 4 December 2018. Australia Department of the Environment and Energy 2017, 'Australian
- 39. Energy Updated 2017', Canberra, Australia. IEA 2017, 'Energy Technology Perspectives 2017', Paris, France
- IEA 2017, 'Real-world policy packages for sustainable energy transitions', Paris, France. Australian Energy Market Operator 2018, 'Integrated System Plan',
- Melbourne, Victoria https://www.aemo.com.au/-/media, tem-Plan-2018 final.pdf Accessed 4 December 2018.

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existing network capacity (Figure E.7).42 Renewable electricity generation in Victoria has increased significantly in recent years, growing from 9% in 2010-11 to nearly 19% in 2017-18.43 This growth has been driven by a combination of high-quality wind and solar resources, state and federal renewable energy targets, declining costs for renewable energy technologies, and growing community support for renewable energy. In Victoria, over 1.6 GW of new large-scale, variable renewables is in place, another 8.5 GW has been proposed and further investment is likely to meet Victoria's legislated renewable energy targets of 25% of Victoria's electricity from renewable energy by 2020 and 40% by 2025.44,45 Rooftop photovoltaics (PV) in Victoria is projected to expand from a capacity of around 1.2 GW in early 2018 to 4-6 GW in 2035-36.46,47,48

The strong uptake of renewable energy in Victoria is reflected across the National Electricity Market (NEM), in which Victoria participates. NEM market conditions have already changed enough that renewable generation technologies are the major class of new entrants.⁴⁹ The costs of renewables and battery storage, at both large and small scales, continue to decline. Customers with solar - and more recently with solar and batteries - are becoming producers and consumers of electricity, changing the way distribution networks are managed. The small-scale local production of electricity combined with improved energy efficiency and demand reductions leads to flat or declining demand for grid-supplied electricity across the NEM.50

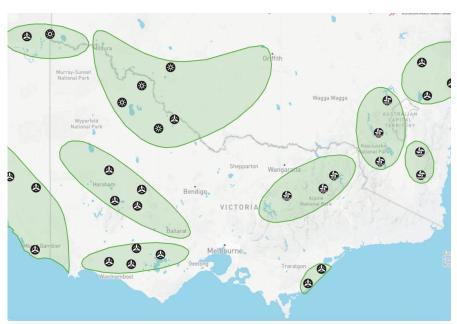


Figure E.7 Australian Energy Market Operator's renewable energy zones in Victoria

(data source: Australian Energy Market Operator)

⁴³ Note that these figures were calculated using the National Electricity Market Review: 'Metered Generation (As Generated)' extracted 3 July 2018 and from data provided by DELWP.

Australian Energy Market Operator, 'Generator Information Page', Melbourne, Victoria http:// formation Accessed 12 September 2018.

Office of the Chief Parliamentary Counsel Victoria 2017, 'Renewable Energy (Jobs and Investment) Act 2017', Melbourne, Victoria http://www.legislation.vic.gov.au/Domino/Web_Notes/LDMS/PubStatbook nsf/51dea49770555ea6ca256da4001b90cd/F9B4F84D96E4E65A 1B3DC7/\$FILE/17-056aa%20authorised.pdf Accessed 4 December 2018.

Clean Energy Regulator, 'Postcode data for small-scale installations', 46.

Australian Energy Market Commission 2018, 'Annual Market Performance Review 2017: Final report', Sydney South, New South Wales 47

Australian Energy Market Operator 2016, 'National Electricity 48. Forecasting Report: for the National Electricity Market', Melbourne, Victoria.

Simshauser P 2018, 'On intermittent renewable generation & the stability of Australia's National Electricity Market', Energy Economics, 72, pp. 1-19.

^{50.} Australian Energy Market Operator 2018, 'Integrated System Plan', Melbourne, Victoria https://www.aemo.com.au/-/media tem-Plan-2018 final.pdf Accessed 4 December 2018.

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Along with the growth of renewable electricity generation, since 2014 Victoria has also recently seen the retirement of three high-emissions brown-coal-fired generators (Anglesea, Morwell and Hazelwood) with a combined capacity of nearly 2GW.⁵¹

Despite these closures, the carbon intensity of Victoria's electricity system is likely to be significantly higher than the best-performing Australian and international jurisdictions for many years because of continuing emissions from Victoria's existing emissions-intensive electricity generators. Recent Australian Energy Market Operator (AEMO) projections, which use browncoal-fired power station retirement dates based on Victorian Government licensing decisions, suggest that by 2030, brown coal could still be used to generate around 50% of electricity in Victoria, and by 2040, brown coal generation could still provide 33% of electricity generated. This is a similar proportion to all electricity projected to be generated from wind in Victoria in the same year. 52,53,54 There is a variability associated with producing electricity generation projections, which is demonstrated by Deloitte Access Economics estimating brown coal will account for 68% of Victorian electricity generation by 2030 (which is higher than the 50% estimated by AEMO).55 AEMO's modelling projects that electricity generated from renewable sources in Victoria will double from 2018-19 to 2032-33 (from ground 26% to 57%). However, growth then flattens and electricity from renewable sources increases by less than 10 percentage points from 2032-33 to 2039-40 (see Figure E.8).56

The timing of retirement for Victoria's browncoal-fired power stations remains uncertain and is subject to a complex range of commercial and financial factors.⁵⁸ AGL have stated that it plans to close Loy Yang power station and mine in 2048. The ongoing operation of coal-fired generation to provide a third of electricity generated in Victoria into the late 2040s would likely present challenges to meeting the state's net-zero-emissions target by 2050.59 Victoria's continued reliance on coal to generate electricity is in contrast to those OECD nations that in 2017 had proportions of electricity generated by fossil fuel combustion considerably lower than AEMO projections for Victoria in 2040, including France (<12%), Sweden (<9%) and New Zealand (<19%).60

Australian Energy Market Operator, 'Generator Information Page', Melbourne, Victoria https://www.gemo.com.gu/Electricity/Nation-al-Electricity-Market-NEM/Planning-and-forecasting/Generation-iformation Accessed 20 June 2018.

^{52.} Australian Energy Market Operator 2018, 'Integrated System Plan', Melbourne, Victoria https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2018/Integrated-System-Plan-2018_final.pdf Accessed 4 December 2018.

Australian Energy Market Operator, 'AEMO Map', http://www.aemo.com.au/oemo/apps/visualisations/map.html Accessed 11 September 2018

DEDJTR, 'Latrobe Valley Mine Rehabilitation: Factsheet June 2018', http://earthresources.vic.gov.au/__data/assets/pdf_ file/0005/1668092/Latrobe-Valley-Mine-Rehabilitation-Factsheet pdf_Accessed_4_December 2019.

pdf Accessed 4 December 2018.
 55. Deloitte Access Economics 2018, 'Megatrends and the Victorian Environment', Melbourne Victoria.

Australian Energy Market Operator, 'AEMO Map', neutral scenario, http://www.aemo.com.au/aemo/apps/visualisations/map.html Accessed 11 September 2018.

Australian Energy Market Operator 2018, 'Integrated System Plan', Melbourne, Victoria https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2018/Integrated-System-Plan-2018_final.pdf Accessed 4 December 2018.

AGL Energy Limited 2017, 'Rehabilitation: AGL's Approach to rehabilitation of power generation infrastructure', http://agl2017.reportonline.com.au/files/rehabilitation_report.pdf Accessed 4 December 2018.

^{60.} IEA, 'Electricity Information 2018', Paris, France.

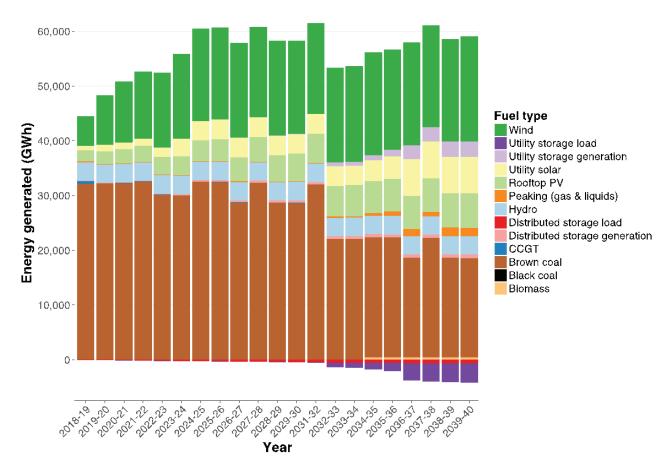


Figure E.8 AEMO Integrated System Plan electricity generation outlook projections for Victoria to 2040⁵⁷

Additional Energy Sector Transformation Challenges

A number of additional challenges for the transformation of Victoria's energy sector towards a net-zero-emissions future are outlined further in Table E.1 to Table E.3 below.

Table E.1 Energy system decarbonisation challenges – electricity

Electricity

50% of Victoria's total 2016 emissions

Fossil-fuelled system legacy

Electricity transmission and distribution networks built to take electricity from a small number of large, centrally controlled, dispatchable fossil-fuelled generators to passive consumers whose electricity demands are assumed to grow over time. 61,62

Electricity markets designed around centrally controlled, dispatchable fossil-fuelled generators providing power and essential system security services (for example, frequency control and inertia).

Transformation challenges

Electricity generation and use represents Victoria's largest emissions reduction opportunity with substantial potential for decarbonisation with existing, proven, low- or zero-carbon technologies. However, technical, institutional, financial and market structure challenges need to be addressed to get the electricity sector to low- or net-zero emissions while maintaining system security and reliability as well as affordability for consumers. The following actions are needed:

- NEM reform to ensure the smooth integration of high
 proportions of variable renewable generation and distributed
 energy resources (including provision of system security
 services and ensuring liquidity of electricity financial
 markets) as well as incentives for new generation capacity
 entry at the right time and in the right location
- new and upgraded transmission networks to link Victoria's REZs with its major load centres
- upgraded distribution networks to manage and increase the integration and participation of distributed energy resources including demand response, small-scale solar and storage in energy markets
- system operators with visibility and possibly some control of small-scale distributed energy resources as well as a possible future need for Distributed System Operator/Distributed Market Operator
- ensuring the smooth withdrawal of major coal-fired generators from the market
- substantially increasing transmission, distribution and end-use efficiencies – Australia currently ranks poorly on international measures of energy efficiency and these national rankings are likely to apply equally well to Victoria.⁶³

^{61.} Australian Energy Market Operator 2018, 'AEMO observations: Operational and market challenges to reliability and security in the NEM', Melbourne, Victoria https://www.aemo.com.au/-/media/Files/Media_Centre/2018/AEMO-observations.pdf Accessed 4 December 2018.

^{62.} Australian Energy Market Operator 2018, 'Integrated System Plan', Melbourne, Victoria https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2018/Integrated-System-Plan-2018 final.pdf Accessed 4 December 2018.

^{63.} American Council for an Energy-Efficient Economy 2018, 'The 2018 International Energy Efficiency Scorecard'.

Table E.2 Energy system decarbonisation challenges – transport

Transport 20%



Fossil-fuelled system legacy

Transport systems built to prioritise road transport using internal combustion engines (including road and fuel distribution infrastructure) and ongoing investment that prioritises road transport. (Road transport makes up 90% of total transport energy emissions.)

Land-use planning historically performed on assumptions of near universal access to personal. motorised road transport with consequent urban sprawl and comparatively long trip distances by international standards.

Transformation challenges

Energy use in transportation makes a substantial contribution to Victoria's GHG emissions. Victoria per capita transport emissions are significantly higher than the OECD average. 64,65 Victorian cars, like those of the rest of Australia, are significantly more emissions-intensive than those of most other OECD nations.66 Challenges for the transition of Victoria's transport sector to a net-zero emissions future include:

- Lack of binding emissions or fuel efficiency standards to improve the carbon efficiency of motorised transport
- Although the electrification of end-use energy services in transport is a key decarbonisation pathway,67,68 electrification of passenger and freight (particularly 'last mile') transport^{69,70} can only make important contributions to meeting Victoria's net-zero emissions goals once substantial reductions in the carbon intensity of electricity production have occurred
- Other low- or zero-carbon energy technologies for transport, for example the use of hydrogen as a fuel or the manufacture of low- and zero- carbon liquid fuels, are not yet commercially available at scale71
- Transitioning Victoria's internal combustion engine (ICE) transport fleet to low- or net-zero-carbon energy is likely to take decades (the average age of Victorian motor vehicles is 10 years⁷²)
- Significant investments in improved infrastructure will be needed, for example refuelling infrastructure for non-ICE vehicles, increased public and active transport investments⁷³ and changes to land use such as increased urban densities in activity centres well serviced by public and active transport.

IEA, 'CO2 Emissions from fuel combustion 2017', Paris, France.

Australian Department of the Environment and Energy, 'Australian Greenhouse Emissions Information System', Canberra, Australia

http://ageis.climatechange.gov.au Accessed 4 December 2018. National Transport Commission 2017, 'Carbon Dioxide Emissions 66. Intensity for New Australian Light Vehicles 2016', Melbourne, Victoria 80F5).pdf Accessed 4 December 2018

IEA 2017, 'Energy Technology Perspectives 2017', Paris, France.

IEA 2017, 'Real-world policy packages for sustainable energy transi-68.

^{69.} Energeia 2018, Australian Electric Vehicle Market Study: Prepared for

Australian Energy Market Operator 2016, 'AEMO Insights: Electric 70. Vehicles', Melbourne, Victoria.

Keith DW, Holmes G, St. Angelo D, Heidel K 2018, 'A Process for Capturing CO2 from the Atmosphere', *Joule*, 2(8), pp. 1573-1594. Australian Bureau of Statistics 2018, '9309.0 Motor Vehicle Census, 71.

^{72.} Australia, 31 Jan 2018', Canberra, Australia.

Climate Council of Australia Limited 2018, 'Waiting for the greenlight: transport solutions to climate change', Potts Point, New South Wales.

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Table E.3 Energy system decarbonisation challenges – other sectors

Remaining energy 20% of Victoria's total 2016

Fossil-fuelled system legacy

Low energy efficiency building stock built on assumptions about ongoing access to abundant and cheap energy (primarily gas) for heating.

Industrial and manufacturing technologies and systems built around access to abundant and cheap electricity, oil and gas.

Transformation challenges

This is a more challenging area likely to require many specific solutions. Electrification of heating in buildings and other nonelectricity energy end-uses in industry and manufacturing is an important option to drive decarbonisation where substantial reductions in the carbon intensity of electricity production have occurred,74,75 as are improved energy efficiency standards for buildings. Options may also exist for decarbonisation pathways for Victoria's gas networks.^{76,77,78} Understanding the carbon intensity of consumption of imported goods and services may be an important long-term goal for further decarbonising Victoria's economy and society.

Table E.4 Energy system decarbonisation challenges – non-energy emissions

Non-energy emissions 10% of Victoria's

Around 10% of Victoria's remaining 2016 emissions do not come from energy sources. The majority of these emissions come from non-energy agricultural emissions with the remainder coming from industrial processes and waste. Land use, land-use change and forestry (LULUCF) sinks reduced Victoria's emissions by roughly 10 Mt CO2-e in 2016 from what they would be if LULUCF sinks are not included in this total emissions calculation.

IEA 2017, 'Energy Technology Perspectives 2017', Paris, France

IEA 2017, 'Real-world policy packages for sustainable energy transitions', Paris, France.

Energy Networks Australia 2017, 'Decarbonising Australia's gas net-76. works', Melbourne, Victoria

Energy Networks Australia 2017, Vision 2050: Reliable, secure energy 77.

and cost-effective carbon reduction', Melbourne, Victoria. Deloitte Access Economics 2017, 'Decarbonising Australia's gas distribution networks', Canberra, Australia.

Fossil Fuel Futures in Victoria

A transition away from fossil fuels as Victoria's primary energy source is likely to relocate energy industries within Victoria, reduce the value of fossil fuel energy assets (unless commercially viable, low-carbon alternative uses can be found), and alter the role of energy technologies in Victoria's energy system. These changes will present many challenges and opportunities to Victoria's workforce, businesses and communities.

The global carbon budget that remains if the world is to meet the Paris targets requires that a significant proportion of the world's fossil fuel reserves are not burnt. 79,80 This has consequences for Victoria's future exploitation of existing reserves, particularly brown coal. The Victorian Government's Statement on Future Uses of Brown Coal states that future, high-value alternative uses of brown coal will only be supported and allowed by the Victorian Government where proponents can demonstrate operations are viable in a lowemission future economy and where a strong emissions standard can be met.

Carbon capture and storage (CCS) will be required for commercial-scale brown coal projects to achieve this outcome. One example is the Hydrogen Energy Supply Chain pilot project.81 Success of the commercial project is conditional on the hydrogen being produced with near-zero greenhouse gas emissions and a CCS solution being available. While the success of this project would enhance the potential for hydrogen to play a role in the decarbonisation of both the transport and electricity sectors, the International Energy Agency (IEA) has recently assessed CCS technology development as currently too slow to be on a trajectory to contribute meaningfully to the Paris Agreement's goals. 82 It remains unclear whether CCS will develop sufficiently as a cost-effective technology that would allow the continued exploitation of fossil fuels such as brown coal in a net-zero emissions future.83,84 Victoria continues to investigate a CCS network via the CarbonNet Project.

Victorian Government Action in the Energy **Transition**

In recognition of the overarching Climate Change Act target, the Victorian Government has also committed to 15-20% emissions reduction on 2005 levels by 2020, and emissions reductions from government operations by 30% below 2015 levels by 2020, which will largely be met by changing government energy use. Further interim targets to take the state to net-zero by 2050 will come into effect from 2021. Alongside the Victorian Renewable Energy Targets (VRETs), the state has committed to a major energy efficiency and productivity strategy, which has an aspirational goal of improving energy productivity by 50% on 2015 levels by 2030.85 Other specific Victorian Government actions are detailed in the next section (linked to the relevant indicators).

Millar RJ, Fuglestvedt JS, Friedlingstein P, Rogelj J, Grubb MJ, Matthews HD, Skeie RB, Forster PM, Frame DJ, Allen MR 2017, 'Emis budgets and pathways consistent with limiting warming to 1.5 C', Nature Geoscience, 10, pp. 741-747.

Meinshausen M, Meinshausen N, Hare W, Raper SCB, Frieler K, Knutti 80. R, Frame DJ, Allen MR 2009, 'Greenhouse-gas emission targets for limiting global warming to 2°C', *Nature*, 458, pp. 1158–1162.

Victorian State Government 2016, 'Latrobe Valley Set To Be World 81. Leader On Hydrogen', Melbourne, Victoria, https://www.p cessed 4 December 2018.

IEA 2017, 'Energy Technology Perspectives 2017', Paris, France Haszeldine RS, Flude S, Johnson G, Scott V 2018, 'Negative emissions technologies and carbon capture and storage to achieve the Paris Agreement commitments', Philosophical Transactions of the Royal Society A, 376(20160447) pp. 1-23

^{84.} Marshall JP 2016, 'Disordering fantasies of coal and technology: Carbon capture and storage in Australia', *Energy Policy*, 99, pp. 288-298.

DELWP 2017, 'Energy Efficiency and Productivity Strategy', East Melbourne, Victoria https://ww pdf Accessed 4 December 2018

Current Victorian Government Settings: Legislation, Policy, Programs

Energy Consumption and Electricity

The Victorian Government has been supporting Victoria's energy transition by increasing the supply of renewable energy and subsequently reducing Victoria's reliance on fossil fuels. Key Victorian Government actions to support the state's energy transition include:

- allocating \$122 million in the 2017–18 Victorian budget for projects to upgrade energy systems⁸⁶
- legislating for an emissions reduction target of net-zero greenhouse gas emissions by the year 2050, in the Climate Change Act 2017.⁸⁷ Interim targets to assist with the end target will come into effect from 2021.
- working towards VRETs (to generate 25% of Victoria's electricity from renewable energy by 2020 and 40% by 2025), legislated in the Renewable Energy (Jobs and Investment) Act 2017.⁸⁸ The government's work on these targets includes \$146 million in investment through the Renewable Energy Action Plan.⁸⁹
- using the government's energy purchasing power to source renewable energy certificates from new wind and solar farms in Victoria

 bringing forward around 351 MW of new renewable capacity, including 35 MW to match the electricity used by Melbourne's tram network.⁹⁰
- DELWP 2017, 'Victorian Budget 2017/18 Factsheet: Energy', East Melbourne https://www2.delwpvic.gov.au/ data/assets/pdf file/0026/63827/Budget-2017-18-Fact-Sheet-Energy-.pdf Accessed 4 December 2018
- Office of the Chief Parliamentary Counsel Victoria 2017, 'Climate Change Act 2017', Melbourne, Victoria http://www.legislation.vic.gov.au/Domino/Web Notes/LDMS/PubStatbook.nsf/f932b6624lecf1b-7ca256e92000e23be/05736C89E5B8C7C0CA2580D50006FF95/\$-FILE/17-005aa%20authorised.pdf
- Office of the Chief Parliamentary Counsel Victoria 2017, 'Renewable Energy (Jobs and Investment) Act 2017', Melbourne, Victoria http://www.legislation.vic.gov.au/Domino/Web Notes/LDMS/PubStatbook. nsf/51dea49770555ea6ca256da4001b90cd/F9B4F84D96E4E65A-CA2581D2001B3DC7/\$FILE/17-056aa%20authorised.pdf
 Accessed 4 December 2018.
- DELWP 2017, 'Renewable Energy Action Plan', East Melbourne, Victoria https://www.energy.vic.gov.au/_data/assets/pdf_file/0014/74012/ Web-pdf-Renewable-Energy-Action-Plan.pdf Accessed 4 December 2018
- DELWP, 'Government renewable energy purchasing', East Melbourne, Victoria https://www.energy.vic.gov.au/renewable-energy/victorias-renewable-energy-roadmap/government-renewable-energy-purchasing Accessed 4 December 2018.

- entering a support agreement with Neoen Australia to deliver the 200 MW Bulgana Green Power Hub project, a major new wind farm with battery storage in Stawell. The wind farm is due to be completed by late 2019.⁹¹
- launching the Victorian Renewable Energy Auction Scheme, Australia's largest ever reverse auction, for up to 650 MW of new renewable energy generation.⁹² This Scheme supports Victoria to achieve the VRETs.
- requiring Victorian electricity retailers to offer a minimum feed-in tariff (a minimum rate that electricity retailers must pay) to households and small businesses for clean electricity exported to the grid⁹³
- releasing the New Energy Technologies –
 Sector Strategy (2016) which aims to position
 Victoria to capture new jobs arising from the
 energy sector's transformation and includes
 \$20 million for a New Energy Jobs Fund⁹⁴
- developing the Energy Efficiency and Productivity Strategy (2017), which outlines \$55 million of investment in new and expanded action on energy efficiency and includes an aspirational energy productivity target of 50% improvement in Victoria's energy productivity from 2015 to 2030⁹⁵
- legislating energy savings targets under the Victorian Energy Efficiency Target Act 2007⁹⁶
- Victorian State Government 2018, 'Construction begins on Bulgana green power hub', Melbourne, Victoria https://www.premiervic.gov.au/wp-content/uploads/2018/05/180516-Construction-Begins-On-Bulgana-Green-Power-Hub.pdf Accessed 4 December 2018.
- DELWP, 'Victorian Renewable Energy Auction Scheme', East Melboune, Victoria https://www.energyvic.gov.au/ data/assets/pdf file/0014/80510/VRET-fact-sheet-Auction.pdf Accessed 4 December 2018
- Essential Services Commission 2018, 'Minimum electricity feed-in tariffs to apply from 1 July 2018', Melbourne, Victoria https://www.esc vic.gov.au/sites/default/files/documents/minimum-electricity-feed-in-tariffs-to-apply-from-1-July-2018-final-decision-20180227.pdf Accessed 4 December 2018.
- DEDJTR 2016, 'New Energy Technologies: sector strategy', Melbourne, Victoria https://www.energy.vic.gov.au/ data/assets/ pdf file/0033/73779/New Energy Technology Strategy - web ver sion - 20160308.PDF Accessed 4 December 2018.
- DELWP 2017, 'Energy Efficiency and Productivity Strategy', East Melbourne, Victoria https://www.energyvic.gov.au/_dota/assets/pdf file/0030/89292/Energy-Efficiency-and-Productivity-Strategy-Web. pdf Accessed 4 December 2018.
- Office of the Chief Parliamentary Counsel Victoria 2007, 'Victorian Energy Efficiency Target Act 2007, Melbourne, Victoria http://www.legislation.vic.gov.au/Domino/Web. Notes/LDMS/PubStatbook.nsf/f932h66241ecf1b7ca256e92000e23be/05736C89E5B8C7C0CA2580D-50006FF95/\$FILE/I7-005aa%20authorised.pdf Accessed 4 December 2018.

- strengthening the Victorian Energy Upgrades program, which, since 2009, has supported approximately 1.8 million households and 80,000 businesses to undertake energy efficiency activities – saving over 46 million tonnes of greenhouse gas emissions97
- allocating \$33 million to improve the energy efficiency of government buildings through the Greener Government Buildings program, which is anticipated to save 25,000 tonnes of greenhouse gas emissions annually98
- assisting Victorian businesses to get expert advice on saving energy and to make capital investments to improve gas efficiency through Sustainability Victoria's \$6.1 million Boosting Business Productivity program99
- supporting 50 poorly performing commercial buildings and tenancies to implement energy efficiency improvements through the Better Commercial Buildings grants program¹⁰⁰
- supporting the Victorian households most in need to undertake energy upgrades through the \$17 million Home Energy Assist program¹⁰¹
- implementing the \$25 million Energy Storage Initiative, which includes funding for two largescale storage facilities in western Victoria - one in Ballarat connected to the Ballarat Terminal Station and another connected to the Gannawarra Solar Farm. 102

boosting energy productivity through the National Energy Productivity Plan 2015-2030, a COAG-led national plan to achieve a 40% improvement in energy productivity in Australia by 2030.103

DELWP, 'Victorian Energy Upgrades', East Melbourne, Melbourne 97. av-upgrades Accessed 4 December 2018.

Victorian State Government 2016, 'Greener Government Buildings to Save \$100 million', Melbourne, Victoria https://www.pre ave-100-million/ Accessed 4

Sustainability Victoria, 'Grants for Businesses', Melbourne, Victoria https://www.sustainability.vic.gov.au/business/effic erations/boosting-business-productivity Accessed 4 December 2018

¹⁰⁰ Sustainability Victoria, 'Better Commercial Buildings', Melbourne, Vic December 2018

DELWP, 'Home Energy Assist Program, Victoria State Government', East Melbourne, Victoria, https:// gram Accessed 4 December 2018

DELWP 2018, 'Renewable Energy Technology: energy storage - largescale batteries, East Melbourne, Victoria https://www age-fact-sheet.pdf Accessed 4 December 2018.

^{103.} COAG Energy Council 2015, 'National Energy Productivity Plan 2015-2030', Canberra, Australia http://www.coagenergycouncil.gov.au/sites/prod.energycouncil/files/publications/documents/National%20 pdf Accessed 4 December 2018.

Transport and Energy

The Commonwealth and Victorian Governments are investing over \$38 billion in road and rail transport infrastructure projects to improve the reliability and efficiency of the Victorian transport system. 104 The extent to which these projects will change Victoria's transport energy use or the carbon intensity of transport is not clear. Many of Victoria's major transport infrastructure projects involve extending or improving freeways; these are likely to support and encourage increased use of internal combustion engine (ICE) vehicles as Victoria's primary transport option.

The Parliament of Victoria Economy and Infrastructure Committee published the report from their Inquiry into Electric Vehicles in May 2018. This was not associated with any project funding, however, it provided important background information on the potential future for electric vehicles in Victoria.

^{104.} Transport for Victoria 2018, 'Overview of current projects', Melbourne, Victoria https://transport.vic.gov.au/our-transport-future/our-projects Accessed 4 December 2018.

Parliament of Victoria 2018, 'Inquiry into electric vehicles', Melbourne, Victoria https://parliament.vic.gov.au/909-eic/inquiry-into-elec-tric-vehicles Accessed 4 December 2018.

Indicator Assessments

Legend

Status

N/A Not Applicable

The indicator assessment is based on future projections or the change in environmental condition and providing a status assessment is not applicable. Only a trend assessment is provided.



Unknown

Data is insufficient to make an assessment of status and trends.



Environmental condition is under significant stress, OR pressure is likely to have significant impact on environmental condition/ human health. OR inadequate protection of natural ecosystems and biodiversity is evident.



Environmental condition is neither positive or negative and may be variable across Victoria, OR pressure is likely to have limited impact on environmental condition/human health, OR moderate protection of natural ecosystems and biodiversity is evident.

Good

Environmental condition is healthy across Victoria, OR pressure is likely to have negligible impact on environmental condition/ human health. OR comprehensive protection of natural ecosystems and biodiversity is evident.

Trend

N/A Not applicable

This indicator assessment is based on current environmental condition only and it is not applicable to provide a trend assessment. Only a status assessment is provided.



Unclear



Deteriorating



Stable



Improving

Data quality



Evidence and consensus too low to make an assessment



Summary

Limited evidence or limited consensus



Good

Adequate high-quality evidence and high level of consensus

ENERGY

Indicator	Energy use per capita is declining and is
E:01 Energy use per	slightly below 1990 levels but remains high by
capita	global standards.



DATA QUALITY

Good

Status

UNKNOWN



POOR



FAIR



GOOD



Trend

Region

Victoria

Measures

G. I

Data custodian

DEE

Indicator

E:02 Total energy consumption by fuel

Region

Victoria

Measures

%

Data custodian

DEE

Total consumption has remained stable despite population growth.











DATA QUALITY

Good

	Summary	Status Trend
Indicator E:03 Consumption of renewable energy as a share of total energy consumption Region Victoria Measures % Data custodian DEE	The proportion of energy consumption from renewables is increasing. However, it still accounts for a small share of total consumption, particularly in relation to the best performing jurisdictions in Australia or internationally.	DATA QUALITY Good
Indicator E:04 Total net energy consumption by industry sector Region Victoria Measures PJ Data custodian DEE	Energy consumption has increased across most sectors and remains primarily supplied by fossil fuels.	DATA QUALITY Good
Indicator E:05 Total electricity consumption Region Victoria Measures GWh Data custodian DEE	Electricity consumption has been declining over the past five years despite population and economic growth. However, it remains well above 1989–90 levels. Overall efficiency of end use will need to improve alongside growth in low-carbon generation if emissions reduction targets are to be achieved.	DATA QUALITY Good
Indicator E:06 Total electricity generation by fuel Region Victoria Measures Twh Data custodian DELWP, NEM Review, Metered Generation and DELWP estimates	Generation from coal has decreased from a high of 90%. However, at 75% of electricity generated, coal remains the primary fuel source for electricity in Victoria.	DATA QUALITY Good

	Summary	Status Trend UNKNOWN POOR FAIR GOOD
Indicator E:07 Share of renewable energy generation of total electricity generation Region Victoria Measures % Data custodian DELWP, NEM Review, Metered Generation and DELWP estimates	The proportion of energy generation from renewables is increasing. However, renewables account for <20% of total generation.	DATA QUALITY Good
Indicator E:08 Energy used in the transport sector Region Victoria Measures PJ Data custodian Department of Environment and Energy, National Greenhouse Gas Inventory	Transport energy use increased by over 40% between 1989-90 and 2015-16.	DATA QUALITY Good
Indicator E:09 Per capita transport energy use Region Victoria Measures GJ Data custodian DEE, National Greenhouse Gas Inventory	Transport energy use per capita has remained stable over the period despite population growth.	DATA QUALITY Good

Energy Consumption

Summary of Energy Indicators

Total energy consumption in Victoria increased by 29% from 1989–90 to 2015–16, however consumption has been relatively stable since 2005–06. Energy consumption per capita has decreased since reaching a peak in 2005–06. However, the data suggests that energy consumption has not yet decoupled from population and economic growth.

Victoria's energy system is highly fossil-fuel dependant. Despite a small decrease in energy consumption from fossil fuels since 2008–09, energy sourced from the burning of fossil fuels provides over 96% of all energy consumed in Victoria in 2015–16. The share of consumption from renewable energy has doubled in this period, but the total share of renewables remains small (<4%) when compared to the consumption of energy from fossil fuels.

Greenhouse gas emissions associated with the energy sector reflect Victoria's heavy reliance on fossil fuels for energy. In 2016, emissions from energy accounted for 90% of Victoria's total greenhouse gas emissions. Energy emissions remain well above 1990 levels, despite generally decreasing since 2012.

Overall Energy Consumption

Indicator	Status				Trend	Data Quality		
	UNKNOWN	POOR	FAIR	GOOD				
E:01 Energy use per capita					\supset			
						DATA QUALITY		
Data Custodian DEE						Good		

Victoria's total energy consumption increased by 29% (317 petajoules (PJ)) between 1989-90 and 2015–16 (Table E.5). Total energy consumption reached a peak in 2011–12 at 1,448 PJ (Figure E.10).

Energy consumption per capita has remained relatively stable over the period, decreasing by around 8.6% since 1990 (Figure E.4). Energy efficiency improvements have helped to reduce per capita consumption, however, these improvements

are not accelerating at the rate required to drive a substantial decrease in total energy consumption. This has implications for Victoria's total greenhouse gas emissions particularly given the majority of Victoria's energy is currently supplied by fossil fuels.

Table E.5 Victoria's energy consumption by sector, difference between 1989–90 and 2015–16¹⁰⁶

Sector	Energy co	nsumption	Energy co	nsumption	Difference		
00001	1989	-90	201	5–16	1989-90 to 2015-16		
	PJ	Share (%)	PJ	Share (%)	PJ		
Agriculture	10.4	0.9	15.5	1.1	5.1		
Mining	25.8	2.3	30.1	2.1	4.3		
Manufacturing	226.3	20.6	205.7	14.5	-20.6		
Electricity generation	377.5	34.3	511.1	36.1	133.6		
Construction	9.8	0.9	4.8	0.3	-5.0		
Transport	260.2	23.7	367.1	25.9	106.9		
Commercial (b)	46.2	4.2	101.3	7.1	55.1		
Residential	124.2	11.3	170.9 12.1		46.7		
Other (c)	19.4	1.8	10.3	0.7	-9.1		
Total	1,099.8	100.0	1,416.9	100.0	317.1		

^{106.} Department of Environment and Energy 2017, 'Australian Energy Statistics 2017', Canberra, Australia.

Energy Consumption by Fuel Source

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
E:02 Total energy consumption by fuel					\rightarrow	DATA QUALITY
Data Custodian DEE						Good
E: 03 Consumption of renewable energy as a share of total energy consumption					7	DATA QUALITY
Data Custodian DEE						Good

Energy consumption in Victoria has remained relatively flat since 2005–06 (Figure E.9). Brown coal is the primary fuel consumed for energy in Victoria, accounting for 44% of total energy consumption in 2015–16 (Table E.6). This is almost entirely used for electricity generation. Since 2011–12, consumption of coal has decreased by 11% (77 PJ). These reductions are associated with a reduction in total electricity generation from brown coal due to the closure of coal-fired power stations in Victoria. The latest Australian Energy

Statistics fuel consumption data for Victoria does not include the closure of Hazelwood power station which occurred in 2017. However, as outlined in Table E.7, additional electricity-only data sets show that brown-coal-fired electricity generation in Victoria decreased from 90% of the state's electricity generation in 2010–11 to 75% in 2017–18. This includes a 15% decrease between 2016–17 and 2017–18, as a result of the closure of the Hazelwood power station.

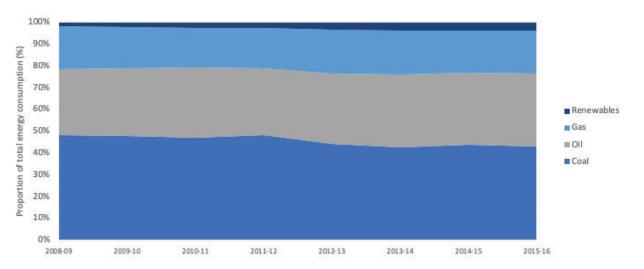


Figure E.9 Proportion of Victoria's energy consumption by fuel type¹⁰⁸

^{107.} Australian Energy Market Operator, 'Generator Information Page', Melbourne, Victoria http://www.aemo.com.au/Electricity/Nation-al-Electricity-Market-NEM/Planning-and-forecasting/Generation-information Accessed 20 June 2018.

^{108.} Department of Environment and Energy 2017, 'Australian Energy Statistics 2017: Table C3', Canberra, Australia. Note there is a 1%–2% statistical discrepancy in these figures.

The decrease in consumption of brown coal has been offset by an increase in consumption of renewables and a minor increase in gas consumption (Table E.6). Renewable energy accounted for 4% of Victoria's energy consumption in 2015-16, increasing from 2% in 2008-09 (Figure E.9). While trending up, renewable energy still accounts for a small amount of total energy consumption in Victoria. For comparison, in 2015–16 over 10 times more energy was consumed from coal than renewable sources (Table E.6). However, as more renewables become available in Victoria's energy system in response to the state's Renewable Energy Target and declining cost of renewable technology, consumption of energy from renewable sources is expected to increase.

Oil is the second largest fuel consumed for energy in Victoria, accounting for 34% of Victoria's total energy consumption in 2015-16 (Table E.6). This includes crude oil, liquefied petroleum gas (LPG) and refined products, which are primarily used for fuel in the transport sector. This sector has experienced an increase in total energy consumption which can account for some of the increase in oil consumption. Refer to the Energy in transport section (below) for further details.

Natural gas comprised 20% of Victoria's energy consumption in 2015–16 (Table E.6). This is primarily used for space heating, industry and other nondomestic uses - such as in hospitals where it accounts for around 50% of total energy use. 110 The share of gas consumption in Victoria has remained stable over the period.

Table E.6 Victoria's energy consumption by fuel type, difference between 2008-09 and 2015-16¹⁰⁹

Fuel type	0.2	nsumption 3–09	0.2	nsumption 5–16	Difference 2008-09 to 2015-16		
	PJ	Share (%)	PJ	Share (%)	PJ		
Coal	695.2	48.9	617.8	43.6	-77.4		
Oil	430.8	30.3	480.3 33.9		49.5		
Gas	280.4	19.7	284.2	20.1	3.8		
Renewables	27.5	1.9	55.1	3.9	27.6		
Total	1,421.0	100.0	1,416.9	100.0	-4.1		

^{110.} DHHS 2017, 'Annual Report 2016-17', Melbourne, Victoria https://dhhs. port-2016-17_20171016.pdf Accessed 4 December 2018.

Energy Consumption by Industry

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
E:04 Total net energy consumption by industry sector					\rightarrow	DATA QUALITY
Data Custodian DEE						Good

Energy consumption across industry sectors has followed a similar pattern to total energy consumption in Victoria, generally increasing between 1989–90 and 2015–16 (Figure E.10). All sectors have an increased total energy consumption, with the exception of manufacturing, construction and other. The decrease in manufacturing energy consumption can be linked to the decline of manufacturing in the Victorian economy over the period.

Electricity generation, transport and manufacturing are the largest energy-consuming sectors, accounting for over three-quarters of total energy consumption in Victoria in 2015–16. As identified in the Background section, these sectors contribute significantly to Victoria's total GHG emissions due to the dominance of fossil fuels in Victoria's energy system. Each sector is discussed in the Electricity, Energy in transport and Other energy sections below.

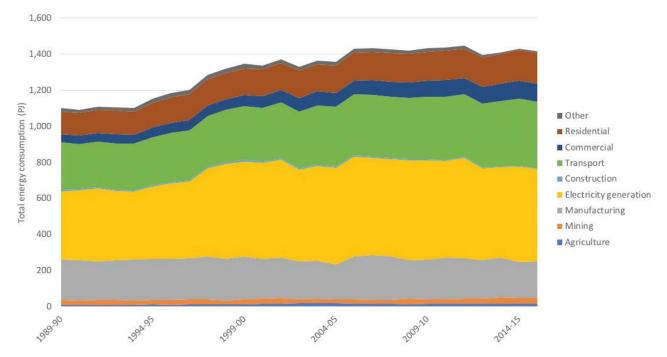


Figure E.10 Energy consumption by industry sector in Victoria, 1989–90 to 2015–16¹¹¹

Department of Environment and Energy 2017, 'Australian Energy Statistics 2017: Table E3', Canberra, Australia.

Electricity

Summary of Indicators

The electricity sector in Victoria continues to be heavily supplied by coal, which contributes 75% of total electricity generation in 2017-18. However, an increasing proportion of electricity is being supplied by renewable sources, increasing from 9% of total generation in 2010-11 to 19% in 2017-18.

This trend is reflected in the changes in Victoria's emissions from electricity. Emissions were increasing until 2011 and have declined since, however, they remain well above 1990 levels. Victoria's electricity system is a major contributor to the state's total emissions, producing over 50% of total emissions in 2016.

Consumption of Electricity

Indicator	Status				Trend	Data Quality		
	UNKNOWN	POOR	FAIR	GOOD				
E:05 Total electricity consumption					\nearrow			
						DATA QUALITY		
Data Custodian DEE						Good		

Data Custodian DEE

Victoria's total electricity consumption increased by around 28% (10,666 GWh) between 1989-90 and 2015–16 (Figure E.11). This has occurred with two main peaks, in 2001–02 (53,091 GWh) and 2009-10 (54,606 GWh). Over the past five years, consumption has not increased and has been declining marginally; however, it remains well above 1989–90 levels.

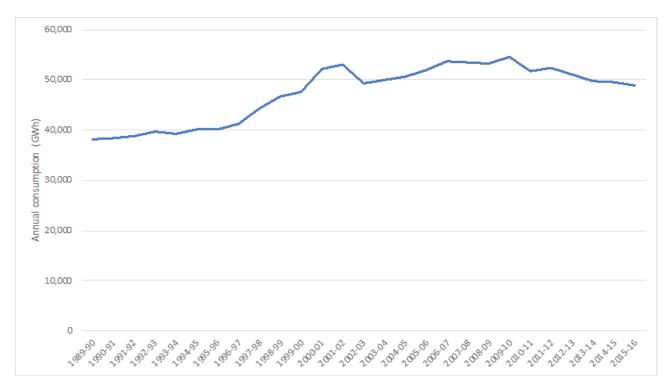


Figure E.11 Total annual electricity consumption, Victoria, 1989–90 to 2015–16112

The change in electricity consumption over the period is predominately due to population and economic growth combined with increasing offsets by small-scale, distributed generation and energy efficiency, which are likely to stabilise overall demand for grid-supplied electricity. 113 Stable demand for grid-supplied energy despite population growth will assist Victoria's energy transformation, particularly if the grid is increasingly supplied from renewable sources.

Department of Environment and Energy 2017, 'Australian Energy Statistics 2017: Table L', Canberra, Australia.

Australian Energy Market Operator 2017, Electricity Forecasting Insights: for the national electricity market, Melbourne, Victoria https:// Forecasting/EFI/2017-Electricity-Forecasting-Insights.pdf Accessed 4 December 2018.

Electricity Generation by Fuel

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
E:06 Total electricity generation by fuel					7	
Data Custodian DELWP, NEM Review, Mete Generation and DELWP estimates	ered					DATA QUALITY GOOD
E:07 Share of renewable energy generation of total electricity generation					\supset	DATA QUALITY
Data Custodian DELWP, NEM Review, Mete Generation and DELWP estimates	ered					Good

Electricity generation in Victoria decreased between 2010-11 and 2017-18 by 15% (8.77 TWh). This decrease primarily occurred between 2016–17 and 2017–18 where generation decreased by 11% (6.35 TWh) due to the closure of the Hazelwood power station (Figure E.12).

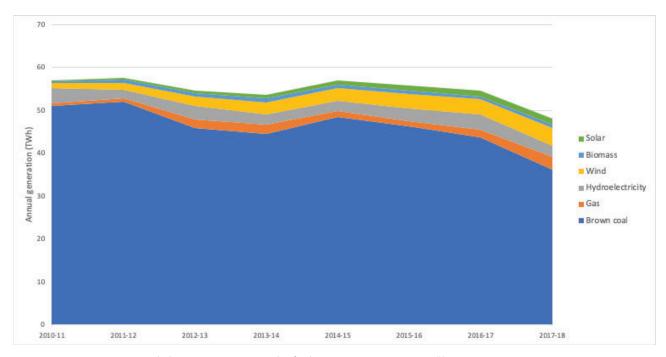


Figure E.12 Victoria's annual electricity generation by fuel type, 2010–11 to 2017–18¹¹⁴

Note that these figures were calculated using the National Electricity Market Review: 'Metered Generation (As Generated)' extracted 3 July 2018 and from data provided by DELWP.

Brown coal remains the major fuel source for electricity generation in Victoria, consisting of 75% of Victoria's total electricity generation in 2017–18. Electricity generation from brown coal has decreased by 29% (14.8 TWh) between 2010–11 and 2017–18, a decrease which has been partially offset by increases in electricity generation from gas and renewables (Table E.7).

The proportion of electricity generation from renewable sources has been gradually increasing, providing approximately 19% of Victoria's electricity generation in 2017–18. This represents almost double the generation between 2010–11 and 2017-18.

Table E.7 Annual electricity generation in Victoria by fuel type, difference between 2010-11 and 2017-18115

	Electricity generation 2010-11 TWh Share (%)		Electricity 201	Difference 2010-11 to 2017-18 TWh					
TWh Share (%) TWh Share (%) T Non-renewable sources									
Coal	50.92	89.5	36.11	75.0	-14.82				
Gas	0.72	1.3	2.98	6.2	2.26				
Total Non-renewable sources	51.64	90.8	39.09 81.2		-12.56				
	Renewo	able sources							
Hydro	3.44	6.0	2.65	5.5	-0.78				
Wind	1.26	2.2	4.22	8.8	2.96				
Biomass	0.34	0.6	0.71	1.5	0.37				
Solar	0.21	0.4	1.45	3.0	1.24				
Total Renewable sources	5.24	9.2	9.04	18.8	3.79				
Total generation	56.89	100.0	48.12	100.0	-8.77				

Wind is the primary source of renewable energy generation in Victoria, accounting for around half of the total renewable energy generation in 2017–18 (Figure E.13). Electricity generation from wind and solar have increased notably between 2010–11 and 2017–18, and there has been a minor increase in generation from biomass. There have been fluctuations in the generation of electricity from hydro that are mainly attributable to below average rainfall in catchment areas. 116

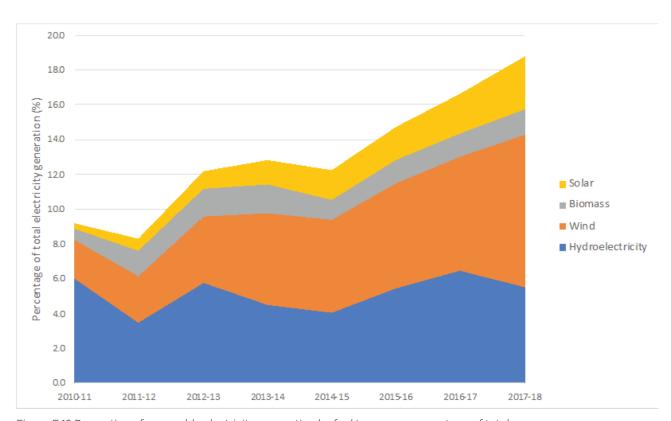


Figure E.13 Proportion of renewable electricity generation by fuel type, as a percentage of total electricity generation in Victoria, 2010-11 to 2017-18117

Clean Energy Council 2018, 'Clean Energy Australia Report 2018', Melbourne, Victoria https://www.clean 4 December 2018

Note that these figures were calculated using the National Electricity Market Review: 'Metered Generation (As Generated)' extracted 3 July 2018 and from data provided by DELWP.

Rooftop solar PV capacity in Victoria has grown significantly over the past decade. The total installed capacity in 2017 was around 1,227 MW (Table E.8). Victoria has the third largest installed capacity in Australia, behind Queensland and New South Wales. ¹¹⁸ In Victoria, solar PV uptake peaked in 2012, with around 206 MW installed due to the rapid decline in the cost of solar PV installation supported by high feed-in tariffs (Table E.8). Installed capacity rose again in 2017, due to

significant cost reductions that have made larger PV systems more affordable to households and a growing level of uptake from the commercial sector. ¹¹⁹ The average Australian solar PV system size has increased from 1.28 kW in 2009 to 6.27 kW in 2017. ¹²⁰

Table E.8 Annual installed capacity of small-scale solar PV in Victoria, 2007–2017¹²¹

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Per year (MW)	1.09	2.84	13.33	58.98	142.09	206.64	135.33	172.91	151.15	146.14	196.1
Cumulative Total (MW) (a)	1.09	3.93	17.26	76.24	218.33	424.97	560.3	733.21	884.36	1,030.5	1,226.6

(a) Total includes pre-2007 installations

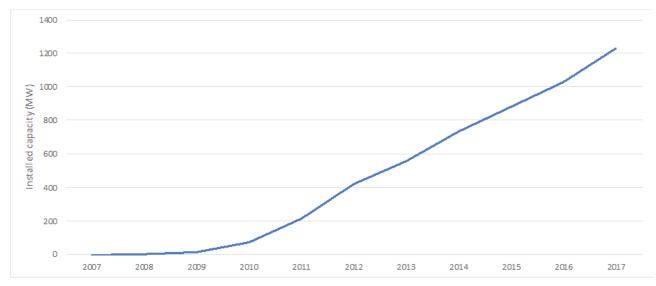


Figure E.14 Cumulative capacity of small-scale solar PV installations in Victoria, 2007–2017¹²²

Clean Energy Council 2018, 'Clean Energy Australia Report 2018', Melbourne, Victoria https://www.cleanenergycouncil.org.au/policy-advocacy/reports/clean-energy-australia-report.html Accessed 4 December 2018.

^{119.} Jacobs Group (Australia) Pty Limited 2017, 'Projections of uptake of small-scale systems', Melbourne, Victoria https://www.aemo.com. au/-/media/Files/Electricity/WEM/Planning. and Forecasting/ESO-O/2017/2017-WEM-ESOO-Methodology-Report---Projections-of-Uptake-of-Small-scale-Systems.pdf Accessed 4 December 2018.

Clean Energy Council 2018, 'Clean Energy Australia Report 2018', Melbourne, Victoria https://www.cleanenergycouncil.org.au/policy-advocacy/reports/clean-energy-australia-report.html Accessed 4 December 2018.

¹²¹. Ibio

¹²². Ibid

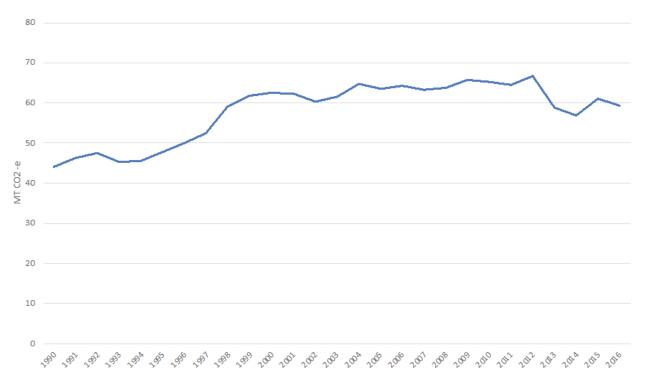


Figure E.15 Annual emissions from public electricity in Victoria, 1990–2016^{123,124}

Electricity emissions, which represented over 50% of Victoria's total emissions in 2016, have dropped from their 2012 peak but remain close to 33% above their 1990 levels (Figure E.15).

Australian Department of the Environment and Energy, 'Australian

Australian Department of the Environment and Energy, Australian Greenhouse Emissions Information System', Canberra, Australia http://ageis.climatechange.gov.gu Accessed 4 December 2018. Australian Government Department of the Environment and Energy 2018, 'National Inventory Report 2016: Volume 11, Canberra, Australia port-2016-volume-1.pdf Accessed 4 December 2018.

Energy in Transport

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
E:08 Energy used in the transport sector					\supset	
Data Custodian Department of Envir Energy, National Greenhouse Gas Invento		id				Good
E:09 Per capita transport energy use					\rightarrow	
Data Custodian DEE, National Greent Gas Inventorys Inventory	nouse					data quality Good

Energy use in the transport sector has steadily increased in Victoria, which has partially driven the increase in consumption of energy from oil. The vast majority of the energy use in the transport sector is associated with road transportation, which is heavily fossil fuel dependant and contributes a significant amount to Victoria's transport emissions – around 90% in 2016.

There are major opportunities in the road transport sector in Victoria to reduce emissions through both fuel efficiency and fuel switching (from fossil fuels to renewable energy). This must occur within the broader context of the rapid transformation of Victoria's energy system to ensure that there is no lag between fuel switching and supply from renewable sources.

Energy Consumption by the Transport Sector

As highlighted in the Energy Consumption section (Table E.5), the transport sector was Victoria's second largest energy consuming sector, accounting for 26% of total energy consumption in 2015–16. Energy consumption in this sector has steadily increased by 44% (112.4 PJ) between 1989–90 and 2015–16, primarily due to the increased transport demands of a growing population.

Energy Use by Fuel Type

Fossil fuels provide energy for most transport in Victoria. Petrol was the primary fuel type consumed by the transport sector, accounting for 41% of total energy consumption in 2015–16 (Table E.9). There was a minor decrease in total consumption of petrol between 1989–90 and 2015–16; however, the share of petrol notably decreased. This was partially offset by an increase in diesel consumption, which accounted for 34% of consumption, increasing by 73.6 PJ in 2015–16. Other fuel types increased between 1989–90 and 2015–16 including biofuels; however, these are very minor compared to petrol and diesel consumption (Figure E.16).

Table E.9 Energy consumption in the transport sector by fuel type, Victoria, difference between 1989–90 and 2015-16125

	Energy consumption 1989–90			onsumption 15–16	Difference 1989-90 to 2015-16		
	PJ	Share (%)	PJ	Share (%)	PJ		
LPG	14.4	5.7	25.8	7.0	11.4		
Petrol	152.9	60.0	151.1	41.2	-1.8		
Diesel	51.0	20.0	124.6	33.9	73.6		
Electricity	1.1	0.4	3.3	0.9	2.2		
Natural gas	0.4	0.2	2.1	0.6	1.7		
Liquid/gas biofuels	0.0	0.0	0.3	0.1	0.3		
Other	34.9	13.7	59.9	16.3	25.0		
Total	254.7	100.0	367.1	100.0	112.4		

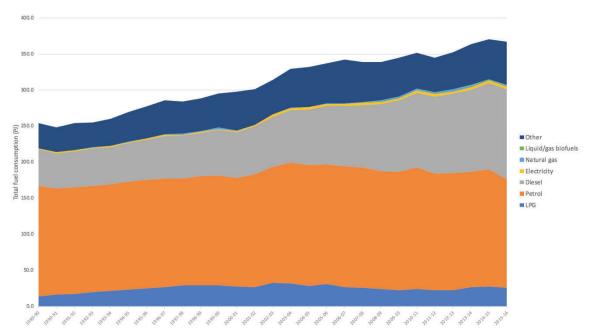


Figure E.16 Energy consumption in the transport sector by fuel type, Victoria, 1989–90 to 2015-16126

Department of Environment and Energy 2017, 'Australian Energy Statistics 2017: Table F3', Canberra, Australia. Note that 'Other' includes fuel oil, lubricants and greases, and aviation fuel (gasoline

Department of Environment and Energy 2017, 'Australian Energy Statistics 2017: Table F', Canberra, Australia.

Consumption by Transport Subsector

Energy consumption in the transport sector is largely associated with road transport (Figure E.17). Petrol is the primary source of energy for the road transport sector, accounting for 51% of fuel consumption in that sector. This is followed by diesel consumption with 40% of road transport energy consumption. The sprawling nature of Victorian cities has led to high household vehicle ownership and longer distances between activities and services, which exacerbates Victoria's reliance on road transport.

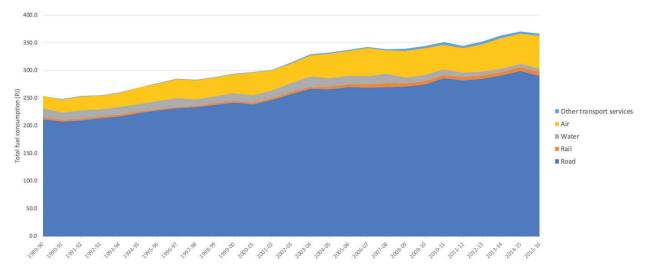


Figure E.17 Total fuel consumption by transport subsector, Victoria, 1989–90 to 2015–16127

Per Capita Transport Energy Use

Per capita transport energy use has remained relatively stable since 1989–90, at around 60 GJ per person. It has varied by little more than 10 percentage points over the entire period. However, per capita use needs to decline along with substantial fuel switching in order to reduce the transport sector's contribution to Victoria's GHG emissions.

127. Ibid.

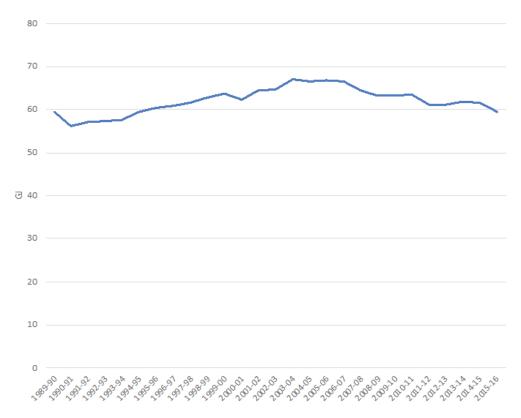


Figure E.18 Per capita transport energy use, Victoria, 1989–90 to 2015–16^{128,129}

Emissions From the Transport Sector

Transport emissions represent around 20% of Victoria's total emissions in 2016. This is primarily associated with the use of cars, light commercial vehicles and heavy trucks (Figure E.19). There are significant emissions reduction opportunities associated with improving the fuel efficiency of Victoria's ICE road transport fleet. There are also longer-term opportunities – shifting Victoria's road transport fleet to electric vehicles powered by renewable sources.

Department of Environment and Energy 2017, 'Australian Energy 128.

Statistics 2017: Table E3', Canberra, Australia.

Australian Bureau of Statistics 2017, '3101.0 - Australian Demographic Statistics, Jun 2017', Canberra, Australia http://www.abs.gov.au/

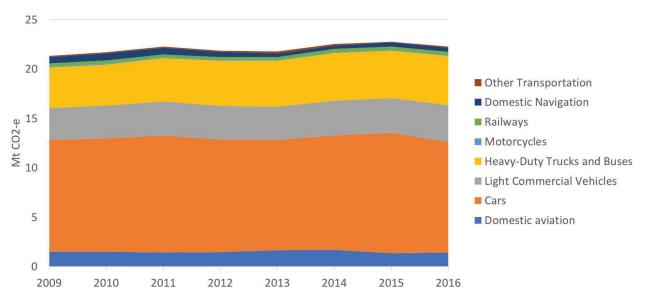


Figure E.19 Energy emissions from the transport sector by type of transport, 2009–2016¹³⁰

Emissions per capita from transport have remained stable between 2009 and 2016, despite an increase in Victoria's population (Figure E.20). Figure E.20 highlights the lack of progress in fuel efficiency and fuel switching to low or zero-carbon alternatives in the transport sector compared to the energy sector as a whole.

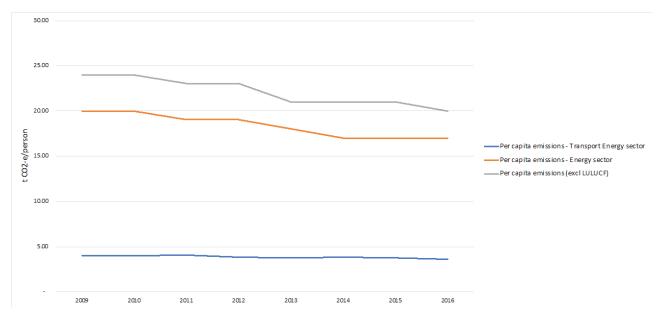


Figure E.20 Transport sector emissions per capita compared to total energy sector and overall emissions between 2009 and 2016^{131,132}

Australian Department of the Environment and Energy, 'Australian Greenhouse Emissions Information System', Canberra, Australia http://ageis.climatechange.gov.au Accessed 4 December 2018.

^{132.} Australian Bureau of Statistics 2017, '3101.0 - Australian Demographic Statistics, Jun 2017', Canberra, Australia http://www.abs.gov.au/AUSSTATS/abs@nsf/DetailsPage/3101.0Jun%202017?OpenDocumen Accessed 4 December 2018.

Other Energy Sectors

This area includes all the remaining sectors, including manufacturing, construction, commercial and residential. Emissions reductions in this area will be challenging as each sector is likely to require many specific solutions. Industry-related data is not available at the level required to be able to make sound judgements on the drivers of change in each sector. In some cases, emissions reduction may be driven by industries closing down in Victoria rather than efficiencies.

Further work will need to be completed to understand the factors influencing change in these sectors in order to develop appropriate indicators, for example AEMO's recent study on the effects of energy efficiency policies and programs on energy usage.133

^{133.} Pitt & Sherry 2016, 'Estimating the Effects of Energy Efficiency Policies and Programs on Usage of Electricity and Gas', http aemo.com.au/-/media/Files/Electricity/NEM/Planning and Forecasting/NEFR/2016/Estimating-the-Effects-of-Energy-Efficiency-Policies-and-Programs-on-Usage-of-Electricity-and-Gas.pdf Accessed 4 December 2018

Future Focus

Monitoring and Reporting on the Targets for Victoria's Energy Transition

In 2017, Victoria passed the Climate Change Act 2017, which explicitly acknowledges the 2015 Paris Agreement's goal of "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels recognizing that this would significantly reduce the risks and impacts of climate change".134

In addition to legislating Victoria's 2050 netzero emissions target, the *Climate Change Act* 2017 requires the Premier and relevant Minister to establish five-yearly interim targets to keep Victoria on track to meeting the 2050 target. The Climate Change Act requires the Minister to obtain expert advice on options for the interim targets, indicative trajectories for Victoria to 2050 based on interim target options, and efficient and costeffective opportunities for achieving the interim targets. Interim emissions targets for the 2021-2025 and 2026–2030 periods must be set on or before 31 March 2020.¹³⁵

Reducing greenhouse gas emissions from energy is Victoria's principal challenge to meet its greenhouse gas emissions reduction goals. The Independent Expert Panel constituted under the Climate Change Act to provide advice on interim emissions reduction targets has identified opportunities to achieve emissions reductions through an energy transition in electricity generation, transport, industry and the built environment. Major opportunities include shifting to zero- and low-carbon electricity generation, electrification of energy services (combined with low-carbon electricity) and increasing enduse efficiencies. 136 Measuring progress against emissions targets and associated policies including the Victorian Renewable Energy Targets and the Energy Efficiency and Productivity Strategy will require appropriate indicators.

The integration of high concentrations of distributed energy resources (including rooftop solar and small-scale battery storage) into Victoria's electricity system requires distribution networks to become "smarter", 137,138 integrating ICT to allow network operators to better understand local, low-voltage network conditions and provide signals or incentives to individual resources to respond and provide system support.139

Similarly, Victoria's transport infrastructure will need to change to meet the challenge of substantial emissions reductions from reducing its reliance on fossil fuel combustion for energy. These changes range from increased availability of charging infrastructure for electric vehicles (or refuelling infrastructure for other fuels like hydrogen), which is an important enabler for a lowcarbon fleet transition, to the broader adoption and integration of low-emissions urban planning principles like those found in the Green Building Council's Green Star Communities. 140

Victoria's buildings and industry energy use will also need to change rapidly to enable the transition to a net-zero emissions future. This includes substantially increasing the energy efficiency of building stock as well as the efficiency of industrial processes and their electrification.

Recommendation 15: That DELWP establish a set of indicators, and implement measures to collect appropriate data, to track the impact of energy emissions reduction to meet interim targets set under the Climate Change Act 2017. The reporting will need to include tracking the transition of Victoria's grid, transport and industry infrastructure to support a low-carbon, high-renewables future.

United Nations 2015, 'Paris Agreement', https://unfo 134. ement.pdf Accessed 4 December 2018. Office of the Chief Parliamentary Counsel Victoria 2017, 'Climate

Change Act 2017', Melbourne, Victoria http://www.legislation.vic.gov. /Web_Notes/LDMS/PubStatbook.nsf/f932b66241ecf1b FILE/17-005aa%20authorised.pdf Accessed 4 December 2018.

^{136.} DELWP 2017, 'Independent Expert Panel: Interim Emissions Reduction Targets for Victoria (2021-2030)', East Melbourne, Victoria <u>htt</u> Paper 28-03-2018.pdf Accessed 4 December 2018.

Australian Energy Market Operator 2018, 'Integrated System Plan', em-Plan-2018 final.pdf Accessed 4 December 2018.

^{138.} Australian Energy Market Operator and Energy Networks Australia 2018, 'Open Energy Networks: consultation paper', <a href="http://example.com/http://exam

^{139.}

Green Building Council of Australia, 'Neighbourhoods and community', Barangaroo, New South Wales <u>htt</u> star/rating-system/communities/ Access 4 December 2018.

Data Capability to Track Impact of Victoria's **Energy Transition on Consumers and Markets**

Victorian consumers are likely to play an increasingly important role in the energy sector during Victoria's transition to its net-zero emissions target. As the extensive (and largely unanticipated) investment Victorian consumers have made in rooftop PV over the last decade shows, energy consumers can no longer be assumed to be passive purchasers of energy with choices limited to purchasing energy-using devices—from cars to heaters and washing machines—and choosing a supplier of electricity, gas or liquid fuels.

Victoria's almost complete smart meter coverage makes engaging active consumers possible, with or without distributed energy resources. However, consumer education and consumer trust are essential for gaining the engagement required for the efficient and effective coordination of demand-side resources, which can include broad behaviour change that alters the demand for energy services.141,142

Further, changes are likely to be required for the National Electricity Market to assist the transition to a low-emissions electricity system. When the NEM was established there was no variable renewable generation supplying its regions, and the Finkel Review described the NEM as "a market for different times". 143 Victoria will need to work with the other NEM states and the Commonwealth Government to assist the NEM evolve to incorporate high proportions of variable renewables and distributed energy resources.^{144,145,146}

Governance arrangements, in particular consumer protection measures will need to be extended to cover new energy products and business models to ensure that consumers understand the risks of participation in new markets and engaging with new types of energy business (e.g. distributed energy resource aggregators).¹⁴⁷ New institutions (such as distributed system and distributed market operators) may also be required to operate distribution system level markets and coordinate and dispatch resources.148

Recommendation 16: That DELWP implement measures to collect data and track the impact of the transition to a low-emissions electricity system on:

- consumer sentiment and behaviour
- investment in distributed, low- and zeroemissions electricity generation
- the associated markets, governance and business models.

Eyre N, Darby SJ, Grünewald P, McKenna E, Ford R 2018, 'Reaching a 1.5° C target: socio-technical challenges for a rapid transition to low-carbon electricity systems', *Philosophical Transactions of the Royal Society A*, 376(2119).

Darby S, Liddell C, Hills D, Drabble D 2015, 'Smart Metering Early Learning Project: Synthesis report', Department of Energy & Climate 142

Change, London, United Kingdom. Finkel A, Moses K, Munro C, Effeney T, O'Kane M 2017, 'Independent Review into the Future Security of the National Electricity Market: Blueprint for the Future', Commonwealth of Australia, Canberra,

^{144.} Ibid.

Nelson T, Orton F, Chappel T 2017, 'Electricity market design in a

decarbonised energy system', working paper.
Pollitt MG, Anaya KL 2016, 'Can current electricity markets cope with high shares of renewables? A comparison of approaches in Germany, the UK and the State of New York', *Energy Journal*, 37(1), pp. 1–21.

Orton F, Nelson T, Pierce M, Chappel T 2017, 'Chapter 14 - Access Rights and Consumer Protections in a Distributed Energy System', in Innovation and Disruption at the Grid's Edge, Academic Press, Cambridge, United States

Perez-Arriaga I, Jenkins JD, Batlle CA 2017, 'Regulatory framework for an evolving electricity sector: Highlights of the MIT utility of the future study', Economics of Energy & Environmental Policy, 6, pp. 1–22

Accounting for the Environment

The System of Environmental-Economic Accounting (SEEA) energy accounts typically present information in physical terms (PJ), but monetary valuations can also be applied to various energy stocks and flows. Two main types of accounts capture relevant energy information in a systematic way - flow accounts and asset accounts.

Energy flow accounts record physical flows of energy from (i) the initial extraction or capture of energy resources from the environment into the economy (energy from natural inputs); (ii) the flows of energy within the economy in the form of the supply and use of energy by industries and households (energy products); and (iii) the flow of energy losses.

Energy from natural inputs include mineral and energy resources (for example: oil, natural gas, coal, uranium) and inputs from renewable energy sources (for example: solar, wind, hydro, geothermal).

These accounts identify the flows between the environment and the economy, and can be used to show the many ways and multiple times that a natural input can be transformed, supplied to the economy, used in production processes, consumed by final users or returned to the environment.

Energy flow accounts allow for a consistent monitoring of the supply and use of energy by energy type and by industry. Indicators of energy intensity, efficiency and productivity can be derived from the accounts in combination with monetary information. This sort of information could be useful, for example, in assessing Victoria's progress towards targeted 50% improvement in energy productivity from 2015 levels by 2030.149

Paired with information from the System of National Accounts, the latest Australian Environmental-Economics Accounts, released in June 2018 by the ABS, have shown a decoupling of economic activity and energy use within Australia, with industry gross value add rising 28% over the period 2006-07 to 2015-2016, while energy consumption increased by only 6% over the same period.

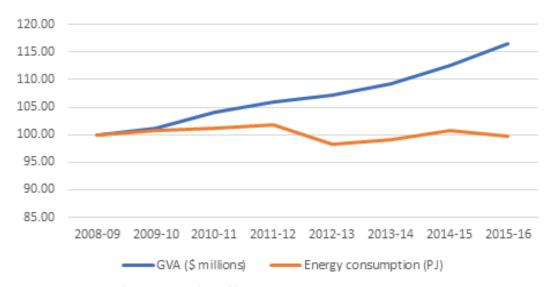


Figure E.21 Victoria industry gross value add vs energy consumption

Index: 2008-09 = 100

DELWP 2017, 'Energy Efficiency and Productivity Strategy', East pdf Accessed 4 December 2018

Figure E.21 shows a similar story for Victoria, with industry gross value add rising 17% over the period 2008-09 to 2015-16, while energy consumption remained relatively stable. 150,151

Energy asset accounts measure the quantity of mineral and energy resources and changes in these resources over an accounting period. These accounts can be compiled in physical terms, which provide valuable information about energy resource availability; or, they can be compiled in monetary terms to show the contribution to, and the depletion of, natural capital reserves of energy resources.

Flows of extraction, depletion and discoveries are central to the energy asset account. Since these assets cannot be renewed on any human timescale, there is use in understanding the rate at which these assets are extracted and depleted, the overall availability of these assets, and the sustainability (dependence) of the industries that exploit them.

There is a direct linkage to be made between the energy accounts and the air quality accounts. The main residuals that flow from the energy sector as a result of economic activity (such as air pollutants) are captured in the air emissions accounts. There is also a link to the water accounts, as surface and groundwater flows are diverted for electricity generation and oil and gas extraction.

For Victoria, 90% of direct greenhouse gas emissions come from the energy sector, having direct links to climate change analysis and policy. Linking the air and energy accounts allows relevant physical (such as energy input and output and emissions) and monetary (such as taxes and expenditure) information to be compared, by industry. This has the potential to provide information to design, measure and monitor policy instruments that will help Victoria reach its net-zero-emissions target by 2050 and VRETs (currently 25% by 2020 and 40% by 2025).

Australian Bureau of Statistics, '5220.0 Australian National Accounts: State Accounts', Canberra, Australia.

Department of Environment and Energy 2017, 'Australian Energy Statistics 2017: Table C3', Canberra, Australia.



Appendix: SoE 2018 Indicators Related to Climate Change Adaptation

The 33 indicators related to climate change adaption are presented below.

Legend

Status

N/A Not Applicable

The indicator assessment is based on future projections or the change in environmental condition and providing a status assessment is not applicable. Only a trend assessment is provided.



Unknown

Data is insufficient to make an assessment of status and trends.



Environmental condition is under significant stress, OR pressure is likely to have significant impact on environmental condition/ human health, OR inadequate protection of natural ecosystems and biodiversity is evident.



Environmental condition is neither positive or negative and may be variable across Victoria, OR pressure is likely to have limited impact on environmental condition/human health, OR moderate protection of natural ecosystems and biodiversity is evident.

Good

Environmental condition is healthy across Victoria, OR pressure is likely to have negligible impact on environmental condition/ human health, OR comprehensive protection of natural ecosystems and biodiversity is evident.

Trend

N/A Not applicable

This indicator assessment is based on current environmental condition only and it is not applicable to provide a trend assessment. Only a status assessment is provided.



Unclear



Deteriorating



Stable



Improving

Data quality



Evidence and consensus too low to make an assessment



Limited evidence or limited consensus



Adequate high-quality evidence and high level of consensus

Chapter	Summary	Description	Status UNKNOWN	POOR	FAIR	GOOD
Air	Indicator	The long-term changes in stratospheric		\bigcirc		
	A:05 Stratospheric	ozone due to ozone depleting substances over a mid-latitude location				0 /
	ozone	such as Victoria are small compared to natural variations. Melbourne's ultraviolet levels have generally been				
			DATA QUALITY			
		stable since the 1980's.	Good			
Climate	Indicator	Victoria has received below average to				\bigcirc \vee
Change	CC:01 Observed	record low cool season rainfall for the most recent 30 years from 1985-2015. This has been influenced by declining cool season rainfall.				
	average rainfall					
			DATA QUALITY			
			Good			

Chapter	Summary	Description	Status Trend UNKNOWN POOR FAIR GOOD
Climate Change	Indicator CC:02 Snow cover	A decline in snow accumulation has been observed at several locations across the Victorian Alps. Snow cover and volume will decline to the extent that eventually only the highest peaks will experience any snow by 2070-99.	DATA QUALITY Good
Climate Change	Indicator CC:03 Observed surface temperature	The five years from 2013-17 were all in the top-ten warmest years on record for Victoria. There has been an observed warming in both maximum (daytime) and minimum (overnight) temperatures.	DATA QUALITY Good
Climate Change	Indicator CC:04 Projected changes in temperature	Physical evidence, past trends and various models all suggest Victoria will continue warming this century, so an ongoing warming is projected with high confidence.	N/A STATE QUALITY Good
Climate Change	Indicator CC:05 Projected changes to average rainfall	The observed reduction in cool season (April-October) rainfall during the last twenty years is projected to continue in the future.	DATA QUALITY Fair (some uncertainty in long-term rainfall projections)
Climate Change	Indicator CC:06 Regional climate projections	Further warming and declines in cool season rainfall are projected. The number of hot days is expected to increase by approximately 50% by 2030 and double by 2070 at most of Victoria's major cities and towns, while the number of frost days is likely to halve.	N/A O S S S S S S S S S S S S S S S S S S
Climate Change	Indicator CC:07 Observed sea level	There have been rises of mean and maximum sea levels, as well as an increasing frequency of very high sea levels	DATA QUALITY Fair (at Victorian sites until 1993 because data until 1993 has not been formally standardised). Good (at Victorian sites since 1993)

Chapter	Summary	Description	Status Trend UNKNOWN POOR FAIR GOOD
Climate Change	Indicator CC:08 Projected sea level	Further mean sea level rises and an increase in the frequency of extreme inundation events are projected.	N/A SOUD STATE QUALITY Good
Climate Change	Indicator CC:09 Sea- surface temperature	Sea surface temperatures in the Australian region have been observed at record warm levels in recent years.	DATA QUALITY Good
Climate Change	Indicator CC:10 Annual greenhouse gas emissions	Victoria's per capita GHG emissions are relatively large compared to OECD countries, however per capita and total GHG emissions have been reducing in Victoria since 2005.	DATA QUALITY Good
Climate Change	Indicator CC:11 Victorian ecosystem carbon stocks	There has been a 1% growth in carbon stocks from 2007-16.	Stable for land sector and Unknown for marine and coastal ecosystems DATA QUALITY Fair (no comprehensive statewide and trend data for marine and coastal ecosystems)
Climate Change	Indicator CC:12 Occurrence and impacts of extreme weather	Extreme weather events (e.g. bushfires, extreme heat events and floods) are already causing significant impacts, with an increased frequency of these events being observed (particularly extreme heat days and more dangerous weather conditions for bushfires).	DATA QUALITY Good

Chapter	Summary	Description	Status Trend UNKNOWN POOR FAIR GOOD
Climate Change	Indicator CC:13 Extent and condition of key climate-sensitive ecosystems	Examples of ecosystems and species under threat include bird species in floodplain forests, alpine Sphagnum bogs and seagrass in Corner Inlet.	PATA QUALITY Fair (good issue-specific research but no comprehensive statewide data)
Climate Change	Indicator CC:14 Community awareness of climate risks and associated responsibilities	Survey results show nearly 80% of Victorians were concerned about climate change, with the main area of concern focussed on water shortage and drought.	Good (for awareness of climate risks and mitigation) and Unknow (for adaptation to climate change
			DATA QUALITY Fair (recent data collected is good but no long-term data is available for trend analysis)
Climate Change	Indicator CC:15 Councils (or other organisations) with urban forestry plans or urban greening or cooling-related strategies	Urban forestry planning is a developing area of research in Victoria. Thirteen of the 32 councils within metropolitan Melbourne and some regional councils such as Geelong and Ballarat have developed or are developing urban forestry strategies.	DATA QUALITY Fair (no monitoring and evaluation provided)
Climate Change	Indicator CC:16 Considering climate change risks in land use planning (including in the coastal zone)	There is good agreement across local councils, particularly coastal councils, that land-use planning should be informed by up-to-date climate science.	Generally Poor for inland councils and Fair for coastal councils DATA QUALITY Fair (no trend analysis)
Climate Change	Indicator CC:17 Percentage of agri-businesses using long-term weather and climate change projections.	Survey results show an increasing climate literacy and decisiveness of management actions in the agricultural sector in relation to climate change.	DATA QUALITY Fair (limited sample)

Chapter	Summary	Description	Status Trend UNKNOWN POOR FAIR GOOD
Energy	Indicator E:01 Energy use per capita	Energy use per capita is declining and is slightly below 1990 levels but remains high by global standards.	DATA QUALITY Good
Energy	Indicator E:03 Consumption of renewable energy as a share of total energy consumption	The proportion of energy consumption from renewables is increasing. However, it still accounts for a small share of total consumption, particularly in relation to the best performing jurisdictions in Australia or internationally.	DATA QUALITY Good
Water Resources	Indicator WR:09 Percentage of agricultural land with approved irrigation	Approximately 27,000 hectares of agricultural land has been upgraded with improved irrigation during the four financial years from 2013-14 to 2016-17, which represents less than 3% of Victoria's total area of irrigated agriculture.	DATA QUALITY Poor (need data on the total area of irrigated land and the area of irrigated land that needs improved irrigation)
Land	Indicator L:10 Land management activities	The six CMAs reporting on the area of land managed for conservation, reported a slight increase in the hectares of land covered by Trust for Nature covenants in 2016-17.	DATA QUALITY Fair (Corangamite, Glenelg Hopkins, North Central, North East, West Gippsland and Wimmera CMAs) Poor (no data available for Port Phillip & Westernport, East Gippsland, Mallee, Goulbourn Broken CMAs)

Chapter	Summary	Description	Status Trend UNKNOWN POOR FAIR GOOD
Land	Indicator L:11 Participation in natural resource management activities	Parks Victoria's volunteer network has provided over \$10 million of in-kind support in 2017-18, the highest ever recorded for Parks Victoria. Participation at CMA natural resource management engagement events has increased each year since data was first reported in 2013-14.	DATA QUALITY Good
Land	Indicator L:12 Use of best practice on agricultural lands	Data is showing an increasing amount of land being used with improved agricultural practices. However, there is no statewide data on the total area of land with suitable agricultural practices.	Poor (no statewide comprehensive data; data isn't granular)
Land	Indicator L:13 Proportion of agricultural area under productive and sustainable agriculture	Evidence of improved management practices on more than 120,000 hectares of land used for stock and more than 50,000 hectares of land used for crops has been recorded from 2013-14 to 2015-16. No statewide data on sustainable agriculture.	Poor (limited examples from two CMAs)
Transport	Indicator T:01 Travel demand	There is a heavy reliance on motor vehicles as a commuting option in Victoria. Population growth is outpacing the mode shift away from motor vehicles to public transport, cycling or walking – more than 400,000 additional Victorians are driving to work than at the start at the 21st century.	DATA QUALITY Good
Biodiversity	Indicator B:11 Area of functional floodplain	Data at state-scale is currently not available to determine floodplain functionality.	Poor

Chapter	Summary	Description	Status UNKNOWN POO	DR FAIR	GOOD	Trend
Marine and Coastal Environments	MC:01 Mangrove extent	Western Port has retained 90-95% of its pre-1750s mangrove habitat that was estimated at 1320ha. Losses have been caused by harvesting, land claim for industrial and port development and the drainage of adjacent land.		CI NMCP	WPT OMAC	?
		Corner Inlet and Nooramunga Mangroves are at their southern-most limit in Corner Inlet and Nooramunga where 80% of the pre-1750s cover remains.	DATA QUALITY GOOD WPT & CI & NI	MCP & OMA	C	
		Other marine and coastal areas				
		On a statewide basis, 90% of the pre- 1750 extent of mangroves remains and their spatial extent may be expanding in response to climate change				
		There are insufficient data to determine condition of mangroves				
Marine and	MC:02 Saltmarsh extent	Port Phillip Bay				OMAC 1
Coastal Environments		About 50% of Port Phillip Bay's pre-1750s saltmarsh cover of 3710 ha remains today.	OMAC	PPB	GLA WPT	PPB -
		Western Port			***	WPT \
		In Western Port, 90–95% of saltmarsh that once covered 1460 ha remains today.	DATA QUALITY			
		Gippsland Lakes	Fair - PPB & V	VPI		
		Historical mapping of the various lakes indicates that between 80 and 100% of pre-1750s saltmarsh has been retained.	DATA QUALITY POOR - GLA &	OMAG		
		Other marine and coastal areas	FOOT - OLA &	OMAC		
		Of 30 coastal sectors surveyed and compared to pre-1750 extent, 7 had 35-65% of saltmarsh remaining, 7 were 100% intact, one had expanded to 130% and 14 ranged between 70-95%.				
		There are insufficient data to determine condition of mangroves.				

Chapter	Summary	Description	Status UNKNOWN POOR	FAIR	GOOD	Trend
Marine and	MC:03 Seagrass	Port Phillip Bay				WPT
Coastal Environments	condition	Baywide extent of seagrasses is relatively constant while there can be large changes in cover in localised areas. Western Port	WPT OMAC	GLA CI	PPB	GLA PPB OMAC
		Variability in Zostera beds, stable Amphibolis antarctica beds, seagrass in Yaringa Marine National Park in good condition.	DATA QUALITY FQIr			
		Gippsland Lakes	T GIII			
		A decline in seagrass extent and an increase in seagrass density have been measured but with only limited data.				
		Corner Inlet				
		Subtidal seagrass extent had varied over time but recent data reveal that it declined on average by 0.5 km² per year between 1965 and 2013, with algal blooms and turbidity both impacting on light penetration. There is limited data on density and epiphytes.				
Forests	Fo:10 Total forest ecosystem biomass and carbon pool by forest type, age class and succession all	The amount of carbon mass is presented by bioregion, tenure and type. Relevant information for a single period is presented as provided from the VFMP. Trend analysis will be possible from 2020, once the five-year panel system is fully implemented.	DATA QUALITY Fair			?
Forests	Fo:11 Contribution of forest ecosystems to the global greenhouse gas balance	Since 2011, there has been an increase in sequestration from forest management activities, driven by 20 vegetation projects funded by the Emissions Reduction Fund over the last 5 years. This trend is observed through an upsurge in the Kyoto Australian carbon credit unit (KACCU), representing abatement from activities that contribute to the nation's emission targets under the Kyoto protocol. Estimated net contribution of the Fund to the sequestration in LULUCF is minimal. Compared to other sectors, including waste and agriculture, proportional contribution of forest related activities to state-scale greenhouse gas balance is minimal.	DATA QUALITY Good			7
Fire	Fi:04 Bushfire risk	The impact of the risk-based planned- burning approach on biodiversity, particularly fauna species is not currently monitored at a state-scale but isolated data exists.	DATA QUALITY Poor			



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