VICTORIAN STATE OF THE ENVIRONMENT 2018 REPORT

SCIENTIFIC ASSESSMENTS

Commissioner *for* Environmental Sustainability Victoria



VICTORIA State Government

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CULTURAL LANDSCAPE HEALTH AND MANAGEMENT (CL)

SCIENTIFIC ASSESSMENTS Part III

Commissioner *for* Environmental Sustainability Victoria



Cultural Landscape Health and Management

Background

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

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

Aboriginal cultural heritage in Victoria is protected under the *Aboriginal Heritage Act 2006* (the Act). The Act establishes a framework of mechanisms for the management and protection of Aboriginal cultural heritage, including cultural heritage management plans, cultural heritage permits, Protection Declarations and Aboriginal cultural heritage land management agreements.

Registered Aboriginal Parties is a status provided under the Act to Traditional Owner organisations that hold decision-making powers under the Act for the protection and management of Aboriginal cultural heritage within a specified geographic area. Registered Aboriginal Parties are appointed by the Victorian Aboriginal Heritage Council. The Council consists of up to 11 Traditional Owners who are appointed by the Minister for Aboriginal Affairs. All members are Victorian Traditional Owners who have relevant experience or knowledge of Aboriginal cultural heritage in Victoria. There are currently 11 Registered Aboriginal Parties covering over 60% of Victoria.

A number of Victorian Traditional Owner organisations, including Registered Aboriginal Parties, are working in partnership with government and non-government organisations in developing Country Plans, strategies and assessment frameworks that articulates a Traditional Owner group's aspirations by integrating cultural heritage and spiritual values, self-determination and governance, health and wellbeing, and economic capacity to improve, care and manage the cultural landscape health of Country. Traditional Owners are formally recognised in three ways by the Victorian Government: through the *Native Title Act 1993* (Cwlth), by way of a determination of a co-operative management agreement through a Recognition and Settlement Agreement under the *Traditional Owner Settlement Act 2010* (Vic.), and through appointment as a Registered Aboriginal Party under the *Aboriginal Heritage Act 2006* (Vic.). These areas of recognition, establishes a partnership between the State Government and Traditional Owner groups to jointly manage and share in decision making over determined areas of Crown Land.

This State of the Environment (SoE) 2018 report provides a transition from the singular focus on Aboriginal cultural heritage reporting in the SoE 2013 report to cultural landscape health and management assessment. This new reporting approach includes indicators aligning to four themes that aim to incorporate the social, economic, spiritual, cultural, environmental, and health and wellbeing values of Victorian

1. Parks Victoria. 2018. 'Managing Country Together', Melbourne, Victoria https://parkweb.vic.gov.au/__data/assets/pdf_file/0006/724695/Managing-Country-Together.pdf Accessed 3 December 2018.
2. Ibid

Traditional Owners, Registered Aboriginal Parties and Aboriginal Victorians (Table CL.1). This SoE report understands that the condition of cultural landscapes is difficult to distil into a single metric. The approach provided below assumes that increased connection, participation and self-determination in managing and looking after Country can lead to improvement in the condition of cultural landscapes and therefore serve as proxy indicators that may be formed from quantitative and/or qualitative data and information (Table CL.1). These themes and indicators were adapted from the *Health and Wellbeing Outcomes of the Aboriginal and Torres Strait Islander Gathering Place Model in Victoria: A Place for Inclusion, Connection and Empowerment* report[3,4] and the Aboriginal Waterways Assessment Program.[5] This approach for future SoE assessments allows indicators to be adapted and modified to suit Traditional Owner and Registered Aboriginal Party reporting needs. Sharing of indicator data and stories to inform reporting on cultural landscape health and management is at the discretion of Traditional Owner groups.

3. Thorpe A, Munro-Harrison E, Kingsley J 2016, 'Health and Wellbeing outcomes of the Aboriginal and Torres Strait Islander gathering place model in Victoria: A place for inclusion, connection and empowerment.' Indigenous Health Equity Unit, The University of Melbourne and Gathering Place Reference Group, Melbourne, Victoria.
4. Kingsley J, Munro-Harrison E, Jenkins A, Thorpe A, 2018. '"Here we are part of a living culture": Understanding the cultural determinants of health in Aboriginal gathering places in Victoria, Australia.' Health & Place, 54, pp. 210-220.
5. Murray-Darling Basin Authority 2015, 'Aboriginal Waterways Assessment Program', Victoria, Australia.

Future Themes and Indicators

Table CL.1 Future themes and indicators

Theme	Future indicator
Connection to Country: Cultural Knowledge, Protocols and Practices	Community storylines and intergenerational learning
	Traditional ecological knowledge projects on Country
	Restoration/Protection of cultural heritage sites on Country; this includes tangible and intangible cultural heritage
	Repatriation of artefacts and ancestral remains to Country
	Cultural harvesting practices
Capacity Building: Programs, Resources, Education and Training Provided by Organisations	Number and types of training programs relating to managing Country
	Number of hours spent in training programs relating to managing Country
	Number of Traditional Owners enrolled in the Certificate IV in Aboriginal Cultural Heritage Management, delivered by Aboriginal Victoria
	Number of Traditional Owners who have been involved in knowledge transfer from training programs to manage Country
Land Justice, Self-determination, Governance and Mechanisms for Sustainability	Number of long-term plans, strategies and partnership agreements developed by Traditional Owners for managing Country, for example, Country Plans. (An example of existing data is provided in Table CL.2)
	Area (ha) of Country under formal recognition (Native Title, Registered Aboriginal Party). (An example of existing data is provided in Table CL.3)
	Area (ha) of Country under Aboriginal ownership. (An example of existing data is provided in Table CL.3)
	Number of Traditional Owner groups working on and managing Country
	Number of Traditional Owner group representation in government decision-making for managing Country
	Number of Traditional Owner enterprises associated with managing Country and/or cultural tourism
	Number of opportunities for Traditional Owner participation in emerging markets for managing Country
Funding and Pathways to other Organisations	Number of Traditional Owner, Registered Aboriginal Party, Native Title and Treaty partnership agreements with other organisations
	Number of Traditional Owner secondments and learning opportunities with other organisations
	Number of cultural awareness training programs provided to other organisations
	Traditional Owner participation in emergency management
	Funding opportunities for Traditional Owners to manage Country

Table CL.2 Formal agreements between the Victorian Government and Traditional Owner groups for joint management of their traditional lands under the *Traditional Owner Settlement Act 2010 (Vic.), Native Title Act 1993* (Cwlth) and *Conservation, Forests and Lands Act 1987* (Vic.)

Agreement Name	Traditional Owner
Yorta Yorta Co-operative Management Agreement (2004)	Yorta Yorta Nation Aboriginal Corporation
Wotjobuluk Co-operative Management Agreement (2005)	Barengi Gadjin Land Council Aboriginal Corporation
Gunditjmara Settlement Agreement (2007) Gunditjmara Co-operative Management Agreement (2007)	Gunditj Mirring Traditional Owners Aboriginal Corporation
Yorta Yorta Traditional Owner Land Management Agreement (2010)	Yorta Yorta Traditional Owner Land Management Board
Gunaikurnai Recognition and Settlement Agreement (2010) Dja Dja Wurrung Recognition and Settlement Agreement (2012)	Gunaikurnai Traditional Owner Land Management Board
Dja Dja Wurrung Joint Management Plan (2018)	Dhelkunya Dja Land Management Board
Taungurung Recognition and Settlement Agreement (2018)	Taungurung Clans Aboriginal Corporation

Table CL.3 Formal and informal management agreements for Victorian Traditional Owner groups to have access and rights that protect their cultural heritage

Agreement	Area (ha)
• Gunditj Mirring Traditional Owners Aboriginal Corporation	14,862,100
• Barengi Gadjin Land Council Aboriginal Corporation	
• Taungurung Clans Aboriginal Corporation	(a)
• Yorta Yorta Nation Aboriginal Corporation	
• Wurundjeri Land and Compensation Cultural Heritage Council Aboriginal Corporation	
• Martang Pty Ltd	
• Dja Dja Wurrung Clans Aboriginal Corporation	
• Wathaurung Aboriginal Corporation	
• Eastern Maar Aboriginal Corporation	
• Gunaikurnai Land and Waters Aboriginal Corporation	
• Bunurong Land Council Aboriginal Corporation	

(a) At the time of writing this report, the Taungurung Recognition and Settlement Agreement 2018 had just been formally recognised and therefore this figure does not reflect this additional land area

Agreement	Area (ha)
Indigenous Protected Areas	
• Deen Marr Indigenous Protected Area is located in the South East Coastal Plain bioregion and was declared in 1999. The land was purchased by the Framlingham Aboriginal Trust in 1993.	453
• Kurtonitj Indigenous Protected Area is located in the centre of the Budj Bim National Heritage Landscape between Mount Eccles volcanic plain and the sea. Declared in 2009, Kurtonitj is owned by the Gunditj Mirring Traditional Owners Aboriginal Corporation and managed by the Winda-Mara Aboriginal Corporation on behalf of the Gunditjmara people.	353
• Tyrendarra Indigenous Protected Area on Darlot Creek, a tributary of Land Condah near Portland, was declared in 2003. Tyrendarra is owned and managed by the Winda-Mara Aboriginal Corporation on behalf of the Gunditjmara people.	248
• Lake Condah Indigenous Protected Area is part of the Budj Bim National Heritage Landscape listed in 2004 due to its outstanding cultural heritage value in Victoria. The Kerrup Gunditj clan traditionally had an extensive and complex aquaculture system at Lake Condah including eel and fish harvesting. Today, it is managed by the Gundtj Mirring Traditional Owners Aboriginal Corporation.	1,700
Private forest	
• Framlingham Forest	1,130
• Lake Condah Indigenous protected area (includes the four properties of Lake Condah, Allambie, Muldoons and Vaughans)	1,700
• Freehold land owned by the Gunditjmara community (Gunditj Mirring Traditional Owners Aboriginal Corporation and Winda Mara Aboriginal Corporation) and declared or intended as Indigenous Protected Areas by the Gunditjmara community owners and recognised by the Australian Government.	4,430
• Lake Tyres Forest	1,600
Other Crown land/Aboriginal co-managed areas	
Dja Dja Wurrung Clans Aboriginal Corporation	
The Dja Dja Wurrung People have been granted title to six parks and reserves within their native title settlement area including: • Greater Bendigo National Park • Hepburn Regional Park • Kara Kara National Park (that falls within the agreement area) • Kooyoora State Park • Paddys Ranges State Park • Wehla Nature Conservation Reserve. These parks will be jointly managed and overseen by the Dhelkunya Dja Land Management Board.	47,502

Agreement	Area (ha)
Grampians National Park	
This includes the very small strip of Crown land (Crown allotment 2A, Parish of William) that is reserved under section 4 of the Crown Land Reserves Act 1978 (Vic.)	167,219
Gunaikurnai Joint Management Plan	
Partnership between the Gunaikurnai Land and Waters Aboriginal Corporation on behalf of the Gunaikurnai people, and the Victorian Government to jointly manage 10 parks and reserves in Gippsland. • Buchan Caves Reserve • Corringle Foreshore Reserve • Gippsland Lakes Coastal Park • Lakes National Park • Lake Tyers State Park • Mitchell River National Park • New Guinea Cave • Raymond Island Gippsland Lakes Reserve • Tarra-Bulga National Park • The Knobs Reserve	47,070

Gunaikurnai Joint Management Plan

The Gunaikurnai Joint Management Plan with the Victorian Government, formally established in July 2018, is the first Joint Management Plan to be approved in Victoria. This plan establishes a partnership between the Gunaikurnai peoples, Parks Victoria and the Department of Environment, Land, Water and Planning (DELWP) in co-managing the following parks and reserves under Aboriginal title in the Gippsland region:

- Buchan Caves Reserve
- The Knobs Reserve
- Corringle Foreshore Reserve
- Gippsland Lakes Reserve on Raymond Island
- Mitchell River National Park
- New Guinea Cave (in Snowy River National Park)
- Tarra-Bulga National Park
- The Lakes National Park

The Joint Management Plan builds on the Gunaikurnai Whole-of-Country Plan (2015), by enabling the knowledge and culture of the Gunaikurnai people to influence, and be recognised in, the management of the parks and reserves.[6] This plan also furthers the Gunaikurnai's Recognition and Settlement Agreement of 2010 through reconciliation, self-determination and social justice objectives. The Gunaikurnai Traditional Owner Land Management Board will monitor and evaluate the plan, with the Gunaikurnai Land and Water Aboriginal Corporation being responsible for plan implementation via partnerships while monitoring compliance and performance. The management plan provides the joint management strategies and actions that are specific to each of the parks and reserves and have a 10-year planning horizon. They describe how the aspirations and strategic direction, outlined in the Strategic Plan, will be translated at an operational level within each jointly managed park and reserve.

6. Gunaikurnai Traditional Owner Land Management Board and State of Victoria 2018, 'Gunaikurnai and Victorian Government Joint Management Plan', Victoria https://www.gunaikurnai.com.au/joint-management/the-plan Accessed 18 October 2018.

Victorian Aboriginal Cultural Heritage

The Victorian Aboriginal Heritage Council (the Council) was established under the *Aboriginal Heritage Act 2006* (Act) to ensure that Traditional Owners throughout Victoria play a central role in the protection and management of their heritage. It is the only Victorian statutory authority embodying Aboriginal self-determination, comprising up to 11 Traditional Owners who are appointed by the Minister for Aboriginal Affairs.[7] Aboriginal cultural heritage can include tangible and intangible archaeological, historical and anthropological Aboriginal heritage places, including landforms and land categories. The Victorian Aboriginal Heritage Register (VAHR) is maintained by the Secretary, Department of Premier and Cabinet through their delegate, the Registrar, Aboriginal Victoria. The VAHR is not an open-access register. Access is limited to persons listed in the Act and information that is listed as sensitive has further access restrictions. Sensitive information includes information about Aboriginal ancestral remains and burials. Registered Aboriginal Parties, and the Council in non-Registered Aboriginal Party areas, have the right to determine if and how information on the VAHR can be accessed.

Aboriginal people are the primary guardians, keepers and knowledge-holders of their heritage. The Act empowers Traditional Owners as protectors of their cultural heritage on behalf of Aboriginal and all other people. Registered Aboriginal Parties are Traditional Owner groups appointed by the Council who have statutory responsibility for the protection and management of Aboriginal cultural heritage in their appointed area. Registered Aboriginal Parties are appointed by the Council according to criteria set out in the Act and the Council's own decision-making principles for Registered Aboriginal Party applications.

7. VAHC 2017, 'Annual Report 2016 -2017', Victorian Aboriginal Heritage Council, Melbourne, Victoria.

As part of the Council's work in the protection and management of cultural heritage, it has provided input into Victoria's Climate Change Adaptation Plan 2017–2020 (the Plan; produced by DELWP) through representation on the Climate Change Advisory Panel. The Plan recommends a specific cultural focus and link to Victorian legislation and/or policy. Although further consultation with Traditional Owners is required regarding the Plan, it provides a foundation for the upcoming State of Cultural Heritage Report that will be led by Council as part of their reporting requirements. This report can then inform future SoE reporting.

Managing Cultural Landscapes in Victoria's Parks and Reserves

Parks Victoria is building on its existing reporting frameworks, which largely focus on ecology and natural systems, by adding three key elements that are special to determining the health of cultural landscapes. These three elements are:

1. social, spiritual and emotional wellbeing of Traditional Owners
2. extent and condition of culturally significant species
3. tangible and intangible Aboriginal cultural heritage

Recognising that changes in landscape condition can take a long time to become apparent, long-term monitoring is required. At the time of developing this report, Parks Victoria in partnership with Victorian Traditional Owners was in a process of realigning reporting frameworks, including State of the Parks reporting, to better incorporate cultural landscape management and condition.

The above three key elements for improving cultural landscapes are underpinned by the following values:

- **Land Justice and Reconciliation** – This includes the right to use, manage and direct what happens on Country. The Victorian Government is committed to self-determination for Aboriginal people through the *Aboriginal Heritage Act 2006, Traditional Owner Settlement Act 2010* and the *Aboriginal Victorians Bill 2018*.
- **Gather, record, share and use traditional and contemporary knowledge** – As the first inhabitants of Victoria, Aboriginal people have a deep knowledge of Country. Supporting Traditional Owner land management, cultural values and knowledge of Country can provide a strong basis for improving management of Country. At the same time, there are opportunities to support non-Aboriginal people to better understand Traditional Owner values and perspectives.

- **Connection to Country** – Maintaining a physical connection to Country is well-recognised as a fundamental pillar of the wellbeing of Aboriginal people and the broader cultural landscape. It can provide a means of cultural and spiritual renewal, employment, improved land management outcomes and economic independence. Importantly, it can provide Traditional Owners with the opportunity to meet their cultural obligations to care for Country.
- **Management** – The cultural landscapes of Victoria are mostly highly modified environments that have been adapted to suit the needs of their inhabitants, while still maintaining the core attributes that have shaped them over thousands of years. The decisions that managers and users of cultural landscapes make can have a significant impact on the natural and cultural values of those places. In many places, modern land management techniques have focused on meeting the needs of growing populations without recognising the underlying needs and capacity of Country. By integrating traditional and modern management approaches, actively protecting and improving cultural heritage values and returning ancestors to rest in their rightful Country, we can take steps to reverse some of this impact.
- **Sustainable natural resources** – According to traditional laws and customs, it is imperative that natural resources are managed sustainably, to ensure they continue to provide for current and future generations. Embedding this principle into the range of ways that cultural landscapes are used – including harvesting, tourism and enterprise development – will help to bring them back to cultural and ecological health.

Joint Management Plan for the Dja Dja Wurrung Parks

The Dja Dja Wurrung Joint Management Plan was officially launched in October 2018.[8] This plan establishes a partnership between the Dja Dja Wurrung people Parks Victoria and DELWP in managing the following Dja Dja Wurrung Parks under Aboriginal title in Loddon Mallee:

- Greater Bendigo National Park
- Hepburn Regional Park
- Kara Kara National Park
- Kooyoora State Park
- Paddys Ranges State Park
- Wehla Nature Conservation Reserve.

The above parks fall within the Country of the Dja Dja Wurrung Traditional Owners and are considered living landscapes that hold sites of Ceremony, lore and healing, stories of ancestral beings, memories and spirits of Djaara ancestors, totemic animals, birds, plants, elements and entities that create a relationship with Country. The Dhelkunya Dja Land Management Board will oversee the Plan's implementation through partnerships while monitoring compliance and performance. This Plan provides opportunities and benefits for all Dja Dja Wurrung People through long-term economic development.[9] The main goal of this Plan is to enable Traditional Owner knowledge and connection to County to be expressed in the planning and management of the lands. The Dhelkunya Dja Land Management Board will work closely with the Dja Dja Wurrung Clans Aboriginal Corporation to ensure the Plan aligns with the goals and aspirations of the Dja Dja Wurrung People as expressed in their Dja Dja Wurrung Country Plan, *Dhelkunya Dja*.

8. Dhelkunya Dja Land Management Board and State of Victoria 2018, 'Joint Management Plan for the Dja Dja Wurrung Parks: Strategy', Victoria http://www.dhelkunyadja.org.au/the-plan/joint-management-plan Accessed on 18 October 2018.
9. Ibid

Current Victorian Government Settings: Legislation, Policy, Programs

The Victorian Aboriginal Heritage Council aims to appoint Registered Aboriginal Parties across all of Victoria to ensure Traditional Owner-led management and protection of Aboriginal cultural heritage. Aboriginal Ancestral Remains are particularly vulnerable to the detrimental effects of climate change and Registered Aboriginal Parties (and other Traditional Owners) are best placed to care for this Country.

Aboriginal cultural heritage land management agreements (ACHLMAs) are voluntary agreements made between a Registered Aboriginal Party and a public land manager under the Act. ACHLMAs are designed to facilitate a proactive, holistic approach to managing and protecting Aboriginal cultural heritage and cultural landscapes during land management activities within a specific area, for an agreed duration.

Aboriginal intangible heritage[10] refers to the practices, expressions, knowledge and skills that communities recognise as part of their cultural heritage. It is communicated from generation to generation and is constantly recreated by communities in response to their environment and their history. It provides communities and individuals with a sense of identity and continuity.

In Victoria, Aboriginal intangible heritage includes:

- Ceremony
- Creation Stories
- skills involved in the creation of cultural items
- knowledge and skills associated with medicinal plant use
- language
- dance
- song
- a great variety of other cultural expressions and cultural knowledge systems.

Aboriginal intangible heritage often has a strong relationship with Country. The Act allows for the registration of Aboriginal intangible heritage on the VAHR. Whereas, for the purposes of the Act, Aboriginal cultural heritage denotes Aboriginal places, objects and Ancestral Remains, Aboriginal intangible heritage denotes elements of living culture – traditional knowledge and cultural expressions, held collectively by Aboriginal people or a particular group of Aboriginal people, and passed down across generations with or without adaptations and evolutions.

By providing a mechanism for registering Aboriginal intangible heritage under the Act, it:

- recognises the central role that intangible heritage plays in keeping Victorian Aboriginal cultures strong
- recognises Traditional Owners' rights as cultural custodians, and the shortcomings of existing laws in adequately protecting these rights
- gives Traditional Owners more control over the protection, management and potential use of their intangible heritage
- encourages a focus broader than physical places and objects within the Victorian Aboriginal cultural heritage management system.

Once Aboriginal intangible heritage is registered on the VAHR, anyone who wants to use that intangible heritage for commercial purposes has a legal responsibility to seek the permission of the representative group of the Traditional Owners, and may enter into an Aboriginal intangible heritage agreement. Agreements allow Traditional Owners to identify and/or negotiate the terms under which the Aboriginal intangible heritage may be used by others.

10. Office of the Chief Parliamentary Counsel 2016, 'Aboriginal Heritage Amendment Act 2016', Melbourne, Victoria http://www.legislation.vic.gov.au/Domino/Web_Notes/LDMS/PubStatbook.nsf/edfb620cf7503d1aca256da4001b08af/1D1B929B4736B758CA257F8C0018EF03/$FILE/16-011aa%20authorised.pdf Accessed on 18 October 2018.

With responsibility for managing more than 4 million hectares of Victoria's most intact landscapes, Parks Victoria recognises the value of working in partnership with Traditional Owners to sustainably manage cultural landscapes. Parks Victoria's Managing Country Together program is an ambitious reform agenda that aims to embed Traditional Owner partnerships into all aspects of park management and build the shared capacity of government and Traditional Owners to jointly manage the parks estate into the future.

The Managing Country Together program aims to improve the natural and cultural values of the parks estate within broader cultural landscapes. It is doing this by working with Traditional Owners to:

- provide for effective management and appropriate development of the parks estate
- provide practical and symbolic recognition of Traditional Owner rights
- foster positive relationships between government and Traditional Owners
- facilitate economic development opportunities for Traditional Owners
- ensure cultural heritage values are understood, conserved and enhanced
- develop agency and sector capacity in joint protected area and cultural heritage management.

The program includes a range of commitments that will support effective management of cultural landscapes, including:

- overarching principles that align with the Victorian charter of human rights and responsibilities and apply obligations under the United Nations Declaration on the Rights of Indigenous Peoples in the Victorian context
- policies, tools and resources to effectively conserve, protect and enhance Aboriginal cultural heritage values across the parks estate
- an Aboriginal employment and wellbeing program to support Aboriginal people working in park management.

DELWP identifies Traditional Owner participation in natural resource management (NRM) is increasing. Traditional Owners have strategies for their participation in NRM detailed within a Natural Resource Agreement (this agreement articulates the rights of Traditional Owners as part of their Recognition and Settlement Agreements).

These strategies determine the scope of Traditional Owner participation in NRM, under their agreements, that involves broad and multiple relationships between Traditional Owner groups with settlement determination and NRM agencies, such as DELWP, Parks Victoria, Catchment Management Authorities and other agencies with a role in NRM. These strategies also have a strong linkage to Joint Management and Strategic Planning being delivered by established Traditional Owner Land Management Boards.

Future Focus

Develop cultural indicators for future SoE reporting

There are opportunities to enhance the role of Victoria's Traditional Owners in cultural landscape health and management based on the objectives outlined in the *Aboriginal Heritage Act 2006*. Importantly, Aboriginal cultural heritage needs to be recognised as a fundamental part of Aboriginal community life and cultural identity, and celebrated as a significant part of the heritage of all Australians. There are many sources of information that can provide insights to progress towards medium and long-term outcomes for cultural landscapes.

Recommendation 1: That the Victorian Government, in consultation with Traditional Owners and relevant agencies, develop contemporary cultural indicators to inform future environmental reporting. These indicators must reflect the priorities of Traditional Owners, have practical and cost-effective data-collection methods, and be meaningful and demonstrate change within a five-year reporting period.



CLIMATE CHANGE IMPACTS (CC)
SCIENTIFIC ASSESSMENTS Part III

Commissioner *for* Environmental Sustainability Victoria

Climate Change Impacts

This chapter includes assessments of how Victoria's climate is changing and the associated impacts of those changes. Three key themes are covered: climate, impacts of climate change and management.

The climate theme incorporates a synthesis of the latest data and science on observed and projected surface temperature, rainfall, sea level, snow cover, and observed sea-surface temperature, while also including an update of Victoria's greenhouse gas (GHG) emissions with respect to the targets in the *Climate Change Act 2017*.

The impacts of climate change theme looks at the occurrence and impacts of extreme weather, the extent and condition of climate-sensitive ecosystems, and community awareness of climate risks and associated responsibilities.

The management theme assesses how councils are developing urban forestry plans and considering climate change risks in land-use planning, and also looks at the way agri-businesses are using long-term weather and climate projections. There are direct links to climate change adaptation, which are listed in Appendix A.

Themes in this chapter are covered in greater detail in other chapters. In particular, the Fire chapter includes commentary on the increased bushfire risk associated with climate change, and the Energy and Transport chapters cover GHG emissions from those sectors in greater detail.

Background

Climate research continues to show that temperatures, sea levels and sea-surface temperatures are rising in Australia.[1] Further changes will drive ongoing and significant ecosystem and biodiversity impacts, and will expose Victorians to more frequent and intense droughts, fires, heatwaves, extreme rainfall events and coastal inundation.[2] SoE 2018 reports on the effect climate change is having in these areas, as well as the potential future implications.

Victoria's climate is influenced by a range of factors, including the effect of major ocean–atmosphere phenomena such as the El Niño–Southern Oscillation, which produces El Niño and La Niña events, and the Indian Ocean Dipole. These drivers of climate contribute to large natural year-to-year variations in temperature and rainfall. However, long-term climate change caused by increasing GHG concentrations is occurring at global scales.[3]

The link between increasing GHG concentrations and climate change has been a growing area of focus for environmental policy-makers since countries adopted the *United Nations Framework Convention on Climate Change* in 1992,[4] which was a precursor to the adoption of the Kyoto Protocol in 1997 [5] and the Paris Agreement in 2015.[6]

1. BoM and CSIRO 2016, 'State of the Climate 2016', Melbourne, Victoria http://www.bom.gov.au/state-of-the-climate/State-of-the-Climate-2016.pdf Accessed 4 December 2018.
2. CSIRO and BoM 2015, 'Climate Change in Australia: Technical Report'.
3. Intergovernmental Panel on Climate Change 2013, 'Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.' Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
4. United Nations 1992, 'United Nations Framework Convention on Climate Change', https://unfccc.int/resource/docs/convkp/conveng.pdf Accessed 4 December 2018.
5. United Nations 1998, 'Kyoto Protocol to the United Nations Framework Convention on Climate Change', https://unfccc.int/sites/default/files/kpeng.pdf Accessed 4 December 2018.
6. United Nations 2015, 'Paris Agreement', https://unfccc.int/sites/default/files/english_paris_agreement.pdf Accessed 4 December 2018.

The challenges associated with mitigating and adapting to climate change impacts are significant. Rising to these challenges will be increasingly important in the coming decades, when the magnitude of climate change is expected to increase. Scientists have produced detailed climate change projections: it is imperative that planning and policy development leverage them to enable decision-making that fully prepares Victoria to manage climate change impacts.

Critical challenges facing Victoria's management of climate change and its associated impacts, now and in the future, include:

- reducing GHG emissions to mitigate the speed and severity of climate change as part of the national and global effort
- developing understanding of the impacts of climate change through better real-time monitoring, trend analysis and predictive capabilities to enable strategic and timely responses to protect the environment and communities
- reducing the health burden associated with heatwaves and other natural disasters
- maintaining/designing vital infrastructure, such as power generation and rail transport, for reliability in the face of changes to the average climate and more frequent and intense weather events
- maintaining secure water supplies across the state as population grows, average rainfall reduces and evaporation increases, leading to less available water
- maintaining the viability of the agricultural sector
- protecting biodiversity from the impacts of climate change
- mitigating the effects of sea-level rise and associated adverse coastal impacts, including more frequent and severe flooding in low-lying coastal areas, dune erosion, loss of coastal ecosystems and reduced public access to coastal environments.

Current Victorian Government Settings: Legislation, Policy, Programs

The *Climate Change Act 2017* took effect on 1 November 2017. It establishes a long-term emissions reduction target of net zero by 2050, with interim emissions reduction targets set for five-year periods from 2021. The Act also requires the government to develop a Climate Change Strategy and Adaptation Action Plans every five years from 2021 for key systems vulnerable to the impacts of climate change. The Act mandates periodic reporting of the following measures:

- standalone reports on the science and data relevant to climate change in Victoria
- annual GHG emissions reports at the end of each interim target period.[7]

To develop the five-yearly emissions reduction targets, the Victorian Government is required to seek expert independent advice. In March 2018, an independent panel of experts released an issues paper that explored the issues relevant to setting interim emissions reduction targets for Victoria for 2021 to 2025 and 2026 to 2030, and trajectories to net zero emissions by 2050.[8]

Climate change responses are being integrated into federal, state and local government policies and strategies across many sectors. Recent notable publications include *Protecting Victoria's Environment – Biodiversity 2037*, which outlines a vision for Victoria's biodiversity in a time of climate change; *Water for Victoria*, the 2016 water plan, which links climate science and adaptation to water management; and the Agriculture Victoria Strategy, which identifies research and capacity-building programs that help farmers adapt to climate change as priorities.[9,10,11]

7. 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/f932b66241ecf1b7ca256e92000e23be/05736C89E5B8C7C0CA2580D50006FF95/$FILE/17-005aa%20authorised.pdf Accessed 4 December 2018.
8. DELWP 2017, 'Independent Expert Panel: Interim Emissions Reduction Targets for Victoria (2021-2030)', East Melbourne, Victoria https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0019/121924/Issues-Paper_28-03-2018.pdf Accessed 4 December 2018.
9. DELWP 2017, 'Protecting Victoria's Environment – Biodiversity 2037', East Melbourne, Victoria https://www.environment.vic.gov.au/__data/assets/pdf_file/0022/51259/Protecting-Victorias-Environment-Biodiversity-2037.pdf Accessed 4 December 2018.

Sustainability Victoria is delivering the TAKE2 program, designed to support individuals, government, business and other organisations to help Victoria achieve net zero emissions by 2050.[12] The program requires government agencies to make pledges to act on climate change, while businesses and the community are invited to make their own public commitments to reduce emissions in Victoria. The program is designed to build momentum towards a lower GHG emissions future as well as recognising organisations that are leading the way.

State and Commonwealth agriculture ministers have initiated a work program on climate change. The program covers climate change impacts, managing emissions across the sector and identifying the risks and opportunities of adaptation in agriculture. A national approach to climate change in the agriculture sector will be delivered to the Agriculture Ministers' Forum by May 2019.

In April 2016, the Victorian and Commonwealth governments jointly funded the construction of a Doppler weather radar in the Wimmera, to extend the Bureau of Meteorology (BoM) to provide farmers in the region with more accurate rainfall data.[13]

Note that the government response to climate change includes additional initiatives, which are covered in other chapters, including the Energy, Land, Biodiversity and Water Resources chapters.

10. 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 4 December 2018.
11. DEDJTR 2017, 'Agriculture Victoria Strategy', Melbourne, Victoria http://agriculture.vic.gov.au/__data/assets/pdf_file/0011/385949/Agriculture-Victoria-Strategy_FINAL.pdf Accessed 4 December 2018
12. Sustainability Victoria, 'TAKE2', Melbourne, Victoria https://www.sustainability.vic.gov.au/About-Us/What-we-do/Campaigns/TAKE2 Accessed 4 December 2018
13. Victorian State Government 2016, 'Media Release: Andrews Labour Government puts Wimmera on the radar', Melbourne, Victoria, https://www.premier.vic.gov.au/wp-content/uploads/2016/04/160406-Andrews-Labor-Government-Puts-Wimmera-On-The-Radar.pdf Accessed 4 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.

Poor
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**

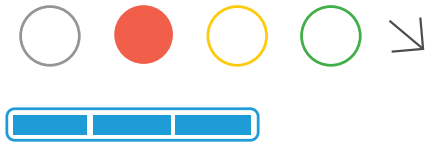
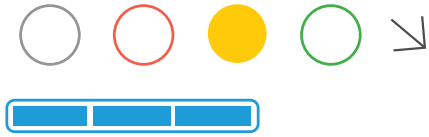
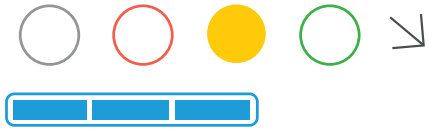
↗ **Improving**

Data quality

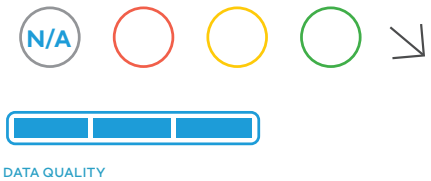
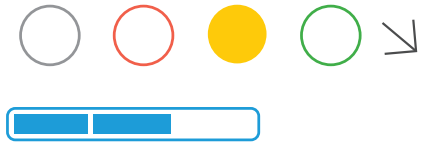
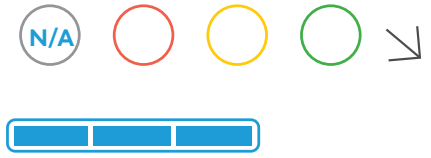
Poor
Evidence and consensus too low to make an assessment

Fair
Limited evidence or limited consensus

Good
Adequate high-quality evidence and high level of consensus

Summary		Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **CC:01** Observed average rainfall **Region** Victoria **Measures** (i) Victorian annual rainfall anomaly (ii) Victorian rainfall deciles for the warm and cool seasons **Data custodian** BoM	Victoria has received below-average to record-low cool season rainfall for the most recent 30 years from 1985-2015. This has been influenced by declining cool season rainfall.	 DATA QUALITY Good	
Indicator **CC:02** Snow cover **Region** Victoria's alpine region **Measures** Snow cover **Data custodian** None	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	
Indicator **CC:03** Observed surface temperature **Region** Victoria **Measures** (i) Victorian annual mean temperature anomaly (ii) Victorian annual maximum temperature anomaly (iii) Victorian annual minimum temperature anomaly **Data custodian** BoM	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	

Summary		Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **CC:04** Projected changes in temperature **Region** Victoria **Measures** Annually averaged warming in 2030 and 2090 for various emission scenarios relative to the climate of 1986-2005 **Data custodian** BoM , CSIRO	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 DATA QUALITY Good	↘
Indicator **CC:05** Projected changes to average rainfall **Region** Victoria **Measures** Percentage change in annual rainfall in 2030 and 2090 for various emission scenarios relative to the climate of 1986-2005 **Data custodian** BoM , CSIRO	The observed reduction in cool season (April-October) rainfall during the past twenty years is projected to continue in the future.	N/A DATA QUALITY Fair (some uncertainty in long-term rainfall projections)	↘

Summary		Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **CC:06** Regional climate projections **Region** Victoria **Measures** Projected number of hot and frost days for various emission scenarios in 2030 and 2070 **Data custodian** BoM, CSIRO	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.	 DATA QUALITY Good	
Indicator **CC:07** Observed sea level **Region** Victoria's coastline **Measures** (i) Annual mean sea level (ii) Annual maximum sea levels **Data custodian** BoM	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)	
Indicator **CC:08** Projected sea level **Region** Victoria **Measures** Projected mean sea level in 2030, 2050, 2070 and 2090 for all emission scenarios **Data custodian** BoM, CSIRO	Further mean sea-level rises and an increase in the frequency of extreme inundation events are projected.	 DATA QUALITY Good	

Summary		Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **CC:09** Sea-surface temperature **Region** Victoria **Measures** (i) Australian region sea surface temperatures (ii) Australian sea surface temperature anomaly – southern region **Data custodian** BoM, CSIRO	Sea surface temperatures in the Australian region have been observed at record-warm levels in recent years.	 DATA QUALITY Good	
Indicator **CC:10** Annual greenhouse gas emissions **Region** Victoria **Measures** (i) Per capita greenhouse gas emissions (ii) net greenhouse gas emissions (iii) greenhouse gas emissions by sector **Data custodian** DELWP	Victoria's per capita GHG emissions are relatively large compared to other OECD countries, however per capita and total GHG emissions have been reducing in Victoria since 2005.	 DATA QUALITY Good	

Summary		Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **CC:11** Victorian ecosystem carbon stocks **Region** Victoria **Measures** (i) land sector carbon stocks (ii) blue carbon stocks **Data custodian** DELWP	There has been a 1% growth in carbon stocks from 2007-16.	 DATA QUALITY Fair (no comprehensive statewide and trend data for marine and coastal ecosystems)	 Stable for land sector and Unknown for marine and coastal ecosystems
Indicator **CC:12** Occurrence and impacts of extreme weather **Region** Victoria **Measures** (i) Frequency of extreme heat days (ii) number of excess deaths associated with extreme heat days (iii) Forest Fire Danger Index (iv) Financial cost associated with natural disasters **Data custodian** BoM, CSIRO, DHHS, EMV	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	

Summary		Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **CC:13** Extent and condition of key climate-sensitive ecosystems **Region** Victoria **Measures** Case study examples **Data custodian** DELWP	Examples of ecosystems and species under threat include bird species in floodplain forests, alpine Sphagnum bogs and seagrass in Corner Inlet.	 DATA QUALITY Fair (good issue-specific research but no comprehensive statewide data)	?
Indicator **CC:14** Community awareness of climate risks and associated responsibilities **Region** Victoria **Measures** (i) Percentage of Victorians are concerned by climate change (categorised by area of concern) (ii) Percentage of Victorians support current GHG targets **Data custodian** SV	Nearly 80% of Victorians surveyed in 2016 and 2017 were concerned about climate change, with the main area of concern focused on water shortage and drought.	 Good (for awareness of climate risks and mitigation) and Unknown (for adaptation to climate change) DATA QUALITY Fair (recent data collected is good but no long-term data is available for trend analysis)	?

Summary		Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **CC:15** Councils (or other organisations) with urban forestry plans or urban greening or cooling-related strategies **Region** Victoria **Measures** Percentage of councils with, or developing, urban forestry plans **Data custodian** Resilient Melbourne, The Nature Conservancy	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)	
Indicator **CC:16** Considering climate change risks in land use planning (including in the coastal zone) **Region** Victoria **Measures** Percentage of councils rated high or advanced for consideration of climate change in land use planning **Data custodian** DELWP	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)	?

Summary

Survey results show an increasing climate literacy and decisiveness of management actions in the agricultural sector in relation to climate change.

Status

UNKNOWN POOR FAIR GOOD





DATA QUALITY

Fair (limited sample)

Trend

Indicator

CC:17 Percentage of agri-businesses using long-term weather and climate change projections

Region

Victoria

Measures

(i) Number of agricultural businesses subscribing to information about climate conditions
(ii) Percentage of businesses strongly agreeing or somewhat agreeing that the information improved their ability to make decisions to manage seasonal risk and improved their knowledge and understanding of seasonal climate variability

Data custodian

DEDJTR

Climate

The climate of Victoria is highly variable and influenced by large-scale climate drivers that occur on interannual timescales in the oceans surrounding Australia, such as the El Niño–Southern Oscillation and the Indian Ocean Dipole.[14] In addition to this natural climate variability, increasing concentrations of GHGs are causing rising surface and ocean temperature and decreasing cool-season rainfall.[15]

Some of the indicators in this chapter refer to different emissions scenarios. Current scenarios are referred to as Representative Concentration Pathways (RCPs). In this report, RCP8.5 is referred to as a 'high emissions scenario', RCP4.5 is referred to as an 'intermediate emissions scenario' and RCP2.6 is referred to as a 'low emissions scenario'. Note that RCP2.6 aligns most closely with the Paris Agreement target.[16]

14. Risbey JS, Pook MJ, McIntosh PC, Wheeler MC, Hendon HH 2009, 'On the remote drivers of rainfall variability in Australia', *Monthly Weather Review*, 137(10), pp. 3233-3253.
15. CSIRO and BoM 2015, 'Climate Change in Australia: Technical Report'.
16. CSIRO and BoM 2016, 'Australia's changing climate', https://www.climatechangeinaustralia.gov.au/media/ccia/2.1.6/cms_page_media/176/AUSTRALIAS_CHANGING_CLIMATE_1.pdf Accessed 4 December 2018.

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
CC:01 Observed average rainfall	○ ● ○ ○	↘	DATA QUALITY: Good

Data custodian BoM

Rainfall over Victoria is highly variable from year to year, due to large-scale climate drivers such as the El Niño–Southern Oscillation. But beyond this variability, a drying trend is emerging. Below-average rainfall has been recorded most years since the late 1990s. The main exceptions are 2010 and 2011 (influenced by strong La Niña events) and 2016 (influenced by a strong negative Indian Ocean Dipole). Since the publication of SoE 2013, below-average rainfall conditions have dominated the climate and extended the overall drying pattern affecting the state.

The drying of Victoria's climate has become increasingly apparent since the mid-1990s, with only four of the past 20 years above the 1961 to 1990 average rainfall (Figure CC.1).

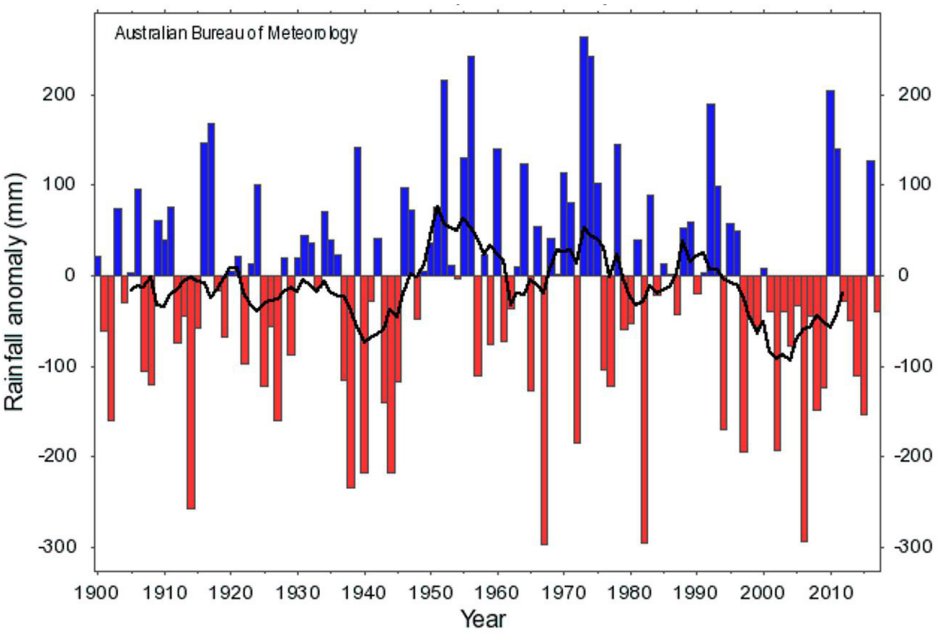


Figure CC.1 Victorian annual rainfall anomaly, 1900–2017

Note: 11-year running averages shown by black curve, Based on a 30-year climatology (1961-1990).

Anomalies calculated with respect to the 30-year climatology period 1961–1990 (average is 660.2 mm per year).

(Data source: BoM, 2018)

This drying mainly affects the cool season, from April to October. Figure CC.2 shows that nearly all of Victoria received below-average to record-low cool-season rainfall, for the most recent 30 years from 1985 to 2015. Therefore the trend for this indicator has been assessed as detiorating. Dry conditions were in part due to increasing GHG concentrations, so they may be indicative of a longer-term change.[17] The dry conditions are also linked to the millennium drought of 1996 to 2010. The decline in cool-season rainfall has particular consequences for agriculture, water resources and water quality.

Warm season (November to March) rainfall was generally above-average in northern Victoria and below-average in southern Victoria for the 30 years from 1985 to 2015 (Figure CC.2).

Rainfall in the coming decades will be determined by both anthropogenic climate change (likely to drive a general continuing decrease in rainfall) and ongoing natural variability. This means that in the short-to-medium term, Victoria may be wet or dry depending on the incidence of drought or wet events.

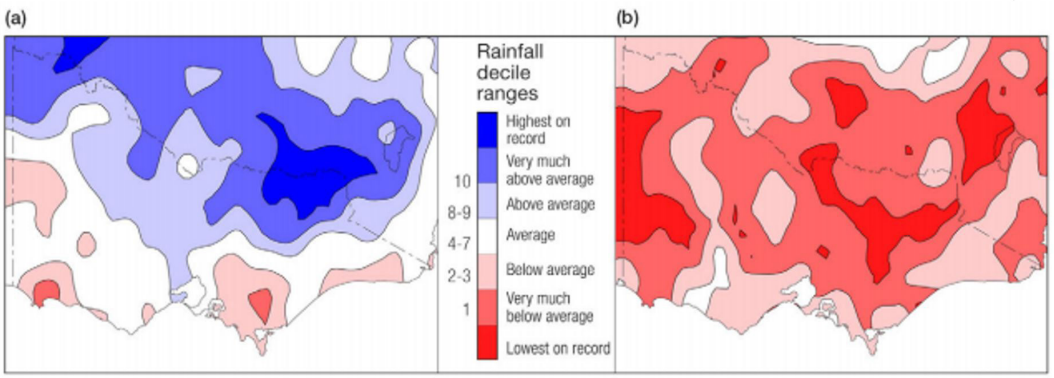


Figure CC.2 Victorian rainfall deciles, 1986–2015[18]

(a) the warm season (November–March)

(b) the cool season (April–October)

Note: Map shows where the rainfall is above-average, average or below-average for the recent period, compared with the rainfall record dating from 1900.

17. Hope P, Timbal B, Hendon H, Ekström M, Potter N 2017, 'A synthesis of findings from the Victorian Climate Initiative (VicCI)', BoM, Australia.
18. Ibid

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
CC:02 Snow cover	○	○	●	○	↘	DATA QUALITY
Data custodian None						Good

Snow cover in alpine areas is critical to Victoria's highland ecosystem resilience, water supply and winter sport recreation. It is also an important indicator of climate change.

A decline in snow accumulation has been observed at several locations across the Victorian Alps.[19,20] Observations have also shown a decline in the frequency of smaller daily snowfall events (under 10 cm) across the Victorian Alps in the past 25 years.[21] These changes are closely linked to increasing maximum temperatures in winter, indicating the role of anthropogenic climate change in reducing snow cover.[22] Snow depth is also influenced by large-scale drivers such as the El Niño–Southern Oscillation and Indian Ocean Dipole.[23]

In addition to ground-based observations, researchers have recently utilised technology such as satellite remote sensing to observe a reduction in snow cover in the Australian Alps from 2000 to 2014.[24] Remote sensing methods were automated as part of this study and can be consistently used to process remotely sensed imagery, enabling efficient monitoring of Australian snow cover changes.[25]

Projections for snow in Australia are based on global climate models, and high-resolution climate modelling that uses global models as an input. There is very high confidence that as warming progresses, there will be a decrease in snowfall and an acceleration in snowmelt, reducing the snow season, particularly at lower elevations.[26,27,28,29,30]

Snow cover and volume will decline to the extent that only the highest peaks will receive any snow by 2070 to 2099.[31] This is likely to have a significant impact on the region's natural ecosystems, and on winter sport recreation. Figure CC.3 shows the change and projected change in snowfall at two elevations in an area where snow is currently observed. Figure CC.3 also demonstrates that the decreasing trend in snow cover that has been observed since 1950 is projected to continue to 2100.

19. Fiddes S, Pezza A, Barras V 2015, 'A new perspective on Australian snow', *Atmospheric Science Letters*, 16(3), pp. 246–252.
20. Timbal B, Ekstrom M, Fiddes S.L, Grose M, Kirono D.G.C, Lim E, Lucas C, and Wilson L, 2016. 'Climate change science and Victoria', Melbourne, Victoria (Bureau of Meteorology).
21. Fiddes S, Pezza A, Barras V 2015, 'A new perspective on Australian snow', *Atmospheric Science Letters*, 16(3), pp. 246–252.
22. Ibid
23. Pepler AS, Trewin B, Ganter C 2015, 'The influences of climate drivers on the Australian snow season', *Australian Meteorological and Oceanographic Journal*, 65(2), pp.195-205.
24. Thompson J 2016, 'A MODIS-derived snow climatology (2000–2014) for the Australian Alps', *Climate Research*, 68(1):25–38.
25. Ibid
26. CSIRO and BoM 2015, 'Climate Change in Australia: Technical Report'.
27. Di Luca A, Evans JP, Ji F 2017. 'Australian snowpack in the NARCliM ensemble: evaluation, bias correction and future projections' *Climate Dynamics*, 51(1-2) pp. 639-666.
28. 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*.
29. Bhend J, Bathols JM, Hennessy KJ 2012, 'Climate change impacts on snow in Victoria. CAWCR Research Report', Centre for Australian Weather and Climate Research, Melbourne, Victoria.
30. Hennessy KJ, Whetton PH, Walsh KJE, Smith IN, Bathols JM, Hutchinson M, Sharples JJ 2008, 'Climate change effects on snow conditions in mainland Australia and adaptation at ski resorts through snowmaking', *Climate Research*, 35, pp. 255-270.
31. Antarctic Climate & Ecosystems Cooperative Research Centre 2016, 'The Potential Impacts of Climate Change on Victorian Alpine Resorts', Hobart, Tasmania http://www.arcc.vic.gov.au/uploads/publications-and-research/The%20Potential%20Impact%20of%20Climate%20Change%20on%20Victorian%20Alpine%20Resorts%20Study_FINAL.pdf Accessed 4 December 2018.

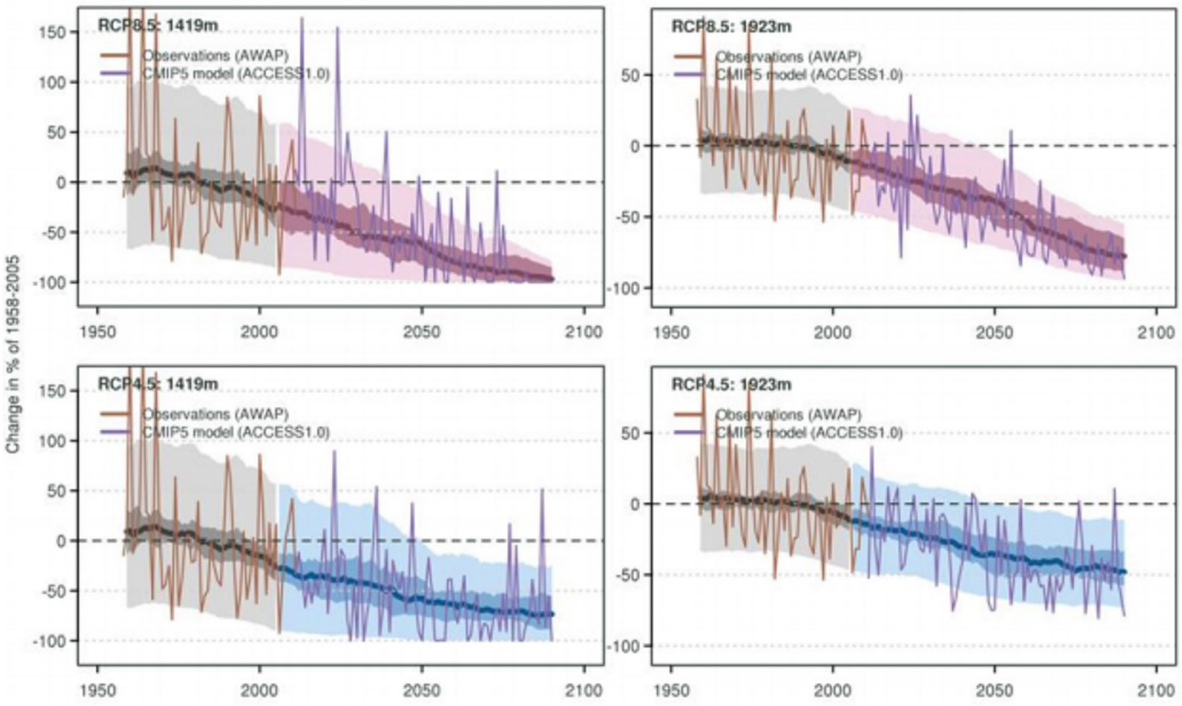


Figure CC.3 Change in snowfall for two grid boxes in the BoM operational 5 km gridded observations[32]

Note: Change corresponds to a lower alpine elevation consistent with the current snowline (left panels) and for the highest elevation in the gridded observations (right panels). Future projections are provided from 2006 onward for high (top row) and intermediate (bottom row) emissions scenarios. Each panel shows the model ensemble median (thick line), the 10th and 90th percentile of annual snowfall (light shading) and the 10th and 90th percentile of the 20-year mean snowfall (dark shading), operational 5 km gridded observations (brown line) and an example of a possible future time series (light purple) from a single model (ACCESS-1.0).[33]

There is a considerable interannual variability in various snow conditions and little research to date on the potential influence of climate change on extreme snowfall events. However, the research that has been conducted for Victoria consistently models a significant reduction in snow cover in the state's alpine locations.

Social research suggests that Australian skiers have a higher sensitivity to low snow cover than European skiers, which may heighten the impacts of reducing snow cover on the Victorian ski industry, with Victorian skiers potentially opting to ski in New Zealand or other international alpine regions.[34,35,36]

Man-made snow could be used increasingly as a replacement for natural snow. However, the most prevalent snow-making techniques are expected to become less reliable as temperatures rise, and they will be limited by water availability. The most reliable way to produce snow in the future is likely to involve an expensive, energy-intensive technology known as a 'snow factory'.[37]

32. CSIRO and BoM 2015, 'Climate Change in Australia: Technical Report'.
33. Ibid

34. Pickering CM, Buckley RC 2010, 'Climate Response by the Ski Industry: The Shortcomings of Snowmaking for Australian Resorts', *AMBIO*, 39, pp. 430-438.
35. Behringer J, Buerki R, Fuhrer J 2000, 'Participatory integrated assessment of adaptation to climate change in Alpine tourism and mountain agriculture', *Integrated Assessment*, 1, pp. 331-338.
36. König U 1998, 'Tourism in a warmer world: implications of climate change due to enhanced greenhouse effect for the ski industry in the Australian Alps', Geographisches Institut, Universität Zürich.
37. Antarctic Climate & Ecosystems Cooperative Research Centre 2016, 'The Potential Impacts of Climate Change on Victorian Alpine Resorts', Hobart, Tasmania http://www.arcc.vic.gov.au/uploads/publications-and-research/The%20Potential%20Impact%20of%20Climate%20Change%20on%20Victorian%20Alpine%20Resorts%20Study_FINAL.pdf Accessed 4 December 2018.

Flora and fauna reliant on snow are unlikely to adapt to the loss of natural snow, and some species are highly likely to be lost. An example is the mountain pygmy possum – an endangered species that is only found in alpine and subalpine regions above 1,400 metres on Mount Buller and the Bogong High Plains in Victoria, and on Mount Kosciuszko in New South Wales.[38] Declining snow cover and earlier snow melting will likely mean the possums awake from hibernation before some of their food sources (for example, bogong moths) are available.[39]

While man-made snow may be able to mitigate the economic effects of a reduced snow cover on the ski industry, it is not expected to ease the stresses on flora and fauna.[40] Snow-making is unlikely to contribute to the survival of snow-dependent flora and fauna, because the area covered by man-made snow is too small, and subject to unusual conditions of management and use, relative to what the species are adapted to. If natural snow is lost, many snow-dependent species will be lost.

38. Museum Victoria, 'Mountain Pygmy-possum', Melbourne, Victoria, https://museumsvictoria.com.au/website/melbournemuseum/discoverycentre/wild/victorian-environments/alps/mountain-pygmy-possum/index.html Accessed 4 December 2018.
39. Broome L, Archer M, Bates H, Shi H, Geiser F, McAllen B, Heinze D, Hand SJ, Evans T, Jackson S 2012, 'A brief review of the life history of, and threats to, *Burramys parvus* with a pre-history based proposal for ensuring that it has a future', *Wildlife and Climate Change: towards robust conservation strategies for Australian fauna*, Royal Zoological Society of NSW, Mosman, New South Wales, pp. 114-126.
40. SGS Economics and Planning 2017, 'Alpine Resort Futures Vulnerability Assessment (Social and Economic)', https://www.forestsandreserves.vic.gov.au/__data/assets/pdf_file/0014/215141/Alpine-Resorts-Vulnerability-Assessment-FINAL_Report-Aug-17.pdf Accessed 4 December 2018.

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
CC:03 Observed surface temperature	FAIR	↘	DATA QUALITY: Good
Data custodian BoM			

Victoria's climate has been warming since the 1950s (Figure CC.4). Since the publication of SoE 2013, every year has been among the top 10 warmest on record for Victoria, with 2014 the second-warmest year on record, behind 2007.[41] The greatest warming, measured as the linear trend across Victoria from 1910 to 2018, has been observed in summer (+0.14°C per decade), with the least warming observed in winter (+0.06°C per decade).[42] The warming has been observed in both maximum (daytime) and minimum (overnight) temperatures. Based on this data, the trend for this indicator has been assessed as deteriorating (warming).

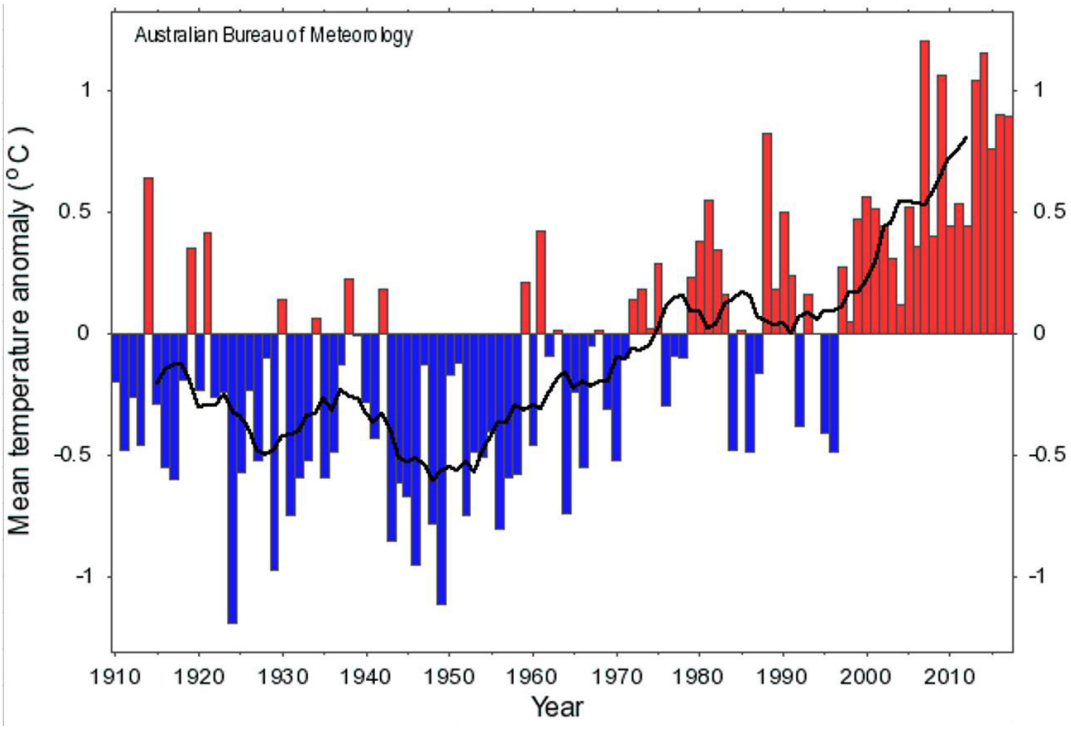


Figure CC.4 Victorian mean temperature anomaly, 1910–2017[43]

Note: 11-year running averages shown by black curve, Based on a 30-year climatology (1961-1990).

41. BoM, 'Climate Change and Variability – Time series graphs', Melbourne, Australia http://www.bom.gov.au/climate/change/ Accessed 4 December 2018.
42. Ibid
43. Ibid

All parts of Victoria have warmed, with the most warming in central and southern parts of the state (Figures CC.5 to CC.7). Daytime temperatures have increased uniformly, except in the far west and in parts of Gippsland and the north-east, where there has been a slightly slower increase. Overnight temperatures have warmed the most in southern coastal areas.

There has been no significant upward trend in night-time temperatures during the cool part of the year (April to October).[44] This is likely due to the reduction in rainfall since the mid-1990s, and hence reduced cloudiness, which allows for greater night-time heat loss from the surface.[45] Decreasing rainfall and cloud cover in the cool season appears to have somewhat offset the overall global warming signal in inland parts of Victoria, which explains the lesser night-time warming in this region: clearer night-time skies are generally associated with cooler minimum temperatures.

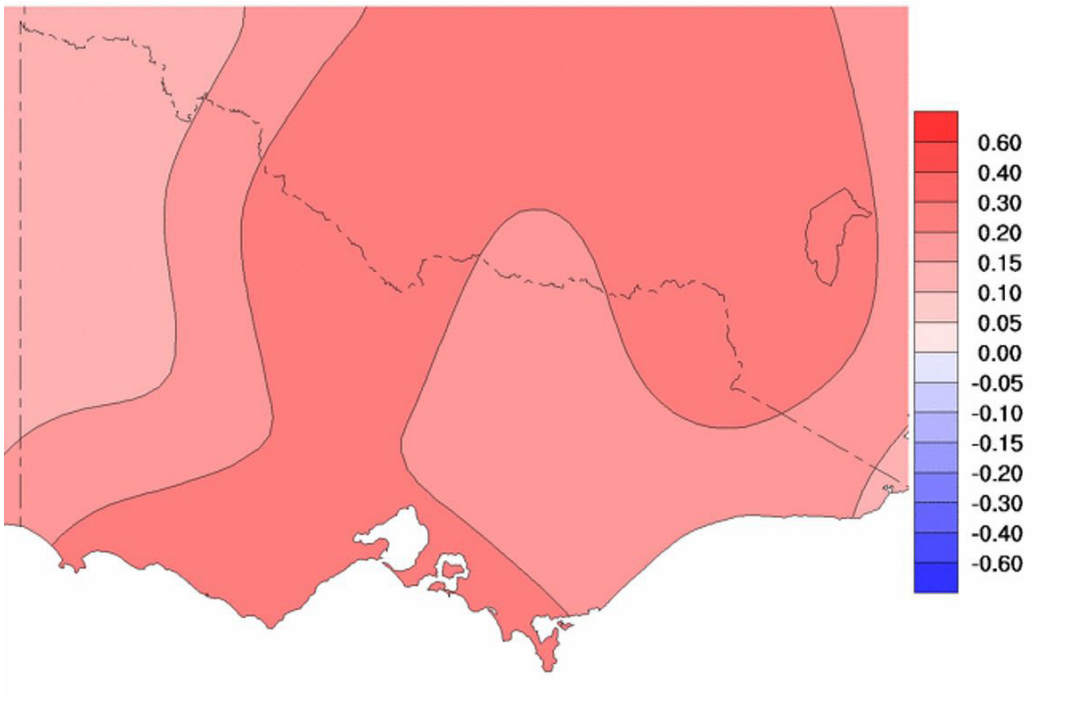


Figure CC.5 Trends in Victorian mean temperatures, annual 1950–2017 (°C/10yr)

(Data source: BoM, 2018)

44. Hope P, Timbal B, Hendon H, Ekström M, Potter N 2017, 'A synthesis of findings from the Victorian Climate Initiative (VicCI)', BoM, Australia.
45. Ibid

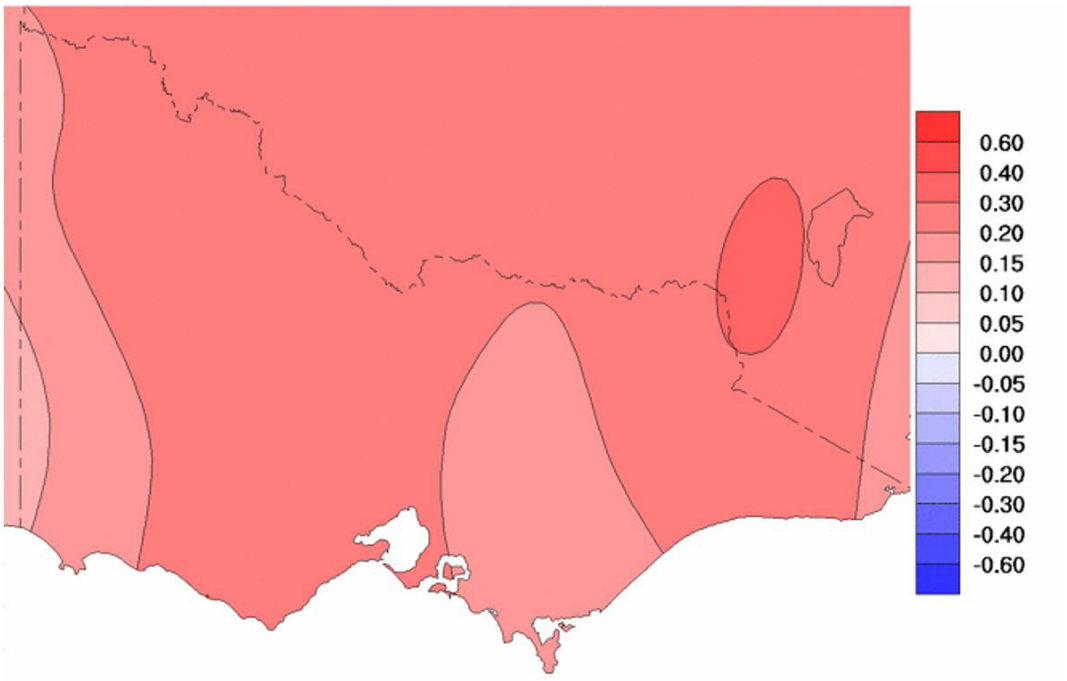


Figure CC.6 Trends in Victorian maximum temperatures, annual 1950–2017 (°C/10yr)

(Data source: BoM, 2018)

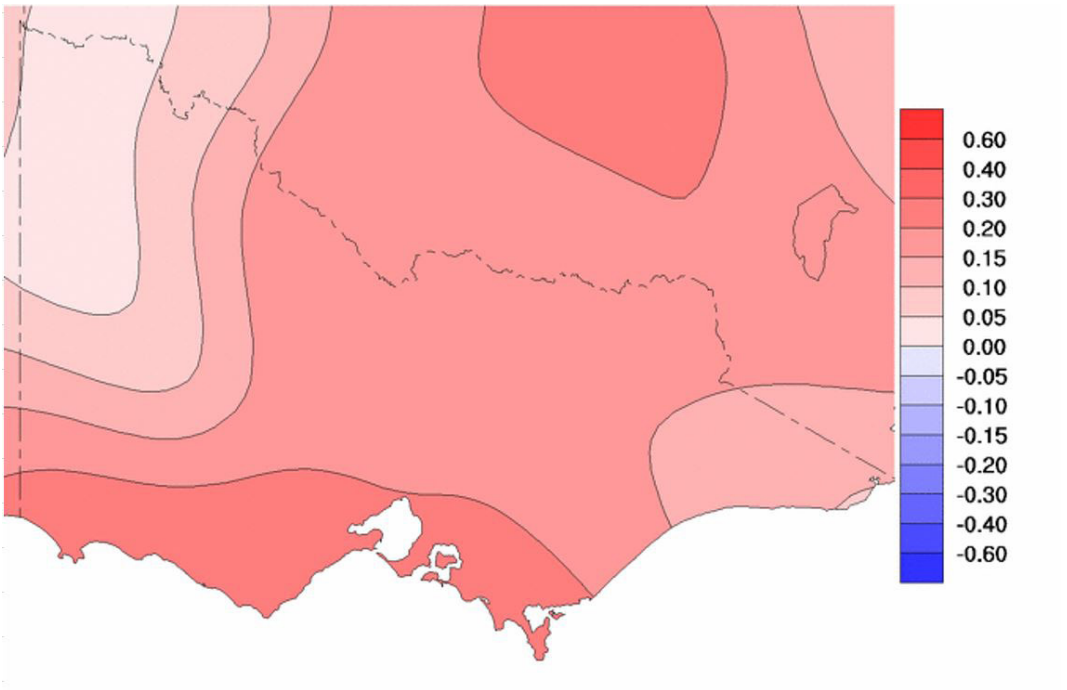


Figure CC.7 Trends in Victorian minimum temperatures, annual 1950–2017 (°C/10yr)

(Data source: BoM, 2018)

Climate – Projections

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
CC:04 Projected changes in temperature	N/A	↘	DATA QUALITY
Data custodian BoM, CSIRO			Good

Temperatures are expected to be an average of 0.4 to 1.3°C warmer across Victoria by 2030, relative to the 1986 to 2005 baseline. Warming is projected to increase further by 2090, in proportion to the scale of emissions from human activity. From the 1986 to 2005 baseline, Victorian temperatures are expected to increase by 2.5 to 4.5°C in 2090 under a high ongoing emissions scenario, by 1.1 to 2.4°C under an intermediate emissions scenario, and by 0.4 to 1.5°C under a lower emissions scenario, which aligns most closely with the Paris Agreement targets.[46,47] The magnitude of the warming is projected to be slightly greater in the Murray Basin region of Victoria than across the Southern Slopes (Table CC.1).[48]

It is important to note that the projection of a 0.4 to 1.3°C temperature increase by 2030 (relative to the 1986 to 2005 average) is likely to be an underestimate, as the observed average temperature for Victoria from 2008 to 2017 is already 0.6°C warmer than the 1986 to 2005 average.[49]

Increases in the magnitude, frequency and duration of extreme temperatures across Victoria are expected to occur at a similar rate to the rises in average temperature. Frost-risk days (minimum temperatures under 2°C) are projected to decrease across the state, possibly halving in northern Victoria by the end of the century.[50] In the short-to-medium term, other factors, such as an increase in clear nights, may lead to increases in frost risk in some places, but in the long term the warming is expected to drive a decrease in frost risk. A decrease in frost days is expected to help the broadacre agricultural sector, which loses an estimated $120 million to $700 million each year in Australia due to frost events.[51] For more information on extreme heat impacts, see indicator CC:12 (Occurrence and impacts of extreme weather).

Physical evidence, past trends and various models all suggest Victoria will continue warming this century, so an ongoing warming is projected with very high confidence, with the full range of projected change considered plausible.

46. Grose M et al 2015, 'Southern Slopes Cluster Report, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports', CSIRO and BoM, Australia.
47. Timbal B et al 2015, 'Murray Basin Cluster Report, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports', CSIRO and BoM, Australia.
48. Climate Change in Australia, 'Projections for Australia's NRM Regions', https://www.climatechangeinaustralia.gov.au/en/climate-projections/future-climate/regional-climate-change-explorer/sub-clusters Accessed 4 December 2018.
49. BoM, 'Climate Change and Variability – Time series graphs', Melbourne, Australia http://www.bom.gov.au/climate/change/ Accessed 4 December 2018.
50. Climate Change in Australia, 'Projections for Australia's NRM Regions', https://www.climatechangeinaustralia.gov.au/en/climate-projections/future-climate/regional-climate-change-explorer/sub-clusters Accessed 4 December 2018.
51. Crimp SJ, Zheng B, Khimashia N, Gobbett DL, Chapman S, Howden M, Nicholls N 2016, 'Recent changes in southern Australian frost occurrence: implications for wheat production risk', *Crop & Pasture Science*, 67, pp. 801–811.

Table CC.1 Projected temperatures across Victoria

Scenario	Victoria °C
2030 annually averaged warming relative to the climate of 1986–2005 for all emissions scenarios	0.4 to 1.3
2090 annually averaged warming relative to the climate of 1986– 2005 for a low emissions scenario (RCP2.6)	0.4 to 1.5
2090 annually averaged warming relative to the climate of 1986– 2005 for an intermediate emissions scenario (RCP4.5)	1.1 to 2.4
2090 annually averaged warming relative to the climate of 1986–2005 for a high emissions scenario (RCP8.5)	2.5 to 4.5

Note: Data derived from results for the three Victorian regions (Murray Basin, Southern Slopes West and Southern Slopes East) reported by Climate Change in Australia.[52]

52. Climate Change in Australia, 'Projections for Australia's NRM Regions', https://www.climatechangeinaustralia.gov.au/en/climate-projections/future-climate/regional-climate-change-explorer/sub-clusters Accessed 4 December 2018.

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
CC:05 Projected changes to average rainfall	N/A	↘	DATA QUALITY: Fair

Data custodian BoM, CSIRO

The observed reduction in cool-season (April to October) rainfall in the past 20 years is projected to continue and possibly intensify. While rainfall reduction was more pronounced in autumn during the millennium drought, reductions are expected to be more even across the cool season.[53]

In the short term (until 2030), there is high confidence that natural climate variability will remain the major driver of rainfall changes, compared with the climate of 1986 to 2005.[54] However, by 2090, there is high confidence that cool-season rainfall will continue to decline. There will be no clear leaning towards wetter or drier conditions in the warm season.[55]

Figure CC.8 shows that under a high emissions scenario, Victoria's annual average rainfall at the end of the century is expected to have declined. This decline is expected to be characterised by longer periods of dry weather, interspersed with more frequent extreme rainfall events.[56]

Table CC.2 Projected rainfall across Victoria[57,58]

Scenario	Victoria (annual) %	Victoria (winter) %	Victoria (summer) %
Percentage change in rainfall in 2030 relative to the climate of 1986–2005 for all emissions scenarios	–11 to 5	–17 to 9	–20 to 16
Percentage change in rainfall in 2090 relative to the climate of 1986–2005 for a low emissions scenario (RCP2.6)	–19 to 5	–13 to 9	–27 to 8
Percentage change in rainfall in 2090 relative to the climate of 1986–2005 for an intermediate emissions scenario (RCP4.5)	–16 to 4	–21 to 7	–24 to 11
Percentage change in rainfall in 2090 relative to the climate of 1986–2005 for a high emissions scenario (RCP8.5)	–27 to 9	–38 to 6	–28 to 27

Note: Data derived from the results for the three Victorian regions (Murray Basin, Southern Slopes West and Southern Slopes East) reported by Climate Change in Australia.

53. Hope P, Timbal B, Hendon H, Ekström M, Potter N 2017, 'A synthesis of findings from the Victorian Climate Initiative (VicCI)', BoM, Australia.
54. 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*.
55. Ibid
56. Australian Climate Change Science Programme 2015, 'Weather extremes and climate change - the science behind the attribution of climatic events', http://www.cawcr.gov.au/projects/Climatechange/wp-content/uploads/2015/11/Weather_Extremes_Report-FINAL.pdf Accessed 4 December 2018.
57. Grose M et al 2015, 'Southern Slopes Cluster Report, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports', CSIRO and BoM, Australia.
58. Timbal B et al 2015, 'Murray Basin Cluster Report, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports', CSIRO and BoM, Australia.

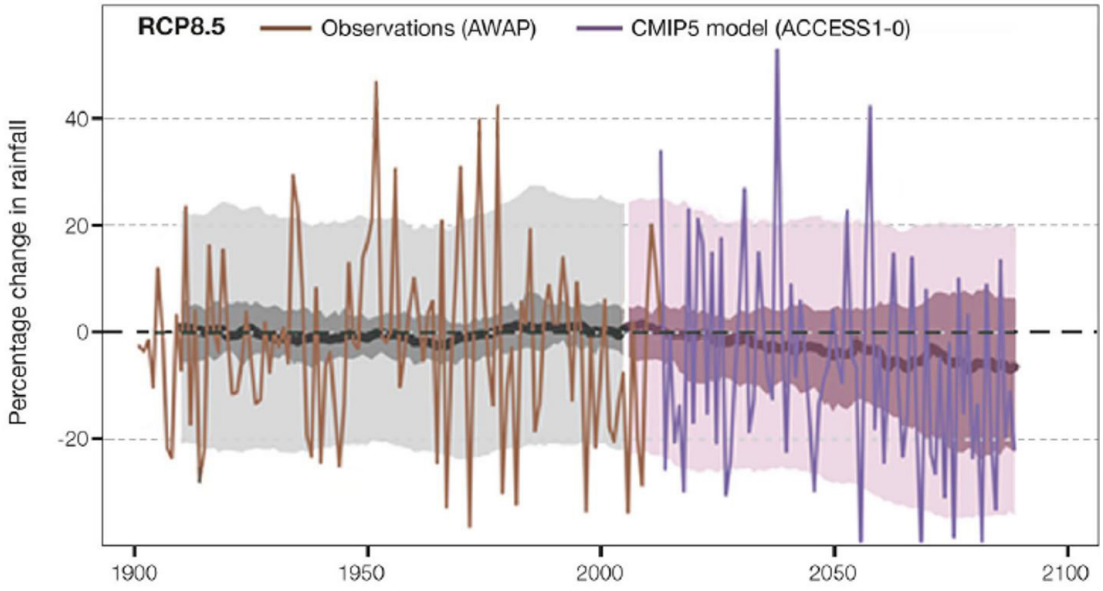


Figure CC.8 Observed annually averaged and simulated historical Victorian rainfall [59]

Note: Observed annually averaged Victorian rainfall (in brown), and simulated historical Victorian rainfall (in grey), with the deeper shade showing the variability across all available CMIP5 models in the 20-year average. Projections of Victorian rainfall from RCP8.5 are in purple, with shading illustrating the spread across all available CMIP5 models. Dark purple shows the median response. One model's output (ACCESS-1.0) is shown to highlight the year-to-year variability observed in all models.[60]

59. Hope P, Timbal B, Hendon H, Ekström M, Potter N 2017, 'A synthesis of findings from the Victorian Climate Initiative (VicCI)', BoM, Australia.
60. Ibid

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
CC:06 Regional climate projections	N/A				↘	DATA QUALITY
Data custodian BoM, CSIRO						Good

As presented in indicators CC:04 (Projected changes in temperature) and CC:05 (Projected changes to average rainfall), climate projections for Victoria have been provided based on data available for three classified regions in Victoria.

Climate Change in Australia projections are reasonably consistent across the three Victorian regions.[61] There is a very high confidence that average temperatures will continue to increase in all seasons, with more hot days and warm spells, while fewer frosts are projected with high confidence.

In south-west Victoria, generally less rainfall is expected in winter and spring, while in the northern areas of the Murray Basin, and in the south-east of the state, changes to rainfall are not expected to exceed natural variability for another few decades. Despite the likely reductions in average rainfall, increased intensity of extreme rainfall events is projected with high confidence.

In 2015, the Department of Environment, Land, Water and Planning (DELWP) produced local data and fact sheets for Victorian towns and regions, based on the climate projections in indicators CC:04 (Projected changes in temperature) and CC:05 (Projected changes to average rainfall).[62] The fact sheets report on the projected annual number of hot days (over 35°C) and frost days (under 2°C) in selected major Victorian towns and cities, according to different emissions scenarios. These projected hot and frost days are shown in Table CC.3. The number of hot days in most cities and major towns in Victoria is expected to double by 2070, while the number of frost days is expected to halve.

61. Climate Change in Australia, 'Projections for Australia's NRM Regions', https://www.climatechangeinaustralia.gov.au/en/climate-projections/future-climate/regional-climate-change-explorer/sub-clusters Accessed 4 December 2018.
62. DELWP, 'Fact sheets about climate change impacts by region', East Melbourne, Victoria https://www.climatechange.vic.gov.au/information-and-resources Accessed 4 December 2018.

Table CC.3 Average number of hot and frost days per year for current, 2030 and 2070 scenarios[63,64,65,66,67,68]

Town	Current hot days	Hot days in 2030	Hot days in 2070		Current frost days	Frost days in 2030	Frost days in 2070	
			(medium emissions – RCP4.5)	(high emissions – RCP8.5)			(medium emissions – RCP4.5)	(high emissions – RCP8.5)
Ballarat	5	8	10	13	36	25	18	10
Bendigo	13	19	23	29	35	25	20	12
Geelong	6	9	11	13	4	2	1	0
Hamilton	8	11	13	16	20	12	8	4
Horsham	18	25	29	36	33	23	17	10
Melbourne	8	12	14	17	3	1	1	0
Mildura	36	46	54	66	14	9	6	3
Orbost	6	9	11	14	6	3	2	1
Shepparton	15	23	29	37	37	27	21	13
Traralgon	6	9	10	14	20	13	8	3
Wodonga	21	31	39	47	40	29	23	13

63. DELWP 2015, 'Barwon South West', East Melbourne, Victoria https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0020/60743/Barwon-South-West.pdf Accessed 4 December 2018.
64. DELWP 2015, 'Gippsland', East Melbourne, Victoria https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0021/60744/Gippsland.pdf Accessed 4 December 2018.
65. DELWP 2015, 'Grampians', East Melbourne, Victoria https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0018/60741/Grampians.pdf Accessed 4 December 2018.
66. DELWP 2015, 'Greater Melbourne', East Melbourne, Victoria https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0019/60742/Greater-Melbourne.pdf Accessed 4 December 2018.
67. DELWP 2015, 'Hume', East Melbourne, Victoria https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0022/60745/Hume.pdf Accessed 4 December 2018.
68. DELWP 2015, 'Loddon Mallee', East Melbourne, Victoria https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0023/60746/Loddon-Mallee.pdf Accessed 4 December 2018.

Sea Level

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
CC:07 Observed sea level	FAIR	↘	DATA QUALITY: Fair

Data custodian BoM

Global sea levels rose by about 1.7 mm per year on average last century, with a greater rate of increase observed in recent decades.[69] Victorian tide gauges show the mean sea level has been increasing around the Victorian coastline, with average increases between 1.59 cm and 3.89 cm per decade between 1993 and 2016.[70] Melbourne (recorded at Williamstown), which has the longest continuous record of observations in Victoria, has reported an average increase in mean sea level of 1.97 cm per decade (that is, ~2 mm per year) since 1966.[71] This equates to a total rise of 10.2 cm over the past 52 years, which has been accompanied by increases in the frequency of extreme sea-level events.[72]

Higher maximum annual sea levels increase the hazards of extreme sea levels, such as coastal erosion and flooding, created by natural variability and climate conditions. This is especially the case when large astronomical tides combine with strong winds and low pressures that produce storm surges. There is also significant variability across seasonal-to-interannual timescales associated with drivers such as the El Niño–Southern Oscillation.[73]

The highest sea level recorded in Melbourne between 1966 and 2016 occurred on 24 June 2014, when the Williamstown gauge recorded values of up to 62 cm above Highest Astronomical Tide (the highest sea level that can be reached by astronomical tides).[74] This event occurred in conjunction with a severe storm and caused inundation of many bayside foreshore reserves and coastal infrastructure such as shared-use paths, beach access points and some roads (Figure CC.9).



Figure CC.9 Sand deposited over the bicycle path at Middle Brighton on 24 June 2014

(Photo: Andrew Watkins)

69. BoM and CSIRO 2016, 'State of the Climate 2016', Melbourne, Victoria http://www.bom.gov.au/state-of-the-climate/State-of-the-Climate-2016.pdf Accessed 4 December 2018.
70. BoM, 'Tide Gauge Metadata and Observed Monthly Sea Levels and Statistics', Melbourne, Australia http://www.bom.gov.au/oceanography/projects/ntc/monthly/ Accessed 4 December 2018.
71. Ibid
72. Ibid
73. CSIRO and BoM 2015, 'Climate Change in Australia: Technical Report'.
74. BoM, 'Tide Gauge Metadata and Observed Monthly Sea Levels and Statistics', Melbourne, Australia http://www.bom.gov.au/oceanography/projects/ntc/monthly/ Accessed 4 December 2018.

Annual maximum sea levels at Melbourne have increased, on average, at a rate of 3.37 cm per decade between 1966 and 2016 – a total of 17 cm over the period. However, observed trends have been higher in recent years, with 12 cm of the total 17 cm occurring since 1993 at an average of 5 cm per decade. Similar trends have also been observed at Geelong (2.3 cm per decade from 1965 to 2016). Data collected from shorter-term Australian Baseline Sea Level Monitoring gauges from 1993 to 2016 shows increases at Portland (2.7 cm per decade) and Stony Point (4.2 cm per decade).[75]

The frequency of very high sea levels has also increased, with statistically significant increases in the frequency at which the Highest Astronomical Tide is exceeded at Geelong, Melbourne and Portland.

Recent tidal inundation has mainly occurred when observed sea-level rise has coincided with high astronomical tides (for example, king tides or spring tides).

75. BoM, 'Australian Baseline Sea Level Monitoring Project', Melbourne, Australia http://www.bom.gov.au/oceanography/projects/abslmp/abslmp.shtml Accessed 4 December 2018.

Sea Level – Projections

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
CC:08 Projected sea level	N/A	↘	DATA QUALITY: Good

Data Custodian BoM, CSIRO

Sea-level rise is one of the biggest threats associated with climate change to coastal areas. Significant impacts experienced this century are expected to intensify. These include:

- more frequent and extensive inundation of low-lying areas
- loss of coastal habitat, such as roosting and nesting sites for shorebirds and seabirds
- cliff, beach and foreshore erosion
- altered saltmarsh and mangrove habitats.[76]

Thermal expansion of the ocean and melting glaciers and ice caps have been the main causes of rising sea levels worldwide in the past century – a trend that is expected to continue. Australian sea levels are projected to rise for the rest of this century, most likely at a faster rate than for the past four decades.[77] Higher sea-level rise, driven by the accelerated melting and disintegration of ice shelves and ice sheets in Greenland and Antarctica, is also possible, meaning the 'worst case' scenario is sea levels above the high-end of projections presented here.

For Victoria, sea-level projections have been produced for Geelong and Williamstown (Table CC.4). Depending on the emissions scenario, sea levels are likely to rise between 3 cm (low emissions scenario) and 10 cm (high emissions scenario) per decade at Geelong and Williamstown during the rest of this century.

To visualise the possible impacts of coastal inundation, Figure CC.10 shows the areas that would be flooded at Queenscliff in 2100 in a high tide under a high emissions scenario, which assumes a median sea-level rise of 0.74 m.

Table CC.4 Likely ranges for projections of regional sea-level rise (m) relative to 1986–2005 under all emissions scenarios[78]

Locations	2030 m	2050 m	2070 m	2090 m
Geelong	0.06–0.17	0.12–0.33	0.18–0.54	0.22–0.82
Williamstown	0.06–0.17	0.12–0.32	0.17–0.54	0.22–0.81

76. Victorian Coastal Council 2018, 'Victoria's coast and marine environments under projected climate change: Impacts, research gaps and priorities', East Melbourne, Victoria http://www.vcc.vic.gov.au/assets/media/files/Victorian_Coastal_Council_Science_panel_report_WEB.pdf Accessed 4 December 2018.
77. CSIRO and BoM 2015, 'Climate Change in Australia: Technical Report – Projections for Australia's NRM regions', https://www.climatechangeinaustralia.gov.au/media/ccia/2.1.6/cms_page_media/168/CCIA_2015_NRM_TechnicalReport_WEB.pdf Accessed 4 December 2018.
78. Ibid

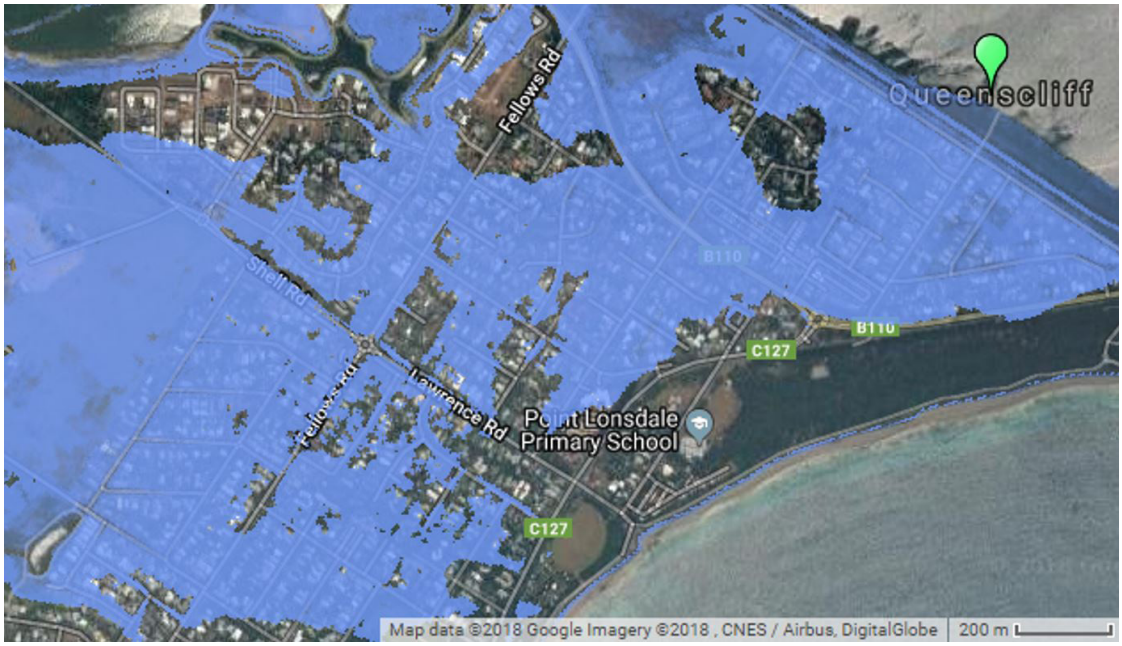


Figure CC.10 Coastal inundation at Queenscliff in high tide and assuming 0.74 m sea-level rise[79]

An increase in mean sea level will result in a larger increase in the frequency of extreme inundation events. For Australia to maintain the current level of exposure of coastal assets to extreme sea levels, protective barriers would need to be raised by at least 0.7 to 1.0 m by 2100 for a high emissions scenario.[80]

79. CRC for Spatial Information and NGIS, 'Coastal Risk Australia', http://www.coastalrisk.com.au/ Accessed 4 December 2018.
80. Climate Change in Australia, 'Projections for Australia's NRM Regions', https://www.climatechangeinaustralia.gov.au/en/climate-projections/future-climate/regional-climate-change-explorer/sub-clusters Accessed 4 December 2018.

Sea Temperature

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
CC:09 Sea-surface temperature	○ ● ○ ○	↘	DATA QUALITY: Good

Data custodian BoM, CSIRO

Oceans play an important role in the global climate system, absorbing more than 90% of the excess heat trapped by GHGs.[81]

Globally, the temperature of the ocean near the surface (upper 75 m) has been steadily increasing, by about 0.11°C per decade from 1971 to 2010.[82] The sea-surface temperature has warmed across the Australian region, with the greatest warming since 1950 around the south-east and to the south-west of Australia (Figure CC.11).

The ocean off the south-east coast of Australia, including the region near eastern Bass Strait, is one of the world's most rapidly warming locations, with a strengthening of the East Australian Current adding to the overall warming trend.[83, 84]

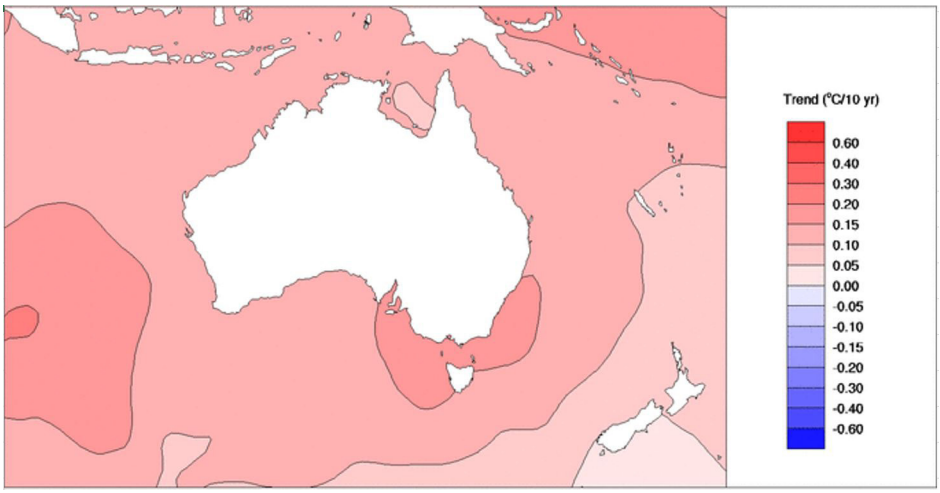


Figure CC.11 Trends in annual Australian region sea-surface temperatures, annual 1950–2017 (°C/10yr)

(Data source: BoM, 2018)

81. Rhein M, Rintoul SR, Aoki S, Campos E, Chambers D, Feely RA, Gulev S, Johnson GC, Josey SA, Kostianoy A, Mauritzen C, Roemmich D, Talley LD, Wang F 2013, 'Observations: Ocean. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change', Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
82. Ibid
83. Hobday AJ, Pecl GT 2014, 'Identification of global marine hotspots: sentinels for change and vanguards for adaptation action', *Reviews in Fish Biology and Fisheries*, 24(2), pp. 415-425.
84. Ridgway KR 2007, 'Long-term trend and decadal variability of the southward penetration of the East Australian Current', *Geophysical Research Letters*, 34(13).

Record-warm sea-surface temperatures have been observed in the Australian region in recent years, with 2016 the warmest year on record.[85] In the southern region (30°S–46°S, 94°E–174°E), recent years have also been warmer than average, with every year since 2010 in the top 10 warmest years on record for the region (Figure CC.12).

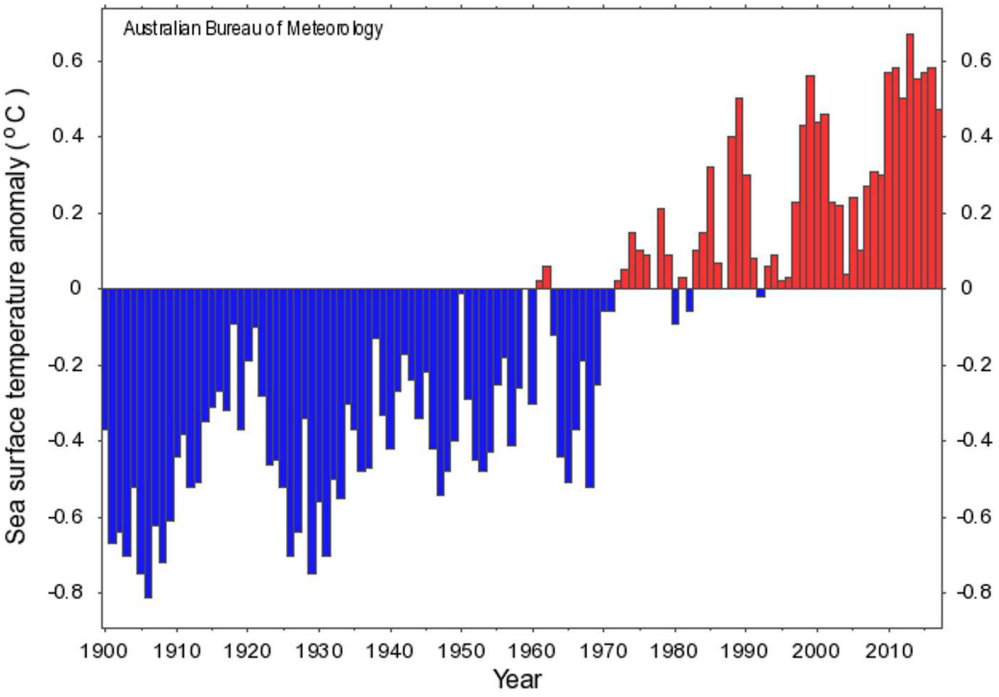


Figure CC.12 Australian sea-surface temperature anomaly – Southern Region, 1900–2017 [86]

Background warming of the oceans has led to an increased frequency of marine heatwaves.[87] Over the summer of 2015 to 2016, an extreme heatwave was observed to the south-east of Victoria in the Tasman Sea. The intensity and duration of the heatwave was increased by climate change and linked to outbreaks of Pacific Oyster Mortality Syndrome in Pacific oysters off the coast of Tasmania.[88] Background warming and the warmer and less nutrient-dense water from the East Australian Current has led to other impacts in the region, such as an almost complete loss of cold-water kelp forests off Tasmania's east coast.[89]

85. BoM, 'Climate change and variability', Melbourne, Australia http://www.bom.gov.au/climate/change Accessed 4 December 2018.
86. Ibid
87. Oliver ECJ et al 2018, 'Longer and more frequent marine heatwaves over the past century', *Nature Communications*, 9.
88. Oliver ECJ, Benthuysen JA, Bindoff NL, Hobday AJ, Holbrook NJ, Mundy CN, Perkins-Kirkpatrick SE 2017, 'The unprecedented 2015/16 Tasman Sea marine heatwave', *Nature communications*, 8.
89. Bennett S, Wernberg T, Connell SD, Hobday AJ, Johnson CR, Poloczanska ES 2016, 'The 'Great Southern Reef': social, ecological and economic value of Australia's neglected kelp forests', *Marine and Freshwater Research*, 67(1), pp.47-56.

Greenhouse Gas Emissions

Indicator	Status	Trend	Data Quality
CC:10 Annual greenhouse gas emissions Data custodian DELWP	UNKNOWN POOR FAIR GOOD Stable for land sector and Unknown for marine and coastal ecosystems	↗	DATA QUALITY Good

Despite a relatively small population, Australia is the world's 13th biggest GHG emitter, ahead of countries such as the United Kingdom and France.[90] Australia's contribution is even more significant at a per capita level: no other country from the Organisation for Economic Co-operation and Development emits more GHGs per person than Australia.[91] Victoria's annual per capita emissions are lower than the national figure of 22 tonnes CO_2-e per person (in 2016), and Victorian per capita emissions have dropped from 24 tonnes CO_2-e per person in 1990 to 18 tonnes CO_2-e per person in 2016 (Figure CC.13).[92]

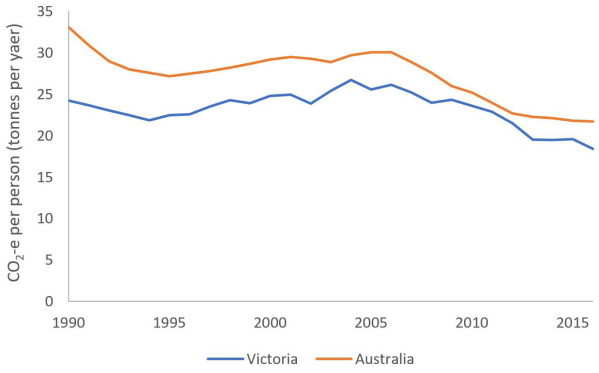


Figure CC.13 Victorian and Australian per capita annual GHG emissions, 1990–2016, including land use, land-use change, and forestry (LULUCF)

(Data source: DELWP, 2018)

In Victoria, carbon dioxide is the most significant GHG, contributing 79% of total emissions in 2016.[93] The majority of carbon dioxide emissions come from industry, transport and energy generation. Emissions of methane and nitrous oxide in 2016, mainly from land management and agriculture, also made contributions of 14% and 4% respectively to the total GHG emissions.[94]

The Victorian Government has committed to reducing the state's emissions by 15 to 20% of 2005 levels by 2020.[95] In 2016, the state's total net GHG emissions were 10.8% lower than in 2005 (but 7.3% higher than in 1990) (Figure CC.14). The reduction on 2005 levels means this indicator has been assessed as improving.

Reductions since 2005 are largely due to improvements in energy efficiency, higher electricity prices (which have reduced electricity demand) and a decline in manufacturing activity.[96,97] There was a 3.5% reduction between 2015 and 2016 alone, primarily because of an increase in carbon sequestration from the land sector, and a reduction in emissions from the generation of electricity.

90. World Resources Institute, 'Climate Analysis Indicators Tool (CAIT) Climate Data Explorer Historical emissions', Washington, DC, http://cait.wri.org/historical Accessed 4 December 2018.
91. Organisation for Economic Co-Operation and Development, 'OECD.stat Greenhouse gas emissions', Paris, France, https://stats.oecd.org/Index.aspx?DataSetCode=AIR_GHG Accessed 4 December 2018.
92. DELWP 2018, 'Victorian Greenhouse Gas Emissions Report 2018', East Melbourne, Victoria https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0033/395079/Victorian-Greenhouse-Gas-Emissions-Report-2018.pdf Accessed 4 December 2018.
93. Australian Department of the Environment and Energy, 'Australian Greenhouse Emissions Information System', Canberra, Australia http://ageis.climatechange.gov.au Accessed 4 December 2018.
94. Ibid
95. Department of Environment, Land, Water and Planning, 'Emissions reduction targets', Melbourne, Victoria, https://www.climatechange.vic.gov.au/reducing-emissions/emissions-targets Accessed 4 December 2018.
96. DELWP 2017, 'Independent Expert Panel: Interim Emissions Reduction Targets for Victoria (2021-2030)', East Melbourne, Victoria https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0019/121924/Issues-Paper_28-03-2018.pdf Accessed 4 December 2018.
97. DELWP 2018, 'Victorian Greenhouse Gas Emissions Report 2018', East Melbourne, Victoria https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0033/395079/Victorian-Greenhouse-Gas-Emissions-Report-2018.pdf Accessed 4 December 2018.

By 2020, net GHG emissions in Victoria are expected to have dropped by 18% relative to 2005 levels.[98] The closure in March 2017 of the Hazelwood power station, which emitted about 15 Mt CO_2-e per year, is expected to be the biggest contributor to the reductions between 2005 and 2020.[99]

For further discussion, see the Energy chapter.

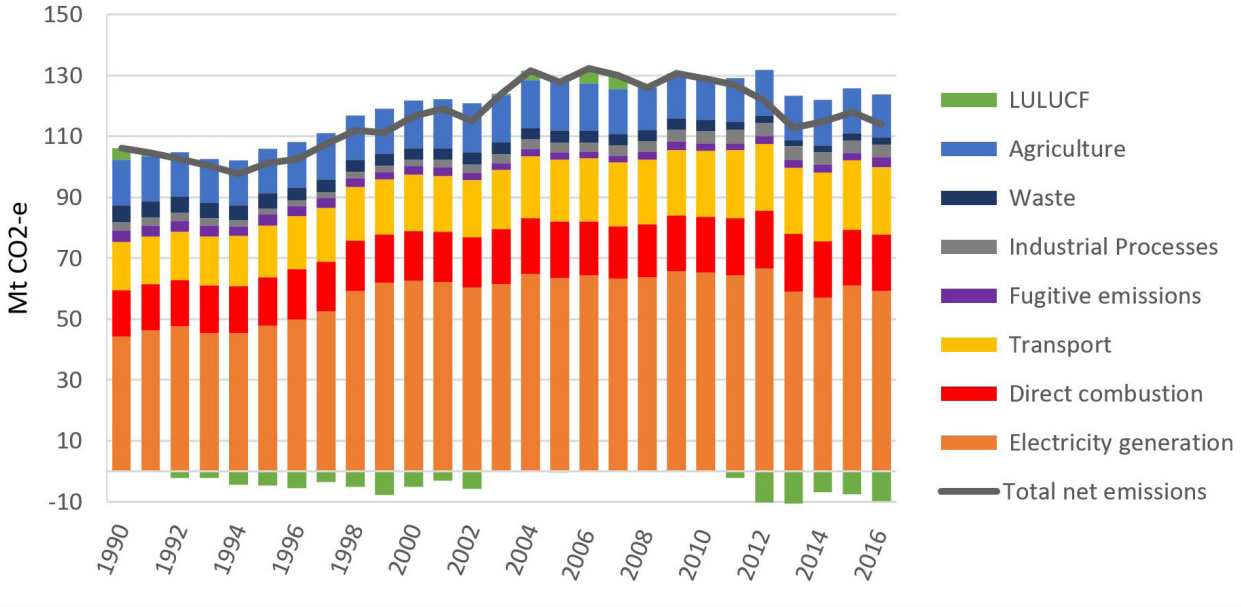


Figure CC.14 Victoria's annual GHG emissions, 1990–2016

(Data source: DELWP, 2018)

The highest contributor to GHG emissions in Victoria in 2016 was the production of electricity, which was responsible for 52% of the state's total emissions (Figure CC.15). The transport sector had the second largest share (20%) and the greatest increase since 1990. The direct combustion of stationary fuels had the third largest share (15%) followed by the agriculture sector (12%). Carbon sequestration from Victoria's land sector offset 9% of total emissions in 2016.

98. Ibid
99. Ibid

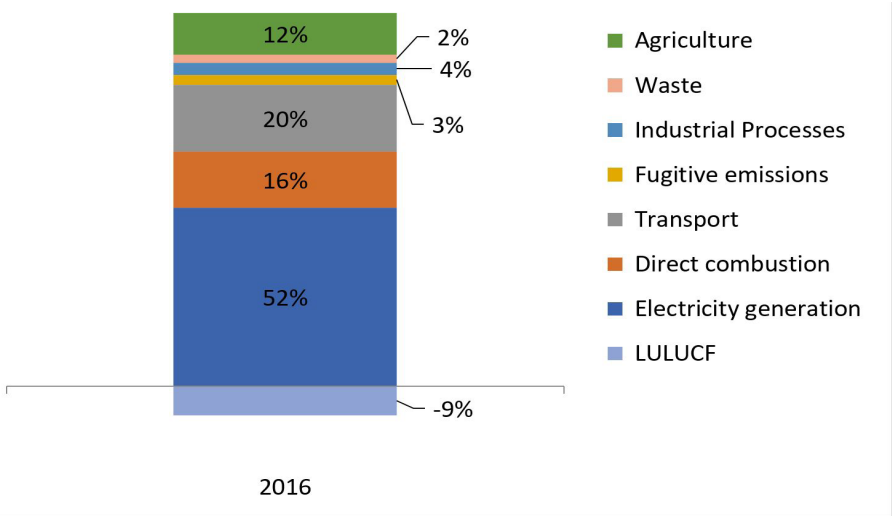


Figure CC.15 Sector GHG emissions percentage contributions in Victoria, including LULUCF, in 2016

(Data source: DELWP, 2018)

Figure CC.16 compares 2016 emissions by sector with emissions in 1990, and the baseline year of 2005 (against which Victoria's emission reduction targets are assessed).[100] Emissions from the electricity, direct combustion, transport and industrial processes sectors all increased between 1990 and 2016. Direct combustion, transport, fugitive and industrial processes emissions were higher in 2016 than in 2005, whereas emissions from other sectors were lower.

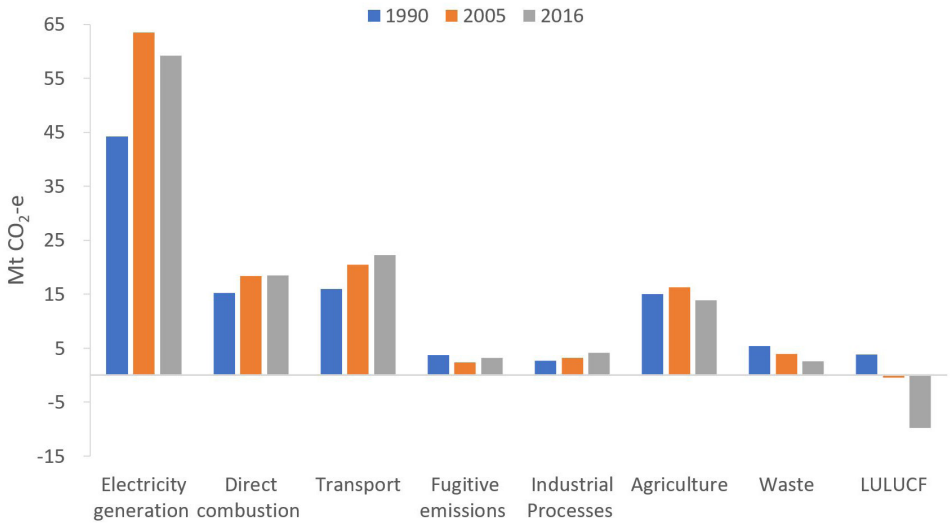


Figure CC.16 Sector GHG emissions in Victoria in 1990, 2005 and 2016

(Data source: DELWP, 2018)

100. 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/f932b66241ecf1b7ca256e92000e23be/05736C89E5B8C7C0CA2580D50006FF95/$FILE/17-005aa%20authorised.pdf Accessed 4 December 2018.

Transport emissions have grown by 39% in the past 26 years. The sector had the highest proportional increase in emissions in Victoria over this period (Figure CC.17). 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. For further detail about energy and GHG emissions, see the Energy and Transport chapters.

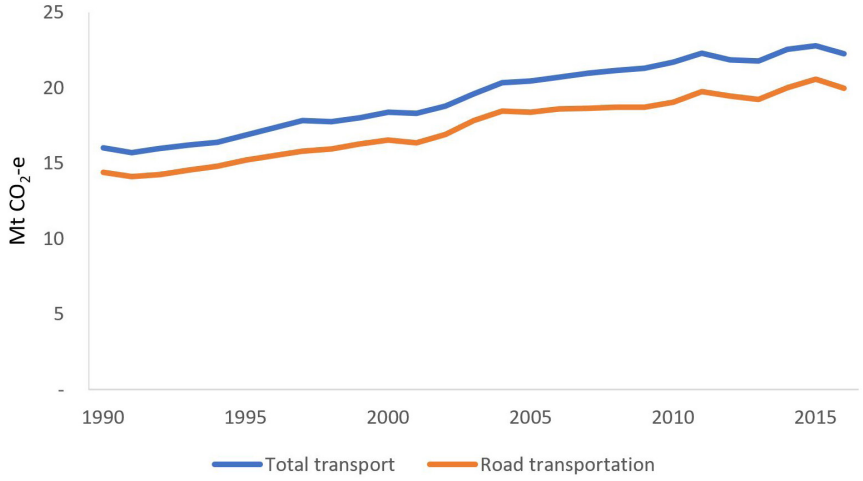


Figure CC.17 Transport GHG emissions in Victoria, 1990–2016

(Data source: DELWP, 2018)

Carbon Storage

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
CC:11 Victorian ecosystem carbon stocks Data custodian DELWP	Stable for land sector and Unknown for marine and coastal ecosystems	→	DATA QUALITY Fair

This indicator looks at the important role ecosystems play in the global carbon cycle and global GHG balance by storing carbon in both trees and soil. Carbon stocks in Victoria are vulnerable to climatic variation and bushfires, which have temporarily decreased carbon stocks in some areas. This has important implications for the management of Victoria's carbon stocks with the ability of forests to take up carbon vital for the mitigation of climate change.

Victoria's forests store a considerable amount of carbon, but carbon stocks are likely to be impacted by climate change, with increased periods of drought and fire risk. Figure CC.18 shows declines in land sector carbon stocks from 2002 to 2003, and 2006 to 2007, directly attributable to bushfire events – although there has been a consistently upward trend in land sector carbon stocks since 2007.[101] The y-axis of the graph in Figure CC.18 has been enlarged to show changes in greater detail, and it is important to note that despite the consistent increase in carbon stocks, the growth from 2007 to 2016 has only been 1%. Based on this small increase, the trend for land sector carbon stocks has been assessed as stable. The growth has been due to net growth of carbon stocks in forests, which is currently occurring at a rate of nearly 2% per year. There has been a decay of carbon stocks in non-forests.

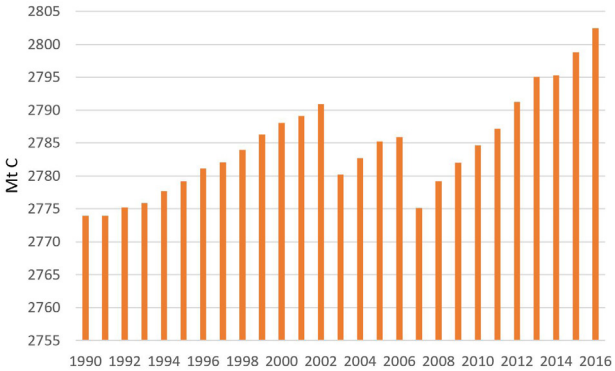


Figure CC.18 Victorian land sector carbon stocks, 1990–2016[102]

Carbon stored in coastal and marine ecosystems is referred to as 'blue carbon'. Potential blue carbon stocks have been estimated at 1,000,000 t in the Port Phillip and Westernport catchment.[103] For further detail on blue carbon, see the Marine and Coastal Environments chapter.

101. Australian Department of the Environment and Energy, 'State and Territory Greenhouse Gas Inventories 2016', Canberra, Australia http://www.environment.gov.au/system/files/resources/a97b89a6-d103-4355-8044-3b1123e8bab6/files/state-territory-inventories-2016.pdf Accessed 4 December 2018.

102. Ibid

103. Carnell P et al 2015, 'The distribution and abundance of 'Blue Carbon' within Port Phillip and Westernport', Deakin University, Melbourne, Victoria.

Impacts of Climate Change

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
CC:12 Occurrence and impacts of extreme weather			 DATA QUALITY Good

Data custodian BoM, CSIRO, DHHS, EMV

Extreme weather affects the frequency and intensity of natural disasters in Australia. The types of natural disasters that occur in Australia are many and varied, ranging from severe thunderstorms, hail storms and floods to heatwaves, bushfires and droughts.

Research has found that heatwaves cause more deaths than any other natural disaster in Victoria,[104] with another study estimating there will be an extra 400 deaths per year in Victoria by 2050 due to heatwaves, if no adaptation measures are taken.[105] A warmer climate has coincided with an increase in the number of extreme heat events in Victoria. There has been a significant increase in the number of days per year when Victorian temperatures are unusually warm (Figure CC.19) – defined as those above the 99th percentile of each month from the years 1910 to 2015.[106]

This century has not seen a year without at least one extreme heat event, compared to the start of the record, which contains many years without extreme events. As described in indicator CC:06 (Regional climate projections), the number of hot days (over 35°C) per year in most cities and major towns in Victoria is expected to double by 2070.

The Department of Health and Human Services (DHHS) operates a heat health alert system.[107] During the summer of 2016 to 2017 (between the start of November 2016 and the end of March 2017), DHHS issued 23 heat health alerts for six days of extreme heat across multiple districts. In the summer of 2015 to 2016, DHHS issued 33 heat health alerts for 10 days of extreme heat.[108] The impacts of extreme heat can be catastrophic, particularly during multiday heatwaves with oppressive overnight weather. In Victoria, during a January 2009 heatwave, there were 374 'excess' deaths (over what would be expected). The majority of those deaths occurred in people aged 75 and older. There were also an estimated 167 excess deaths during a January 2014 heatwave.[109, 110]

Heat stress can also significantly affect tree-dwelling and nocturnal wildlife such as possums, koalas and birds, while grey-headed flying foxes are particularly prone to heat stress.[111]

Increased probability of extreme rainfall events in a given season can be predicted with reasonable accuracy months in advance when La Niña, negative Indian Ocean Dipole and high Southern Annular Mode align in spring. These predictions can be used for improved management of Victorian water resources.

BoM predicted the extreme rainfall across eastern Australian in spring 2010 up to one season in advance.[112] BoM also issues more immediate flood watches and warnings for most major rivers in Australia. A flood watch provides early advice of potential flooding, while a flood warning is issued when flooding is occurring or expected to occur. From July 2015 to June 2017, BoM issued

104. Steffen W, Hughes L, Perkins S 2014, 'Heatwaves: Hotter, Longer, More Often', Climate Council of Australia Limited, Potts Point, New South Wales.
105. Keating A, Handmer J 2013, 'Future potential losses from extremes under climate change: the case of Victoria, Australia', Victorian Centre for Climate Change Adaptation Research, Melbourne, Victoria.
106. BoM and CSIRO 2016, 'State of the Climate 2016', Melbourne, Victoria http://www.bom.gov.au/state-of-the-climate/State-of-the-Climate-2016.pdf Accessed 4 December 2018.
107. Department of Health and Human Services 2017, 'Heat health alert system', Melbourne, Victoria.
108. Emergency Management Victoria 2017, 'Emergency Management Operational Review 2016-17', Melbourne, Victoria, https://files-em.em.vic.gov.au/public/EMV-web/OpsReview2017.pdf Accessed 4 December 2018.
109. Department of Human Services 2009, 'January 2009 Heatwave in Victoria: an Assessment of Health Impacts', Melbourne, Victoria.
110. Department of Health 2014, 'The health impacts of the January 2014 heatwave in Victoria', Melbourne, Victoria.
111. DELWP, 'Heat stress in wildlife', East Melbourne, Victoria https://www.wildlife.vic.gov.au/wildlife-emergencies/heat-stress-in-wildlife2 Accessed 4 December 2018.
112. Hope P, Timbal B, Hendon H, Ekström M, Potter N 2017, 'A synthesis of findings from the Victorian Climate Initiative (VicCI)', BoM, Australia.

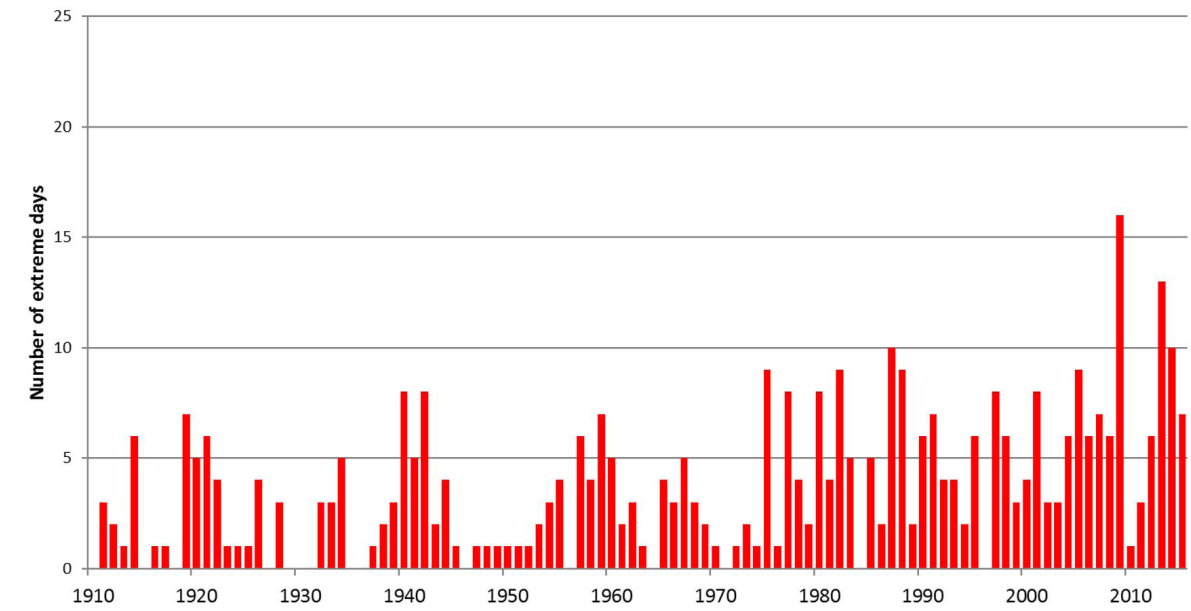


Figure CC.19 Days per year when Victorian averaged daily mean temperature is 'unusually warm' – above the 99th percentile of each month, 1910–2015

(Data source: BoM)

nearly 1,300 flood watches and flood warnings for Victoria. About two-thirds of these flood watches and warnings were issued in spring 2016, when substantial amounts of rain fell across the state and led to flooding.[113] No trend on flood watches and flood warnings could be determined based on the limited period of this dataset.

With increased nutrient runoff from land practices, warmer temperatures and reduced flows, the prevalence of algal blooms is expected to increase. A recent example of such an event is the blue-green algae event in the Murray River in February 2016.[114]

Environmental conditions that encourage mosquito breeding, such as heavy rainfall, floods, high tides and warm temperatures, can lead to outbreaks of Ross River virus, a disease spread by mosquitos that can cause joint inflammation and pain, fatigue and muscle aches.[115] The recent wetter rainfall years have been linked to increased incidences of Ross River virus. A record number of notifications of Ross River virus infection were recorded in 2017 (mostly during January and February) associated with a wetter 2016 in Victoria.[116] A similar spike was recorded in the early months of 2011, coinciding with heavy rainfall during the summer of 2010 to 2011.

There is a clear trend towards more dangerous weather conditions for bushfires in south-east Australia, including significant increases in the frequency and magnitude of extreme conditions in some regions. The Forest Fire Danger Index (FFDI) is used throughout Victoria by fire agencies to plan and manage resources in response to the risk of bushfires. The FFDI is based on temperature, rainfall, humidity and wind speed. FFDI patterns have changed over recent decades, with the strongest increases in fire danger generally in summer and spring. Changes to the springtime pattern indicate a shift towards an earlier start to the fire season. These changes are attributable, at least in part, to increasing temperatures associated with anthropogenic climate change.[117]

113. Emergency Management Victoria 2017, 'Emergency Management Operational Review 2016-17', Melbourne, Victoria, https://files-em.em.vic.gov.au/public/EMV-web/OpsReview2017.pdf Accessed 4 December 2018.
114. Emergency Management Victoria 2016, 'Year in Review 2015-16', Melbourne, Victoria, https://files-em.em.vic.gov.au/public/EMV-web/EMV-Year-in-Review-2015-2016.pdf Accessed 4 December 2018.
115. Department of Health and Human Services 2018, 'Ross River virus disease', Melbourne, Victoria https://www.betterhealth.vic.gov.au/health/ConditionsAndTreatments/ross-river-virus-disease?viewAsPdf=true Accessed 4 December 2018.
116. Australian Department of Health, 'National Notifiable Diseases Surveillance System', Canberra, Australia http://www9.health.gov.au/cda/source/cda-index.cfm Accessed 4 December 2018.
117. Dowdy AJ 2018, 'Climatological variability of fire weather in Australia', *Journal of Applied Meteorology and Climatology*, 57(2), pp. 221-234.

Currently, natural disasters cost Victoria an estimated $1 billion per year, on average. Population growth, concentrated infrastructure density and migration to more vulnerable parts of the state means this expense is forecast to grow by 3.4% per year. By 2050, the estimated cost is expected to be $3.2 billion. This projection does not include the impacts of climate change, so the actual cost is likely to be much higher.[118]

Since publication of SoE 2013, notable natural disasters due to extreme weather have included:

- January 2014 heatwave. Across four consecutive days from 14 to 17 January 2014, Melbourne recorded maximum temperatures above 41°C, while other parts of the state recorded temperatures of 45°C or more on three consecutive days. There were an estimated 167 excess deaths during the heatwave – a 24% increase in mortality. By contrast, during a heatwave in January 2009, a 62% increase in mortality was observed. The introduction of a heatwave plan for Victoria in 2011 may have contributed to the decrease in estimated excess mortality in 2014.[119]
- December 2015 and January 2016 bushfire in Wye River. A fire that started by lightning strike in the Otway National Park near Lorne broke containment lines during strong northerly winds on Christmas Day, travelling rapidly towards coastal townships. During the next week, communities from Wye River, Separation Creek, Kennett River, Grey River and Wongarra were evacuated and the Great Ocean Road was closed. The fire remained active until 15 January 2016; 116 properties were destroyed.[120]
- Spring 2016 floods. Extensive rainfall was experienced across the state on 8 September 2016, with significant impacts to communities on 13 and 14 September 2016. Widespread flooding occurred in the following catchments: Barwon South West, Grampians, Loddon Mallee, and Hume, and parts of the Metropolitan Regions. The cost of damage to essential public assets was estimated to be more than $115 million.[121]
- November 2016 epidemic thunderstorm asthma event. Epidemic thunderstorm asthma is thought to be triggered by an uncommon combination of high grass-pollen levels and a certain type of thunderstorm. On the evening of 21 November 2016, a severe thunderstorm moved from Geelong and passed through Melbourne. An epidemic thunderstorm asthma event, unprecedented in size and severity, occurred immediately following the storm. The event was associated with a 681% increase in asthma-related admissions to all Victorian public hospitals in the 30 hours from 6 pm on 21 November 2016. It is thought to have contributed to the deaths of 10 people.[122, 123, 124]

118. Deloitte Access Economics 2017, 'Building resilience to natural disasters in our states and territories', Sydney, New South Wales https://www2.deloitte.com/content/dam/Deloitte/au/Documents/Economics/deloitte-au-economics-building-resilience-natural%20disasters-states-territories-161117.pdf Accessed 4 December 2018.
119. Department of Health 2014, 'The health impacts of the January 2014 heatwave in Victoria', Melbourne, Victoria.
120. Emergency Management Victoria 2017, 'Emergency Management Operational Review 2016-17', Melbourne, Victoria, https://files-em.em.vic.gov.au/public/EMV-web/OpsReview2017.pdf Accessed 4 December 2018.
121. Ibid
122. Department of Health and Human Services 2017, 'The November 2016 Victorian epidemic thunderstorm asthma event: an assessment of the health impacts – The Chief Health Officer's Report, 27 April 2017', Melbourne, Victoria.
123. Emergency Management Victoria 2017, 'Emergency Management Operational Review 2016-17', Melbourne, Victoria, https://files-em.em.vic.gov.au/public/EMV-web/OpsReview2017.pdf Accessed 4 December 2018.
124. The Age, 'Coronial investigation uncovers tenth thunderstorm asthma death', https://www.theage.com.au/national/victoria/coronial-investigation-uncovers-tenth-thunderstorm-asthma-death-20171018-gz3j59.html Accessed 4 December 2018.

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
CC:13 Extent and condition of key climate-sensitive ecosystems		?	 DATA QUALITY Fair

Data custodian DELWP, Parks Victoria

Some ecosystems are more sensitive to a changing climate than others. Vulnerable ecosystems include those in the mountains, along the coast, in cool-temperature rainforests and in freshwater and wetlands. Species such as seagrass, and certain fish, birds and plants, are particularly sensitive to a changing climate. Changes in the extent and condition of these ecosystems could serve as an indicator of changes in climate risk to natural ecosystems.[125]

As climate change intensifies, existing pressures on Victoria's biodiversity will be amplified and new threats will emerge. The primary climate change impacts expected to affect biodiversity are:

- increased frequency and severity of some types of extreme weather events
- increased frequency and intensity of bushfires and drought
- rising sea levels
- changes in ocean temperatures, currents and ocean acidification
- changes to waterway flows, levels and regimes
- shifts in the range, distribution, abundance and seasonality of species, particularly in association with phenology changes
- changes in the range, distribution and impacts of introduced plants and animals, including the introduction of new pests taking advantage of a changed climate.[126]

Victoria has been experiencing biodiversity loss, partly due to reduced resilience under climate change. An example of this is repeated fires in the Victorian alpine region inhibiting the regrowth of alpine ash trees.[127] The increase in fire danger weather in recent decades has been linked to anthropogenic climate change.[128] At a national level, changes to phenology are now being measured, with the plant and flowering cycle starting earlier by 9.7 days per decade.[129] Earlier and prolonged flowering of Victoria's plants has been linked to an increase in the occurrence of asthma, hay fever, allergic conjunctivitis and eczema.[130]

Recent research has found climate change is likely to exacerbate the impacts of invasive terrestrial and inland aquatic species.[131] See the Biodiversity chapter for discussion of how climate change has been found to be contributing to ecological declines at some Ramsar sites.

125. Australian Department of Industry, Innovation, Climate Chance, Science, Research and Tertiary Education 2013, 'Climate Adaptation Outlook: A proposed national adaptation assessment Framework', Canberra, Australia https://www.environment.gov.au/system/files/resources/e70b19e5-e378-499b-8ae3-cbb42875328c/files/climate-adaptation-outlook.pdf Accessed 4 December 2018.
126. DELWP 2017, 'Protecting Victoria's Environment – Biodiversity 2037', East Melbourne, Victoria https://www.environment.vic.gov.au/__data/assets/pdf_file/0022/51259/Protecting-Victorias-Environment-Biodiversity-2037.pdf Accessed 4 December 2018.
127. Bassett OD, Prior LD, Slijkerman CM, Jamieson D, Bowman DMJS 2015, 'Aerial sowing stopped the loss of alpine ash (Eucalyptus delegatensis) forests burnt by three short-interval fires in the Alpine National Park, Victoria, Australia', *Forest Ecology and Management*, 342, pp. 39-48.
128. Dowdy AJ 2018, 'Climatological variability of fire weather in Australia', *Journal of Applied Meteorology and Climatology*, 57(2), pp. 221-234.
129. Chambers LE et al 2013, 'Phenological Changes in the Southern Hemisphere', *PLoS ONE*, 8(10).
130. Commissioner for Environmental Sustainability 2012, 'Climate Change Victoria: the science, our people and our state of play', Melbourne, Victoria.
131. White M, Cheal D, Carr GW, Adair R, Blood K, Meagher D 2018, 'Advisory list of environmental weeds in Victoria', *Arthur Rylah Institute for Environmental Research Technical Report Series No. 287*, DELWP, Heidelberg, Victoria.

Surveys of species richness and species' ecological attributes at multiple sites (including Ramsar) over different years conclude that native fauna have little if any predictable resilience to significant changes in crucial environmental factors. Examples of this research include a 2015 study that found the majority of bird species in floodplain forest in south-eastern Australia declined substantially during drought conditions between 1998 and 2009, with only a very small minority increasing in prevalence by 2013 after the drought broke and rainfall increased.[132]

A 2018 study found bird species in locations with high vegetation greenness are more resistant to severe drought.[133] This research discusses the effectiveness of prioritising conservation investments in areas with locally high vegetation productivity to increase the resistance of bird species to extreme drought.[134]

Efforts to ensure the ecological health of Corner Inlet by protecting the broadleaf seagrass species *Posidonia australis* is an example of recent work to protect Victoria's biodiversity against the impacts of climate change. Corner Inlet is the only area of Victoria where *Posidonia australis* forms. A native purple sea urchin species – *Heliocidaris erythrogramma* – had been multiplying at Nooramunga Marine and Coastal Park in Corner Inlet. The sea urchin species was eating the seagrass at Coastal Park and creating bare patches that were expected to increase in size without management action.[135] Parks Victoria undertook work to reduce the number of sea urchins in the affected area, most notably working with the Victorian Fisheries Authority and a dedicated group of volunteers to snorkel through the shallow waters and hand-cull more than 57,000 urchins.[136] This work was deemed successful, with evidence of seagrass returning in the areas where the urchins were culled.[137] The distributional range of black sea urchins is also believed to be expanding, driven by climate-related changes to the East Australian Current.[138]

Another example of research of a climate-sensitive ecosystem can be found in Victoria's alpine region, where Arthur Rylah Institute have been mapping alpine sphagnum bogs across their 10,000 km^2 range in the high country for more than a decade.[139] Alpine sphagnum bogs contribute to plant and animal diversity in Australia's high country and provide significant benefits to the environment by storing carbon and filtering out sediments, nutrients and pathogens from water.[140] Alpine sphagnum bog mapping has been produced as a spatial dataset. This dataset is a key resource for land managers that are mitigating and adapting to the challenges posed by climate change and other threats, especially increased fire, deer and feral horses.[141] However, very few vegetation communities are mapped as comprehensively as alpine sphagnum bog, so this degree of informed land management is not available for other parts of the state.[142] The value of alpine sphagnum bog mapping was shown during the 2018 Tamboritha fire, when Parks Victoria accessed mapping to minimise damage to bogs during fire suppression activities, preserving the internationally significant Caledonia Fen.[143]

132. Selwood KE, Clarke RH, Cunningham SC, Lada H, McGeoch MA, Mac Nally R 2015, 'A bust but no boom: responses of floodplain bird assemblages during and after prolonged drought', *Journal of Animal Ecology*, 84(6), pp. 1700-1710.
133. Selwood KE, McGeoch, Clarke RH, Mac Nally R 2018, 'High-productivity vegetation is important for lessening bird declines during prolonged drought', *Journal of Applied Ecology*, 55(2), pp. 641-650.
134. Ibid
135. Crockett P, Johnson K, Brenker M, Ierodiaconou 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*, Parks Victoria, Melbourne, Victoria.
136. Parks Victoria, 'Protecting seagrass meadows from sea urchin attack', Melbourne, Victoria, http://parkweb.vic.gov.au/about-us/news/protecting-seagrass-meadows-from-sea-urchin-attack Accessed 4 December 2018.
137. Ibid
138. Victorian Fisheries Authority, 'Sea urchin', https://vfa.vic.gov.au/about/publications-and-resources/status-of-victorian-fisheries/sea-urchin Accessed 4 December 2018.
139. Arthur Rylah Institute, 'Alpine Sphagnum bogs: if we map them we can manage them', Heidelberg, Victoria, https://www.ari.vic.gov.au/research/wetlands-and-floodplains/alpine-sphagnum-bogs-if-we-map-them-we-can-manage-them Accessed 4 December 2018.
140. Ibid
141. Ibid
142. Ibid
143. Ibid

Further research completed since SoE 2013 shows birds are more resistant to severe drought in locations with high vegetation productivity.[144] Floodplains are potential refuge areas for biota during drought, as they have greater water availability through shallow groundwater and flooding.[145] The white-naped honeyeater (*Melithreptus lunatus Vieillot*), grey currawong (*Strepera versicolor Latham*) and golden whistler (*Pachycephala pectoralis Latham*) are examples of species that have shown a tendency to use floodplain forests for drought refuge.[146] Vegetation greenness is an important factor for biodiversity due to a more reliable water availability and sheltering from topography, with the provision of environmental water an important part of this process.[147, 148]

144. Selwood KE, McGeoch, Clarke RH, Mac Nally R 2018, 'High-productivity vegetation is important for lessening bird declines during prolonged drought', *Journal of Applied Ecology*, 55(2), pp. 641-650.
145. Selwood KE, Thomson JR, Clarke RH, McGeoch MA, Mac Nally R 2015, 'Resistance and resilience of terrestrial birds in drying climates: do floodplains provide drought refugia?', *Global Ecology and Biogeography*, 24, pp. 838–848.
146. Ibid
147. Selwood KE, Clarke RH, McGeoch MA, Mac Nally R 2017, 'Green Tongues into the Arid Zone: River Floodplains Extend the Distribution of Terrestrial Bird Species', *Ecosystems*, 20(4), pp. 745-756.
148. Horner GJ, Cunningham SC, Thomson JR, Baker PJ, MacNally R 2016, 'Recruitment of a keystone tree species must concurrently manage flooding and browsing', *Journal of Applied Ecology*, 53, pp. 944–952.

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
CC:14 Community awareness of climate risks and associated responsibilities Data custodian Sustainability Victoria	 Good (for awareness of climate risks and mitigation) and Unknown (for adaptation to climate change)	?	 DATA QUALITY Fair

Victorians' knowledge and awareness of climate change and its associated risks is an important marker of the state's successful climate change adaptation and mitigation. Public engagement and participation are crucial to create change to address global problems such as climate change.[149] This indicator also describes current actions of Victorians to reduce the effects of climate change.

Sustainability Victoria commissioned a social research study, conducted over 2016 and 2017, that aimed to gain baseline data on Victorian residents' attitudes, beliefs and behaviours in relation to climate change.[150] The results of this study have been used to inform the assessment of this indicator.

The study suggested most Victorians accept that climate change is influenced by human activities. More than 90% of those surveyed agreed there is some level of human causation. The other respondents believed that either climate change is due entirely to natural processes or there has been no climate change.

Nearly 80% of respondents were concerned about climate change. Their main areas of concern were:

- water shortage and drought (72% of respondents were concerned about this)
- crop failures (71%)
- severe bushfires (68%)
- air pollution (68%)
- heatwaves (67%)
- severe storms and floods (65%)
- coastal erosion (51%).

Most respondents (78%) supported the Victorian Government's target of net zero GHG emissions by 2050. Even more (84%) supported the associated targets of 25% of power to be generated by renewable energy sources by 2020 and 40% by 2025.

The survey results also point to the opportunity and incentive for businesses to act on climate change, with nearly three-quarters of respondents preferring to buy goods and services from businesses that show they care about climate change.

149. Weaver C et al 2014, 'From global change science to action with social sciences', *Nature Climate Change*, 4, pp. 656-659.
150. Sustainability Victoria 2017, *'Victorians' perceptions of climate change'*, Melbourne, Victoria http://www.sustainability.vic.gov.au/-/media/SV/Publications/About-Us/Research/Victorians-perceptions-of-climate-change/Victorians-Perceptions-of-Climate-Change.pdf Accessed 4 December 2018.

Management

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
CC:15 Councils (or other organisations) with urban forestry plans or urban greening or cooling-related strategies			 DATA QUALITY Fair

Data custodian: Resilient Melbourne, The Nature Conservancy

Rezoning and infill development are resulting in less green space and higher population densities across major population centres in Victoria, particularly in inner and middle Melbourne. On Melbourne's fringes, new suburbs are being built on arable land and areas of remnant native vegetation. Where rain once soaked easily into permeable soils, reducing peak streamflows and the risk of flash floods, hard surfaces such as roofs and roads now dominate. These same hard surfaces, unshaded by vegetation, also absorb the sun's heat and contribute to daily inner metropolitan temperatures that can peak up to 7°C higher than those in surrounding rural areas.[151]

This urban expansion is occurring in the context of climate change, which is likely to cause greater impacts from heatwaves, droughts and extreme rainfall. While the effects of these phenomena will be widespread, they can disproportionately affect those already vulnerable, including older residents, people who are unwell, and the financially disadvantaged.

Urban forestry planning is an emerging area of research in Victoria. Of the 32 councils in metropolitan Melbourne, 13 councils have developed, or are developing, urban forestry strategies. Some regional councils, such as Geelong and Ballarat, have also developed urban forestry strategies. The need for these plans and strategies is clear: some of Melbourne's local government areas already have among the lowest urban tree canopy ratios in Australia.[152]

The development of urban forestry plans by some councils is encouraging. But work by The Nature Conservancy and Resilient Melbourne on a Melbourne Metropolitan urban forest strategy is expected to bring widespread benefits that cannot be achieved by individual councils, suburbs, infrastructure operators or neighbourhoods in isolation. The strategy is expected to be launched in 2019.

Discussion of green infrastructure was prominent throughout Infrastructure Victoria's 30-year infrastructure strategy, released in 2016.[153] Green infrastructure is described in that strategy as the network of natural and built landscape assets, including green spaces and water systems within and between settlements. The strategy noted that the delivery of green infrastructure can often be ad hoc and opportunistic. It recommended an increase in the amount and quality of green infrastructure in urban settings over the next 30 years and the production of a statewide green infrastructure plan in partnership with local government, leveraging opportunities to unlock restricted public land held by, for example, water or transport authorities.[154]

151. AM Coutts, J Beringer, S Jimi, NJ Tapper 2009, 'The Urban Heat Island in Melbourne: Drivers, Spatial and Temporal Variability, and the Vital Role of Stormwater', https://www.clearwater.asn.au/user-data/resource-files/Urban_Heat_Island_in_Melbourne2009.pdf Accessed 4 December 2018.

152. Horticulture Australia Ltd 2014, 'Benchmarking Australia's Urban Tree Canopy: An i-Tree Assessment', Sydney, New South Wales.

153. Infrastructure Victoria 2016, 'Victoria's 30-year infrastructure strategy', Melbourne, Victoria, http://www.infrastructurevictoria.com.au/sites/default/files/images/IV%2030%20Year%20Strategy%20WEB%20V2.PDF Accessed 4 December 2018.

154. Ibid

In addition to a range of amenity and biodiversity benefits, a greener Melbourne means:

- shadier, cooler metropolitan areas
- lower flood risk for people and assets
- less storm water and nutrients entering waterways, including Port Phillip Bay.

A greener environment also benefits human health. Research has shown that greener cities can reduce mortality, improve general health and wellbeing, increase physical activity and reduce violence.[155, 156]

155. Kondo MC, Fluehr JM, McKeon T, Branas CC 2018, 'Urban Green Space and Its Impact on Human Health', *International Journal of Environmental Research and Public Health*, 15(3), 445.
156. Bowen KJ, Parry M 2015, 'The evidence base for linkages between green infrastructure, public health and economic benefit', *Paper prepared for the project Assessing the Economic Value of Green Infrastructure*.

Indicator	Status	Trend	Data Quality
CC:16 Considering climate change risks in land use planning (including in the coastal zone) Data custodian DELWP	UNKNOWN POOR FAIR GOOD Generally Poor for inland councils and Fair for coastal councils	?	DATA QUALITY Fair

This indicator is designed to report on management actions to reduce the impacts of climate change. DELWP has supplied data that categorises each Victorian council's incorporation of climate change into land-use planning decisions. The data was generated by making qualitative assessments of publicly available corporate governance documents. Figure CC.20 shows that 14% of all Victorian councils integrate climate change into land-use planning at a level considered high or advanced, while 65% of councils consider climate change at only a basic level, or not at all, during land-use planning. There is a strong pattern when comparing inland and coastal councils, with coastal councils three times more likely to have an intermediate, high or advanced consideration of climate change in land-use planning than inland councils (Figure CC.20).

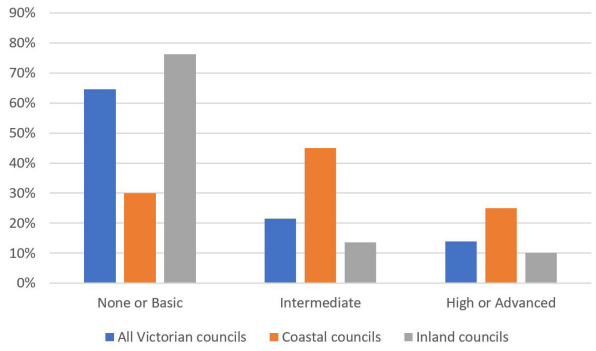


Figure CC.20 Percentage of Victorian councils that integrate climate change into land-use planning

Note: Results are shown by council type (coastal or inland) and level of integration (none or basic, intermediate, high or advanced).

(Data source: DELWP, 2018)

Further information on the integration of climate change into land-use planning was generated as part of DELWP's engagement with local governments during the development of the *Victorian Climate Change Adaptation Plan 2017–2020*.[157]

There is strong agreement across local councils, particularly coastal councils, that land-use planning needs to be informed by up-to-date climate science. As part of this feedback provided by councils, DELWP commissioned a Victorian Coastal Hazard Assessment that analysed the likely impacts of anticipated climate change on the Victorian coastline.[158] The assessment provided ratings for vulnerability to coastal erosion, sea-level rise and storm surge across Victorian coastal areas and coastal priority assets.

Council planners have also expressed strong support for regulatory change to allow for better consideration of climate change impacts in land-use planning.[159] Despite the absence of quantitative data, this support suggests that councils are already aware of the importance of climate change considerations in land-use planning.

The links between climate change and land-use planning extend to the alpine regions. As discussed in indicator CC:02 (Snow cover), a decline in snow accumulation has been observed at several locations across the Victorian Alps, with further reductions expected this century. The alpine resort community is already adapting to the changing landscape, with more focus on year-round activities to ensure long-term business viability. These activities include the development of mountain-biking and walking trails. There have also been developments of other sustainable operations including water recycling and treatment systems, waste recovery processes, renewable energy systems and programs to protect the sensitive alpine ecosystems.

157. Department of Environment, Land, Water and Planning 2016, 'Local Government Engagement on Victoria's Climate Change Adaptation Plan 2017 – 2020', Melbourne, Victoria, https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0015/73050/2017-Local-Government-Input-in-Adaptation-Plan_final.pdf.
158. Spatial Vision 2017, 'Victorian Coastal Hazard Assessment 2017', https://www.coastsandmarine.vic.gov.au/__data/assets/pdf_file/0021/122709/VCHA2017_R1_Victorian_Coastal_Hazard_Assessment_2017_Final_R1.compressed.pdf Accessed 4 December 2018.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
CC:17 Percentage of agri-businesses using long-term weather and climate change projections	○	○	●	○	↗	DATA QUALITY: Fair
Data custodian DEDJTR						

This indicator aims to provide a measure of agricultural management actions to adapt to a changing climate.

Victoria has a large agricultural sector, valued at more than $13 billion. There are almost 31,000 farm businesses employing about 80,000 people and operating across more than 12 million hectares of farmland.[160] The agricultural industry is sensitive to changes in climate: Victorian agriculture yields are generally forecast to decline in coming years in the absence of climate change adaptation measures.[161]

Understanding climate variability can assist growers to take financial advantage of better-than-average years and manage risk in drier years. Since 2005, Agriculture Victoria has published a newsletter explaining climate conditions to primary producers. The newsletter, distributed to more than 3,000 subscribers, helps farmers to make better use of seasonal climate forecasts. As of 2018, Agriculture Victoria is also providing seasonal climate updates for Victoria on YouTube.[162]

The number of subscribers to the newsletter has increased nearly fivefold during the past decade, indicating the value of the information provided in the newsletter. DEDJTR conducts periodic surveys of the newsletter readers, and the last survey in 2016 found that more than half of subscribers share the newsletter with others, which increases its reach and value. More than 90% of respondents also 'strongly agreed' or 'somewhat agreed' that the newsletter improved their ability to make decisions to manage seasonal risk, and improved their knowledge and understanding of seasonal climate variability. The main management decisions made due to information provided in the newsletter included changing sowing plans and crop types, changing nitrogen and urea application, and changing stocking numbers.

These results should be interpreted with caution: businesses subscribing to the newsletter and participating in the survey may be more proactive than others in the agricultural sector. Nonetheless, the survey results are a sign of the sector's increasing 'climate literacy' and decisiveness in relation to climate change. In the future, the newsletter survey could be supplemented by a broader study to provide a more holistic understanding of how Victorian agricultural businesses are adapting to climate change.

159. DELWP 2016, 'Local Government Engagement on Victoria's Climate Change Adaptation Plan 2017 – 2020', East Melbourne, Victoria https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0015/73050/2017-Local-Government-Input-in-Adaptation-Plan_final.pdf Accessed 4 December 2018.
160. DEDJTR 2017, 'Agriculture Victoria Strategy', Melboune, Victoria http://agriculture.vic.gov.au/__data/assets/pdf_file/0011/385949/Agriculture-Victoria-Strategy_FINAL.pdf Accessed 4 December 2018.
161. Victorian Department of Environment and Primary Industries 2013, 'Climate Change Adaptation in Agriculture: Technical Report'.
162. DEDJTR, 'The Very Fast Break', https://www.youtube.com/channel/UCIDCIII7gRZhUs03opGqH1g Accessed 4 December 2018.

Future Focus

Improve localised climate projections

Localised climate projections at a finer spatial resolution, and more accurate rainfall projections, are required to improve management outcomes. Greater detail in climate projections can improve the proactive planning for many natural assets and sectors, including agriculture, with rainfall projections a particularly valuable tool for long-term policy development. An excellent example of this is the runoff projections that have been produced at river-basin level in indicator WR:02 (Projected runoff to dams and catchments). Rainfall projections are currently associated with reasonably large uncertainties (relative to other climate variables such as temperature) and reducing these uncertainties would enhance environmental management, planning and outcomes.

Recommendation 2: That DELWP, in coordination with research partners, conduct further analysis to improve localised climate projections (particularly in agricultural regions). These projections would aim to reduce the uncertainties associated with rainfall projections as a minimum.

Note: refer to Recommendation 15: Monitoring and reporting on the targets for Victoria's energy transition regarding obligations under the *Climate Change Act 2017*.

AIR (A)
SCIENTIFIC ASSESSMENTS Part III

Commissioner *for* Environmental Sustainability Victoria



Air

This chapter includes assessments of Victoria's ambient air quality and the associated health impacts of air pollution, emissions of major air pollutants, indoor air quality, stratospheric ozone, light pollution and odour pollution. It also includes an assessment of noise pollution and its associated health impacts.

Background

Good air quality is essential for human health. The links between air quality, population exposure and health are an increasing focus for research and policy development. The greatest adverse health effects from air pollution are usually experienced in densely populated areas that are exposed to emissions from motor vehicles, industrial facilities and domestic activities (such as using wood heaters), while significant smoke impacts from bushfires and planned burns (for example, fuel reduction, coupe and ecological burns) can cause poor air quality in urban and rural areas.

Victoria's air quality is considered good relative to international standards, although poor air quality is still measured near major industrial facilities, during major incidents (such as bushfires, industrial fires and dust storms) and during periods of planned burns.

Recently, poor air quality in populated areas has been recorded for multiple consecutive days near major fires – notably the Hazelwood mine fire in 2014,[1] the industrial fire at a recycling facility near Coolaroo in 2017[2] and the peat fires near Cobden in 2018.[3]

Between 1996 and 2013, the length of the fire season in eastern Australia has increased, in association with climate change.[4] This has necessitated more intensive fuel reduction burns over shorter periods. As fuel reduction burns must be undertaken during calm weather conditions that facilitate the buildup of air pollution, more intense burn programs increase the risk of widespread particle pollution.

As Victoria's population increases, and the average age of the population increases, the health impacts of poor air quality are likely to increase, unless there is a decrease in air pollution. Climate change will compound existing threats: higher temperatures and longer periods of reduced rainfall are likely to increase the risk of frequent and severe fires and dust storms and exacerbate conditions for summer smog formation.[5]

Environment Protection Authority Victoria (EPA Victoria) has increased the number of air-monitoring stations since the publication of SoE 2013. EPA Victoria now monitors air quality at 19 sites across Victoria – 12 in Melbourne (Figure A.1), 5 in the Latrobe Valley (Figure A.2) and 1 each in Geelong and Wangaratta. Since the 2014 Hazelwood mine fire, EPA Victoria has worked with the Latrobe Valley community to design a more extensive air-monitoring network in the region.[6]

1 EPA 2015, 'Summarising the air monitoring and conditions during the Hazelwood mine fire, 9 February to 31 March 2014', Carlton, Victoria http://www.epa.vic.gov.au/~/media/Publications/1598.pdf Accessed 3 December 2018.

2 EPA, 'EPA completes air monitoring campaign in Coolaroo', Carlton, Victoria http://www.epa.vic.gov.au/about-us/news-centre/news-and-updates/news/2017/july/21/epa-completes-air-monitoring-campaign-in-coolaroo. Accessed 3 December 2018.

3 EPA, 'Last EPA air monitoring station leaving as Cobden gets the all clear', Carlton, Victoria http://www.epa.vic.gov.au/about-us/news-centre/news-and-updates/news/2018/may/08/last-epa-air-monitoring-station-leaving-as-cobden-gets-the-all-clear Accessed 3 December 2018.

4 Jolly M, Cochrane M, Freeborn P, Holden Z, Brown T, Williamson G, Bowman D 2015, 'Climate-induced variations in global wildfire danger from 1979 to 2013', *Nature Communications*, 6(7537), pp. 1-11.

5 EPA 2013, 'Future Air Quality in Victoria: Final Report, 2013', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1535.pdf Accessed 3 December 2018.

6 EPA, 'Latrobe Valley air monitoring co-design', Carlton, Victoria http://www.epa.vic.gov.au/our-work/programs/latrobe-valley-air-monitoring/latrobe-valley-air-monitoring-codesign Accessed 3 December 2018.

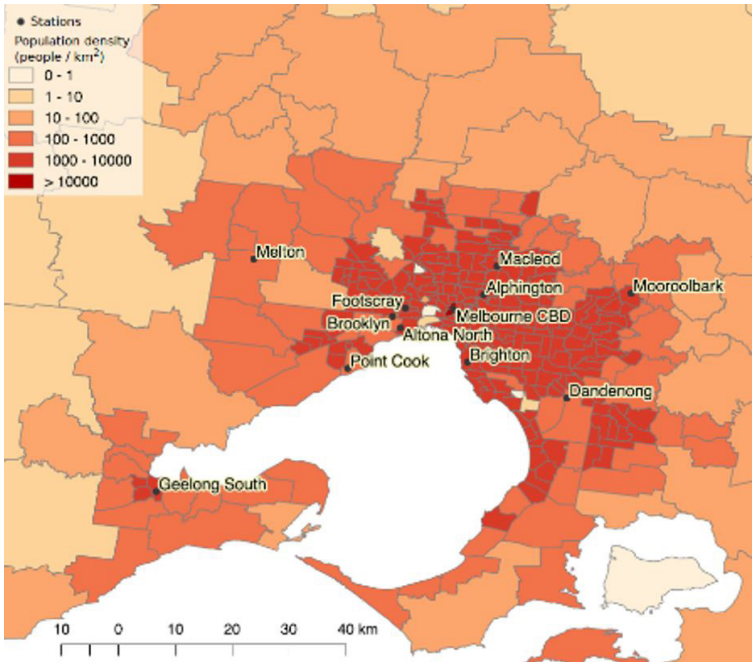


Figure A.1 EPA Victoria air-monitoring stations in Melbourne and Geelong

(Image source: EPA Victoria, 2018)

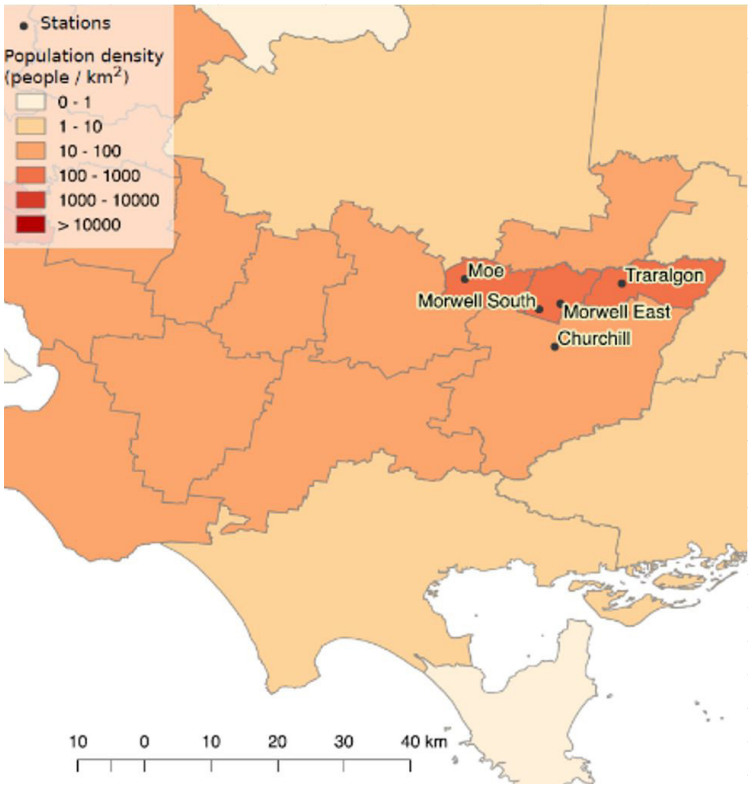


Figure A.2 EPA Victoria air-monitoring stations in the Latrobe Valley

(Image source: EPA Victoria, 2018)

Despite EPA Victoria expanding its air-monitoring network, a 2018 Victorian Auditor-General's Office (VAGO) report found EPA Victoria cannot demonstrate that its current monitoring provides a representative measure of ambient air quality across the state. The VAGO report recommended an expanded air-monitoring network for Victoria that better aligns coverage with pollution risks.[7]

Studies investigating the long-term health effects of air pollution have been conducted in Australia,[8,9] but there is no comprehensive understanding of the impacts on human health. Few long-term studies that document the association between mortality and air pollution exposure have been carried out in Australia. Given the delay between the publication of long-term studies and policy development, it is important to complement longer studies with epidemiological studies that generate useful associations between air pollution and health impacts from just a few years of data. There is a increasing body of evidence demonstrating that air pollution, even at concentrations below the current air-quality standards, is associated with adverse health effects.[10] The strongest evidence relates to premature mortality and effects on the respiratory and cardiovascular system.[11]

Odour and noise can also impact wellbeing, while excessive exposure to noise can impact human health. Odour is the most frequent type of pollution report received by EPA Victoria, prompting about 4,000 reports per year.[12] Common sources of odour pollution are landfills and composting facilities, animal processing and intensive agriculture.

The critical challenges facing Victoria's air-quality management now and in the future include:

- reducing air-pollution emissions and population exposure to air pollution emissions
- reducing human health impacts associated with an increasing and ageing population, particularly during pollution events and in areas with greater air-pollution emissions
- expanding Victoria's air-monitoring network to include a greater coverage across regional Victoria and some areas of Melbourne, as well as including targeted roadside air-monitoring sites
- improving understanding of the sources and extent of air pollution through better monitoring and reporting and a more comprehensive pollution inventory
- improving knowledge of the link between air quality and health, particularly during short-to-medium pollution events (for example, the effects of being exposed to significant amounts of smoke from bushfires, industrial fires or planned burns)
- ensuring suitable buffer protection measures are in place between odorous industries and residential communities
- identifying opportunities to include air quality in urban planning decisions, particularly in relation to urban green space, and opportunities to reduce reliance on causes of pollution (for example, motor vehicles)[13]
- identifying and managing the effects of climate change on the impact of pollution from bushfires, planned burns, summer smog formation and dust storms.

7 VAGO 2018, 'Improving Victoria's Air Quality', Melbourne, Victoria, https://www.audit.vic.gov.au/sites/default/files/2018-03/20180308-Improving-Air-Quality.pdf Accessed 3 December 2018.
8 Lazarevic N, Dobson AJ, Barnett AG, Knibbs LD 2015, 'Long-term ambient air pollution exposure and self-reported morbidity in the Australian Longitudinal Study on Women's Health: a cross-sectional study', British Medical Journal 5(10), pp. 1-10.
9 Knibbs LD, Cortés de Waterman AM, Toelle BG, Guo Y, Denison L, Jalaludin B, Marks GB, Williams GM 2018, 'The Australian Child Health and Air Pollution Study (ACHAPS): A national population-based cross-sectional study of long-term exposure to outdoor air pollution, asthma, and lung function', Environment International, 120, pp. 394-403.
10 EPA 2018, 'Air pollution in Victoria – a summary of the state of knowledge', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1709.pdf Accessed 3 December 2018.
11 Ibid.
12 EPA 2017, '2016-17 Annual Report', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1665.pdf Accessed 3 December 2018.
13 World Health Organization Regional Office for Europe 2016, 'Urban green spaces and health', Copenhagen, Denmark http://www.euro.who.int/__data/assets/pdf_file/0005/321971/Urban-green-spaces-and-health-review-evidence.pdf Accesed 3 December 2018.

Current Victorian Government Settings: Legislation, Policy, Programs

In May 2018, the Victorian Government released *Clean Air for All Victorians – Victoria's Air Quality Statement*. The statement contains ideas on what could be done to protect Victoria's air quality through to 2030. Public comments on the statement, and a subsequent Clean Air Summit and workshops, are informing the development of a Victorian Clean Air Strategy for release in 2019. The Victorian Government has allocated $1.2 million to develop this strategy, which will articulate policy and programs to underpin air-quality management to 2030.

In 2016, a Ministerial Advisory Committee (MAC) completed its inquiry into EPA Victoria. One of the MAC's recommendations was for 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).[14] Another recommendation was to 'create a consolidated and enhanced environmental health capability for Victoria within the EPA, with appropriate governance arrangements recognising its critical relationship with the Department of Health and Human Services' (recommendation 6.2), which was completed in December 2016.[15,16]

The Victorian Government is investing $182.4 million to reform EPA Victoria into a modern environmental regulator focused on preventing pollution, and to give the agency stronger powers and tools to prevent and manage instances of air pollution. The *Environment Protection Act 1970* has been reformed through two pieces of legislation: the *Environment Protection Act 2017*, which establishes EPA Victoria as a statutory authority and legislates the role of its board, chief executive officer and chief environmental scientist, and the *Environment Protection Amendment Act 2018*, which provides the foundation for transforming Victoria's environment protection laws. The Victorian Government intends for this new legislation to take effect from 1 July 2020.

The updated legislation provides the foundation for the following changes:

- a preventative approach through a general environmental duty
- a tiered system of EPA Victoria permissions to support risk-based and proportionate regulatory oversight
- significant reforms to contaminated land and waste management
- increased maximum penalties
- requirements for more environmental information to be publicly available
- modernising and strengthening EPA Victoria's compliance and enforcement powers.

The 2018 VAGO report, *Improving Victoria's Air Quality*, recommended EPA Victoria:

- expand its air-monitoring network
- improve its reporting on air quality
- expand and update its knowledge of Victoria's air quality
- work with all relevant councils to address air-quality issues at the Brooklyn Industrial Precinct
- work with the Department of Environment, Land, Water and Planning (DELWP) to clarify the roles and responsibilities of relevant Victorian Government agencies with respect to air-quality management.

DELWP and EPA Victoria have accepted all recommendations of the VAGO report and are commencing actions to address them.

14 MAC 2016, 'Independent inquiry into the Environment Protection Authority', http://www.epa-inquiry.vic.gov.au/__data/assets/file/0008/336698/Inquiry-report-EPA_June.pdf Accessed 3 December 2018.
15 Ibid.
16 EPA, 'Environmental public health', Carlton, Victoria https://www.epa.vic.gov.au/our-work/environmental-public-health Accessed 3 December 2018.

National and state ambient air quality legislation was amended in 2016 to reflect the adoption of annual and daily $PM_{2.5}$ standards and an annual PM_{10} standard.[17] The Victorian annual PM_{10} standard was set to a much more stringent level than the national standard. The amendment also included a future tightening of the particle standards in 2025.

Some regulations relevant to this chapter have been revised, or are in the process of being revised, including the:

- Environment Protection (Vehicle Emissions) Regulations
- *State Environment Protection Policy (Control of Noise from Commerce, Industry and Trade) No. N-1*
- *State Environment Protection Policy (Control of Music Noise from Public Premises) No. N-2*
- Environment Protection (Residential Noise) Regulations 2008.[18,19,20]

Other noise policies related to the material presented in indicator A:06 (Odour and noise) include the standard for internal noise levels in apartment developments located near noise sources. This standard was introduced in the planning framework in 2017.[21]

VicRoads administers a traffic noise reduction policy that was developed in 2005 sets noise criteria for freeways and aims to limit noise impacts from new or upgraded roads.[22]

In the absence of a coordinated indoor air quality strategy or policy document, there are federal guidance documents relevant to indoor air quality published by the Department of the Environment and Energy, the Australian Building Codes Board, and the Department of Health.[23,24,25]

17 EPA, 'Review of national ambient air quality standards', Carlton, Victoria https://www.epa.vic.gov.au/your-environment/air/review-of-national-ambient-air-quality-standards Accessed 3 December 2018.
18 EPA, 'Air legislation', Carlton, Victoria https://www.epa.vic.gov.au/about-us/legislation/air-legislation Accessed 3 December 2018.
19 EPA, 'Review of the noise SEPPs', Carlton, Victoria https://www.epa.vic.gov.au/our-work/setting-standards/environmental-standards-reform/noise Accessed 3 December 2018.
20 EPA, 'Review of Residential Noise Regulations', Carlton, Victoria https://www.epa.vic.gov.au/our-work/setting-standards/review-of-residential-noise-regulations Accessed 3 December 2018.
21 DELWP, 'Better Apartments', East Melbourne, Victoria https://www.planning.vic.gov.au/policy-and-strategy/planning-reform/better-apartments Accessed 3 December 2018.
22 VicRoads 2005, 'Traffic Noise Reduction Policy', Melbourne, Victoria https://www.vicroads.vic.gov.au/-/media/files/documents/planning-and-projects/environment/noise/trafficnoisereductionpolicy.ashx?la=en&hash=6C28650833D6FD178B03FC47E5C7B60F Accessed 3 December 2018.
23 Australian Department of the Environment and Energy, 'Indoor air', Canberra, Australia http://www.environment.gov.au/protection/air-quality/indoor-air Accessed 3 December 2018.
24 Australian Building Codes Board 2018, 'Indoor Air Quality Handbook 2018', Canberra, Australia http://www.abcb.gov.au/-/media/Files/Resources/Education-Training/11HandbookIndoorAirQuality2018.pdf Accessed 3 December 2018.
25 Australian Department of Health 2002, 'Healthy Homes - A guide to indoor air quality in the home for buyers, builders and renovators', Canberra, Australia.

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.

Poor
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

Poor
Evidence and consensus too low to make an assessment

Fair
Limited evidence or limited consensus

Good
Adequate high-quality evidence and high level of consensus

AIR

Summary

Ozone standards have only been exceeded on a small number of days in Victoria since 2000.

Status
UNKNOWN POOR FAIR GOOD

Trend

DATA QUALITY
Good

Indicator

A:01 Ambient ozone levels (summer smog)

Region

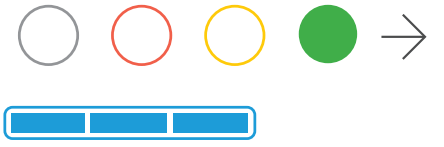
Melbourne, Geelong, Latrobe Valley

Measures

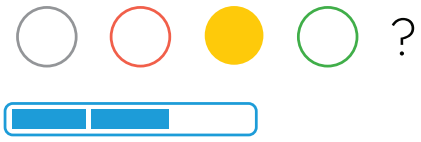
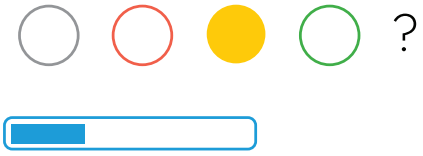
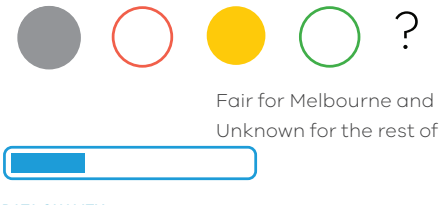
Ambient ozone concentrations (measured in ppb)

Data custodian

EPA Victoria

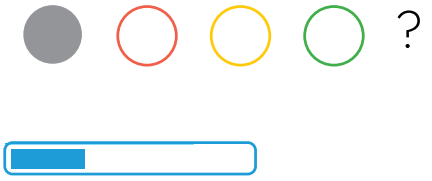
Summary		Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **A:02** Carbon monoxide and nitrogen dioxide **Region** Melbourne, Geelong, Latrobe Valley **Measures** Ambient carbon monoxide (measured in ppm) and nitrogen dioxide (measured in ppb) concentrations **Data custodian** EPA Victoria	Carbon monoxide and nitrogen dioxide concentrations rarely exceed air quality standards and peak concentrations are still reducing in Victoria, albeit at a slower rate during the 21st century than during the 1980s and 1990s.	 DATA QUALITY Good	
Indicator **A:03** Particle pollution (PM_{10} and $PM_{2.5}$) **Region** Melbourne, Geelong, Latrobe Valley **Measures** Ambient concentrations (measured in µg/m^3) of particles less than 2.5 micrometres in size ($PM_{2.5}$) and less than 10 micrometres in size (PM_{10}). **Data custodian** EPA Victoria	The air quality standards for particle pollution are exceeded more frequently than for other pollutants. Despite this Victoria's particle pollution is reasonably low by global standards. PM_{10} pollution remains an issue in Brooklyn in Melbourne's inner west associated with dust emissions generated by industry and vehicles.	 Elsewhere in Victoria Brooklyn Geelong, the Latrobe Valley and most of Melbourne  DATA QUALITY Fair (lacking coverage in regional Victoria and near major Roads)	
Indicator **A:04** Sulfur dioxide **Region** Melbourne, Geelong, Latrobe Valley **Measures** Ambient sulfur dioxide concentrations (measured in ppb) **Data custodian** EPA Victoria	There have been no significant trends in sulfur dioxide concentrations in Victoria since the 1980s, with levels remaining well below the three air quality standards legislated in this state.	 DATA QUALITY Good	

Summary		Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **A:05** Stratospheric ozone **Region** Melbourne **Measures** (i) Ultraviolet radiation (UV index) (ii) Average total column ozone (Dobson Units) (iii) Emissions of ozone depleting substances (M tonnes) **Data custodian** DEE, BoM	The long-term changes in stratospheric ozone due to ozone-depleting substances over a mid-latitude location such as Victoria are small compared to natural variations. Melbourne's ultraviolet levels have generally been stable since the 1980's.	 DATA QUALITY Good	
Indicator **A:06** Odour and noise **Region** Victoria **Measures** (i) Odour pollution reports (ii) Noise pollution reports **Data custodian** EPA Victoria, local councils	Odour is the type of pollution most frequently reported to EPA and noise is the second most. Apart from a spike in 2014, odour reports have generally increased from 2013-17 and noise reports were generally stable until a spike of reports in 2017.	 DATA QUALITY Fair (No compatibility between data collected by EPA and councils – so the data presented here is just EPA data)	
Indicator **A:07** Light pollution **Region** Victoria **Measures** Artificial sky brightness as a ratio to the natural sky brightness (assumed to be 174 µcd/m^2) **Data custodian** None	Artificial lighting has reduced bat activity and species richness in Victoria as well as affecting bird survival patterns on Phillip Island.	 DATA QUALITY Poor - (data mainly collected as case-studies or at a national level)	?

Summary		Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **A:08** Emissions of major air pollutants by sector **Region** Victoria **Measures** Emissions by source in t/yr inventories **Data custodian** EPA Victoria	Motor vehicles and large industry are estimated to account for the majority of carbon monoxide, oxides of nitrogen and sulfur dioxide emissions across Victoria.	 DATA QUALITY Fair (current emissions data unable to be compared to historical emissions data)	?
Indicator **A:09** Health impacts of air pollution **Region** Victoria **Measures** (i) Number of respiratory illnesses related to adverse air quality (ii) Cost (in $) associated with health effects due to adverse air quality **Data custodian** None	Associations between adverse health effects and exposure to $PM_{2.5}$ have been found in Victoria.	 DATA QUALITY Poor (a limited amount of local research and exposure studies)	?
Indicator **A:10** Health impacts of noise pollution **Region** Melbourne **Measures** The proportion of population exposed to high levels of road traffic noise in Melbourne **Data custodian** EPA Victoria	Melbourne has a lower percentage of its population exposed to excessive night time noise than many of Europe's major cities.	 Fair for Melbourne and Unknown for the rest of Victoria DATA QUALITY Poor (a limited amount of local research and exposure studies)	?

Summary

Relatively little research has been done on the quality of air in our homes, schools, recreational buildings, restaurants, public buildings, offices, or inside cars.



DATA QUALITY

Poor (a limited amount of local research and exposure studies)

Indicator

A:11 Indoor air quality

Region

Victoria

Measures

Indoor air quality concentrations of common indoor air pollutants (e.g. volatile organic compounds)

Data custodian

None

Ambient Air Pollutants

Note that:

1. The data for these indicators (A:01 to A:04) has been sourced from EPA Victoria's air-monitoring database (MONSYS).
2. The data included in these indicators does not contain all of EPA Victoria's air-monitoring stations. However, stations have been selected for inclusion in this report based on their length of operation (so as to provide a trend), proximity to populated areas and frequency of peak results.
3. Data for Geelong comes from two sites (Geelong #1 from 1991 to 1996, and Geelong South from 1998 to 2017).
4. Data for Melbourne City comes from four sites (Science Museum from 1981 to 1986, Parliament from 1992 to 1995, RMIT from 1996 to 2006, and Richmond from 2007 to 2014).
5. The data included in these indicators is only taken from monitoring equipment that meets current or historical reference criteria for assessment against the legislated air-quality standards in Australia and Victoria (For example, $PM_{2.5}$ data includes only data measured by a Partisol or Beta Attenuation Monitor.)
6. Air-quality standards used in the assessment of these indicators come from the *State Environment Protection Policy (Ambient Air Quality)*.[26]

26 EPA, 'State Environment Protection Policy (Ambient Air Quality)', Carlton, Victoria https://www.epa.vic.gov.au/about-us/legislation/~/media/Files/About%20us/Legislation/Air/160726consolidatedvariedSEPPAAQ.pdf Accessed 3 December 2018.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
A:01 Ambient ozone levels (summer smog)						 DATA QUALITY Good
Data custodian EPA Victoria						

Ozone is the primary pollutant in summer smog, which forms around large cities on sunny days with light winds.[27,28] Ozone is formed when reactions between hydrocarbons and oxides of nitrogen take place during intense sunlight. Ozone can increase respiratory problems and most strongly affects the elderly and those with lung disease.[29]

The frequency and magnitude of peak ambient ozone concentrations have reduced in Victoria since the early 1980s (Figure A.3 and Figure A.4). The rate of air-quality improvement has slowed considerably since the turn of the century, although very few summer smog days have been recorded in Melbourne this century, with all Victorian stations recording 10 or fewer days exceeding the four-hour average ozone standard this century. The few days exceeding ozone standards in recent years have generally been due to smoke from bushfires, as occurred during the 2002 to 2003 and 2006 to 2007 summer bushfire seasons.[30]

There are two air-quality standards for ozone in Victoria, and the data selected for this indicator is based on the four-hour average standard, which is the standard exceeded most frequently in Victoria.[31]

The main sources of pollutants leading to the formation of ozone are motor vehicle and industrial emissions, as well as domestic activities such as solvent use or the operation of gardening equipment with small engines.[32] Despite maintaining reduced ozone pollution during recent years, if emissions are not kept in check, climate change is predicted to cause significant increases in summer smog, particularly beyond 2030.[33] These increases would occur because the formation of ozone would be enhanced by more frequent periods of warm, sunny conditions in summer. An increase in inner-city ozone is also expected in Melbourne.[34] A projected increase in the frequency and severity of bushfires is also likely to increase peak ozone levels.

Monitoring in major towns such as Ballarat,[35] Bendigo,[36] Geelong,[37] Mildura,[38] Shepparton,[39] Traralgon[40] and Warrnambool[41] has shown that, apart from smoke impacts during intense bushfires, ozone concentrations do not exceed air-quality standards. This situation is likely to continue.

27 EPA, 'Ozone in air', Carlton, Victoria https://www.epa.vic.gov.au/your-environment/air/air-pollution/ozone-in-air Accessed 3 December 2018.
28 EPA 2007, 'Summer Smog in Victoria', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1188.pdf Accessed 3 December 2018.
29 EPA, 'Ozone in air', Carlton, Victoria, https://www.epa.vic.gov.au/your-environment/air/air-pollution/ozone-in-air Accessed 3 December 2018.
30 EPA 2018, 'Air monitoring report 2017 – Compliance with the National Environment Protection (Ambient Air Quality) Measure', Carlton Victoria, https://www.epa.vic.gov.au/~/media/Publications/1703.pdf Accessed 3 December 2018.
31 Ibid.
32 EPA, 'Ozone in air', Carlton, Victoria https://www.epa.vic.gov.au/your-environment/air/air-pollution/ozone-in-air Accessed 3 December 2018.
33 EPA 2013, 'Future Air Quality in Victoria: Final Report, 2013', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1535.pdf Accessed 3 December 2018.
34 Ibid
35 Environment Protection Authority Victoria 2007, 'Air monitoring at Ballarat August 2005 to August 2006', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1111.pdf.
36 Environment Protection Authority Victoria 2006, 'Air monitoring at Bendigo, May 2004 to July 2005', Carlton, Victoria
37 EPA 2018, 'Air monitoring report 2017 – Compliance with the National Environment Protection (Ambient Air Quality) Measure', Carlton Victoria, https://www.epa.vic.gov.au/~/media/Publications/1703.pdf Accessed 3 December 2018.
38 Environment Protection Authority Victoria 2008, 'Airborne particle monitoring at Mildura, December 2004 to June 2006', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1201.pdf Accessed 3 December 2018.
39 Environment Protection Authority Victoria 2005, 'Airborne particle monitoring at Shepparton, December 2003 to December 2004', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/992.pdf Accessed 3 December 2018.
40 Environment Protection Authority Victoria 2017, 'Air monitoring report 2016 – Compliance with the National Environment Protection (Ambient Air Quality) Measure', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1663.pdf Accessed 3 December 2018.
41 Environment Protection Authority Victoria 2008, 'Air monitoring at Warrnambool, October 2006 to October 2007', Carlton, Victoria.

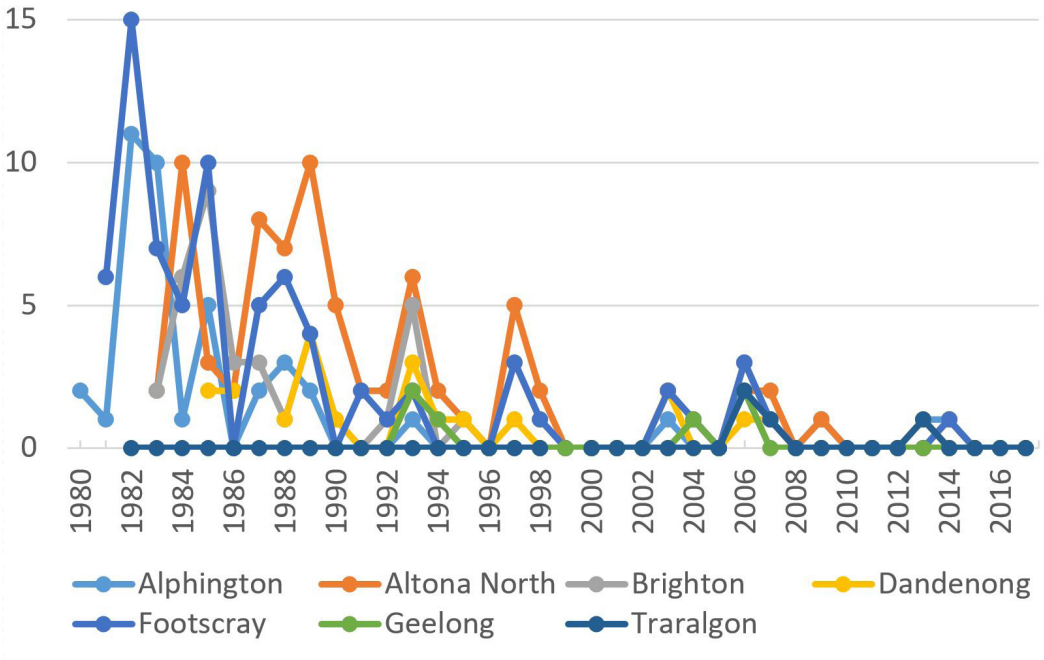


Figure A.3 Number of days exceeding the ozone (4-hour average) standard at monitored sites in Victoria, 1980–2017

(Data source: EPA Victoria, 2018)

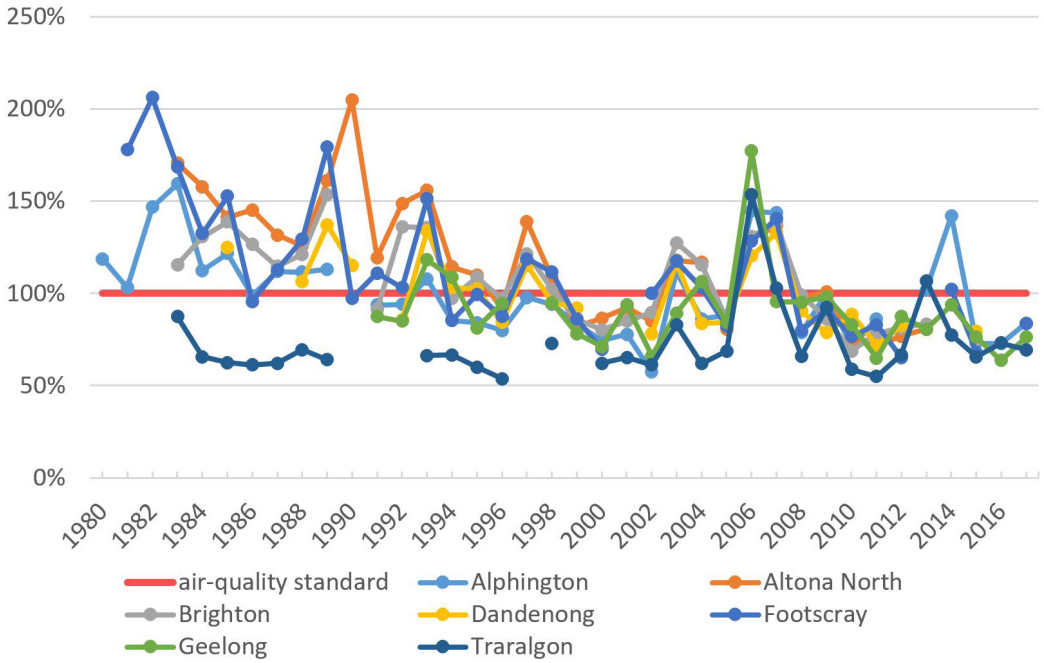


Figure A.4 Annual maximum ozone (4-hour average) concentrations at monitored sites in Victoria, 1980–2017

Note: Concentrations are shown as a percentage of the air-quality standard.

(Data source: EPA Victoria, 2018)

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
A:02 Carbon monoxide and nitrogen dioxide	○	○	○	●	↗	DATA QUALITY
Data custodian EPA Victoria						Good

Exposure to elevated concentrations of carbon monoxide in the air can cause tissue damage in humans and animals. People with cardiovascular disease are particularly at risk.[42]

Increased concentrations of nitrogen dioxide can affect the throat and lungs. Those most at risk from nitrogen dioxide pollution are people with respiratory problems, particularly infants, children and the elderly.[43]

Carbon monoxide and nitrogen dioxide concentrations are closely linked to motor vehicle emissions. Large industrial facilities also emit these pollutants, but industrial emissions are often treated before release from tall stacks, so rarely impact significantly on ground-level concentrations in populated areas.

Both carbon monoxide and nitrogen dioxide concentrations are expected to gradually reduce in-line with forecast improvements in vehicle and fuel technology, and with the potential significant increase in the proportion of motor vehicles that are electric.

Carbon Monoxide

Carbon monoxide concentrations have dramatically reduced in Victoria since the early 1980s, with a steady reduction in peak levels still recorded to the end of 2017 (Figure A.5). A notable exception to this was the spike in carbon monoxide recorded in the southern area of Morwell during the Hazelwood mine fire in February 2014. Measurements showed the carbon monoxide standard was exceeded for three days during the fire, but it is likely that the standards were also exceeded at the start of the fire, before air monitoring commenced. The last time EPA Victoria recorded similiar levels of carbon monoxide in populated areas was more than 25 years ago, when motor vehicle carbon monoxide emissions were much higher.

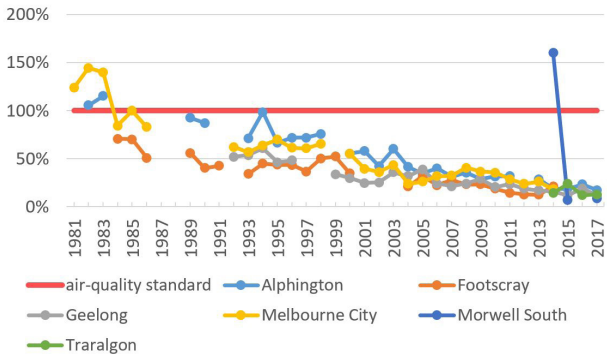


Figure A.5 Annual maximum carbon monoxide (8-hour average) concentrations in Victoria, 1981–2017

Note: Concentrations are shown as a percentage of the air-quality standard.

(Data source: EPA Victoria, 2018)

42 Environment Protection Authority Victoria 'Carbon monoxide in air', Carlton, Victoria https://www.epa.vic.gov.au/your-environment/air/air-pollution/carbon-monoxide-in-air Accessed 3 December 2018.

43 Environment Protection Authority Victoria 'Nitrogen dioxide in air', Carlton, Victoria https://www.epa.vic.gov.au/your-environment/air/air-pollution/nitrogen-dioxide-in-air Accessed 3 December 2018.

Nitrogen Dioxide

There are two air-quality standards for nitrogen dioxide in Victoria. One standard is based on hourly average data, the other for annual average data. The hourly average standard has not been exceeded in Victoria since autumn 1991, when it was exceeded at Footscray on a day when an accumulation of motor vehicle emissions during calm weather was the likely cause of pollution (Figure A.6). The annual standard has never been exceeded (Figure A.7). Peak nitrogen dioxide (based on hourly average data) decreased significantly in Melbourne during the late 1980s and early 1990s: despite more vehicles, changing technology has meant fewer emissions per vehicle. The trend has continued this century, albeit at a much slower rate.[44] After a slight reduction in annual average concentrations for nitrogen dioxide during the first 10 years since monitoring began, there has been no noticeable trend during the past decade.

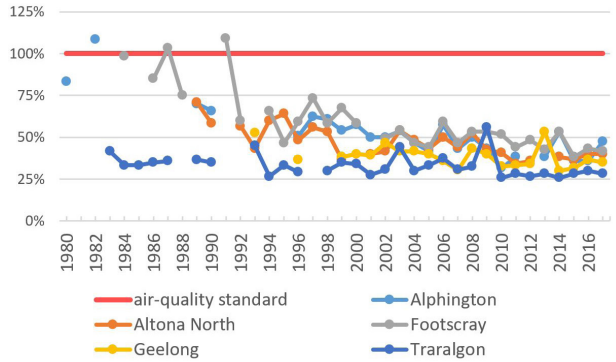


Figure A.6 Annual maximum nitrogen dioxide (1-hour average) concentrations in Victoria, 1980–2017

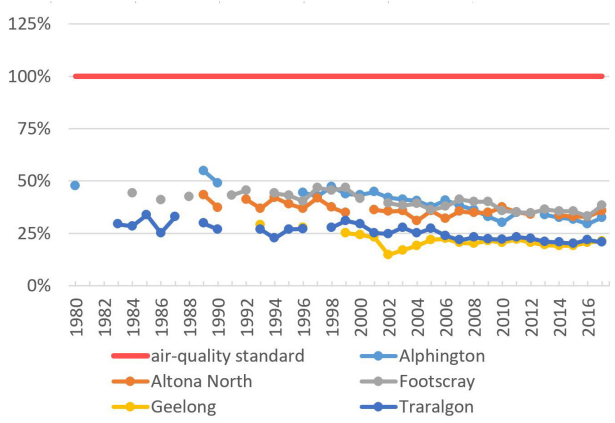


Figure A.7 Annual average nitrogen dioxide concentrations in Victoria, 1980–2017

Note: A.6 and A.7 Concentrations are shown as a percentage of the air-quality standard.

(Data source: EPA Victoria, 2018)

44 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.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
A:03 Particle pollution (PM_{10} and $PM_{2.5}$)	Elsewhere in Victoria	Brooklyn	Geelong, the Latrobe Valley and most of Melbourne		→	DATA QUALITY: Fair
Data custodian EPA Victoria						

Two main particle pollutants are measured in Victoria: $PM_{2.5}$ (particles less than 2.5 micrometres in diameter) and PM_{10} (particles less than 10 micrometres in diameter). Monitoring technology to measure $PM_{2.5}$ has not been available for as long as the instruments that measure PM_{10}, so the $PM_{2.5}$ dataset is shorter and, until recently, quite limited in spatial coverage.

Greater concentrations of $PM_{2.5}$ and PM_{10} particles in the air can cause wheezing, chest tightness and difficulty breathing for people with existing heart or lung conditions (including asthma).[45,46] $PM_{2.5}$ particles are smaller than PM_{10} and can be breathed deeper into the lungs. Children and people over 65, and those with existing heart or lung conditions (including asthma), are more sensitive to the effects of breathing in smaller particles.[47]

The air-quality standards for particle pollution are exceeded more frequently than for other pollutants. Despite this, Victoria's particle pollution is reasonably low by global standards.[48] Particle pollution sources in Victoria include:

- smoke from bushfires, planned burns, industrial fires and domestic wood-heating
- windblown dust during dry and windy conditions
- exhaust emissions from motor vehicles
- road dust from vehicles travelling on unsealed roads
- industrial facilities
- small particles formed in the air by chemical reactions between other pollutants.

45 EPA, 'PM10 particles in air', Carlton, Victoria https://www.epa.vic.gov.au/your-environment/air/air-pollution/pm10-particles-in-air Accessed 3 December 2018.
46 EPA, 'PM2.5 particles in air', Carlton, Victoria https://www.epa.vic.gov.au/your-environment/air/air-pollution/pm25-particles-in-air Accessed 3 December 2018.
47 Ibid.
48 World Health Organization, 'WHO Global Urban Ambient Air Pollution Database (update 2016)', Geneva, Switzerland http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/ Accessed 3 December 2018.

Smoke from large bushfires has resulted in the most widespread particle pollution impacts across Victoria, with smoke from large fires capable of travelling across vast parts of Victoria. This happened in February 2014, when smoke from a large bushfire in the far east of the state blew over Bass Strait and resulted in poor air quality in Melbourne for four consecutive days. The smoke plume from this fire is visible in Figure A.8.

Other events, such as the 2014 Hazelwood mine fire, have caused more severe impacts for nearby populations, while PM_{10} pollution remains an issue in Brooklyn in Melbourne's inner west, and is associated with dust emissions generated by industry and vehicles.

Smoke from domestic wood heaters also contributes to particle pollution in the cooler months. It is estimated that Victoria has nearly 150,000 wood heaters.[49]

As recommended by VAGO, a more comprehensive air-monitoring network for Victoria that better aligns coverage with pollution risks is required. This would enable a better understanding of the magnitude of particle pollution affected by wood smoke and dust (especially in regional areas), as well as improving knowledge of the impacts associated with motor vehicle exhaust emissions near major urban roads.

49 EPA 2017, 'Variation to the Waste Management Policy (Solid Fuel Heating) policy impact assessment', Carlton, Victoria.

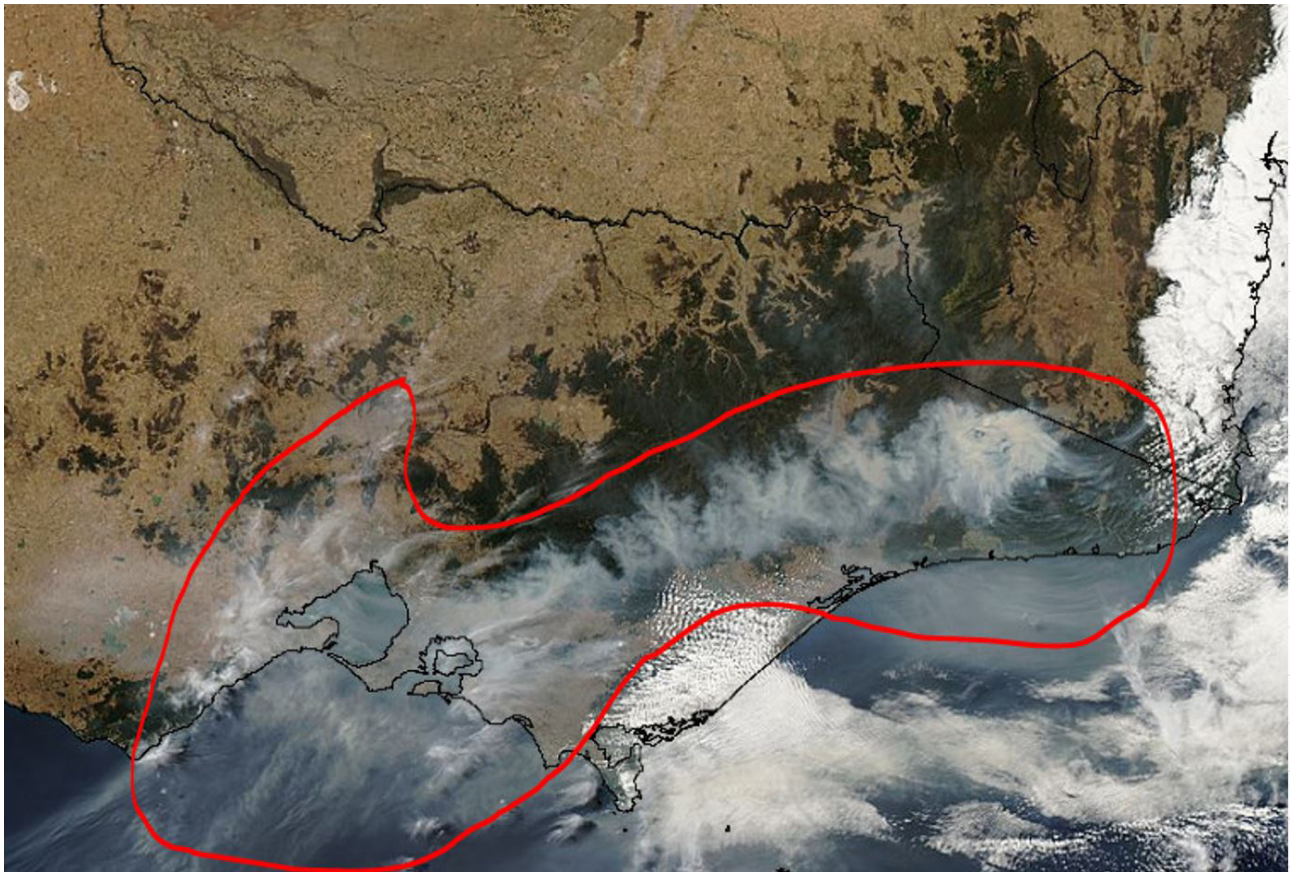


Figure A.8 NASA satellite image, 11 February 2014[50]

Note: Red shows the extent of smoke plume from a fire that started in the far east.

Ultrafine particles (particles less than 1 micrometre in diameter) are smaller than $PM_{2.5}$ and PM_{10}, and can therefore penetrate further into the lungs.[51] Ultrafine particles are difficult to measure and are not included in national or state ambient air quality standards. Therefore, no ultrafine particle data is available for this report. A small number of studies have investigated the health effects of ultrafine particles and found some evidence of an association between ultrafine particles and cardiovascular health effects, although more research is needed to determine the nature of this association.[52]

50 United States National Aeronautics and Space Administration, 'Australia6 Subset – Aqua 1km True Color 2014/042', https://lance-modis.eosdis.nasa.gov/imagery/subsets/?subset=Australia6.2014042.aqua.1km Accessed 3 December 2018.

51 EPA 2018, 'Air pollution in Victoria – a summary of the state of knowledge', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1709.pdf Accessed 3 December 2018.

$PM_{2.5}$

$PM_{2.5}$ trend data in Victoria is only available from 2003, with data up to 2013 confined to Alphington and Footscray in Melbourne, other than for a few short-term monitoring projects. Alphington and Footscray were selected as initial monitoring locations as they are long-term trend stations in Melbourne for other pollutants and are in populated areas near $PM_{2.5}$ pollution sources (industrial and wood-heating). $PM_{2.5}$ monitoring has increased, particularly in Melbourne and the Latrobe Valley since the 2014 Hazelwood mine fire.

The frequency of days exceeding the $PM_{2.5}$ air-quality standard has been relatively stable since 2003: fewer than four days typically exceed the standard each year (Figure A.9). Years with major fires are exceptions – for example, the summer of 2006 to 2007 (Alpine fires) and 2014 (the Hazelwood mine fire and a large East Gippsland fire).[53,54,55]

Poor air quality has also been recorded during cool, calm and stable atmospheric conditions when particles from a wide variety of sources (including smoke from planned burns and wood heaters) accumulate over populated areas. Notably, in 2017, a record number of days exceeded the $PM_{2.5}$ air-quality standard at Alphington.[56] The magnitude of the peak $PM_{2.5}$ concentrations recorded at Morwell South air-monitoring station during the 2014 Hazelwood mine fire were unprecedented in Victoria, with peak levels recorded at nearly 17 times the air-quality standard (Figure A.10).

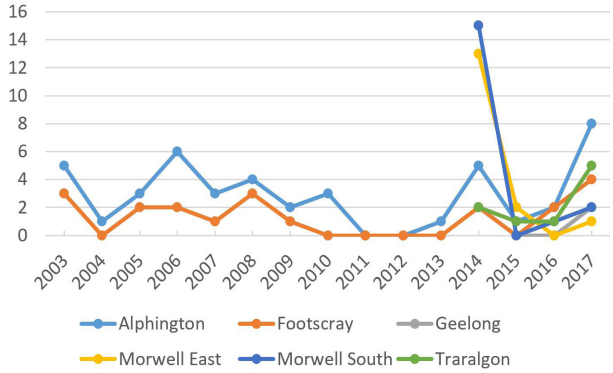


Figure A.9 Number of days exceeding the $PM_{2.5}$ (daily average) standard in Victoria, 2003–2017

(Data source: EPA Victoria, 2018)

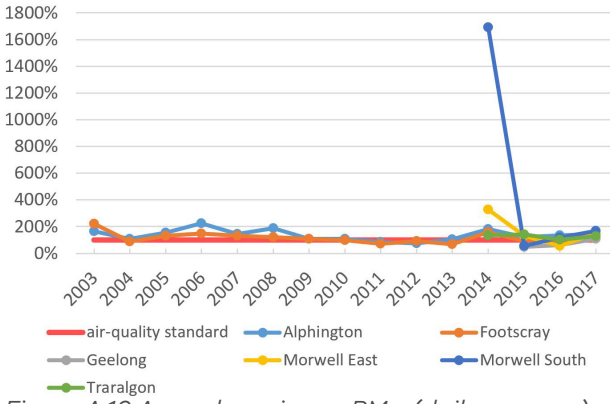


Figure A.10 Annual maximum $PM_{2.5}$ (daily average) concentrations in Victoria, 2003–2017

Note: Concentrations are shown as a percentage of the air-quality standard.

(Data source: EPA Victoria, 2018)

The annual average $PM_{2.5}$ air-quality standard is currently 8 µg/m³(micrograms per cubic metre), although this will tighten in Victoria to 7 µg/m³ by 2025.[57] The current annual average $PM_{2.5}$ standard has been met for every year of monitoring in Footscray, but has been exceeded nearly half the time at Alphington (Figure A.11). It is likely that Alphington records slightly greater levels of $PM_{2.5}$ pollution than Footscray due to greater urban emissions (including from wood heaters) in Alphington and surrounding suburbs. The annual standard has been achieved in each

52 Ibid.
53 EPA 2007, 'Air monitoring report 2006 – Compliance with the National Environment Protection (Ambient Air) Measure', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1137.pdf Accessed 3 December 2018.
54 EPA 2008, 'Air monitoring report 2007 – Compliance with the National Environment Protection (Ambient Air Quality) Measure', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1231.pdf Accessed 3 December 2018.
55 EPA 2015, 'Air monitoring report 2014 – Compliance with the National Environment Protection (Ambient Air Quality) Measure', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1604.pdf Accessed 3 December 2018.
56 EPA 2018, 'Air monitoring report 2017 – Compliance with the National Environment Protection (Ambient Air Quality) Measure', Carlton Victoria https://www.epa.vic.gov.au/~/media/Publications/1703.pdf Accessed 3 December 2018.

57 EPA, 'State Environment Protection Policy (Ambient Air Quality)', Carlton, Victoria https://www.epa.vic.gov.au/about-us/legislation/~/media/Files/About%20us/Legislation/Air/160726consolidatedvariedSEPPAAQ.pdf Accessed 3 December 2018.

year of monitoring in the Latrobe Valley since 2014, except for Morwell South and Morwell East in 2014 (associated with smoke impacts from the Hazelwood mine fire) and Traralgon in 2017. It is likely that areas of regional Victoria that most frequently use wood heaters and are impacted by smoke from planned burns will have greater $PM_{2.5}$ concentrations. However, due to the limitations associated with the extent of the current monitoring network, these assumptions cannot be verified.

The closure of the Hazelwood mine and power station in March 2017 does not appear to have significantly changed $PM_{2.5}$ levels in the region, with the annual $PM_{2.5}$ average at the Morwell South air-monitoring station, adjacent to the former mine and power station site, dropping by just 3% from 2016 to 2017. A full, detailed analysis - accounting for variations in bushfire, planned burns and wood smoke - is required to determine the exact impact of the mine and power station closure on $PM_{2.5}$ levels. The results presented here suggest the closure has not significantly improved $PM_{2.5}$ levels.

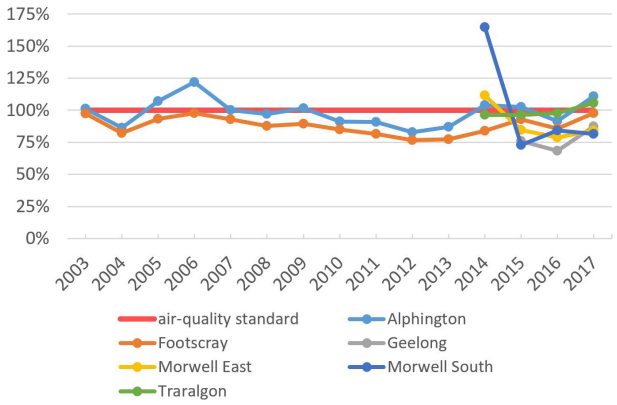


Figure A.11 Annual average $PM_{2.5}$ concentrations in Victoria, 2003–2017

Note: Concentrations are shown as a percentage of the air-quality standard.

(Data source: EPA Victoria, 2018)

PM_{10}

The pattern of days exceeding the PM_{10} standard has traditionally aligned with that for $PM_{2.5}$, although more days generally exceed the PM_{10} standard. This pattern has changed over the past few years, particularly in 2017 when there were widespread $PM_{2.5}$ impacts and no days exceeding the PM_{10} standard, except at dust hotspots in Brooklyn and, to a lesser extent, Geelong (Figure A.12). Peak PM_{10} readings are associated with major fires (which occurred, for example, in 2003) or windblown dust events (which occurred, for example, in Geelong in 2015) (Figure A.13).

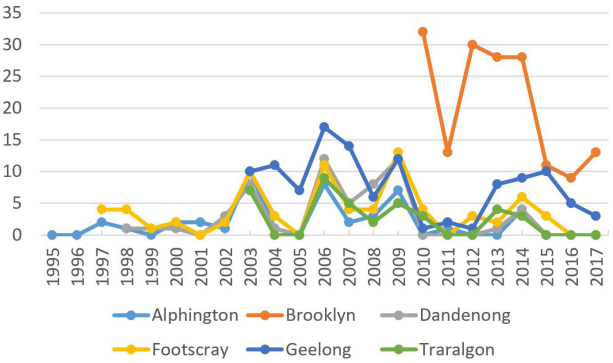


Figure A.12 Number of days exceeding the PM_{10} (daily average) standard in Victoria, 1995–2017

(Data source: EPA Victoria, 2018)

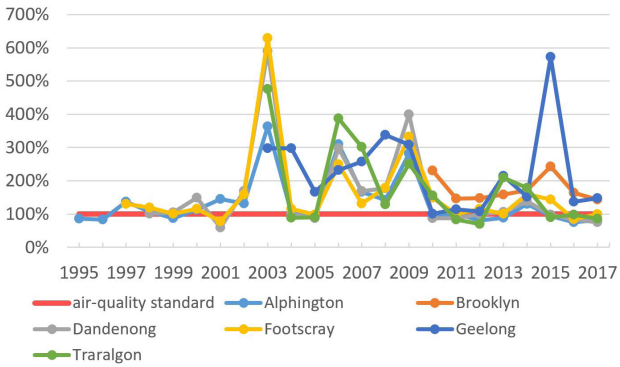


Figure A.13 Annual maximum PM_{10} (daily average) concentrations in Victoria, 1995–2017

Note: Concentrations are shown as a percentage of the air-quality standard.

(Data source: EPA Victoria, 2018)

Due to PM_{10} impacts, Brooklyn is still Victoria's biggest air-pollution hotspot in terms of the number of days exceeding air-quality standards. The impacts in Brooklyn are linked to the large industrial precinct that sits immediately to the north of its residential area. Unsealed roads frequently used by heavy vehicles were sealed during 2015, resulting in a significant improvement in local air quality,[58] although more improvements are required to bring the suburb's air quality in-line with neighbouring suburbs such as Footscray.

An annual average PM_{10} standard was adopted in Victoria in 2016; previously, there had been no annual average PM_{10} standard at state or national level.[59] The Victorian annual PM_{10} standard of 20 µg/m³ is significantly more stringent than the national standard of 25 µg/m³. Annual average PM_{10} concentrations have been trending slightly down across Victorian this decade (Figure A.14), with 2014 the only year when monitoring sites exceeded the PM_{10} annual standard since 2009 (except for Brooklyn). The higher annual average PM_{10} readings from 2000 to 2009 may be due to drier conditions associated with the millennium drought. To demonstrate the recent improvement in annual PM_{10} concentrations, the current annual standard of 20 µg/m³ has only been exceeded at Footscray once from 2010 to 2017, compared with eight times in the period 1997 to 2009.

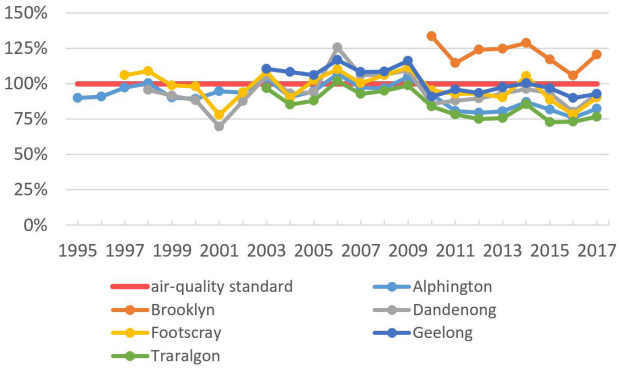


Figure A.14 Annual average PM_{10} concentrations in Victoria, 1995–2017

Note: Concentrations are shown as a percentage of the air-quality standard.

(Data source: EPA Victoria, 2018)

58 EPA 2016, 'Brooklyn air quality update: effectiveness of road sealing', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1627.pdf Accessed 3 December 2018.

59 EPA, 'Review of national ambient air quality standards', Carlton, Victoria https://www.epa.vic.gov.au/your-environment/air/review-of-national-ambient-air-quality-standards Accessed 3 December 2018.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
A:04 Sulfur dioxide	○	○	○	●	→	DATA QUALITY: Good
Data custodian EPA Victoria						

Prolonged exposure to sulfur dioxide can lead to increases in respiratory illnesses such as chronic bronchitis. The effect of sulfur dioxide on health is increased by the presence of airborne particles.[60] Acute effects can also occur, particularly irritation of the upper respiratory tract and the eyes, with asthmatics most sensitive to these effects.[61]

Power stations are the main driver of peak sulfur dioxide concentrations in Victoria. Ships that travel near the coast and dock at Victoria's ports are a secondary source. There have been no significant trends in sulfur dioxide concentrations in Victoria since the 1980s, with levels remaining well below the three air-quality standards legislated in this state (Figure A.15 to Figure A.17).[62] Victoria's peak sulfur dioxide levels are measured near major industrial facilities in Altona North and Traralgon.

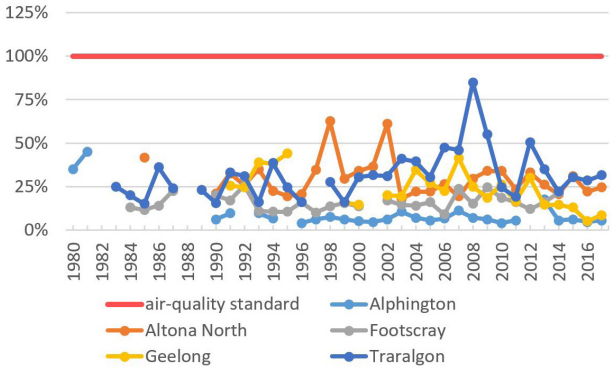


Figure A.15 Annual maximum sulfur dioxide (hourly average) concentrations in Victoria, 1980–2017

(Data source: EPA Victoria, 2018)

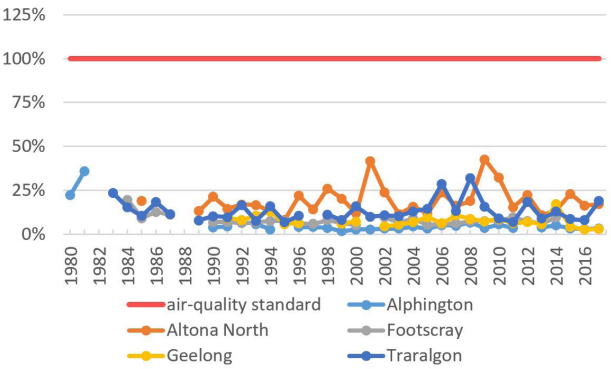


Figure A.16 Annual maximum sulfur dioxide (daily average) concentrations in Victoria, 1980–2017

(Data source: EPA Victoria, 2018)

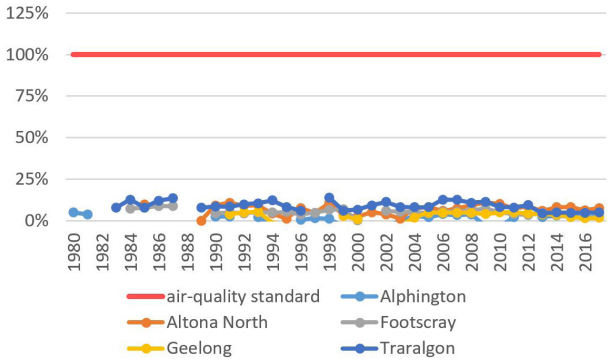


Figure A.17 Annual average sulfur dioxide concentrations in Victoria, 1980–2017

(Data source: EPA Victoria, 2018)

Note: Concentrations are shown as a percentage of the air-quality standard.

60 EPA Victoria, 'Sulfur dioxide in air', Carlton, Victoria https://www.epa.vic.gov.au/your-environment/air/air-pollution/sulfur-dioxide-in-air Accessed 3 December 2018.

61 United States National Research Council 2010, 'Acute Exposure Guideline Levels for Selected Airborne Chemicals: Volume 8', National Academies Press (US), Washington, DC https://www.ncbi.nlm.nih.gov/books/NBK219999/ Accessed 3 December 2018.

62 EPA, 'State Environment Protection Policy (Ambient Air Quality)', Carlton, Victoria https://www.epa.vic.gov.au/about-us/legislation/~/media/Files/About%20us/Legislation/Air/160726consolidatedvariedSEPPAAQ.pdf Accessed 3 December 2018.

The closure of the Hazelwood mine and power station in March 2017 does not appear to have significantly changed sulfur dioxide levels in the region, however this assessment is only based on the nine months of data available since the closure and it would be ideal to do the comparison with at least 12 months of data to cover a full range of weather patterns. Annual average sulfur dioxide concentrations at Morwell South, adjacent to the former mine and power station site, were stable at 0.6 parts per billion (ppb) in 2015, 2016 and 2017, with similarly stable readings of between 0.9 and 1.0 ppb recorded at Traralgon. Morwell East's annual average sulfur dioxide concentrations decreased to 0.5 in 2017 relative to the two preceding years when the average was 0.7 ppb. Combining air quality results with modelling is required to determine the exact impact of the power station closure. However, this analysis suggests the power station closure has not significantly improved annual average sulfur dioxide levels in the region – although it may have contributed to a minor improvement in Morwell East.

Stratospheric Air Pollutants

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
A:05 Stratospheric ozone			 DATA QUALITY Good

Data custodian DEE, BoM

Stratospheric ozone impacts on ultraviolet radiation (UV). Less stratospheric ozone means more UV reaches the earth's surface. January is generally the month of greatest impact in Victoria: more people are on holidays and outside in the sun, and UV levels are greatest. Figure A.18 shows Melbourne's average UV levels in January since 1980. Measurement of the long-term trend includes satellite-based observations of UV levels without the impact of clouds. By contrast, recent ground-based measurements include the effect of clouds, which is why those UV levels are shown to be lower and more variable. Melbourne's UV levels have generally been stable since the 1980s, with a slight increase during the final two decades of the 20th century.

The long-term changes in stratospheric ozone due to ozone-depleting substances over a mid-latitude location such as Victoria are small compared to natural variations. Stratospheric ozone is currently measured as total column ozone (the total amount of ozone in a column from the surface to the edge of the atmosphere) and this is done by satellite and ground-based measurements. There is significant variability in ozone levels from year to year, largely due to changes in cloud cover. Overall, there was a clear decreasing trend in ozone during the 1980s and 1990s, followed by an increase this century (Figure A.19).

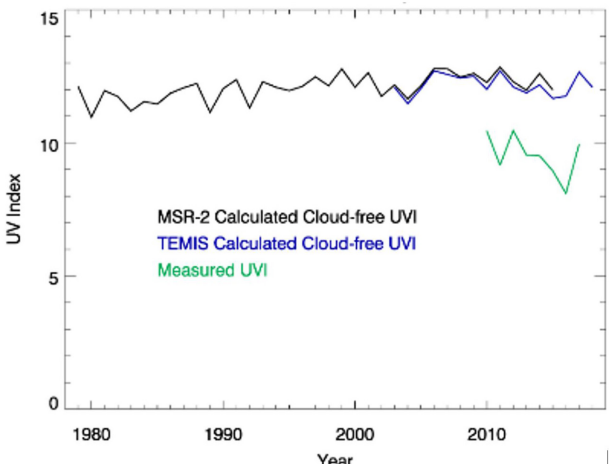


Figure A.18 Average UV index for Melbourne, 1979–2017

(Data source: BoM, 2018)

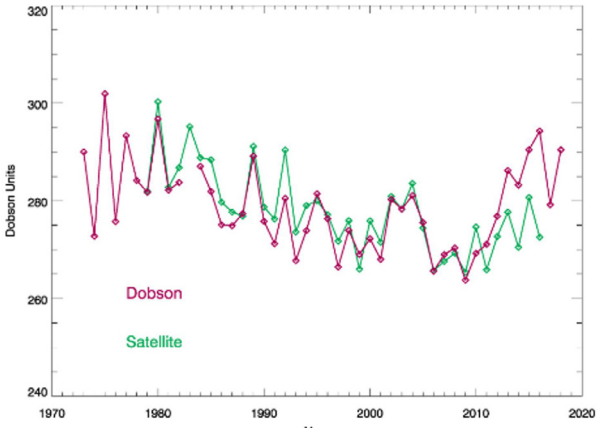


Figure A.19 Average total column ozone for Melbourne, 1973–2018

Note: A Dobson Unit is the number of molecules of ozone that would be required to create a layer of pure ozone 0.01 mm thick at 0°C and a pressure of 1 atmosphere.[63]

(Data source: BoM, 2018)

63 United States National Aeronautics and Space Administration, 'What is a Dobson Unit?', https://ozonewatch.gsfc.nasa.gov/facts/dobson_SH.html Accessed 3 December 2018.

Emission of chemicals such as chlorofluorocarbons (CFCs) into the air leads to the depletion of stratospheric ozone, exposing both marine and terrestrial life to additional harmful amounts of UV radiation. Under the Montreal Protocol, which started in 1989, signatory countries are formally required to control their emissions of ozone-depleting substances to protect the ozone layer. The protocol achieved global participation in 2009, and has been effective, particularly over Antarctica and polar regions. However, recent research has found the ozone layer recovery has not been as pronounced outside the polar regions (between 60°S and 60°N).[64]

Global emissions of ozone-depleting substances included in the Montreal Protocol peaked at 1.46M tonnes in the late 1980s, then declined at a rate of 10% per year to 314 tonnes in 2014. Australian emissions of ozone-depleting substances, weighted by ozone-depleting potential, also fell by about 13% per year from 1995 to 2005, then remained relatively constant through to 2013.[65]

Australia continues to achieve its committed targets as part of the Montreal Protocol, meeting or exceeding all of its phase-out obligations up until the end of 2016.

64 Ball et al 2018, 'Evidence for a continuous decline in lower stratospheric ozone offsetting ozone layer recovery', Atmospheric Chemistry and Physics, 18, pp. 1379–1394.

65 Fraser P, Dunse B, Krummel P, Steele P, Derek N 2014, 'Australian and Global Emissions of Ozone Depleting Substances', ***Report prepared for Department of the Environment,*** CSIRO Marine and Atmospheric Research, Centre for Australian Weather and Climate Research, Aspendale, Australia, pp. 29.

Amenity

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
A:06 Odour and noise		↘	DATA QUALITY: Fair

Data Custodian EPA Victoria, local councils

Impacts from odour and noise are a significant issue in Victoria, both in terms of amenity and complaints to regulators, while excessive exposure to noise can impact human health. Data for this indicator is limited to pollution reports received by EPA Victoria. Local councils and Victoria Police also receive a significant number of amenity reports. However, variation in recording of pollution report data by Victoria's 79 councils and the police dataset makes its use alongside the EPA Victoria data unfeasible.

Those who notify EPA Victoria of pollution may allege a source (such as a person or a business). Forty-six per cent of all odour and noise pollution reports in EPA Victoria's database have an alleged source.

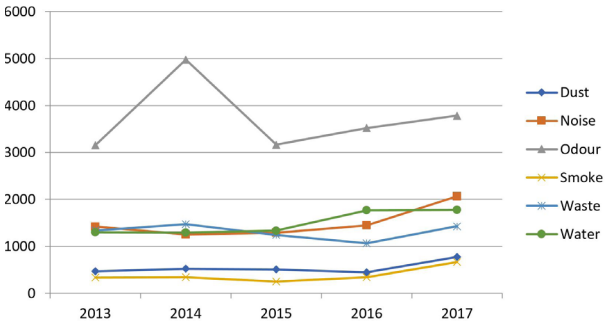


Figure A.20 Pollution reports received by EPA Victoria, 2013–17

(Data source: EPA Victoria, 2018)

Odour is the type of pollution most frequently reported to EPA Victoria. The regulator received more than twice as many complaints about odour from 2013 to 2017 (Figure A.20) than about noise, the next most-frequent source of complaints in that period. In EPA Victoria's pollution report database, a single pollution event can be duplicated if more than one reporter makes a report.

The location of pollution reports is heavily weighted towards populated areas: areas with more people are, on balance, more likely to have more pollution reports. Because of this, pollution reports are displayed as the total number of reports for each local government area (LGA) and the per capita reports for each LGA in Tables A.1 and A.2. Table A.1 shows the top five LGAs for pollution reports on a per capita basis, and Table A.2 shows the top five LGAs for pollution reports in total. There are some associations between per capita pollution reporting hotspots (from the 2013 to 2017 pollution report data) and socio-economic disadvantage. Victorians living in more affluent areas are generally reporting more impacts from noise, while Victorians in less affluent areas are reporting disproportionately more impacts from odour. This analysis of linking pollution report and socio-economic disadvantage data should be treated as indicative. Future reporting could expand on this analysis and formalise a methodology for evaluating environmental justice.

Table A.1 Top five LGAs for odour and noise pollution reports (ranked per capita) received by EPA Victoria, 2013–2017

LGA	Odour reports 2013–2017	Rank (per capita)
Hobsons Bay	1,791	1
Central Goldfields	247	2
Moyne	304	3
Kingston	2,550	4
Hepburn	256	5

LGA	Noise reports 2013–2017	Rank (per capita)
Hepburn	315	1
Glenelg	74	2
Banyule	459	3
Warrnambool	126	4
Corangamite	55	5

(Data source: EPA Victoria, 2018)

Table A.2 Top five LGAs for odour and noise pollution reports (ranked bytotal reports) received by EPA Victoria, 2013–17

(Data source: EPA Victoria, 2018)

LGA	Odour reports 2013–2017	Rank
Kingston	2,550	1
Melton	2,082	2
Hobsons Bay	1,791	3
Casey	1,397	4
Brimbank	1,337	5

LGA	Noise reports 2013–2017	Rank
Banyule	459	1
Moreland	424	2
Brimbank	418	3
Whitehorse	413	4
Hume	350	5

Odour

Odour continues to account for most pollution reports received by EPA Victoria. An average of almost 9,000 pollution reports were made to EPA Victoria each year from 2013 to 2017, with 42% of all those reports relating to odour pollution. Landfills and meat renderers dominate the list of the 10 most frequently alleged sources of odour pollution. The location of these facilities is represented by the red dots in the heat map in Figure A.21, which shows the distribution of odour pollution reporting hotspots in the Melbourne metropolitan area.

EPA served six notices to address odours in 2016–17.[66] This number represents only a fraction of odour inspections conducted. However, EPA Victoria has developed a capability to conduct proactive odour surveillance, and can now better understand trends in odour pollution reporting, allowing it to work with its licensed sites to better prevent pollution.[67]

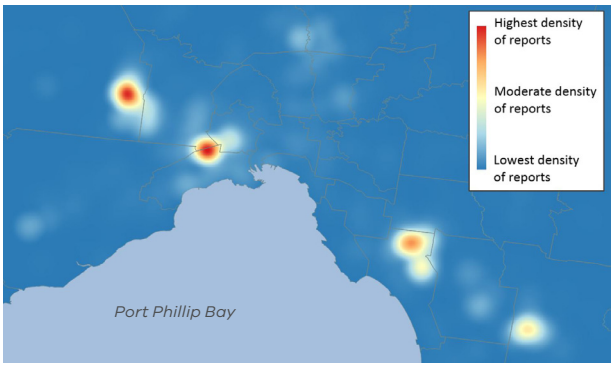


Figure A.21 Odour pollution reporting hotspots in Melbourne, 2013–17

(Data source: EPA Victoria, 2018)

66 EPA 2017, '2016-17 Annual Report', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1665.pdf Accessed 3 December 2018.

67 Marshall A, Bydder C 2017, 'Can you attend the site of a pollution incident before it occurs?', *Journal of the Australian Institute of Professional Intelligence Officers*,. 25(2), pp. 3-17.

Noise

The frequency of noise pollution reporting was fairly stable from 2013 to 2016, with between 1,255 and 1,446 reports received each year by EPA Victoria. Noise pollution reports recorded by EPA Victoria provide good intelligence on noise sources within the scope of regulations and policies for which EPA Victoria is custodian. However, EPA Victoria's noise pollution report data provides limited insight to major issues, such as residential and traffic noise. Future reporting needs to include assessments of noise monitoring and pollution reports from local councils and Victoria Police.

There was a significant spike in noise reports to EPA Victoria in 2017, with 2,066 reports made. Nearly half of this spike was driven by the emergence of localised noise issues near industrial facilities in Heidelberg West, Coolaroo and Blackburn South.

Figure A.22 shows locations of noise pollution reporting 'hotspots' in the Melbourne metropolitan area as red dots on a heat map. Note there are more noise hotspots than for odour (Figure A.21).

EPA conducted noise measurements at 66 locations in 2016–17 in response to noise pollution reports, and consequently issued 11 pollution abatement notices.[68] EPA Victoria's noise monitoring is generally reactive, and it is limited in scope to noise from industrial and commercial premises and music venues.

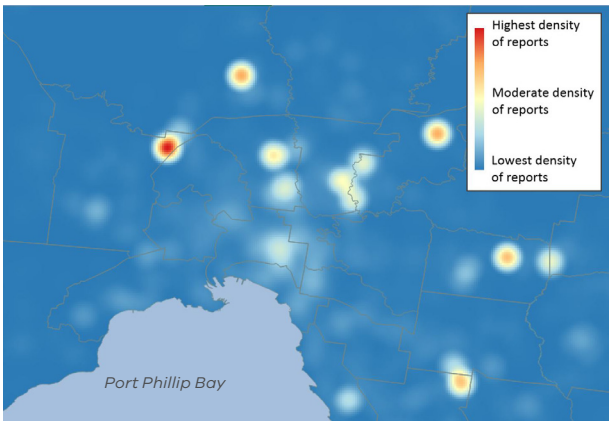


Figure A.22 Noise pollution reporting hotspots in the Melbourne metropolitan area, 2013–17

(Data source: EPA Victoria, 2018)

68 EPA 2017, '2016-17 Annual Report', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1665.pdf Accessed 3 December 2018.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
A:07 Light pollution	●	○	○	○	?	DATA QUALITY
Data custodian None						Poor

Light pollution is excessive or obtrusive artificial light that has an adverse impact on biodiversity, and potentially human health.[69] It is a global issue, felt at both national and regional scales, and increasing in prevalence as the world becomes increasingly populated and industrialised. Light pollution due to poorly-aimed and unshielded outdoor lights is estimated to waste $US2 billion of energy in the United States each year.[70]

Australia is the sixth least polluted G20 country, according to the measure of population percentage exposed to extremely bright skies.[71] There are no systematic measurements of light pollution conducted in Victoria.

Light pollution also threatens reproduction and migratory habits of insects, amphibians, fish, birds, bats and other animals, while a distortion of the natural day/night cycle can affect plants.[73]

There is little published research about light pollution impacts in Victoria. A study published in 2017 analysed seabird survival patterns on Phillip Island in relation to artificial light. The study found many birds became grounded on roads after being attracted by artificial light. Short-tailed shearwater (*Ardenna tenuirostris*) fledglings captured at colonies just before departure were compared with fledglings washed up on beaches and with fledglings attracted by artificial light along roads.[74] Fledglings collected at the beach were much lighter in weight, and hence had a much lower chance of survival, than fledglings collected at the colony or on the roads. A conclusion of the study was that rescue programs should focus on rescuing birds from roads generally, as these weigh more, and have a higher probability of survival than beach-washed birds. Another piece of Victorian research, also published in 2017, found that artificial lighting reduced bat activity and species richness.[75]

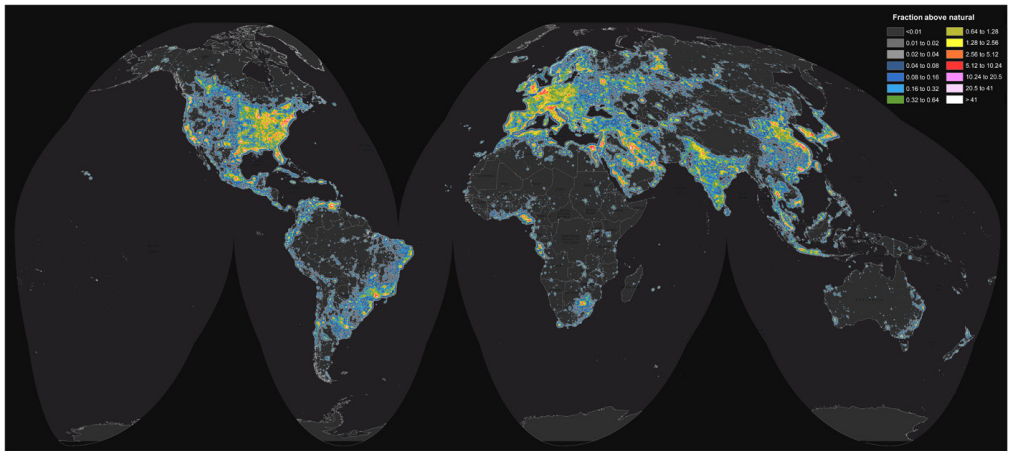


Figure A.23 World map of artificial sky brightness based on data collected in 2014[72]

69 Falchi F, Cinzano P, Duriscoe D, Kyba CCM, Elvidge CD, Baugh K, Portnov BA, Rybnikova NA, Furgoni R 2016, 'The new world atlas of artificial night sky brightness', *Science Advances*, 2(6).
70 United States National Optical Astronomy Observatory, 'Wasted lights and wasted nights: Globe at night tracks light pollution', https://www.noao.edu/news/2011/pr1101.php Accessed 3 December 2018.
71 Falchi F, Cinzano P, Duriscoe D, Kyba CCM, Elvidge CD, Baugh K, Portnov BA, Rybnikova NA, Furgoni R 2016, 'The new world atlas of artificial night sky brightness', *Science Advances*, 2(6).
72 Ibid
73 Hölker F, Wolter C, Perkin EK, Tockner K 2010, 'Light pollution as a biodiversity threat', *Trends in Ecology and Evolution*, 25, pp. 681–682.
74 Rodríguez A, Moffett J, Revoltós A, Wasiak P, McIntosh RR, Sutherland DR, Renwick L, Dann P, Chiaradia A 2017, 'Light pollution and seabird fledglings: Targeting efforts in rescue programs', *Journal of Wildlife Management*, 81, pp. 734–741.
75 Linley G 2017, 'The impact of artificial lighting on bats along native coastal vegetation', *Australian Mammalogy*, 39, pp. 178–184.

Elsewhere in Australia, a study found artificial light in Western Australia was causing some tammar wallabies to delay giving birth. This led to their misalignment with the resource cycle, meaning the wallabies could not sufficiently feed their young.[76] In another Western Australian study, researchers found increased artificial lighting at nesting beaches has the potential to disrupt turtle breeding success, with baby turtles becoming attracted to the artificial light and moving towards the light, rather than the ocean.[77] All species of marine turtles demonstrate similar sea-finding behaviour, so further damage to turtle nesting is likely as coastal development increases, unless lighting is addressed.

Mitigating the effects of light pollution can be achieved using the following measures:

- full shielding of lights
- using the minimum light for the task
- shutting off light or lowering levels substantially when areas are not in use
- decreasing the total installed flux (the amount of light produced)
- strongly limiting the 'blue' light that interferes with the approximate 24-hour cycle in the physiological processes of living beings (including plants and animals) and scotopic vision (the eyes' vision in poorly lit conditions).[78]

76 Robert KA, Lesku JA, Partecke J, Chambers B 2015, 'Artificial light at night desynchronizes strictly seasonal reproduction in a wild mammal', *Proceedings of the Royal Society B: Biological Sciences*, 282(1816).

77 Pendoley K, Kamrowski R 2015, 'Influence of horizon elevation on the sea-finding behaviour of hatchling flatback turtles exposed to artificial light glow', *Marine Ecology Progress Series*, 529, pp. 279-288.

78 Falchi F, Cinzano P, Duriscoe D, Kyba CCM, Elvidge CD, Baugh K, Portnov BA, Rybnikova NA, Furgoni R 2016, 'The new world atlas of artificial night sky brightness', *Science Advances*, 2(6).

Air Pollutants: Sources

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
A:08 Emissions of major air pollutants by sector Data custodian EPA Victoria		?	 DATA QUALITY Fair

An understanding of air-pollution sources is a critical input for developing effective air-quality strategies. Determining the contribution of each major air-pollution source enables air-quality issues and initiatives to be prioritised, as well as enhancing the capability to model air-quality concentrations across Victoria.

EPA Victoria is compiling an air-pollution inventory for Victoria for emissions from the year 2016. As at 30 June 2018, EPA Victoria had completed the inventory update for most major emissions sources including motor vehicles, industry and wood heaters. The preliminary results are reported here (Note: these results are still to undergo peer review and may be revised by EPA Victoria at a later date). Key sources not available for inclusion in this report are natural sources such as biogenic emissions (emissions from natural sources such as plants and trees) and windblown dust. Upon completion, the inventory will contain estimations of all the air pollutants emitted in Victoria categorised by source (for example, motor vehicle, industrial, domestic), location (for example, council area, or '1 km by 1 km grid cell') and time. The completion of an air-pollution inventory at a state level requires significant resourcing and has not been completed by EPA Victoria since emissions were estimated for 2006.

The main findings from work completed so far on the 2016 inventory include:

- Motor vehicles contribute most of the carbon monoxide and oxides of nitrogen. As a proportion of total emissions across the state, motor vehicles are estimated to account for about 70% of carbon monoxide and 60% of nitrogen dioxide emissions in 2016.
- Large industry contributes 95% of the sulfur dioxide and significant amounts of oxides of nitrogen. More than 85% of the industrial sulfur dioxide emissions occur in the Latrobe LGA. However, in most cases, these industrial emissions are from tall stacks high above the ground, and therefore have minimal impact at ground level. Shipping also contributes a significant amount of sulfur dioxide emissions.
- Wood heaters and airports are significant $PM_{2.5}$ emission sources.

Bushfires, planned burns and structural fires are also expected to be large sources of $PM_{2.5}$ emissions, although these sources have not yet been quantified for the 2016 inventory.

EPA Victoria has also released an emissions trend report on air quality in Victoria, discussed in SoE 2013.[79] Key findings included:

- Total vehicle exhaust emissions are decreasing because of the introduction of better vehicle exhaust controls. The trend towards improved exhausts is outpacing growth in vehicle traffic, resulting in a net reduction in total exhaust emissions from cars and trucks over time. In contrast, road dust, caused by the movement of vehicles on roads in dry weather, is expected to increase in-line with traffic growth.
- Industrial emissions are relatively stable over time. Some growth in industrial emissions can be expected due to general economic growth.
- Emissions linked to domestic and business activity are expected to grow in-line with population growth. In most cases these emissions are not well regulated.

79 EPA 2013, 'Future Air Quality in Victoria: Final Report, 2013', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1535.pdf Accessed 3 December 2018.

Health

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
A:09 Health impacts of air pollution		?	 DATA QUALITY
Data custodian None			Poor

This indicator looks at major air pollution and health impact studies published in the five years since SoE 2013. The indicator is focused on Victorian studies, but relevant research in other states has also been included.

Understanding of the health impacts associated with air quality continues to improve as researchers analyse the links between human health and air pollution. State and Commonwealth legislation currently define air-quality standards that are designed to adequately protect human health and wellbeing. However, adverse health effects also occur below the current air-quality standards, and any reduction in concentrations of pollutants – even if concentrations are already below the air-quality standards – will result in health benefits.[80,81,82,83]

Poor air quality can harm people's health and quality of life, and has been linked to respiratory and cardiovascular health effects, and premature mortality.[84] Because of this, the concept of continuous improvement is important for air-quality management. Gradual tightening of air-quality standards and reductions in pollutant concentrations and emissions are important markers for progress in reducing the health burden associated with air pollution.

Two major health studies analysing the health effects associated with smoke exposure during the 2006-07 summer were released in 2015 and 2016. The first study used ambulance records and found an association between exposure to forest fire smoke and an increase in the rate of cardiac arrests. This study, believed to be the first of its kind in the world linking ambulance data with bushfire smoke impacts, estimated that 24 to 29 extra out-of-hospital cardiac arrests occurred in Melbourne because the air quality was affected by smoke from the forest fires that summer.[85]

The second study also investigated health impacts associated with smoke exposure from the Victorian alpine bushfires of summer 2006-07, but with a particular focus on asthma. This study found a strong association between exposure to $PM_{2.5}$ from bushfire smoke and emergency department attendances for asthma during the bushfire season of 2006-07 in Victoria.[86]

A larger study is investigating the long-term health effects of the 2014 Hazelwood mine fire. The fire was one of the most significant air-pollution incidents in Victoria's history, due to the amount of smoke generated, the proximity of the fire to the township of Morwell, and its duration (45 days). Work on the 20-year study, funded by the Victorian Government, began in the Latrobe Valley in 2014.[87]

80 National Environment Protection Council, 'National Environment Protection (Ambient Air Quality) Measure', http://www.nepc.gov.au/nepms/ambient-air-quality Accessed 3 December 2018.
81 National Environment Protection Council, 'National Environment Protection (Air Toxics) Measure', http://www.nepc.gov.au/nepms/air-toxics Accessed 3 December 2018.
82 EPA, 'State Environment Protection Policy (Ambient Air Quality)', Carlton, Victoria https://www.epa.vic.gov.au/about-us/legislation/~/media/Files/About%20us/Legislation/Air/160726consolidatedvariedSEPPAAQ.pdf Accessed 3 December 2018.
83 EPA 2018, 'Air pollution in Victoria – a summary of the state of knowledge', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1709.pdf Accessed 3 December 2018.
84 DELWP 2018, 'Clean Air for All Victorians – Victoria's Air Quality Statement', East Melbourne, Victoria, https://www.environment.vic.gov.au/__data/assets/pdf_file/0025/125719/Clean-Air-Statement.pdf Accessed 3 December 2018.
85 Dennekamp M, Straney LD, Erbas B, Abramson MJ, Keywood M, Smith K, Sim MR, Glass DC, Del Monaco A, Haikerwal A, Tonkin AM 2015, 'Forest fire smoke exposures and out-of-hospital cardiac arrests in Melbourne, Australia: a case-crossover study', *Environmental Health Perspectives*, 123, pp. 959–964.
86 Haikerwal A, Akram M, Sim MR, Meyer M, Abramson MJ, Dennekamp M 2016, 'Fine particulate matter (PM2.5) exposure during a prolonged wildfire period and emergency department visits for asthma', *Respirology*, 21, pp. 88–94.
87 Hazelwood Health Study, 'Hazelinks', https://hazelwoodhealthstudy.org.au/research-areas/hazelinks/ Accessed 3 December 2018.

Various studies are also being undertaken within the overall Latrobe Valley project study. Some initial findings have been published,[88,89,90,91] although these should be considered with caution, as some are based on small sample sizes.

Research elsewhere in Australia has also contributed to understanding the health impacts of air pollution. One study found that a 10% reduction in $PM_{2.5}$ exposure in Sydney would, over a 10 year period, result in approximately 650 fewer deaths – a gain of 3,500 life-years (calculated as the sum of the healthy years gained from avoiding a premature death linked to a pollution-related illness) and about 700 fewer respiratory and cardiovascular hospital visits.[92] These results suggest that small reductions in air pollution in major Australian cities could have substantial health benefits.

As climate change lengthens the fire season in southern Australia, the window for planned burns is likely to be shorter, meaning a more intensive planned-burning period. Planned burns reduce the risks associated with bushfires, but produce large amounts of smoke that can blanket nearby population centres and adversely affect health. Planned burns around Sydney reportedly caused smoky conditions during May 2016, with increased $PM_{2.5}$ concentrations on several days.[93] Poor air quality was recorded for multiple days across Victoria in autumn 2018 associated with smoke from planned burns.[94]

Victoria's responsible agencies now have increased capability and capacity to respond to smoke impacts from fires, with the introduction of a *State Smoke Framework* and improved incident air-monitoring capability, deployed to a variety of fires (bushfires, peat fires, planned burns and industrial fires) in 2016–17 and 2017–18.[95] The increased capability and capacity for incident air-monitoring in relation to significant smoke events is encouraging. However, the smoke impacts from autumn 2018 indicate that more needs to be done to manage planned-burning smoke impacts on Victorians.

88 Hazelwood Health Study 2017, 'Medicare Benefits Schedule and Pharmaceutical Benefits Scheme data: Time Series Analyses', http://hazelwoodhealthstudy.org.au/wp-content/uploads/2018/08/Hazelinks-MBS-PBS-Technical-Report-Version-1.4.pdf Accessed 3 December 2018.

89 Hazelwood Health Study 2018, 'The Latrobe Early Life Follow-up Cohort Study Vol 1', http://hazelwoodhealthstudy.org.au/wp-content/uploads/2017/01/20180201-_-HHS-_-ELF-Volume-1-Research-Summary.pdf Accessed 3 December 2018.

90 Hazelwood Health Study 2017, 'Adult Survey Comparison of Morwell to Sale'

91 Bond J, Dickinson HO, Matthews F, Jagger C, Brayne C 2006, 'Self-rated health status as a predictor of death, functional and cognitive impairment: a longitudinal cohort study', ***European Journal of Ageing***, 3, pp. 193-206.

92 Broome RA, Fann N, Cristina TJ, Fulcher C, Duc H, Morgan GG 2015, 'The health benefits of reducing air pollution in Sydney, Australia', ***Environmental Research***, 143, pp. 19–25.

93 Broome RA, Johnston FH, Horsley J, Morgan GG 2016, 'A rapid assessment of the impact of hazard reduction burning around Sydney, May 2016', ***The Medical Journal of Australia***, 205, pp. 407-408.

94 EPA, 'EPA warns of smoky conditions' , https://www.epa.vic.gov.au/about-us/news-centre/news-and-updates/news/2018/april/30/epa-warns-of-smoky-conditions Accessed 3 December 2018.

95 Emergency Management Victoria, 'A new approach to smoke events', Melbourne, Victoria https://www.emv.vic.gov.au/news/a-new-approach-to-smoke-events Accessed 3 December 2018.

Indicator	Status	Trend	Data Quality
A:10 Health impacts of noise pollution	UNKNOWN / POOR / FAIR / GOOD	?	DATA QUALITY
Data custodian None	Fair for Melbourne and Unknown for the rest of Victoria		Poor

This indicator looks at the impacts of noise pollution on human health. As with air pollution, understanding of population exposure to noise pollution is increasing, which will enable a better understanding of the impacts of noise pollution on the community. An EPA Victoria investigation into population noise exposure tallied the number of people across metropolitan Melbourne exposed to various ranges of environmental noise using data from 2011 for road, rail and industrial zones.[96]

EPA Victoria compared the population exposure results with the European Union Environmental Noise Directive, which lists a night-time threshold of 50 dB, and with the World Health Organization recommended interim night-time target of 55 dB.[97,98,99] The thresholds and targets focus on night-time, when typically most people are at home.

Estimated population exposures from the investigation are provided below and presented as a range to account for a 95% confidence interval in the noise exposure model. The study showed:

- 19 to 35% of Melburnians were exposed to night-time noise levels of 50 dB or more
- 9 to 21% of Melburnians were exposed to night-time noise levels of levels of 55 dB or more.

The main source of noise exposure was road traffic, mostly from arterial roads. When considering traffic noise only:

- 11 to 22% of Melburnians were exposed to night-time traffic noise levels of 50 dB or more
- 4 to 12% of Melburnians were exposed to night-time traffic noise levels of 55 dB or more.

Figure A.24 shows that the proportion of the population exposed to high levels of road traffic noise in Melbourne for the base year 2011 was similar to that in the quieter European capital cities.[100]

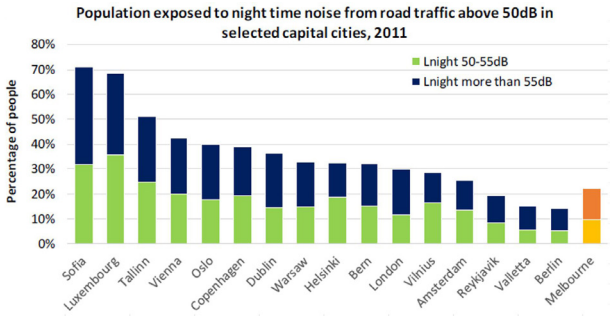


Figure A.24 Indicative comparison of the night-time exposure to road traffic noise for metropolitan Melbourne (2011) compared with selected capital cities of the European Union [101,102]

As a lower proportion of people are exposed to excessive night-time noise in Melbourne than in many of Europe's capital cities (where similar data is available to enable a comparison), the status for this indicator has been assessed as fair for Melbourne. No data is available for the rest of Victoria, and there is no trend data, so the status of the health impacts of noise pollution in regional Victoria is unknown, and the trends across Victoria are unclear. It is important that future work quantifies the health burden associated with population exposure to noise pollution.

96 EPA, communication dated 26/09/2018 ("Additional noise submission for SOE report").
97 Note: Night time noise levels, as mentioned here, are defined as the $L_{Aeq,8h}$ for the period of 10pm-6am (i.e. the average sound between 10pm-6am).
98 European Union Environmental Noise Directive 2002, 'Document 32002L0049', https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32002L0049 Accessed 3 December 2018.
99 World Health Organization Europe 2009, 'Night Noise Guidelines for Europe', http://www.euro.who.int/__data/assets/pdf_file/0017/43316/E92845.pdf?ua=1 Accessed 3 December 2018.
100 Note: The methodology to estimate noise exposure may vary from country to country and these comparisons should be treated as indicative.
101 Note: Based on data reported by countries by 28 August 2013. Noise mapping and assessment methods differ by country, which means information reported for cities is not always comparable. 55dB L_{night} is the World Health Organization (WHO) Interim Target.
102 European Environment Agency, 'The NOISE Observation & Information Service for Europe', http://noise.eea.europa.eu/ Accessed 3 December 2018.

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
A:11 Indoor air quality		?	 DATA QUALITY
Data custodian None			Poor

People typically spend most of their time indoors, which means good indoor air quality is critical for health and wellbeing. A study found that Americans spend 93% of their time indoors – 87% in buildings and 6% in vehicles.[103] An Australian study showed that Australians aged 15 to 20, and over 60, spend 2 to 4 hours outdoors per day, approximately 1 hour in transport and generally more than 20 hours indoors.[104] Despite this, relatively little research has been done on the quality of air in homes, schools, recreational buildings, restaurants, public buildings and offices, or in cars.[105]

Only a handful of Victoria-specific indoor air quality studies have been published, and the concentrations of indoor air pollutants in Victoria are not well understood. One indoor air quality study conducted in Melbourne in 2008 and 2009 found older residential properties generally had better indoor air quality, most likely due to newer homes having less ventilation to meet energy efficiency regulations, to the detriment of indoor air quality.[106] The study also noted that combustion and cooking activities affect multiple indoor air quality pollutants. Some pollutants, including formaldehyde and total volatile organic compounds, had indoor concentrations that were higher than outdoor concentrations.[107]

Another recent study investigated volatile organic compounds from building materials and fragranced consumer products, also finding the pollutant concentrations were higher in all indoor environments than outdoor.[108]

Most other Victorian studies are more than 15 years old. Research conducted in the Latrobe Valley and published in 1998 found gas stove exposure was a significant risk factor for respiratory symptoms in children aged 7 to 14.[109] In another study, focused on Melbourne in 2002, total volatile organic compounds (that is, vapours of gases associated with painted surfaces, fabrics, carpets, household cleaners and cosmetics) were found to be low, but still four times greater than in outdoor air.[110] The presence of attached garages, site contamination and wool carpet were associated with higher indoor pollution.[111]

Biological contaminants such as moulds and fungi are known air contaminants that can degrade indoor air quality.[112] Moulds and fungi can produce toxins and irritants that are suspected to damage respiratory health.[113] Mould germination is more likely to occur overnight when heating is turned off and the indoor temperature drops below 14°C. Inadequate ventilation and building design (for example, cooler surfaces such as concrete walls) can have adverse effects on indoor air quality.

103 Klepeis NE, Nelson WC, Ott WR, Robinson JP, Tsang AM, Switzer P, Behar JV, Hern SC, Engelmann WH 2001, 'The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants', *Journal of Exposure Analysis and Environmental Epidemiology*, 11, pp. 231–252.
104 Environment Protection and Heritage Council 2004, 'Time Activity Study – Summary of Finding' http://www.nepc.gov.au/system/files/resources/220add0d-0265-9004-1d22-0c312998402c/files/aq-tas-time-activity-study-summary-findings-final-200405.pdf Accessed 3 December 2018.
105 Australian Department of the Environment and Energy, 'Indoor air', Canberra, Australia http://www.environment.gov.au/protection/air-quality/indoor-air Accessed 3 December 2018.
106 Molloy SB, Cheng M, Galbally IE, Keywood MD, Lawson SJ, Powell JC, Gillett R, Selleck PW 2012, 'Indoor air quality in typical temperate zone Australian dwellings', *Atmospheric Environment*, 54, pp. 400-407.
107 Ibid.
108 Goodman NB, Wheeler AJ, Paevere PJ, Selleck PW, Cheng M, Steinemann A 2018, 'Indoor volatile organic compounds at an Australian university', *Building and Environment*, 135, pp. 344-351.
109 Garrett MH, Hooper MA, Hooper MB, Abramson MJ 1998, 'Respiratory symptoms in children and indoor exposure to nitrogen dioxide and gas stoves', *American Journal of Respiratory and Critical Care Medicine*, 158, pp. 891–895.
110 National Pollutant Inventory, 'Total Volatile Organic Compounds', Canberra, Australia http://www.npi.gov.au/resource/total-volatile-organic-compounds Accessed 3 December 2018.
111 Brown SK 2002, 'Volatile organic pollutants in new and established buildings in Melbourne, Australia', *Indoor Air*, 2002, 12, pp. 55–63.
112 Australian Building Codes Board 2018, 'Indoor Air Quality Handbook 2018', Canberra, Australia http://www.abcb.gov.au/-/media/Files/Resources/Education-Training/11HandbookIndoorAirQuality2018.pdf Accessed 3 December 2018.
113 Australian Building Codes Board 2014, 'Condensation in Buildings Handbook 2014', Canberra, Australia http://www.abcb.gov.au/-/media/Files/Resources/Education-Training/Handbook-Condensation-in-Buildings-2014.pdf Accessed 3 December 2018.

Future Focus

Improve air-quality assessment capability

EPA Victoria currently compiles an air-pollution inventory to quantify the sources of air pollution spatially and temporally across Victoria. However, the immediacy of data access is an issue, with data generally unavailable until at least two years after the base year of the pollution inventory. Future versions of the inventory need to be more dynamic, and coupled with meteorology and ambient air-quality modelling. Blending air-quality monitoring and modelling will enable more robust and real-time assessments of the Victorian population's exposure to air pollution.

As determined by VAGO,[114] Victoria's current air-monitoring network is inadequate and needs to be expanded, to cover more of regional Victoria and the growth areas of Melbourne, and have the flexibility to target hotspots such as major roadsides and industrial areas. This is an opportunity to ensure adequate air-monitoring in disadvantaged communities and, by working with the Victorian community, to design a comprehensive and targeted monitoring network. Monitoring must be expanded to include ultrafine particles and would include consultation with the National Environment Protection Council to determine whether an ambient air-quality standard is required for ultrafine particles.

In 2016, a ministerial advisory committee completed an inquiry into EPA Victoria. The committee's recommendations included for 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). It also recommended implementation, through DELWP, of statewide environmental monitoring, a spatial data system and reporting on outcomes (recommendation 7.2).[115]

It is critical that the implementation of these two recommendations be prioritised and expedited to enable comprehensive, real-time (or near real-time) estimates of air pollution across Victoria, including in areas currently without local air-monitoring stations. The results would be published online and clearly explained, so any member of the community could understand their local air quality. Health researchers would be able to use the data to develop population exposure metrics.

The Air chapter identifies the significant knowledge gap for indoor air quality in Victoria. This is significant, considering that Victorians are likely to spend up to 90% of their time indoors.[116]

It is also critical to couple improved data on population exposure with modern health studies that improve understanding of the health effects associated with air pollution in Victoria, particularly those incorporating indoor air quality. There needs to be an ongoing commitment to epidemiology in Victoria, and to pushing the boundaries of this science to shift the focus to developing accurate exposure metrics. Being able to quantify and understand the population's exposure to air pollution will be an essential component of air-quality management, enabling the future development of air-quality policies and timely assessments on the effectiveness of policy interventions.

Recommendation 3: That EPA Victoria prioritise the implementation of the EPA Inquiry Recommendations 6.3 and 7.2 to develop a publicly accessible, real-time assessment of air quality across Victoria that incorporates air-quality monitoring data, citizen science observations, air-quality modelling and an up-to-date air-pollution inventory. Future monitoring and assessments would also be expanded to include ultrafine particles and data on indoor air quality.

114 Victorian Auditor-General's Office 2018, 'Improving Victoria's Air Quality', Melbourne, Victoria, https://www.audit.vic.gov.au/sites/default/files/2018-03/20180308-Improving-Air-Quality.pdf. Accessed 3 December 2018

115 Ministerial Advisory Committee 2016, 'Independent inquiry into the Environment Protection Authority', http://www.epa-inquiry.vic.gov.au/__data/assets/file/0008/336698/Inquiry-report-EPA_June.pdf. Accessed 3 December 2018

116 Australian Department of the Environment and Energy, 'Indoor air', Canberra, Australia http://www.environment.gov.au/protection/air-quality/indoor-air Accessed 3 December 2018

Improve community access to timely information on pollen levels in air

Up to 50% of the population has the potential to suffer from the allergy conditions of hay fever and seasonal asthma, with 25% of the population suffering regularly.[117]

Pollen is monitored at eight locations across Victoria, with a single measurement recorded and reported every 24 hours at each location through a process reliant on significant manual work.[118] Recent investment in this field has focused on enhancing pollen forecasting – and a six-day outlook of daily pollen forecasts is now provided for the eight locations with pollen monitors.[119] Additional three-day epidemic thunderstorm asthma forecasts are provided by region across the state.[120] This information is available to the public online and via the mobile phone app Melbourne Pollen Count. App users can help researchers by answering a hay fever symptom survey.[121]

As many Victorians are affected by pollen levels, and pollen is a factor in the formation of epidemic thunderstorm asthma events, future SoE reports will include an indicator that reports on the status and trends for pollen levels. Advances in forecasting need to be complemented by a contemporary pollen-monitoring network that operates with statewide coverage, increased automation and real-time observations. The ability to measure pollen on an hourly, or at minimum three-hourly, basis would enable the development of a pollen profile. This would enhance the ability of allergy sufferers to reduce their exposure risk, and allow forecasters to produce forecasts at a finer time resolution than a daily forecast.

Developments in technology are leading to increasing automation of pollen monitoring in other parts of the world, with eight automatic pollen monitors installed in Bavaria, Germany during 2018.[122, 123]

Recommendation 4: That Victoria's Chief Environmental Scientist, supported by relevant government agencies and research partners, lead the establishment of a contemporary pollen-monitoring network to enable community access to information on pollen levels in the air in a timely manner, through actions including increasing the number of locations monitored, the frequency of the monitoring, and automating the monitoring process.

117 The University of Melbourne, *'Melbourne Pollen Count and Forecast'*, Parkville, Victoria https://www.melbournepollen.com.au/who-are-we/about-us/. Accessed 3 December 2018

118 The University of Melbourne, *'Melbourne Pollen Count and Forecast'*, Parkville, Victoria https://www.melbournepollen.com.au/. Accessed 3 December 2018

119 The Premier of Victoria, *'New Thunderstorm Asthma Forecasting System'*, Melbourne, Victoria https://www.premier.vic.gov.au/new-thunderstorm-asthma-forecasting-system/. Accessed 3 December 2018

120 Department of Health and Human Services, *'Epidemic thunderstorm asthma forecast'*, Melbourne, Victoria https://www2.health.vic.gov.au/public-health/environmental-health/climate-weather-and-public-health/thunderstorm-asthma/forecasting?sc_camp=63FD78C0EDAA4C3B87FA92A400469DEE&%20utm_source=web&utm_medium=melbournepollen&utm_campaign=thunderstorm_asthma_awareness&utm_term=thunderstorm-asthma. Accessed 3 December 2018

121 The University of Melbourne, *'Melbourne Pollen Count and Forecast'*, Parkville, Victoria https://www.melbournepollen.com.au/mobile-app/. Accessed 3 December 2018

122 Buters J, Schmidt-Weber C, Oteros J 2018, 'Next-generation pollen monitoring and dissemination', Allergy, 73(10), pp. 1944-1945. https://doi.org/10.1111/all.13585.

123 Buters JTM, Antunes C, Galveias A, Bergmann KC, Thibaudon M, Galan C, Schmidt-Weber C 2018, 'Pollen and spore monitoring in the world', Clinical and Translational Allergy, 2018;8:9. https://doi.org/10.1186/s13601-018-0197-8.

Accounting for the Environment

Under the System of Environmental-Economic Accounting (SEEA), air pollution is categorised as a residual flow from the economy to the environment. An air emissions account records the connection between economic activity and flows of waste to the atmosphere by reporting the generation of air emissions by economic units (such as industry sectors, government and households) and by type of pollutant. Tracking this connection over time, along with economic activity, can help highlight trends in the relative contributions of different sectors, including 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 emissions.

Air pollution can reduce amenity, and exposure to air pollution can cause a number of adverse health effects and even death. Cardiovascular and respiratory impacts are most common and contribute to increased general practice and hospital presentations, hospital admissions and general health-system use.

The impact of air pollution on people and the environment already appears to some extent in Victoria's traditional economic accounts (the System of National Accounts). For example, impacts would be captured as expenditure in the health system from doctor visits and hospital admissions, medication costs, productivity losses from absenteeism and costs related to premature death. However, the amounts attributable to air pollution are not identified in the traditional accounts.

A 2014 study suggested the annual costs of air pollution in Australia may be more than $24 billion.[124] Expenditure to prevent and manage health impacts from air pollution currently count towards Victoria's gross state product, rather than being recorded as a cost to the Victorian community.

The SEEA framework also recognises the benefit that environmental assets provide through the ecosystem service of air-quality regulation, for example with vegetation improving air quality as it absorbs or traps particles, air toxics, sulfur dioxide and nitrogen dioxide.

However, ecosystems can also be a source of air emissions that flow from the environment to the economy. Australian native vegetation can increase the level of ozone and secondary particle pollution through emission of natural volatile organic compounds, with a consequent impact on human health. Forest and grass fires are a key source of emissions from the environment to the economy.

An ecosystem asset account linked to ecosystem services and benefits would record these connections between the environment and the economy, showing both the quantity of pollutants removed and produced by environmental assets, and the impact of this on air quality and the corresponding benefit (or cost) to the Victorian community in terms of reduced exposure to air pollution and avoided health impacts.

As outlined above, air-quality regulation is complex and the amount and value of air-quality regulation provided in any location in Victoria would vary depending on topographic and air shed (atmospheric) characteristics; the amount, type and location of vegetation in relation to pollution sources and populations; and the population density, with greater benefits in higher-density areas, as more people would benefit from improvements in air quality.

An example from the United Kingdom of quantifying the service of air-quality regulation following the environmental-economic accounting logic is shown in Table A.3. This demonstrates how accounts can help provide information on the trade-offs between investing in more health services or investing in urban vegetation to reduce the demand for health services.

124 National Environment Protection Council 2014, 'Draft variation to the National Environment Protection (Ambient Air Quality) Measure: impact statement', Canberra, Australia http://www.environment.gov.au/system/files/pages/dfe7ed5d-1eaf-4ff2-bfe7-dbb7ebaf21a9/files/aaq-nepm-draft-variation-impact-statement.pdf Accessed 3 December 2018.

Table A.3 Air quality regulation in an environmental-economic accounting framework[125]

Asset	Condition	Services	Benefits
Urban vegetation	Vegetation characteristics	Absorption of pollutants	Avoided health impacts
Example from scoping study of UK natural capital accounts			
Urban vegetation including woodland (99,400 ha), grassland (420,400 ha), and freshwater/saltwater habitat (22,700 ha)	Vegetation age, height, width, size, species diversity	Absorption of 2.78 kilotonnes of fine particles; reducing the concentration of fine particles in the atmosphere by 0.056 µg/m^3 in 2015	Avoided impacts in 2015: respiratory hospital admissions (123) cardiovascular hospital admissions (108) loss of life-years (5,538) Economic value of £195 million per annum

In addition to air-quality regulation, ecosystems also provide important noise regulation services. Noise pollution can directly affect people, harming health and reducing amenity. Ecosystems play an important role in reducing noise as vegetation forms natural noise reduction infrastructure. For example, vegetated areas near busy roads can help reduce the impact of noise pollution from traffic.

125 Jones L, Vieno M, Morton D, Cryle P, Holland M, Carnell E, Nemitz E, Hall J, Beck R, Reis S, Pritchard N, Hayes F, Mills G, Koshy A, Dickie I 2017, 'Developing Estimates for the Valuation of Air Pollution Removal in Ecosystem Accounts', *Final report for Office of National Statistics*

BIODIVERSITY (B)

SCIENTIFIC ASSESSMENTS Part III

Commissioner *for* Environmental Sustainability Victoria



Biodiversity

The Biodiversity chapter has 32 indicators divided across 5 themes, including: Invasive Plants and Animals, Threatened Species, Protecting Victoria's Biodiversity, Freshwater Biodiversity and *Biodiversity 2037* Indicators. This chapter does not include indicators on marine and coastal biodiversity or forests biodiversity which are reported in the Marine and Coastal Environments and Forests chapters respectively.

Background

Healthy land, water and biodiversity are essential for the health and wellbeing of all Victorians. For example, providing ecosystem services such as clean air, drinking water, improved soil health for food production and human to nature contact resulting in a variety of health benefits. A healthy Country is fundamental to the cultural, spiritual, physical and economic wellbeing of Traditional Owners and Aboriginal Victorians.

Victoria's terrestrial area covers 22.8 million hectares, with public land making up 8.4 million hectares or 37% of the state.[1] Public land includes all Crown land and land owned by Victorian Government entities and excludes private freehold land, land owned by local councils and Commonwealth land. The 2017 Victorian Environmental Assessment Council (VEAC) Assessment of Public Land found that terrestrial biodiversity values were highest on public land, with over 70% categorised as having the highest biodiversity values.[2] Victoria's protected area system supports 40% of the highest biodiversity values on less than 20% of public land.[3]

Biodiversity in this chapter is defined as the diverse range of native animal and plant species that create ecological communities (habitats) that form Victoria's natural environment. Local and international tourism contributes $26 billion to Victoria's economy annually.[4] Of this, $1.4 billion is spent visiting Victoria's parks to experience the state's natural environment.[5] This generates $1 billion gross value added to Victoria's economy, while supporting 14,000 jobs across the state.[6] Biodiversity is also essential for Victoria's agriculture, forestry and fisheries sectors, which economically contribute approximately $8 billion, comprising 2.8%, of the annual Gross State Product. Biodiversity research also attracts significant investment from multiple research institutions, where on average 215 research permits are issued annually for land managed by Parks Victoria.[7] This research contributes to a greater understanding of Victorian biodiversity while supporting local community economies.

Victoria has experienced extensive biodiversity loss over the past two centuries due to land clearing, fire, pest plants and animals, land development, river regulation, water pollution and, more recently, reduced resilience under climate change. This loss and degradation impacts the supply of essential ecosystem services, posing a potential risk to sectors dependent on functioning ecosystems and the future health, wellbeing and prosperity of all Victorian communities.

Victoria's native species are integral to the functioning of Victoria's natural and agricultural systems. Due to the cumulative physical pressures, and a historically fragmented approach to policy investment and management implementation, many of Victoria's native species are now considered threatened.[8]

Native vegetation continues to be lost at approximately 4,000 habitat hectares per year.[9] Native vegetation clearing has created fragmented and degraded habitats across Victoria. Reduced extent and quality of native vegetation increases risk, vulnerability and exposure of native animals and plants to other pressures and threats.

1 VEAC 2017, 'Statewide Assessment of Public Land Final Report', Melbourne, Victoria.
2 Ibid
3 Ibid
4 Victorian Tourism Industry Council 2018, https://www.vtic.com.au Accessed 24 October 2018.

5 DELWP 2017, 'Protecting Victoria's Environment – Biodiversity 2037', Melbourne, Victoria.
6 Ibid
7 VEAC 2017, 'Statewide Assessment of Public Land Final Report', Melbourne, Victoria.
8 DEPI 2014, 'Advisory list of rare or threatened plants in Victoria – 2014', Melbourne, Victoria.
DEPI 2013, 'Advisory list of threatened vertebrate fauna – 2013', Melbourne, Victoria.
DEPI 2009, 'Advisory list of threatened invertebrate fauna in Victoria – 2009', Melbourne, Victoria.
9 Ibid

Victoria has the highest number of threatened species by subregion in Australia. Since European settlement there has been a progressive rate of native animal and plant extinction with Victoria losing 18 mammal species, 2 birds, 1 snake, 3 freshwater fish, 6 invertebrates and 51 plants.[10] Conserving habitats and connecting fragmented native vegetation to create nature corridors that allow species movement will minimise the vulnerability of Victoria's threatened species.

There are several overarching policy and management challenges facing Victoria's biodiversity now and into the future, including:

- streamlining land management units, for example: bioregions; Catchment Management Authority (CMA) regions; State Environment Protection Policy (SEPP) bioregions; forest regions; Victoria's weed biomes; and Department of Environment, Land, Water and Planning (DELWP) Biodiversity Response Planning regions, to present a coherent and integrated evidence base to improve management interventions and, ultimately, biodiversity outcomes
- complementary investment in improving data capability to routinely monitor progress towards biodiversity outcomes
- lack of coordination and a strategic approach to investing in the critical research that will enable better, and timelier, decision making and policy interventions
- protecting native vegetation to halt habitat loss and reduce habitat fragmentation and degradation, especially on private land
- reducing the increasing number and distribution of invasive species across public and private land and water systems that are causing habitat degradation and impacting on native species populations
- maintaining and/or increasing populations of the growing number of threatened native species and threatened ecological communities
- planning and implementing environmental adaptation to climate change pressures
- annual reporting on biodiversity investment programs to increase transparency of spending and improve consistency and accuracy of results and outcomes from management actions to better understand and manage Victoria's biodiversity
- increasing rigour of rehabilitation programs and access to them and, as a last resort, offsetting schemes to achieve strategic biodiversity outcomes on private land
- The general lack of an integrated and well-designed monitoring and assessment program to answer key biodiversity, ecological and management questions poses persistent challenges in conserving Victoria's natural assets, including:
- cessation of funding for long-term strategic biodiversity monitoring programs
- disparate biodiversity datasets that are not routinely updated, reducing accessibility and utility of available data for real-time application and planning
- lack of data making it difficult to establish the status of threatened species, specifically their abundance, population age structure and distribution
- methodological changes and new emerging short-term funded target projects that make it difficult to determine biodiversity trends over time. While changes can improve data quality, it is often unclear whether biodiversity changes are due to actual ecological changes or increased accuracy in the methodological approach
- difficulty in establishing the distribution and abundance of invasive plants and animals due to the lack of data
- the need to improve poor knowledge regarding the status of reptiles, amphibians, invertebrates, lichens and fungi

10 Ibid

Current Victorian Government Settings: Legislation, Policy, Programs

In 2017, the Victorian Government released *Protecting Victoria's Environment – Biodiversity 2037* (*Biodiversity 2037*) with the aim of stopping the decline of Victoria's biodiversity and achieving an overall biodiversity improvement over the next 20 years.[11] Under the two goals of 'Victorians value nature', and 'Victoria's natural environment is healthy', *Biodiversity 2037* is committed to providing an opportunity for Traditional Owners and Aboriginal Victorians to be involved in biodiversity planning, management and decision-making; self-determination; land justice; and economic advancement. Key targets under the plan include five million Victorians acting to protect the natural environment; ensuring that endangered species will persist in natural environments; and achieving a net gain in the overall extent and condition of terrestrial, marine and waterway habitats.

Under *Biodiversity 2037*, State Government funding has been made available to support on-ground biodiversity action to protect and manage threatened species and communities. Incentives include:

- 2018 Community and Volunteer Action Grants – $2.4 million for 73 projects across Victoria, with durations of between 1 and 3 years, to support communities to conserve their local biodiversity and threatened species
- regional landscapes and targeted action – $4.7 million to fund 67 projects that include large-scale and targeted management projects to protect threatened species and research to better understand native flora and fauna conservation
- 2018 biodiversity response planning – $35.6 million for on-ground biodiversity actions and $2.5 million for marine-targeted actions to be delivered across 3 years over 11 geographic areas
- 2018 crowdfunding – $116,000 to match efforts of community crowdfunded projects in 2018 to support threatened species and biodiversity conservation campaigns
- regional biodiversity hubs – $7.7 million for 26 large-scale regional hubs and associated projects to remove woody weeds, pest plants and animals and implement protection measures. Additional funding of over $1 million allocated to delivering eight urgent projects and $2 million to support intensive management actions for iconic threatened species such as the Baw Baw frog, brushtailed rock wallaby, eastern barred bandicoot, mountain pygmy possum, orange-bellied parrot, hooded plover, regent honeyeater and plains-wanderer
- support programs – DELWP in collaboration with scientists and communities to increase and share knowledge to manage and respond to biodiversity risks, including seminars, regional events, forums and tools to complement on-ground activities.

All the above incentives, and their projects, will be assessed on how well they contribute to *Biodiversity 2037* targets under the goal 'Victoria's natural environment is healthy'.

The Guidelines for the Removal, Destruction or Lopping of Native Vegetation aim to prevent net loss to biodiversity.[12] The guidelines provide a three-step approach:

- Avoid the removal, destruction or lopping of native vegetation.
- Minimise impacts from the removal, destruction or lopping of native vegetation that cannot be avoided.
- Provide an offset to compensate for the biodiversity impact from the removal, destruction or lopping of native vegetation.

11 DELWP 2017, 'Protecting Victoria's Environment – Biodiversity 2037', Melbourne, Victoria. This plan is supported by a technical document Protecting Victoria's Environment – Biodiversity 2037: Supporting Technical Supplement containing references, further reading and sources for all factual statements included in the Plan.

12 DELWP 2017, 'Guidelines for the removal, destruction or lopping of native vegetation', Melbourne, Victoria.

The guidelines are an incorporated document in Victoria's planning system, which requires a permit to remove native vegetation. The three-step approach is applied when assessing whether or not to grant a permit, and when determining the conditions on any permits granted.

The Victorian Government has also reviewed the *Flora and Fauna Guarantee Act 1988* (FFG Act) with the aim to more effectively protect Victoria's biodiversity in the face of existing and emerging threats. The Flora and Fauna Guarantee Amendment Bill was introduced to Parliament on 23 May 2018 to amend the Act with a new framework for biodiversity protection and management, including Victoria's native species and important habitats. The Bill was debated in the Legislative Assembly and passed without amendment. It was subsequently introduced into the Legislative Council but was not debated before the final scheduled parliamentary sitting day of the 58th Parliament of Victoria.

The Invasive Plants and Animals Policy Framework (IPAPF) represents the government's approach to managing existing and potential invasive species across the whole of Victoria.[13] It prioritises actions based on a biosecurity approach that aims to:

- prevent the entry of new high-risk invasive species
- eradicate those that are at an early stage of establishment
- contain where possible species that are beyond eradication
- take an asset-based approach to managing widespread invasive species.

DELWP's *Science Statement*, released in 2017, outlines how DELWP will increase connectivity and discoverability and promote science across the department, with department agencies, partners, stakeholders and the community.[14] The statement has three main foci: community participation and ownership, informing policy and operational decisions, and building blocks for the future. DELWP's *Science Statement Implementation Plan*, launched in 2018, is structured on four key themes: we value and lead in science, we build our capability, we connect and collaborate, and we share.[15] Each key theme will be delivered through priority actions during 2018, with finalisation and release of a *Science Statement* evaluation framework, data standards and data catalogues in 2019.

13 DEDJTR 2018 ,'Invasive plants and animals policy framework', Melbourne, Victoria http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/protecting-victoria-from-pest-animals-and-weeds/invasive-plants-and-animals/invasive-plants-and-animals-policy-framework Accessed 3 October 2018

14 DELWP 2017, 'DELWP Science Statement', Melbourne Victoria.

15 DELWP 2018, 'DELWP Science Statement Implementation Plan', Melbourne, Victoria.

Indicator Assessments

Biodiversity Themes

There are many data gaps which limit the ability to report on long-term and statewide biodiversity trends in SoE 2018. These data gaps are due to: (i) the lack of recent biodiversity monitoring, and (ii) a change in a number of biodiversity indicators due to new methodologies and assessments outlined in the *Biodiversity 2037* plan released in 2017. Where possible, trends are reported. Where appropriate and relevant, case studies are used to highlight management approaches implemented to address a biodiversity threat, impact or pressure.

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.

Poor
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

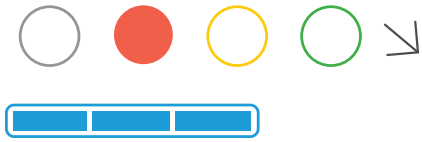
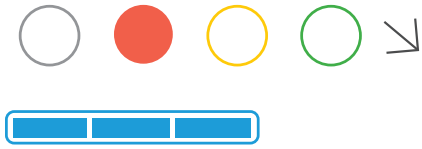
Improving

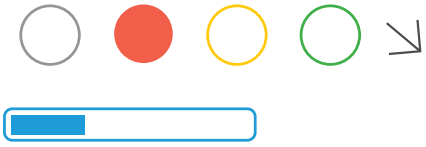
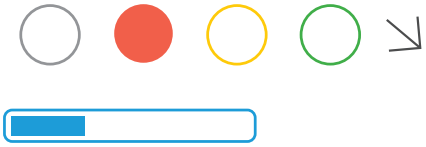
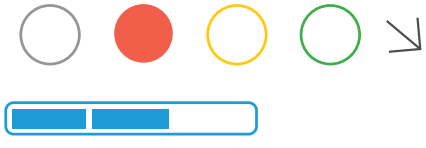
Data quality

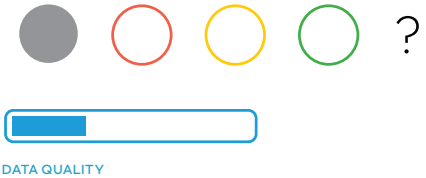
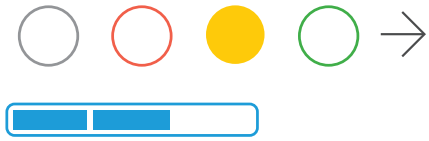
Poor
Evidence and consensus too low to make an assessment

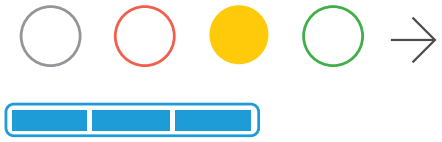
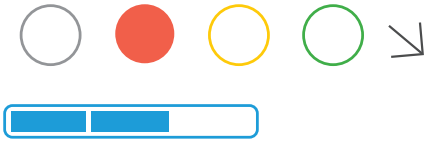
Fair
Limited evidence or limited consensus

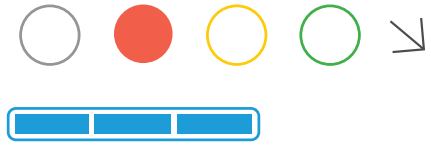
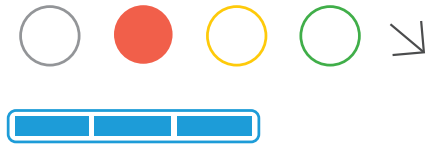
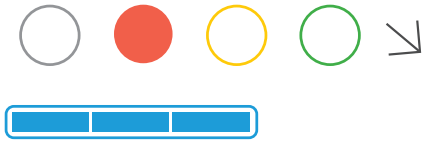
Good
Adequate high-quality evidence and high level of consensus

Summary		Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **B:01** Invasive freshwater plants and animals **Region** Victoria **Measures** Change in types and extent of freshwater invasive plants and animals Threatening processes impacting on native freshwater plants and animals **Data custodian** DELWP & DEDJTR	Aside from Carp ***(Cyprinus carpio)***, there is a lack of comprehensive and accurate statewide data on population numbers and trends of invasive freshwater pest plants and animals, and their threatening processes.	 DATA QUALITY Poor	?
Indicator **B:01A** Trend in Carp *(Cyprinus carpio)* Distribution **Region** Victoria **Measures** Population distribution **Data custodian** DELWP & DEDJTR	Carp are a highly successful, invasive fish species, abundant in south-east Australia. They dominate Victorian freshwater environments to the detriment of native fish species and other parts of the freshwater ecosystem.	 DATA QUALITY Good	↘
Indicator **B:02** Invasive terrestrial plants **Region** Victoria **Measures** Change in number, types and extent of terrestrial invasive plants **Data custodian** DELWP & DEDJTR	The number of naturalised plants and environmental weeds established in Victorian native vegetation between 1909-18.	 DATA QUALITY Good	↘

Summary		Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **B:03** Invasive terrestrial animals **Region** Victoria **Measures** Number, type and extent of invasive animals **Data custodian** DELWP & DEDJTR	Statewide invasive animal population numbers in Victoria are currently unknown. However, it is thought that populations and their distribution, are expanding across Victoria.	 DATA QUALITY Poor	
Indicator **B:03A** Trend in deer populations and their distributions **Region** Victoria **Measures** Number, type and extent of deer species **Data custodian** DELWP & DEDJTR	Four deer species have been expanding their distribution across Crown and private land. There is limited understanding of deer ecology to guide deer management.	 DATA QUALITY Poor	
Indicator **B:03B** Trend in horse populations and their distributions **Region** Alpine National Park and Barmah National Park **Measures** Number and extent of feral horses **Data custodian** DELWP & DEDJTR	Significant populations of feral horses occur in two Victorian National Parks (see Region). Feral horse population surveys in the Alpine National Park across two decades have shown that without management control, and severe natural events such as fire, feral horse populations can increase by 10-20% every 2-4 years.	 DATA QUALITY Fair	

Summary		Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **B:04** Trend in populations and distributions of threatened freshwater species **Region** Victoria **Measures** Change in conservation status of freshwater species based on FFG Act Trends in populations of threatened freshwater species. Management of freshwater threatened species Recovery & action plans for freshwater threatened species Re-established threatened freshwater species in the wild **Data custodian** DELWP	Since European settlement, three freshwater fish are known to have become extinct and 55% of freshwater fish are considered threatened. There is a lack of statewide data for the majority of threatened freshwater animal and plant species.	 DATA QUALITY Poor	?
Indicator **B:04A** Trend in population number and distribution of trout cod *(Maccullochella macquariensis)* **Region** Ovens River, Murray River, Goulburn River and Seven Creeks. **Measures** Population abundance and distribution. **Data custodian** DELWP	Since 2010, trout cod *(Maccullochella macquariensis)* have been stable or increasing their abundance and distribution across four waterways (see Region).	 DATA QUALITY Fair	→

Summary		Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **B:04B** Trend in population number and distribution of Macquarie perch *(Macquaria australasica)* **Region** Ovens River, Lake Dartmouth, Seven Creeks, King Parrot Creek, Hughes Creek, Yea River, Hollands Creek, Yarra River, Broken River and Buffalo (upper) River. **Measures** Population abundance and distribution **Data custodian** DELWP	Since 2012, Macquarie perch *(Macquaria australasica)* have been stable or increasing their abundance and distribution across ten waterways (see Region).	 DATA QUALITY Good	
Indicator **B:04C** Trend in population number and distribution of Murray crayfish *(Euastacus armatus)* **Region** Southern Murray-Darling **Measures** Population abundance and distribution **Data custodian** DELWP	Abundance and distribution of Murray crayfish, *Euastacus armatus*, in the southern Murray-Darling Basin have been decreasing due to cumulative pressures of recreational harvesting, river regulation, pesticides and pollutants, habitat change and events of low dissolved oxygen (hypoxic 'blackwater' disturbance).	 DATA QUALITY Fair	

Summary		Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **B:04D** Trend in population number and distribution of spotted tree frog *(Litoria spenceri)* **Region** Ovens River, Murray River, Goulburn River and Seven Creeks. **Measures** Population abundance and distribution **Data custodian** DELWP	Spotted tree frog *(Litoria spenceri)* populations have been declining due to the infectious disease chytridiomycosis and introduction of predatory fish, specifically the brown trout *(Salmo trutta)* and rainbow trout *(Onchorhynchus mykiss)* predating on tadpoles.	 DATA QUALITY Good	
Indicator **B:04E** Trends in population number and distribution of Booroolong tree frog *(Litoria booroolongensis)* **Region** Victoria **Measures** Population abundance and distribution **Data custodian** DELWP	Booroolong tree frog *(Litoria booroolongensis)* populations have been declining due to the infectious disease chytridiomycosis and the introduction of predatory fish, specifically European carp *(Cyprinus carpio)*, Redfin perch *(Perca fluviatilis)* and Mosquito fish *(Gambusia hobrooki)* predating on tadpoles.	 DATA QUALITY Good	
Indicator **B:04F** Trends in population number and distribution of Baw Baw frog *(Philoria frosti)* **Region** Mt Baw Baw plateau and escarpment **Measures** Population abundance and distribution **Data custodian** DELWP	The Baw Baw frog (*Philoria frosti*) is the only Victorian endemic frog species. Reasons for decline in population numbers and distribution include: habitat loss and degradation of their restricted range on the Baw Baw plateau and escarpment area (totalling only 135km^2) and spread of the infectious disease chytridiomycosis.	 DATA QUALITY Good	

Summary		Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **B:05** Threatened species that are wetland dependent **Region** Victoria **Measures** Species population abundance and distribution **Data custodian** DELWP	Due to a lack of statewide data, five fauna groups from the Threatened Species Advisory Lists for Victoria have been used as a proxy for the percentage of Victoria's wetland dependent threatened species.	 DATA QUALITY Poor	
Indicator **B:06** Trends in populations and distributions of threatened terrestrial species **Region** Victoria. **Measures** For B6 – B6C: Conservation status of terrestrial threatened species, which measures changes in the status of threatened terrestrial species Trends in population and distribution of selected threatened terrestrial species over time Threatening processes impacting and affecting native terrestrial threatened species **Data custodian** DELWP	See B6A, B6B and B6C below.	 DATA QUALITY Poor	

Summary		Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **B:06A** Vascular Plants **Region** Victoria **Measures** Conservation status of terrestrial threatened species, which measures changes in the status of threatened terrestrial species Trends in population and distribution of selected threatened terrestrial species over time Threatening processes impacting and affecting native terrestrial threatened species **Data custodian** DELWP	There has been an increasing trend in the number of endangered, vulnerable and rare vascular plants in Victoria.	 DATA QUALITY Fair	
Indicator **B:06B** Vertebrates **Region** Victoria **Measures** Conservation status of terrestrial threatened species, which measures changes in the status of threatened terrestrial species Trends in population and distribution of selected threatened terrestrial species over time Threatening processes impacting and affecting native terrestrial threatened species **Data custodian** DELWP	There has been an increasing trend in the number of critically endangered and vulnerable vertebrate groups, specifically reptiles. To a lesser extent, there has been an increase in the number of endangered vertebrates. There is limited trend information on the number of threatened invertebrates, where currently 178 known species are considered to be threatened.	 DATA QUALITY Fair	

Summary	Status	Trend
	UNKNOWN POOR FAIR GOOD	

Indicator

B:06C Invertebrates

Region

Victoria

Measures

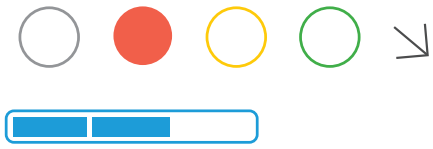
Conservation status of terrestrial threatened species, which measures changes in the status of threatened terrestrial species

Trends in population and distribution of selected threatened terrestrial species over time

Threatening processes impacting and affecting native terrestrial threatened species

Data custodian

DELWP



DATA QUALITY

Fair

Indicator

B:07 Private Land Conservation

Region

Victoria

Measures

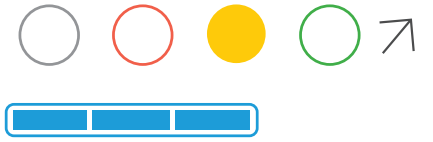
Conservation on private land which assesses the area of private land under conservation agreements

Management of biodiversity on private land which assesses activities taken to conserve species, conserve communities and maintain, improve or restore habitat on private land

Data custodian

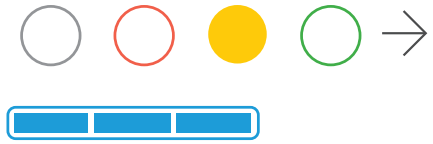
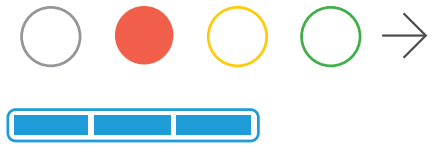
Trust for Nature

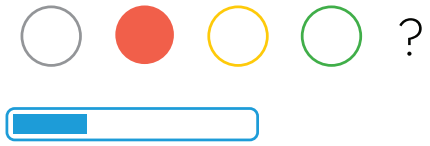
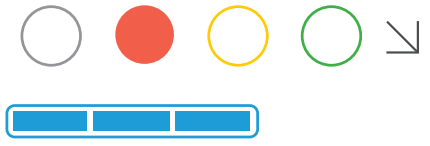
Trust for Nature has assisted with the permanent protection of more than 100,000 hectares of native habitat on private land using a range of conservation tools, including conservation covenants, land acquisition, donations of land and its Revolving Fund. There are 1416 voluntary conservation covenants and 43 Trust for Nature properties and/or reserves.

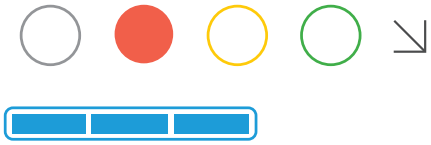
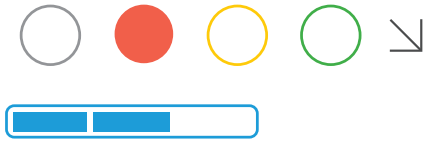


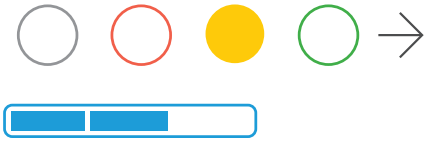
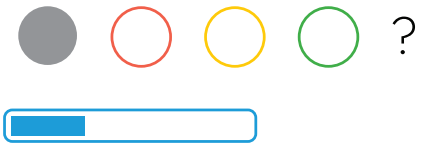
DATA QUALITY

Good

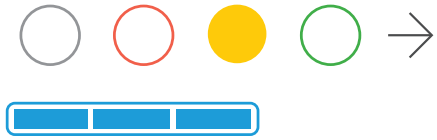
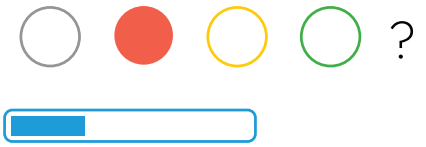
Summary		Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **B:08** Conservation of Victorian Ecosystems **Region** Victoria **Measures** Victorian conservation categories, their area in hectares and threatened species in conservation areas **Data custodian** PV & DELWP	Conservation categories across the Parks Victoria Estate has remained stable but the number and type of threatened native plants and animals have been increasing.	 DATA QUALITY Good	
Indicator **B:09** River Health **Region** Victoria **Measures** Percentage of major rivers that remain in a near pristine or largely unmodified state Assessment of freshwater biodiversity information Area of management in priority locations Restoration of habitat **Data custodian** DELWP	There is no update for the Index of Stream Condition (ISC) data due to the revised assessment regime. National Assessment of River Condition (ARC) program and the national Assessment of River Condition and River Monitoring and Assessment Program (RiverMAP) found that Victorian river health was influenced by grazing, land clearing for agriculture, timber production and urban development causing disturbance to natural river drivers.	 DATA QUALITY Good	

Summary		Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **B:10** Riparian Vegetation Habitat Extent **Region** Victoria **Measures** Riparian vegetation cover and extent **Data custodian** DELWP	Twenty one of 29 Victorian river basins had less than 50% of assessed river length with riparian vegetation in good condition. Riparian zone removal and degradation in Victoria is due to agricultural activity that occurs alongside rivers and the channelisation of drainage (through drainage channels) from agriculture and urban land rather than using naturally-formed stream channels.	 DATA QUALITY Poor	?
Indicator **B:11** Area of functional floodplain **Region** Victoria **Measures** Change to floodplain area as a natural approach to mitigate, and reduce the risk, of flood and drought impacts and provide refuge to plants and animals during extreme weather events **Data custodian** DELWP	Data at state-scale is currently not available to determine floodplain functionality.	 DATA QUALITY Poor	?
Indicator **B:12** Distribution and abundance of frogs **Region** Victoria **Measures** Population abundance and distribution **Data custodian** DELWP	There have been declines in the population number of native frog species (threatened and non-threatened species) over the past few decades.	 DATA QUALITY Good	↘

Summary		Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **B:13** Distribution and abundance of fish **Region** Victoria **Measures** Population abundance and distribution **Data custodian** DELWP	Distribution and abundance of fish data is only available for regulated rivers that receive environmental watering through the VEFMAP program.	 DATA QUALITY Good	
Indicator **B:14** Distribution and abundance of waterbirds in the Murray Darling Basin **Region** Murray Darling Basin **Measures** Population abundance and distribution **Data custodian** DELWP	Distribution and abundance of waterbird for the Murray Darling Basin through the Eastern Australian Waterbird Survey.	 DATA QUALITY Fair	

Summary		Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **B:15** Distribution and abundance of macroinvertebrates **Region** Victoria **Measures** Total macroinvertebrate richness Total Ephemeropter, Plecoptera and Trichoptera SIGNAL2invertebrate grade number AUSRIVAS O/E indicator of communities composition **Data custodian** EPA Victoria	At the statewide scale, the overall condition of inland aquatic macroinvertebrates across Victoria's 66 long-term monitoring sites is stable.	 DATA QUALITY Fair	
Indicator **B:16** Wetland extent and condition **Region** Victoria **Measures** Extent and condition **Data custodian** DELWP	There have not been any further statewide assessments on wetland condition using the Index of Wetland Condition since the release of the SoE 2013 report.	 DATA QUALITY Poor	?
Indicator **B:17** Health and status of Ramsar wetlands in Victoria **Region** Victoria **Measures** Ecological condition **Data custodian** DELWP	Victoria has 11 Ramsar sites, of which 6 are inland and cover 98,623ha. The 2016 Victorian Auditor-General Office report, Meeting Obligations to *Protect Ramsar Wetlands*, found limited evidence that ecological character descriptions for each site were being maintained. The status of the ecological character of some sites cannot be fully determined due to limitations such as a lack of data.	 DATA QUALITY Poor	?

Summary		Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **B:18** Net Gain in Extent and Condition of Native Vegetation **Region** Victoria **Measures** Estimates of the overall rate of change in extent and quality of native vegetation on public and private land in Victoria **Data custodian** DELWP	There has been a loss in native vegetation on public and private land between 2008-2014. The largest contributor to net loss in native vegetation on private and freehold land is entitled uses (e.g. grazing, removal of trees and fallen logs for personal use), unmanaged threats beyond legislative obligations (e.g. environmental weeds) and clearing that is exempt from requiring a permit (e.g. fences and fire protection).	 DATA QUALITY Good	
Indicator **B:19** Landscape Scale Change **Region** Victoria **Measures** Trends in native vegetation extent and land use from 1987-2015 **Data custodian** DELWP	Analysis of landscape scale change shows an increase in landscapes associated with human-based activities and an overall decrease in native vegetation and intermittent and seasonal wetlands not of a marine water source.	 DATA QUALITY Fair	
Indicator **B:20** Change in Suitable Habitat **Region** Victoria **Measures** Estimating net improvement in suitable habitat and the most effective options for improving the future of native species across the state under climate change **Data custodian** DELWP	The average percentage change in suitable habitat in 50 years for all native species is 5.24%. For threatened species, the average percentage change in suitable habitat in 50 years is 5.3%, based on the on-ground management actions taken. For some species, the percentage change in suitable habitat was much higher than the average.	 DATA QUALITY Good	

Summary		Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **B:21** Area of Management in Priority Locations **Region** Victoria **Measures** Achieving targets for hectares of management in priority locations, including restoration of habitat **Data custodian** DELWP	Because this is a new indicator associated with the Biodiversity Plan 2037, it is still too early to determine if targets are on track to being achieved.	 DATA QUALITY Fair	
Indicator **B:22** Victorians value nature **Region** Victoria **Measures** Measures are still to be determined **Data custodian** DELWP	This indicator describes the relationship between people connecting with nature, valuing nature and acting to protect or enhance biodiversity while improving their health and wellbeing. This is a new indicator associated with the Biodiversity 2037 Plan. It is too early to determine if targets are on track to being achieved.	 DATA QUALITY Poor	?
Indicator **B:23** Number of Victorian Government organisations that manage environmental assets that contribute to DELWP Standard Output Data **Region** Victoria **Measures** Measures are still to be determined **Data custodian** DELWP	Twelve percent of Victorian Government organisations who manage Victoria's natural assets have contributed some data. In most cases this data is not complete and does not reflect all on-ground works those organisations have delivered or funded.	 DATA QUALITY Poor	?

Invasive Plants and Animals

This theme will report on invasive (pest) terrestrial and freshwater plants and animals. These are defined as species that have been brought into a natural system by humans across a geographical barrier and are recognised as a serious threat to biodiversity.[16] Their impacts are likely to be exacerbated by operating in combination with other emerging and ongoing threats such as climate change and habitat degradation.[17] These animal and plant species pose a major threat to biodiversity, ecosystem health, primary production and landscape aesthetics. The terms 'invasive' and 'pest' are used interchangeably in this section of the report. Current Victorian legislation that addresses the management of invasive plants and animals includes: *Catchment and Land Protection Act 1994* allows weeds to be declared noxious, the FFG Act, *National Parks Act 1975* and *Sustainable Forests (Timber) Act 2004*. These regulatory frameworks set out environmental objectives to manage invasive plants and animals. The IPAPF provides a whole-of-Victorian-Government approach to managing existing and potential invasive species. Marine and coastal invasive plants and animals are reported in the Marine and Coastal Environments chapter.

16 White M, Cheal D, Carr GW, Adair R, Blood K, Meagher D 2018, 'Advisory list of environmental weeds in Victoria', Arthur Rylah Institute for Environmental Research Technical Report Series No. 287, Heidelberg, Victoria.
17 Ibid

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
B:01 Invasive freshwater plants and animals	●	○	○	○	?	DATA QUALITY: Poor

Data custodian DELWP, DEDJTR

The following SoE biodiversity indicators have been aggregated to inform the distribution and management of freshwater invasive species:

- trends in the types and extent of freshwater invasive plants and animals
- threatening processes impacting on native freshwater plants and animals.

Freshwater invasive plant species can form dense infestations that reduce the diversity of freshwater plants and have secondary impacts on freshwater animals such as invertebrates and fish.[18] These impacts can alter freshwater habitats and threaten their long-term function if not managed.[19] Freshwater invasive plants can also impact on recreational values such as swimming, fishing and boat navigation. In some cases of dense plant populations, unpleasant odours can affect those living near the water body or interacting with it.[20] In irrigation channels, invasive plant species can limit water flow, and, in some cases of excessive plant growth, cause channels to overflow.[21]

The costs of the impact that invasive species have on waterways in Victoria have not been fully estimated.[22] The Victorian Waterway Management Strategy outlines a risk-based approach framework for managing invasive species dependent on freshwater and riparian habitats in Victorian waterways.[23] Investment spent on controlling and preventing the spread of freshwater and riparian invasive species to date includes:[24]

- approximately $15.8 million per annum spent on carp control in Australia
- $1.8 million spent in 2006 at Rocklands Reservoir to restrict the spread of carp in the Glenelg River
- approximately $250,000 per annum spent by Goulburn–Murray Water and Murray Irrigation Ltd to control the spread of arrowhead (an inland aquatic weed) in irrigation channels and natural waterways in northern Victoria
- considerable sums spent on willow control by Victorian waterway managers.

In addition to the direct costs of freshwater invasive species management, invasive species can undermine the outcomes of previous investment into waterway management activities.[25]

Aside from carp *(Cyprinus carpio)*, the SoE 2018 is unable to report on these indicators. There is a lack of comprehensive and accurate statewide data on population numbers and trends of invasive freshwater pest plants and animals, and their threatening processes. Where data is available, it is limited to artificial standing water bodies and irrigation channels[26] and some regulated rivers such as the Murray–Darling Basin river.[27]

18 Dugdale TM, Hunt TD, Clements D 2013, 'Aquatic weeds in Victoria: where and why are they a problem, and how are they being controlled?' *Plant Protection Quarterly*, 28(2), pp. 35-40.
19 Ibid
20 Ibid
21 Ibid
22 DEPI 2013, 'Improving our waterways. Victorian waterway management strategy', Melbourne, Victoria.
23 DEPI 2013, 'Improving our waterways, Victorian waterway management strategy', Melbourne, Victoria.
24 Ibid
25 Ibid
26 Ibid
27 DELWP 2017, 'Victorian environmental flows monitoring and assessment program (VEFMAP) stage 6. Project update – 2017 pilot monitoring of aquatic and river bank vegetation', Melbourne, Victoria.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
B:01A Trend in Carp *(Cyprinus carpio)* Distribution	○	●	○	○	↘	DATA QUALITY Good

Data custodian DELWP, DEDJTR

Carp is a highly prolific, invasive fish species, abundant in south-east Australia. Carp are considered pests because they can dominate aquatic environments to the detriment of native fish species and other parts of the freshwater ecosystem. Control of carp is difficult; actions to date have largely been localised, with a focus on harvesting adult fish. Carp control through mortality is only part of the approach to manage populations. Management needs to consider the capacity of populations to increase through reproduction and recruitment, both locally and from movements from other locations.[28]

Reproduction and movement of carp is linked to flows – especially over-bank flows that inundate wetlands and floodplains, giving them access to favoured habitats for spawning and recruitment of young. The delivery of water, either for irrigation demands or to achieve environmental outcomes, may inadvertently benefit carp by enhancing their access to preferred breeding habitats, creating management trade-offs.[29]

In 2016, the Australian Government initiated the National Carp Control Plan.[30] The plan, due to be completed in 2018, will be based on research, planning and consultation necessary to enable an informed decision on carp biocontrol using cyprinid herpesvirus 3 (CyHV-3), a naturally occurring strain of carp herpesvirus. As part of the National Carp Control Plan, Victoria's Arthur Rylah Institute for Environmental Research, in partnership with La Trobe University, will lead a five-state collaborative project to determine how many carp are in eastern Australia.[31] The project, 'A carp biomass estimate for eastern Australia', will be undertaken across a range of habitat types including rivers, lakes, billabongs and estuaries and will allow for fluctuating carp numbers through time. The project aims to:

- provide a robust estimate of carp abundance, distribution and biomass
- contribute to the development of virus release strategies
- help predict locations where there may be high carp mortalities to plan for clean-up and management of potential impacts on water quality
- benchmark environmental condition prior to release of the carp virus.

The results of this study and any management actions will inform future SoE reporting for this indicator.

28 Koehn JD, Todd CR, Zampatti BP, Stuart IG, Conallin A, Thwaites L, Ye Q 2018, 'Using a population model to inform the management of river flows and invasive carp *(Cyprinus carpio)*', *Environmental Management*, 61, pp. 432-442.
29 Ibid
30 Australian Government 2018, 'National carp control plan restoring native biodiversity', http://www.carp.gov.au/ Accessed 16 November 2018.
31 Arthur Rylah Institute 2018, 'Preparing for carp herpesvirus', https://www.ari.vic.gov.au/research/pests-weeds-and-overabundant-species/preparing-for-carp-herpesvirus Accessed 24 November 2018.

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:02 Invasive terrestrial plants			 DATA QUALITY Good

Data custodian DELWP, DEDJTR

This SoE 2018 indicator includes the following terrestrial pest plant categories:

- Naturalised flora taxa – Naturalised taxa originate from either outside Australia or interstate, or they are Victorian natives that have become established long-term self-sustaining populations outside their pre-European range. Examples of Victorian natives that have become naturalised taxa include spotted gum (*Corymbia maculata*) and coastal umbrella-bush (*Acacia cupularis*), used as ornamental plantings.[32] Naturalised flora taxa may not adversely impact native plants and/or animals or functioning ecosystems.
- Environmental weeds – Environmental weeds are a subset of naturalised taxa. These plants invade native ecosystems and have the potential to adversely affect the survival of native plants, animals and functioning ecosystems. They include plant species that have been introduced to Australia from other countries, as well as native plant species that have spread beyond their previous natural range due to changed land management or practices (examples include sallow wattle, coastal wattle and coastal tea tree).[33] Environmental weeds are a threat to Australia's biodiversity because they can displace native plant species, disrupt ecological processes such as fire and soil erosion patterns, and alter the genetic composition of native plant populations.[34]

The number of naturalised plants has increased steadily since settlement, with a fivefold increase since the early 20th century (Table B.1).[35,36] Victoria is home to at least 1,451 naturalised plant taxa which is about 25% of the total flora.[37,38] Of these, 1,235 species (85%) are environmental weeds that are established in Victorian native vegetation (Figure B.1).[39] This is almost double the number of environmental weeds identified in 1992 (584, equating to 48%) (Figure B.2).[40,41] Many more plant species than those currently recognised as environmental weeds have been introduced into Victoria, and a proportion of these are likely to escape their current confines (such as gardens and aquariums) and become established in the wild.[42]

32 White M, Cheal D, Carr GW, Adair R, Blood K, Meagher D 2018, 'Advisory list of environmental weeds in Victoria', Arthur Rylah Institute for Environmental Research Technical Report Series No. 287, Heidelberg, Victoria.
33 Ibid
34 Ibid

35 Carr GW, 1993, 'Exotic flora of Victoria and its impacts on indigenous biota', In: Flora of Victoria Volume 1, pp 256-97. Foreman, D. B and Walsh, N. G. (eds). Inkata Press, Port Melbourne, Victoria.
36 White M, Cheal D, Carr GW, Adair R, Blood K, Meagher D 2018, 'Advisory list of environmental weeds in Victoria', Arthur Rylah Institute for Environmental Research Technical Report Series No. 287, Heidelberg, Victoria.
37 VNPA 2014, 'Natural Victoria: conservation priorities for Victoria's natural heritage. Nature conservation review. Full Report', Melbourne, Victoria.
38 White M, Cheal D, Carr GW, Adair R, Blood K, Meagher D 2018, 'Advisory list of environmental weeds in Victoria', Arthur Rylah Institute for Environmental Research Technical Report Series No. 287, Heidelberg, Victoria.
39 Ibid
40 Carr GW, Yugovic JV, Robinson KE 1992, 'Environmental weed invasions in Victoria: conservation and management implications', Department of Conservation and Environment, Melbourne, Victoria.
41 White M, Cheal D, Carr GW, Adair R, Blood K, Meagher D 2018, 'Advisory list of environmental weeds in Victoria', Arthur Rylah Institute for Environmental Research Technical Report Series No. 287, Heidelberg, Victoria.
42 Ibid

Table B.1 Increasing trend in the number of naturalised plants and environmental weeds established in Victorian native vegetation, 1909–2018[43]

Year	Naturalised plants	Environmental weeds
1909	363	Unknown
1928	461	Unknown
1976	747	Unknown
1988	878	Unknown
1992	1,221	584
1993	1,221	584
2018	1,451	1,235

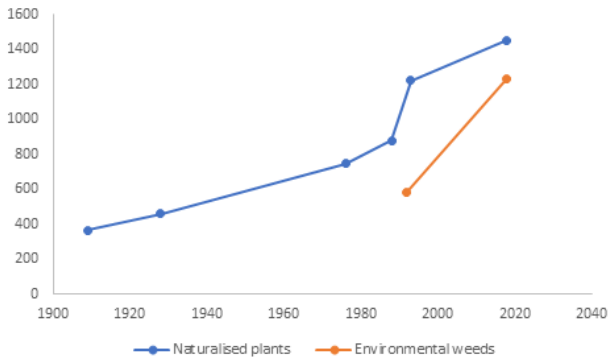


Figure B.1 Number of naturalised plants and environmental weeds in Victoria, 1909–2018

Note: The steep incline in naturalised plants between 1988 and 1993 coincides with the publication of the *Flora of Victoria*, which created awareness of the distribution and impact of these species on native vegetation.[44]

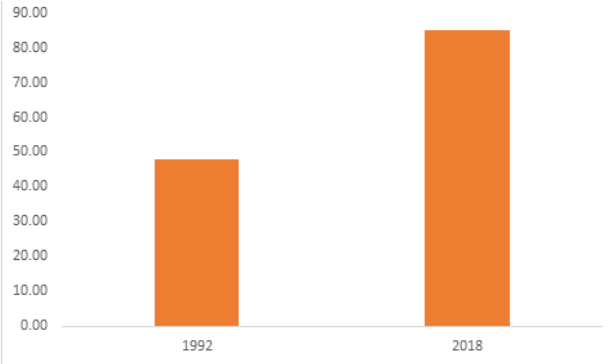


Figure B.2 Increase in percentage of naturalised plants considered to be environmental weeds, 1992–2018 [45]

43 Carr GW, Yugovic JV, Robinson KE 1992, 'Environmental weed invasions in Victoria: conservation and management implications', Department of Conservation and Environment, Melbourne, Victoria.
Carr GW, 1993, 'Exotic flora of Victoria and its impacts on indigenous biota', In: Flora of Victoria Volume 1, pp 256-97. Foreman, D. B and Walsh, N. G. (eds). Inkata Press, Port Melbourne, Victoria.
White M, Cheal D, Carr GW, Adair R, Blood K, Meagher D 2018, 'Advisory list of environmental weeds in Victoria', Arthur Rylah Institute for Environmental Research Technical Report Series No. 287, Heidelberg, Victoria.
Forbes SJ, Ross JH 1988, 'A Census of the vascular plants of Victoria (2nd ed)', Department of Conservation, Forests and Lands, Melbourne, Victoria.

44 White M, Cheal D, Carr GW, Adair R, Blood K, Meagher D 2018, 'Advisory list of environmental weeds in Victoria', Arthur Rylah Institute for Environmental Research Technical Report Series No. 287, Heidelberg, Victoria.

45 Ibid

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
B:03 Invasive terrestrial animals	○	●	○	○	↘	DATA QUALITY
Data custodian DELWP, DEDJTR						Poor

Pest animals originate from either outside Australia or interstate, and they have established long-term self-sustaining populations. Overabundant population numbers of local native animals can also be pest animals (for example, koalas, kangaroos and possums). Pest animals are also referred to as invasive animals in this indicator.

Established terrestrial pest animals in Victoria include foxes, rabbits, feral pigs, feral goats, feral horses, deer and feral cats, with their impacts recognised through several listings under the FFG Act (Table B.2). Statewide pest animal population numbers in Victoria are currently unknown, however, it is thought that populations, and their distribution, are expanding across Victoria.[46] Although specific population numbers are not available, the issues posed by increasing deer and horse numbers are described in detail below.

The Environment, Natural Resources and Regional Development Committee Inquiry into the Control of Invasive Animals on Crown Land found that there is a lack of robust data about population numbers and extent of invasive animals and the effectiveness of control methods.[47] Additionally, the Inquiry found that Victoria's complex legislative framework and division of responsibilities have contributed to confusion and inefficiencies in controlling invasive animals. Of the 33 Inquiry recommendations, the Victorian Government accepted 29 with one under review.

Recommendation 1 tasked government to allocate resources to the appropriate authority to undertake work to quantify and measure the numbers and impact of invasive species populations.[48] The government supports this recommendation in principle, with Agriculture Victoria – in the Department of Economic Development, Jobs, Transport, Resources (DEDJTR) – having responsibility for the government's investment in research and development to advance effective policy tools for invasive animal management.[49] The government agencies involved in the development of the government's response will be responsible for prioritising the delivery of the 29 recommendations. Decisions about resourcing to implement these recommendations will be subject to budget processes in the context of the government's investment and service delivery priorities.[50]

46 Environment, Natural Resources and Regional Development Committee 2017, 'Inquiry into the control of invasive animals on Crown land', Parliament of Victoria, Melbourne, Victoria.
47 Ibid
48 Ibid
49 DELWP 2017, 'Government response to the Environment, Natural Resources and Regional Development Committee Inquiry into the control of invasive animals on Crown land. Final Report', Melbourne, Victoria https://www.environment.vic.gov.au/invasive-plants-and-animals/invasive-animals-parliamentary-inquiry
50 Ibid

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:03A Trend in deer populations and their distributions		↘	DATA QUALITY: Poor

Data custodian DELWP, DEDJTR

Increasing populations of four deer species have been expanding their distribution across Crown and private land. The environmental impacts of deer include: destruction to native vegetation and regeneration; increased revegetation costs; and damage to orchards, vegetable gardens, pastures and fencing.[51] Deer can also cause soil erosion and concentration of nutrients.[52] An understanding of deer ecology could guide deer management, yet at present this is limited. Addressing this knowledge gap can assist in developing and prioritising cost-effective management strategies.[53] At the time of writing this report, the Draft Deer Management Strategy, a partnership document between DELWP and DEDJTR, has been released for public comment.[54] The strategy is an action under the Victorian Government's *Sustainable Hunting Action Plan 2016–2020* and it is recognised in the *Biodiversity 2037 Implementation Framework*. The objectives of the draft strategy are to protect ecological, social, economic, cultural and agricultural assets from the impacts of deer and provide diverse, quality hunting opportunities. The performance objectives and associated management actions of the final management strategy will be assessed in the next SoE report.

Sambar Deer

There is a wild, self-sustaining breeding population of sambar deer across an estimated 66,915 km^2 of Crown land in Victoria, equivalent to 29% of the state's land area. There are four discrete – that is, reproductively isolated – populations located in eastern Victoria (population distribution range 66,300 km^2), French Island (170 km^2), Mount Cole (330 km^2) and Timboon (115 km^2).[55]

Fallow Deer

There are 61 wild, self-sustaining breeding populations of fallow deer in Victoria distributed across 21,400 km^2.[56] Population distribution has increased since the 1980s, due to deliberate releases, escapes from farms and dispersal from established populations. It is likely that the distributions will continue to increase in Victoria.

Red Deer

There are 27 wild, self-sustaining breeding populations of red deer in Victoria distributed across 3,900 km2.[57] They have greatly increased their distribution since the 1980s, due to deliberate releases, escape from farms and dispersal from established populations. It is likely that the distributions will continue to increase in Victoria.

Hog Deer

There is one wild, self-sustaining breeding population of hog deer in Victoria with a current breeding distribution of 2,336 km^2,[58] confined to the coastal strip between Tarwin River and Point Hicks. The current population number and its distribution in Victoria is limited by the biophysical factors of its geography and will not further increase from natural dispersal. However, there is a possibility that new hog deer populations could establish themselves in the coastal strip in western Victoria as a result of deliberate releases or escapes from farms.[59]

51 VCMC 2017, 'Catchment Condition and Management Report 2017', Melbourne, Victoria.
52 ibis
53 Davis NE, Bennett A, Forsyth DM, Bowman DMJS, Lefroy EC, Wood SW, Woolnough AP, West P, Hampton JO, Johnson CN, 2016, 'A systematic review of the impacts and management of deer (family Cervidae) in Australia. *Wildlife Research*, 43, pp. 515-532.
54 DELWP 2018, 'Draft deer management strategy', Melbourne, Victoria https://www.environment.vic.gov.au/invasive-plants-and-animals/draft-deer-management-strategy Accessed on 24 October 2018.
55 Forsyth DM, Stamation K, Woodford L, 2015, 'Distributions of Sambar Deer, Rusa Deer and Sika Deer in Victoria', Arthur Rylah Institute for Environmental Research unpublished client report for the Biosecurity Branch, Department of Economic Development, Jobs, Transport and Resources, Heidelberg, Victoria.
56 Forsyth DM, Stamation K, Woodford L, 2016, 'Distributions of Fallow Deer, Red Deer, Hog Deer and Chital Deer in Victoria', Arthur Rylah Institute for Environmental Research unpublished client report for the Biosecurity Branch, Department of Economic Development, Jobs, Transport and Resources, Heidelberg, Victoria.
57 Ibid
58 Ibid
59 Ibid

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:03B Trend in horse populations and their distributions *(Equus caballus)*			 DATA QUALITY Fair

Data custodian DELWP, DEDJTR

Australia has the largest population of wild horses in the world, being in excess of 300,000 animals.[60] Significant populations of feral horses (*Equus caballus*) occur in two Victorian National Parks: Alpine National Park and Barmah National Park. Feral horse population surveys in the Alpine National Park across two decades have shown that, without management control or severe natural events such as fire, feral horse populations can increase by 10 to 20% every two to four years.[61] At the time of writing this report, the *Alpine National Park – Feral Horse Action Plan 2018–2021* had been approved, with performance objectives and management actions to be assessed in the next SoE report.

Table B.2 Pest animal species and their impacts on Victoria's native ecosystem as listed in the FFG Act

Pest animal	Impact listed under the FFG Act
Feral horse *(Equus caballus)*	Degradation and loss of native vegetation habitats
Cat *(Felix catus)*	Predation on native Victorian wildlife
Introduced red fox *(Vulpes vulpes)*	Predation on native Victorian wildlife
Sambar deer *(Cervus unicolor)*	Reduction and degradation in biodiversity of native Victorian vegetation
European rabbit *(Oryctolagus cuniculus)*	Reduction in biomass and biodiversity of native vegetation through grazing
Feral goat *(Capra hircus)*	Soil degradation and reduction of biodiversity through browsing and competition

60 Hobbs RJ, Hinds LA 2018, 'Could current fertility control methods be effective for landscape-scale management of populations of wild horses (*Equus caballus*) in Australia?', *Wildlife Research*, 45, pp. 195-207.

61 Hobbs RJ, Hinds LA 2017, 'Review of the feasibility of current fertility control methods for management of wild horse populations (Equus caballus) in Kosciuszko National Park', Summary report to the Science Division, Office of Environment and Heritage, New South Wales.

Threatened Species

The current Holocene (or Anthropocene) extinction spike represents the sixth and latest extinction episode in the earth's history.[62] Human activities are the main cause of the Holocene extinction.[63] Since European settlement, 18 mammal, 2 bird, 1 snake, 6 invertebrate and 51 plant species are known to have become extinct in Australia. Further, 6 Australian frog species have not been observed in the wild for the past 15 to 36 years, with concerns that they may be extinct.[64]

The FFG Act provides the Victorian framework for listing threatened species, conserving threatened species and communities, and managing potentially threatening processes. Under this legislation, there are over 700 fauna and flora species and ecological communities listed as threatened. In addition to the FFG lists, DELWP also maintains Threatened Species Advisory Lists. Currently, these include Rare or Threatened Plants in Victoria; Threatened Vertebrate Fauna and Threatened Invertebrate Fauna. The Advisory Lists do not have a legislative basis, and they include species that are considered likely to be threatened but have not been through the formal listing processes required under the FFG Act. The Advisory Lists are based on technical information and advice obtained from a range of experts, and they are reviewed periodically. The information in these lists can be used in planning processes, such as the preparation of National Park Management Plans, local government planning schemes and regional catchment strategies, and in setting priorities for actions to conserve biodiversity.

There are no direct legal requirements or consequences that flow from inclusion of a species in an Advisory List, although they are afforded some protection through Victoria's Native Vegetation Management Framework. Also, some of the species in these advisory lists are also listed as threatened under the FFG Act. The FFG Act Threatened List only includes species and communities that have been nominated, assessed by the Scientific Advisory Committee and approved for listing by the Minister for Energy, Environment and Climate Change and the Minister for Agriculture.

The increase in the number of Victorian flora and fauna species and ecological communities listed as threatened is due to the loss, fragmentation and degradation of habitat due to clearing for agriculture, urban development, timber harvesting, weed invasion, inappropriate fire regimes, grazing, climate change and alternation to flows and temperatures in rivers and streams.[65] Competition for resources and predation by introduced species (such as foxes, rabbits, deer and carp) has had a significant effect on many native species.[66]

In 2018, Victoria signed the Intergovernmental Memorandum of Understanding Agreement on a Common Assessment Method for Listing of Threatened Species and Threatened Ecological Communities (CAM MoU).[67] The CAM MoU requires signatory parties to adopt the International Union for Conservation of Nature (IUCN) Red List of Threatened Species categories and criteria through legislative reform, to establish a single operational list of threatened species in each jurisdiction and to collaborate in the assessment and periodic review of the conservation status of native species in Australia.

62 Clemann N 2015, 'Cold-blooded indifference: a case study of the worsening status of threatened reptiles from Victoria, Australia', *Pacific Conservation Biology*, 21, pp.15-26.
63 Ibid
64 Skerratt LF, Berger l, Clemann N, Hunter DA, Marantelli G, Newell DA, Philips A, McFadden M, Hines HB, Scheele BC, Brannelly LA, Speare R, Versteegen S, Cashins SD, West M 2016, 'Priorities for management of chytridiomycosis in Australia: saving frogs from extinction', *Wildlife Research*, 43(2), pp.105-120.
65 Arthur Rylah Institute 2018, 'Threatened plants and animals', Heidelberg, Victoria https://www.ari.vic.gov.au/research/threatened-plants-and-animals Accessed 27 September 2018.
66 Ibid
67 Intergovernmental Memorandum of Understanding 2017, 'Agreement on a common assessment method for listing of threatened species and threatened ecological communities' https://www.environment.gov.au/system/files/resources/36ece4ab-82dc-4de9-aac6-9cc54bd7a820/files/mou-cam.docx Accessed 27 September 2018.

The IUCN Red List of Threatened Species provides taxonomic, conservation status and distribution information on plants, fungi and animals that have been globally evaluated using the IUCN Red List Categories and Criteria.[68] This system is designed to determine the relative risk of extinction, with the main purpose to catalogue and highlight those plants, fungi and animals that are facing higher risk of global extinction. Applying the IUCN Red List Categories and Criteria can assess and determine whether plants, fungi and animals are: Data Deficient, Least Concern, Near Threatened, Vulnerable, Endangered, Critically Endangered, Extinct in the Wild, Extinct, or Not Evaluated.[69] DELWP is midway through a project to reassess all currently listed Victorian rare and/or threatened species, according to the IUCN Red List Categories and Criteria, including species listed in the FFG Act Threatened List and the DELWP Advisory Lists. Apart from yielding a single, comprehensive list of Victorian threatened species, this work will also provide the baseline for key targets in *Biodiversity 2037*. This new list will not be comparable to the current DELWP Advisory Lists, creating a new baseline for future trend reporting. An update on this new comprehensive Victorian threatened species list will be made available in 2019.

At the time of writing this report, DELWP was leading a review process for the FFG Act. This review process included public consultation which informed the development of reforms to the FFG Act, resulting in the Flora and Fauna Guarantee Amendment Bill.

68 IUCN 2018, 'IUCN Red List of Threatened Species', http://www.iucnredlist.org Accessed 27 July 2018.
69 IUCN 2018, 'IUCN Red List of Threatened Species Technical Documents', http://www.iucnredlist.org/technical-documents/categories-and-criteria Accessed 27 July 2018.

Data custodian: None

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:04 Trend in populations and distributions of threatened freshwater species in the wild.		?	 DATA QUALITY Poor

Data custodian DELWP

Since European settlement, three freshwater fish are known to have become extinct and 55% of freshwater fish are considered to be threatened.[70] Due to a lack of statewide data for the majority of threatened freshwater animal and plant species, the following SoE biodiversity indicators have been aggregated:

- conservation status of freshwater species – measuring the change in the status of FFG Act–listed threatened freshwater species
- trends in populations of selected threatened freshwater species – measuring change in population and distribution of selected freshwater threatened species over time
- management of freshwater threatened species – providing information on threatened species management programs
- recovery and action plans for threatened freshwater species – assessing the comprehensiveness of plans and actions for threatened freshwater species
- re-establishment of threatened freshwater species in the wild, where feasible under climate change – assessing the percentage of critically endangered and endangered species that have at least one option available for being conserved ex situ or re-established in the wild by 2037.

Statewide information is available for three freshwater fish species: trout cod (*Maccullochella macquariensis*), Macquarie perch (*Macquaria australasica*) and Murray Crayfish *(Eustacus armatus)* and three frog species: spotted tree frog (*Litoria spenceri*), Booroolong tree frog (*Litoria booroolongensis*) and Baw Baw frog (*Philoria frosti*) which are reported below. There is no statewide information on threatened freshwater plant species. Some localised threatened species information is available for Victorian rivers which receive environmental watering, such as the Murray–Darling Basin.[71]

70 DELWP 2016, 'Protecting Victoria's Environment – Biodiversity 2036 Supporting Technical Supplement', Melbourne, Victoria.

71 DELWP 2017, 'Progress towards outcomes from environmental water in Victoria. Five years into Basin Plan implementation', Melbourne, Victoria.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
B:04A Trend in population number and distribution of trout cod *(Maccullochella macquariensis)*	○	○	●	○	→	DATA QUALITY Fair

Data custodian DELWP

Since 2008, trout cod has been monitored in the Ovens River, Murray River, Goulburn River and Seven Creeks. Since 2010, populations across all of these water systems have been stable or increasing in their abundance and distribution.[72]

72 Lyon JP, Todd C, Nicol SJ, MacDonald A, Stoessel D, Ingram BA, Barker RJ, Bradshaw CJ 2012, 'Reintroduction success of threatened Australian trout cod (*Maccullochella macquariensis*) based on growth and reproduction', *Marine and Freshwater Research*, 63(7), pp. 598-605.
Koehn JD, Lintermans M, Lyon JP, Ingram BA, Gilligan DM, Todd CR, Douglas JW 2013, 'Recovery of the endangered trout cod, *Maccullochella macquariensis*: what have we achieved in more than 25 years?', *Marine and Freshwater Research*, 64(9), pp. 822-837.
Lyon JP, Lintermans M, Koehn JD 2018, 'Against the flow: the remarkable recovery of the trout cod in the Murray–Darling Basin', Recovering Australian Threatened Species: A Book of Hope, p.199.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
B:04B Trend in population number and distribution of Macquarie perch *(Macquaria australasica)*	○	○	●	○	→	DATA QUALITY Good

Data custodian DELWP

Since 2008, Macquarie perch has been monitored in the following water systems: Ovens River, Lake Dartmouth, Seven Creeks, King Parrot Creek, Hughes Creek, Yea River, Hollands Creek, Yarra River, Broken River and Buffalo (upper) River. It should be noted that some water systems have only been surveyed three times during this monitoring period. Similar to trout cod, most of these populations have been stable or are increasing in abundance and distribution since 2012. The upper Broken River has seen little recovery from the millennium drought, lasting from 1996 to 2010, creating concern for the remaining Macquarie perch population.[73]

Trend drivers for Macquarie perch and trout cod will vary between species and populations; however, as a whole, stable-to-improving trends are likely due to a combination of post-drought recovery, riparian and in-stream habitat restoration, environmental water delivery (for relevant water systems), conservation stocking; and improved community education and fisheries regulations.

73 Tonkin Z, Lyon J, Ramsey DS, Bond NR, Hackett G, Krusic-Golub K, Ingram BA, Balcombe SR 2014, 'Reservoir refilling enhances growth and recruitment of an endangered remnant riverine fish', *Canadian Journal of Fisheries and Aquatic Sciences*, 71(12), pp. 1888-1899.
Tonkin, Z, Kearns, J, Lyon, J, Balcombe, SR, King, AJ and Bond, NR 2017, 'Regional-scale extremes in river discharge and localised spawning stock abundance influence recruitment dynamics of a threatened freshwater fish', *Ecohydrology*, 10(6), pp. 1-11.
Pavlova A, Beheregaray LB, Coleman R, Gilligan D, Harrisson KA, Ingram BA, Kearns J, Lamb AM, Lintermans M, Lyon J, Nguyen TTT, Sasaki M, Tonkin Z, Yen JDL, Sunnucks P 2017, 'Severe consequences of habitat fragmentation on genetic diversity of an endangered Australian freshwater fish: A call for assisted gene flow', *Evolutionary Applications*, 10(6), pp. 531-550.

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:04C Trend in population number and distribution of Murray crayfish *(Euastacus armatus)*			 DATA QUALITY Fair
Data custodian DELWP			

The Murray crayfish occurs in the southern Murray–Darling Basin, south-east Australia. It is the second largest freshwater crayfish in the world, growing up to 0.5 m in length and 3 kg in weight and living to 25 years or more.[74] Commercial harvest of this species stopped in 1987 but there is an active recreational fishery. The cumulative pressures from recreational harvesting, river regulation, pesticides and pollutants, habitat change and events of low dissolved oxygen (hypoxic 'blackwater' disturbance) have contributed to declines in both its distribution and abundance. It is now considered a threatened species.[75]

A population viability model for the Murray crayfish assessed the potential effects of a population decline due to the occurrence of a hypoxic blackwater event and the effects of recreational fishing. Results highlighted that Murray crayfish face high risk of population declines due to increasing fishing pressure, particularly when combined with a hypoxic blackwater event. By testing various fishery regulations (such as length limits), the modelling showed that recent changes to the harvestable length limit (10–12 cm, occipital carapace length) for legally harvesting crayfish appears to be a suitable protection measure, given background levels of blackwater disturbance. While the modelling was based on the best available information, some parameters are uncertain due to lack of knowledge associated with survival rates of young crayfish.

74 Todd CR, Whiterod N, Raymond SMC, Zukowski S, Asmus M, Todd MJ 2018, 'Integrating fishing and conservation in a risk framework: a stochastic population model to guide the proactive management of a threatened freshwater crayfish', *Aquatic Conservation: Marine and Freshwater Ecosystems,* 28, pp.954-968.

75 Ibid

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
B:04D Trend in population number and distribution of spotted tree frog *(Litoria spenceri)*	○	●	○	○	↘	DATA QUALITY Good

Data custodian DELWP

The spotted tree frog is currently listed as endangered nationally (*Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)) and at state level (FFG Act). It occurs in upland streams of south-eastern Australia. A main driver for decreasing population numbers is the infectious disease chytridiomycosis, caused by the temperature sensitive chytrid fungus *Batrachochytrium dendrobatidis*.[76] Another driver is the introduction of predatory fish, specifically the brown trout (*Salmo trutta*) and rainbow trout (*Onchorhynchus mykiss*) predating on tadpoles of this species.[77]

76 DEE 2016, 'Threat abatement plan for infection of amphibians with chytrid fungus resulting in chytridiomycosis', Australian Government, Commonwealth of Australia.

77 Gillespie GR 2001, 'The role of introduced trout in the decline of the spotted tree frog (*Litoria spenceri*) in south-eastern Australia', *Biological Conservation*, 100, pp.187-198.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
B:04E Trends in population number and distribution of Booroolong tree frog *(Litoria booroolongensis)*	○	●	○	○	↘	DATA QUALITY Good

Data custodian DELWP

The Booroolong tree frog is currently listed as endangered nationally (EPBC Act) and at state level (FFG Act). It occurs predominantly in streams west of the Great Dividing Range in Victoria. Populations have declined due to habitat degradation, the infectious disease chytridiomycosis and predation by introduced predatory fish, such as European carp (*Cyprinus carpio*), redfin perch (*Perca fluviatilis*) and mosquito fish (*Gambusia hobrooki*) predating on tadpoles of this species.[78,79]

78 Hunter DA, Smith MJ, Scroggie MP, Gilligan D 2011, 'Experimental examination of the potential for three introduced fish species to prey on tadpoles of the endangered Booroolong frog, *Litoria booroolongensis*', *Journal of Herpetology*, 45(2), pp.181–185.

79 DEE 2016, 'Threat abatement plan for infection of amphibians with chytrid fungus resulting in chytridiomycosis', Australian Government, Commonwealth of Australia.

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
B:04F Trends in population number and distribution of Baw Baw frog *(Philoria frosti)* Data custodian DELWP	○	●	○	○	↘	DATA QUALITY Good

The Baw Baw frog is the only Victorian endemic frog species. It is currently listed as endangered nationally (EPBC Act) and at state level (FFG Act). Reasons for decline in population numbers and distribution include habitat loss and degradation of their restricted range on the Baw Baw plateau and escarpment area (totalling only 135 km^2), and spread of the infectious disease chytridiomycosis.

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:05 Threatened species that are wetland dependent		?	 DATA QUALITY Poor

Data custodian DELWP

Wetlands are defined as natural, modified or artificial areas subject to permanent or temporary inundation that hold static or very slow-moving water and develop, or have the potential to develop, biota adapted to inundation and the aquatic environment.[80] Data for five fauna groups (Table B.3), based on the Threatened Species Advisory Lists for Victoria, has been used as a proxy for the percentage of Victoria's threatened species that are wetland-dependent.

Table B.3 Number of wetland-dependent threatened species as per the Advisory Lists for Victoria[81]

Fauna group	***n* (%)**
Mammals	1 (2%)
Birds	54 (42%)
Reptiles	7 (15%)
Amphibians	13 (72%)
Fish	13 (39%)

80 DELWP 2018, 'Wetlands', https://www.water.vic.gov.au/waterways-and-catchments/rivers-estuaries-and-waterways/wetlands Accessed 9 September 2018.

81 DEPI 2014, 'Advisory list of rare or threatened plants in Victoria – 2014', Melbourne, Victoria.
DEPI 2013, 'Advisory list of threatened vertebrate fauna – 2013', Melbourne, Victoria.
DEPI 2009, 'Advisory list of threatened invertebrate fauna in Victoria – 2009', Melbourne, Victoria.

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
B:06 Trends in populations and distributions of threatened terrestrial species Data custodian DELWP	○	●	○	○	↘	 DATA QUALITY Poor

The following SoE 2018 biodiversity indicators have been aggregated to inform the status of terrestrial threatened species:

- conservation status of terrestrial threatened species – measuring changes in the status of threatened terrestrial species
- trends in population and distribution of selected threatened terrestrial species over time
- threatening processes impacting and affecting terrestrial threatened species.

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:06A Vascular Plants			 DATA QUALITY Fair

Data custodian DELWP

There has been an increasing trend in the number of endangered, vulnerable and rare vascular plants in Victoria. Of the 3,330 known Victorian species, 49 are extinct and 2,097 (63%) are on the Threatened Species Advisory Lists.[82]

Table B.4 Increasing number of vascular plants on the Advisory Lists for Victoria 2003–14[83]

Year	Presumed extinct	Endangered	Vulnerable	Rare	Poorly known	Total
2003	48	250	473	818	311	1,900
2005	51	280	493	834	305	1,963
2014	49	366	516	854	318	2,103

82 DEPI 2014, 'Advisory list of rare or threatened plants in Victoria – 2014', Melbourne, Victoria
83 Ibid

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:06B Vertebrates			 DATA QUALITY
Data custodian DELWP			Fair

There has been an increasing trend in the number of critically endangered and vulnerable vertebrate groups, specifically reptiles. To a lesser extent, there has been an increase in the number of endangered vertebrates. Of the known species, those that are threatened include: 22% terrestrial mammals, 19% birds, 30% reptiles and 43% amphibians.[84]

Table B.5 Number of vertebrates on the Advisory Lists for Victoria 2003–13[85]

Year	Extinct	Regionally extinct	Extinct in the wild	Critically endangered	Endangered	Vulnerable	Near-threatened	Data deficient	Total
2003	10	14	-	37	53	70	71	20	275
2007	9	15	-	37	52	72	68	24	277
2013	9	15	1	50	57	84	64	14	294

84 DEPI 2013, 'Advisory list of threatened vertebrate fauna – 2013', Melbourne, Victoria.
85 Ibid

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:06C Invertebrates			 DATA QUALITY
Data custodian DELWP			Fair

There is limited trend information on the number of threatened invertebrates, where currently 178 known species are considered to be threatened.[86]

Table B.6 Number of invertebrates on the Advisory Lists of threatened invertebrate fauna for Victoria, 2009[87]

Year	Extinct	Regionally extinct	Extinct in the wild	Critically endangered	Endangered	Vulnerable	Near-threatened	Data deficient	Total
2009	1	5	0	20	28	79	7	38	178

In 2016, the State Government funded $2 million across 98 projects in Round Two of the Threatened Species Protection Initiative Community Volunteer Action Grants. At the time of writing this report, the results from these projects were not available.

DELWP is also participating in a research project under the National Environmental Science Program that aims to develop a prototype Threatened Species Index for Australia. The research partners, led by University of Queensland and Birdlife Australia, have already developed a 'proof of concept' index for birds and are now expanding their focus to consider other groups. The index would be accessible via an interactive, web-based application, allowing users to display trend data for particular regions and/or groups of species. The index is based on the methods of the Living Planet Index and incorporates multiple time-series datasets for species populations. A key feature is the ability to combine datasets based on differing parameters and survey methods into one index.

86 DEPI 2009, 'Advisory list of threatened invertebrate fauna in Victoria – 2009', Melbourne, Victoria.
87 Ibid

Protecting Victoria's Biodiversity

This theme will report on the management for protecting and conserving Victoria's biodiversity on both Crown and private land.

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:07 Private Land Conservation	○ ○ ● ○	↗	DATA QUALITY: Good
Data custodian Trust for Nature			

Two biodiversity indicators from previous SoE reports have been combined for this report:

- conservation on private land – assessing the area of private land under conservation agreements
- management of biodiversity on private land, assessing activities taken to conserve species, conserve communities and maintain, improve or restore habitat on private land.

It should be noted that data from this indicator can also contribute to *Biodiversity 2037* indicators – Net gain in extent and condition of native vegetation, Landscape scale change, Change in suitable habitat, Area of management in priority locations and Victorians valuing nature – where private land conservation contributes to environmental stewardship.

Victoria has nearly 23 million hectares of land, public land accounts for 37% and private land 63%.[88] Private land conservation data reported here has been provided by Trust for Nature (the Trust). Other private land conservation agreement types – such as Bush Tender, Bush Heritage and Land for Wildlife – are not reported here as data was not available. Since its establishment under the *Victorian Conservation Trust Act 1972*, the Trust has assisted with the permanent protection of more than 100,000 hectares of native habitat on private land using a range of conservation tools including conservation covenants, land acquisition, donations of land and its Revolving Fund (Figure B.3).[89] At the time of writing this report, there were 1,416 voluntary conservation covenants and 43 Trust for Nature properties and/or reserves.

Results from on-ground management actions include:

- 3,700 hectares of weed control
- 68,000 hectares of invasive animal control
- more than 135 ecological surveys and assessments mostly for threatened species

The Trust's current strategic plan commits to an additional 50,000 hectares of permanent protection by 2021, in its own right and with partners. This target closely aligns with *Biodiversity 2037*, which includes a target to protect 200,000 hectares on private land in the next 20 years. Since 2000–01, the Trust has seen an average annual growth of 57 covenants and 2,654 hectares under permanent protection (Figure B.4).

88 VEAC 2016, 'Statewide assessment of public land discussion paper', East Melbourne, Victoria.

89 Trust for Nature 2018, 'Impact Report 2017-18. Conserving Melbourne, Victoria's most threatened native plants and wildlife for future generations', https://issuu.com/tfnvictoria/docs/tfn3979_2018impactreport_web?e=33399755/65188052 Accessed 24 October 2018.

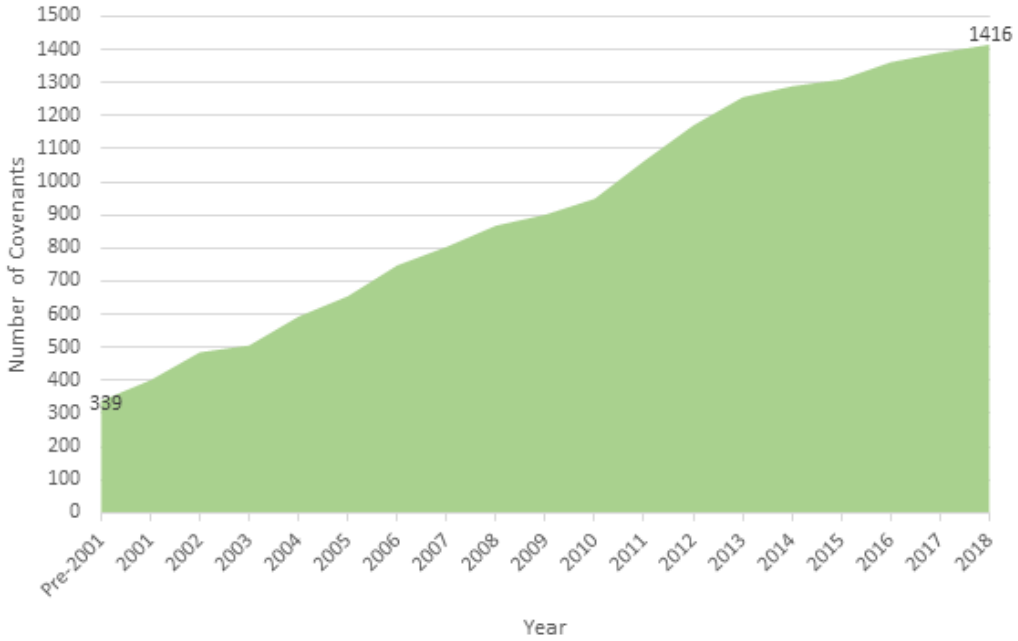


Figure B.3 Growth in the total number of private land covenants, 2001–18

(Data source: TfN, 2018)

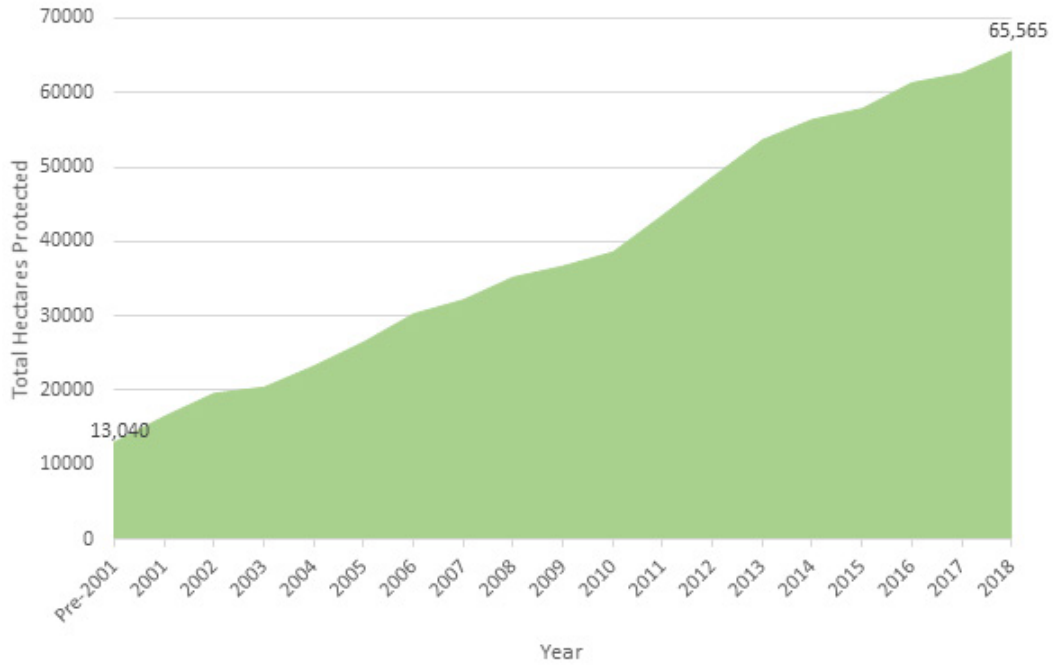


Figure B.4 Growth in total hectares of private land under covenant, 2001–18

(Data source: TfN 2018)

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:08 Conservation of Victorian Ecosystems			 DATA QUALITY
Data custodian Parks Victoria, DELWP			Good

This indicator assesses Victorian conservation categories, their area in hectares and threatened species in conservation areas. Of the Parks Estate, the top three conservation category types with the greatest area are:

1. National Parks with 2,908,941 hectares
2. Wilderness Parks (Schedule 2A, National Parks Act) with 262,480 hectares
3. State Park (Schedule 2B, National Parks Act) with 149,325 hectares [90]

These are illustrated in Table B.7.

90 Victorian conservation categories and their area have been obtained from VICGRID94 https://www.data.vic.gov.au/data/dataset/vicgrid94-graticule-1-km-interval Accessed August 20 2018.

Table B.7 Parks Estate conservation categories and their area in hectares

Category of conservation area	Area (ha)
Coastal Reserve	8,657.4
Education Area	9,715.9
Historic Reserve	36,001.1
Lighthouse Reserve	344.0
Marine National Park - Schedule 7, National Parks Act	52,244.5
Marine Sanctuary - Schedule 8, National Parks Act	864.2
Metropolitan Park	6,609.4
National Park - Schedule 2, National Parks Act	2,908,941.9
National Parks Act Schedule 4 park or reserve	76,857.1
Natural Features Reserve	3,300.0
Natural Features Reserve - Bushland Reserve	44,526.1
Natural Features Reserve - Cave Reserve	527.1
Natural Features Reserve - Geological Reserve	402.3
Natural Features Reserve - Gippsland Lakes Reserve	7,086.2
Natural Features Reserve - Highway Park	387.7
Natural Features Reserve - Lake Reserve	64,418.4
Natural Features Reserve - Natural Features and Scenic Reserve	8,491.5
Natural Features Reserve - River Murray Reserve	14,832.8
Natural Features Reserve - Scenic Reserve	9,263.0
Natural Features Reserve - Streamside Reserve	7,707.9
Natural Features Reserve - Wildlife Reserve (hunting)	63,852.0
Natural Features Reserve - Wildlife Reserve (State Game Reserve classification pending reservation)	16,914.6
Nature Conservation Reserve	131,108.0
Nature Conservation Reserve - Flora and Fauna Reserve	101,388.7
Nature Conservation Reserve - Flora Reserve	19,333.6
Nature Conservation Reserve - Wildlife Reserve (Nature Conservation Reserve classification pending reservation)	947.0
Nature Conservation Reserve - Wildlife Reserve (no hunting)	8,950.6
Other	29,181.7
Other Park - Schedule 3, National Parks Act	68,934.3
Port & Coastal Facility	553.9
Proposed National Parks Act park or park addition	10,254.7
PV Management Services Agreement Other Land	1,249.3
Regional Park - not scheduled under National Parks Act	51,860.4
Reservoir Park	465.3
State Park - Schedule 2B, National Parks Act	149,325.8
Wilderness Park - Schedule 2A, National Parks Act	200,699.4
Grand total	4,116,197.8

(Data source: VicGrid94)

The total number of threatened native Victorian plant and animal species in Parks Estate conservation areas[91] varies across advisory lists (Table B.8).

Table B.8 The total number of threatened native Victorian flora and fauna species, for various advisory lists, in Victorian Parks Estates[92]

	FFG Act	EPBC Act	DELWP Threatened Species Advisory Lists
Fauna	222	98	313
Flora	334	127	1,702

For the Parks Estate, the top three endangered ecological vegetation divisions (EVDs) are high-altitude alpine sphagnum bogs and associated fens[93] (68.5%) followed by closed-forest (33%) and damp scrub (11%). The EVDs of least concern are lowan Mallee (69%), hummock-grass Mallee (65.7%) and broombush whipstick (57.6%) (Figure B.5). Bioregional threat status determines how EVDs' conservation statuses are defined. Due to the large number of ecological vegetation classes (EVCs) in Victoria and the challenge of graphing them in a meaningful way for SoE 2018, EVDs were applied for this indicator's assessment.

Outside of Parks Victoria managed estate, there are a number of EVCs protected on Crown and private land through permanent protection mechanisms, for example Trust for Nature Covenants, Section 69 and Indigenous Protected Areas. At the time of writing this report, DELWP was updating this EVC extent map and bioregional conservation status based on new native vegetation extent mapping. It is intended that this update be available towards the end of 2019.

The 2017 VEAC Statewide Assessment of Public Land found that native vegetation is a key indicator for the overall state of terrestrial biodiversity. Approximately 45% (11.2 million hectares) of Victoria's original coverage of native vegetation remains. This consists mostly of native trees (92%), which occur in large connecting blocks in Victoria's east and north-west.[94]

This assessment also identified Victorian areas where there is a concentration of poorly represented EVCs on public land outside of current protected areas. The top three Victorian areas with poor EVC representation include Strzelecki Ranges and Gippsland Plains, South West Victoria, and Central Victorian Uplands.[95] The VEAC report identified that rainforest is rare in Victoria, where only 80% of the original 50,500 hectares remains.[96] Additionally, the 2011 VEAC Remnant Native Vegetation Investigation found that used and unused road reserves and rail reserves support a significant proportion of native vegetation in Victoria's fragmented landscapes. These linear reserves make a major contribution to ecological connectivity and in some landscapes provide key habitat for many species.[97]

91 Note: Parks Estate conservation areas applying VicGrid94 spatial delineation.
92 Ibid
93 High altitude alpine sphagnum bogs and associated fens are referred to as high altitude wetlands in Figure B.5.
94 VEAC 2017, 'Statewide assessment of public land final report', Melbourne, Victoria.
95 VEAC 2017, 'Statewide assessment of public land supplement to the discussion paper. Melbourne, Victoria. Note: an extensive list of under-represented EVCs can be found in Table 4.1 on page 23.
96 Ibid
97 VEAC 2011, 'Remnant native vegetation investigation final report', Melbourne, Victoria.

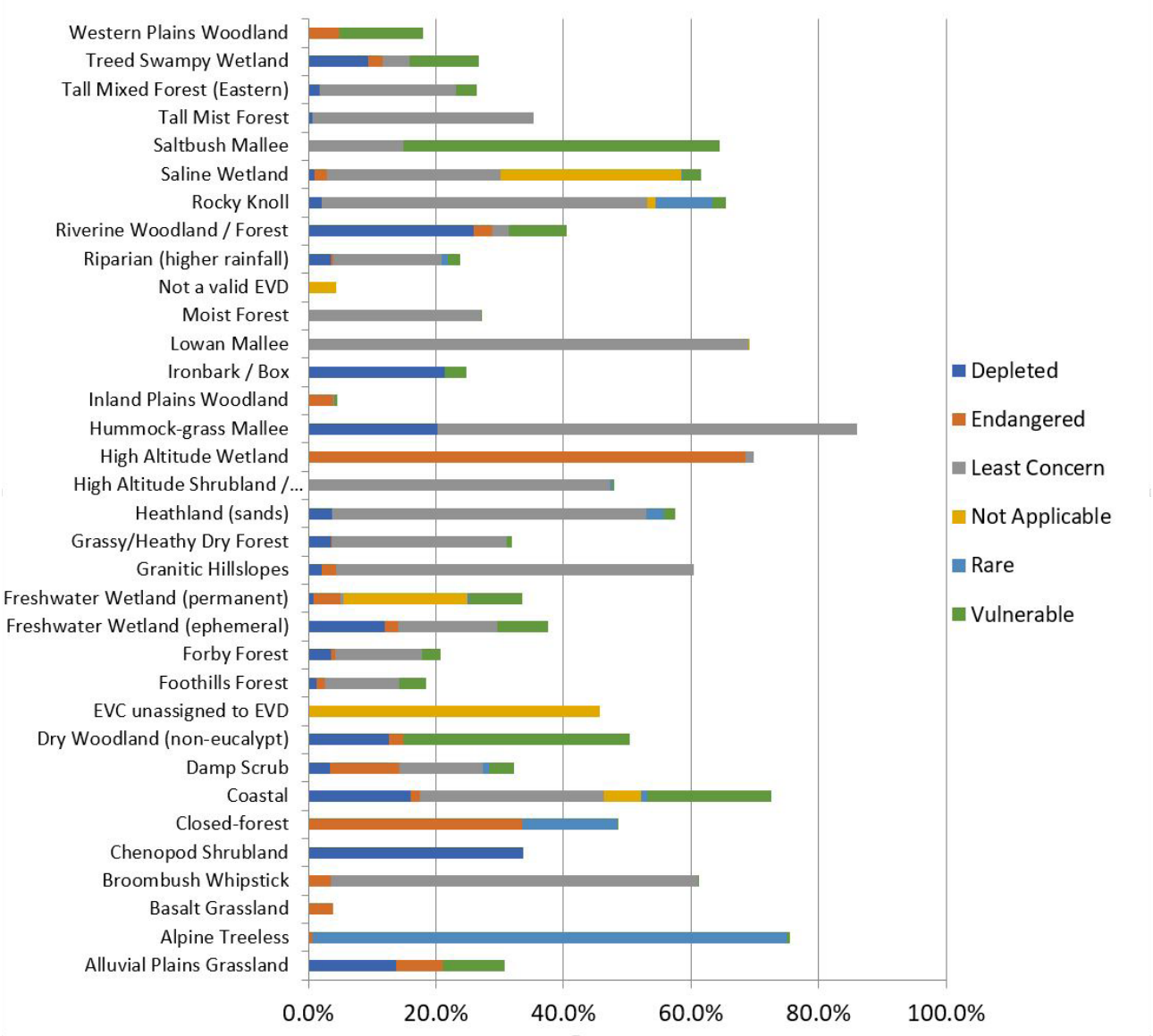


Figure B.5 Current state of EVDs for Parks Estate defined by bioregional threat status

(Data source: Parks Victoria 2018)

Freshwater Biodiversity

This theme will report on freshwater ecosystem health and management. Freshwater ecosystems are defined here as all terrestrial aquatic systems including rivers (streams, creeks and tributaries) lakes, wetlands and ponds that are not estuarine or marine (see Marine and Coastal Environments chapter). Freshwater ecosystems support environmental values such as native animals (including fish, riparian vegetation, bird habitat and drought refuges) and provide habitat for rare and threatened species. These freshwater systems provide water for food and energy production, purify drinking water, provide spaces for recreation and play an important role in flood and erosion control. For an assessment of water quality and resources, refer to the Water Quality and Water Resources chapters.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
B:09 River Health						 DATA QUALITY
Data custodian DELWP						Good

Biodiversity indicators from previous SoE reports have been combined for this report:

- river health
- percentage of major rivers that remain in a near pristine or largely unmodified state
- assessment of freshwater biodiversity information
- area of management in priority locations
- restoration of habitat

The indicators have been combined because, since the publication of SoE 2013, no updated Index of Stream Condition (ISC) data is available to inform them. The ISC provides a snapshot, informed by trends, across the following datasets:

- aquatic macroinvertebrates
- streamside zone vegetation
- the river channel
- water quality and quantity.

The next ISC data analysis is due to be completed in 2028.

The lack of data to inform this report is due to the shift in the ISC's monitoring regime from every 6 years to every 12 years. The reduced frequency of ISC statewide assessments is due to a redesign and implementation of monitoring programs that can detect ecological change at scales relevant to waterway management. The previous three ISC assessments (1999, 2004 and 2010) indicated that overall stream condition had remained largely stable across Victoria during that period.[98]

Two other assessments that provide information on Victorian river health are the 2001 national Assessment of River Condition (ARC) program and the national Assessment of River Condition and River Monitoring and Assessment Program (RiverMAP).

98 DEPI 2010, 'Index of stream condition: The third benchmark of Victorian river condition', Melbourne, Victoria.

ARC found that 79% of Victorian river lengths have been moderately or substantially modified, due to: catchment disturbance, hydrological disturbance, habitat and nutrient/suspended sediment load.[99] Of these Victorian rivers, 33% were observed to have damage to biological (macroinvertebrate) communities.[100] Rivers in catchments with agricultural activity are affected by added stressors, such as elevated nutrient concentration, increased inputs of fine sediments and pesticides, alterations in flow regimes and disturbances to the riparian habitat.[101] Degradation of Victorian rivers and streams, and loss of freshwater biodiversity is a result of growing human populations and expanding land use.[102]

Similarly, RiverMAP found that Victorian river health was influenced by grazing, land clearing for agriculture, timber production and urban development causing disturbance to natural river drivers.[103] Disturbances cause river health issues such as increased sedimentation, runoff, nutrient and pollutant loads, removal and/or reductions of riparian vegetation and loss of in-stream habitat for aquatic biota.[104]

99 EPA 2016, 'River monitoring and assessment program (RiverMAP): river health modelling project technical report;, Melbourne, Victoria.
100 Norris RH, Prosser I, Young B, Liston P, Bauer N, Davies N, Dyer F, Linke S, Thoms M, 2001, 'The assessment of river conditions (ARC): An audit of the ecological condition of Australian rivers', Cooperative Research Centre for Freshwater Ecology, University of Canberra; Commonwealth Scientific and Industrial Research Organisation, Division of Land and Water, Canberra.
101 Allan JD 2004, 'Landscapes and riverscapes: the influence of land use on stream ecosystems', Annual Review of Ecology, Evolution and Systematics, 35, pp.257-84.
102 Strayer DL, Dudgeon D 2010, 'Freshwater biodiversity conservation: recent progress and future challenges', The North American Benthological Society, 29(1), pp.344-358.
103 EPA 2016, 'River monitoring and assessment program (RiverMAP): river health modelling project technical report, Melbourne, Victoria.
104 Ibid

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:10 Riparian Vegetation Habitat Extent		?	 DATA QUALITY
Data custodian DELWP			Poor

Riparian refers to the land and vegetation that adjoins a freshwater system such as a river, creek or wetland. The national ARC in 2001 identified that riparian zones have been extensively degraded in Victoria.[105,106] Between 25 and 28% of Victorian river lengths have substantially to severely modified riparian condition.[107,108] Results of the SoE Report 2013 highlighted that 21 of 29 river basins had less than 50% of assessed river length with riparian vegetation in good condition. Removal of riparian vegetation impacts terrestrial and aquatic food webs by reducing the inputs of food in forms of leaves, branches, and terrestrial invertebrates into the aquatic system, and by limiting the availability of prey from the aquatic environment to terrestrial predators such as spiders, birds and bats.[109] Riparian vegetation removal also has downstream impacts on estuarine and marine ecosystems.

Riparian zone removal and degradation in Victoria is due to agricultural activity that occurs alongside rivers and the channelisation of drainage (through drainage channels) from agriculture and urban land rather than using naturally-formed stream channels. This has resulted in a decreased ability of the stream network to retain flow and hold and transform nutrients and organic matter to prevent their input into downstream river ecosystems.[110]

A reduced dependence on streams to drain water also results in the loss of critical habitat and breeding habitat for amphibians, some fish and many macroinvertebrates.[111] Riparian habitat loss is also linked to natural increased light levels due to vegetation loss, nutrient concentration and water temperature, all of which are associated with increased algal production and changes in autotroph assemblages (organisms that can produce their own food using light, water, carbon dioxide or other chemicals).[112] Under certain circumstances, these changes can lead to toxic algal blooms which can pose a risk to both freshwater plants and animals and human health.[113]

The Riparian Intervention Monitoring Program led by DELWP in partnership with the Arthur Rylah Institute, Victorian Catchment Management Authorities and Melbourne Water aims to understand how riparian systems change in response to management for various sites across Victoria.[114] Developed in 2014, this program assesses vegetation condition and bank stability at intervention sites where management actions are planned and implemented and at similar control sites where no management actions are carried out. Comparing changes that occur at intervention sites with those that occur at control sites will inform:

- the degree of change that is due to management actions
- the length of time it takes for condition to change
- understanding on variability in changes in response to management actions.

105 Norris RH, Prosser I, Young B, Liston P, Bauer N, Davies N, Dyer F, Linke S, Thoms M, 2001, 'The assessment of river conditions (ARC): An audit of the ecological condition of Australian rivers', Cooperative Research Centre for Freshwater Ecology, University of Canberra; Commonwealth Scientific and Industrial Research Organisation, Division of Land and Water, Canberra.
106 EPA 2016, 'River monitoring and assessment program (RiverMAP): river health modelling project technical report;, Melbourne, Victoria.
107 Ibid
108 Norris RH, Prosser I, Young B, Liston P, Bauer N, Davies N, Dyer F, Linke S, Thoms M, 2001, 'The assessment of river conditions (ARC): An audit of the ecological condition of Australian rivers', Cooperative Research Centre for Freshwater Ecology, University of Canberra; Commonwealth Scientific and Industrial Research Organisation, Division of Land and Water, Canberra.
109 Ibid
110 Ibid

111 Ibid
112 EPA 2016, 'River monitoring and assessment program (RiverMAP): river health modelling project technical report;, Melbourne, Victoria.
113 Ibid
114 ARI 2018, 'Riparian ntervention monitoring program fact sheet', Heidelberg, Victoria. https://www.ari.vic.gov.au/__data/assets/pdf_file/0025/72754/RIMP-overview-fact-sheet-2017.pdf Accessed 27 July 2018.

Riparian Intervention Monitoring Program management actions can be a single intervention (such as livestock exclusion) or a combination intervention (such as livestock exclusion, revegetation and weed management). The riparian attributes that are monitored to determine effectiveness of management actions include: invasive vegetation cover and stem density, native vegetation cover and composition, bare ground and litter cover, vegetation structure, recruitment of native trees and shrubs, native vegetation extent and continuity, and bank stability. To date, 12 sites have been monitored across Victoria after three years of management action. Prior to management action, these sites were generally of poor riparian condition. Changes across all 12 sites after three years of management action include:[115]

- total native vegetation cover increased by approximately 2-fold
- native species richness increased by approximately 1.5-fold
- planted and natural woody recruits increased by approximately 9-fold
- woody weed abundance decreased to almost zero at most sites
- bare ground cover did not increase as compared to unmanaged sites.

Future site monitoring over the next five to eight years (medium term) and greater than ten years (long-term) will determine whether improvement in vegetation condition at this early stage will be maintained over time or deteriorate over time due to pressures such as weed invasion.

A preliminary program of re-capture and assessment of Light Detection and Ranging data over the 2018–19 summer will be conducted by DELWP to estimate change in Riparian and Physical Form measures. Metrics will include: large trees, tree cover, shrub cover, vegetation structure, vegetation overhang, riparian fragmentation, vegetation width and geomorphic change. These results will form a subset of the ISC 2028 data (making up approximately 12% of the total data) to assess change from the ISC 2010 data. Preliminary results will also be available in late 2019.

115 DELWP 2018, 'Riparian intervention monitoring program (RIMP): early signs of improved riparian condition following management. fact sheet', Melbourne, Victoria.

Indicator	Status	Trend	Data Quality
B:11 Area of functional floodplain		?	
Data custodian DELWP			Poor

This SoE 2018 indicator assesses change to floodplain area as a natural approach to mitigate and reduce the risk of flood and drought impacts and provide refuge to plants and animals during extreme weather events. Future predictions under climate change suggests an increasing intensity and frequency of floods and drought. Strengthening the capacity of ecosystems to deal with climate extremes is a key management strategy for minimising the adverse effects of climate change on flora and fauna.[116] Floodplains are potential drought refuges as they:[117]

- are cooler
- have localised microclimates compared to adjacent areas
- have greater water availability through groundwater and flooding.

An example is the Murray–Darling Basin, where floodplains with high vegetation productivity have greater resistance to climate change impacts such as drought.[118,119] Protecting floodplains by maintaining vegetation productivity and condition through environmental watering and ecological restoration can enhance the system's resistance to more frequent and severe climate change threats.[120] The black box (*Eucalyptus largiflorens*) woodlands situated in the floodplains along the Murray River has received different flooding regimes (a mixture of natural flooding and environmental watering) between 1993 and 2018 across different sites.[121] Examining the effects of different flooding regimes found that frequently flooded sites (due to environmental watering and natural flooding) were healthier, with greater canopy foliage cover and canopy extent, greater growth of new leaf tips, and greater reproductive output (buds, flowers and fruits). At frequently flooded sites there was a greater range of life stages present with more saplings and seedlings, and fewer dead trees. At sites that had not been flooded for over 23 years, no seedlings or saplings were recorded, suggesting that the structure of the black box woodland is not sustainable under these conditions. These results suggest that flooding, using environmental water, is important in maintaining the health of black box woodlands and their value for native flora and fauna. The challenge for using environmental watering to achieve such flooding is to determine an optimal regime including the timing, frequency and duration of managed flood events.

Although the Murray River black box woodlands is a good example of protecting floodplains, a statewide assessment for this indicator could not be completed. This is due to a lack of statewide data on functional floodplain areas and how they are changing over time associated with land use and climate change pressures.

116 Selwood KE, McGeoch MA, Clarke RH, Mac Nally R 2018, 'High-productivity vegetation is important for lessening bird declines during prolonged drought', *Journal of Applied Ecology*, 55, pp.641-650.
117 Selwood KE, Thomson JR, Clarke RH, McGeoch MA, Mac Nally R 2015, 'Resistance and resilience of terrestrial birds in drying climates: do floodplains provide drought refugia?', *Global Ecology and Biogeography*, 24, pp.838-848.
118 Selwood KE, McGeoch MA, Clarke RH, Mac Nally R 2018, 'High-productivity vegetation is important for lessening bird declines during prolonged drought', *Journal of Applied Ecology* 55, pp.641-650.
119 Selwood KE, Thomson JR, Clarke RH, McGeoch MA, Mac Nally R 2015, 'Resistance and resilience of terrestrial birds in drying climates: do floodplains provide drought refugia?', *Global Ecology and Biogeography*, 24, pp.838-848.
120 Ibid

121 Moxham C, Duncan M, Moloney P 2018, 'Tree health and regeneration response of Black Box (*Eucalyptus largiflorens*) to recent flooding', *Ecological Management & Restoration*, 19, pp. 58-65.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
B:12 Distribution and abundance of frogs	○	●	○	○	↘	DATA QUALITY
Data custodian DELWP						Good

There have been declines in the population number of native frog species (threatened and non-threatened species) over the past few decades.[122] There are 37 amphibian species in Victoria, with 17 frog species listed as threatened, excluding species for which data is insufficient to assess the extinction risk.[123] Approximately 86% of Victorian frog species are dependent on permanent or ephemeral wetlands to complete their life cycle. Of these wetland-dependent species, 7 frogs are listed as threatened (Table B.9). In the last 20 years, the number of threatened frog species on the FFG Act list has doubled.[124]

Threats facing Victorian frog populations include: climate change (and associated issues, such as droughts, increasing frequency of large fires and change in long-term temperatures), elevated predation rates due to feral terrestrial and aquatic predators, habitat destruction, degradation and the impacts of exotic herbivores on frog breeding habitats. The main driver for decreasing frog population numbers is the infectious disease chytridiomycosis, caused by the temperature-sensitive chytrid fungus *Batrachochytrium dendrobatidis*.[125,126] This fungus is capable of causing sporadic deaths in some populations and 100% mortality in other populations.[127] The disease was introduced in Australia in the 1970s and has been recorded in four regions including the east coast. A threat abatement plan was developed to address this key threatening process under the Commonwealth EPBC Act.[128] Poor advice and planning in matters such as putative mitigation strategies and biodiversity trading also contributes to declines and losses of threatened frog populations.[129] Current ongoing research has found that some native frog species, such as the common eastern froglet (*Crinia signifera*), are hosts to the chytrid fungus and are sustaining the ongoing impact of this disease by transmitting it to declining threatened species populations.[130] This has implications for trying to reintroduce locally extinct species as they will be susceptible to the fungus with reintroductions unlikely to be effective.

122 Hunter DA, Smith MJ, Scroggie MP, Gilligan D 2011, Experimental examination of the potential for three introduced fish species to prey on tadpoles of the endangered Booroolong frog *Litoria booroolongensis*', *Journal of Herpetology*, 45(2), pp.181-185.
123 Morris K 2012, 'Wetland connectivity: understanding the dispersal of organisms that occur in Victoria's wetlands', Arthur Rylah Institute for Environmental Research Technical Report Series No.225, Heidelberg, Victoria.
124 Clemann N 2015, 'Cold-blooded indifference: A case study of the worsening status of threatened reptiles from Victoria, Australia', *Pacific Conservation Biology*, 21, pp.15-26.
125 DEE 2016, 'Threat abatement plan for infection of amphibians with chytrid fungus resulting in chytridiomycosis', Department of Environment and Energy, Australian Government, Commonwealth of Australia.
126 Skerratt LF, Berger l, Clemann N, Hunter DA, Marantelli G, Newell DA, Philips A, McFadden M, Hines HB, Scheele BC, Brannelly LA, Speare R, Versteegen S, Cashins SD, West M 2016, 'Priorities for management of chytridiomycosis in Australia: saving frogs from extinction', *Wildlife Research*, 43(2), pp.105-120.
127 Ibid
128 Ibid
129 Ibid
130 Brannelly LA, Webb RJ, Hunter DA, Clemann N, Howard K, Skerratt LF, Berger l, Scheele BC 2017, 'Non-declining amphibians can be important reservoir hosts for amphibian chytrid fungus', *Animal Conservation*, 21, pp.91-101.

Table B.9 Threatened Victorian frog species that are wetland-dependent for completing their life cycle[131]

Common name	*Species name*
Giant bullfrog	*Limnodynastes interioris*
Alpine tree frog	*Litoria verreauxii alpina*
Baw Baw frog	*Philoria frosti*
Growling grass frog or southern bell frog	*Litoria raniformis*
Giant burrowing frog	*Heleioporus australiacus*
Green and golden bell frog	*Litoria aurea*
Rugose toadlet	*Uperoleia rugosa*

Frogs rely on water for reproduction and some species move hundreds of metres away from water to forage and find shelter. Over winter, shelter sites can be considerable distances from water. The terrestrial elements of frog habitat, and connectivity between aquatic and terrestrial elements of these habitats, are important for maintaining frog populations. The habitat boundary for some Victorian frog species may be 300–1,000 m beyond the wetland perimeter.[132]

In temperate landscapes the prevalence and diversity of amphibians declines where the distances among wetlands is large, road densities are high, or habitats are surrounded by agriculture or other intensive land uses.[133] All these factors decrease the capacity of amphibians to move between habitats and maintain populations across multiple habitats.[134]

131 Morris K 2012, 'Wetland connectivity: understanding the dispersal of organisms that occur in Victoria's wetlands', Arthur Rylah Institute for Environmental Research Technical Report Series No.225, Heidelberg, Victoria.
132 Ibid
133 Ibid
134 Ibid

Indicator	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
B:13 Distribution and abundance of fish	○	●	○	○	↘	 DATA QUALITY Good

Data custodian DELWP

This indicator assessment was informed by fish data from Victorian rivers that receive environmental watering, also referred to as regulated rivers. Data was obtained from the Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP) Stage 5[135] and Stage 6[136] reports. VEFMAP Stage 5 incudes 2004–16 monitoring results across nine regulated river systems: the Goulburn, Campaspe, Loddon, Broken, Thomson, Glenelg, Macalister, Yarra and Wimmera. VEFMAP Stage 6 monitoring results from 2016–17 focused on:

- coastal rivers – Barwon, Werribee, Bunyip, Tarwin, Glenelg and Thomson Rivers and Cardinia Creek
- northern rivers – Murray, Campaspe, Goulburn, Loddon and Broken Rivers, Little Murray River and Pyramid Creek.

Further VEFMAP Stage 6 monitoring will continue to take place in 2018–19, with a full analysis and program evaluation in 2020.

Monitoring of these rivers provides data on environmental responses to environmental watering. Both VEFMAP Stage 5 and Stage 6 fish data results were linked to regional environmental flow delivery schedules to:

- understand the relationship between environmental flows and native fish species population demography, dispersal and immigration
- understand if environmental flow management used for large-bodied fish species enhance their survival, abundance and distribution[137]
- enable DELWP and its water-delivery partners to demonstrate the ecological value of environmental water management to the community and water industry stakeholders[138]
- fill knowledge gaps to improve planning, delivery and evaluation of environmental water management in regulated rivers across Victoria
- examine the importance of environmental flows in promoting immigration, dispersal and subsequent recruitment of diadromous fish (fish that spend portions of their life cycles partially in fresh water and partially in salt water) in coastal rivers, specifically for Stage 6.[139,140]

135 DELWP 2018, 'Victorian environmental flows monitoring and assessment program – Stage 5 report', Melbourne, Victoria.
136 DELWP 2017, 'VEFMPA stage 6 project update 2017. Fish study – northern Victoria rivers', Melbourne, Victoria.
DELWP 2017, 'VEFMAP stage 6 Part A: program context and rationale', Melbroune, Victoria.
137 DELWP 2017, 'VEFMPA stage 6 project update 2017. Fish study – northern Victoria rivers', Melbourne, Victoria.
138 DELWP 2017, 'VEFMAP stage 6 Part A: program context and rationale', Melbourne, Victoria.
139 Ibid
140 DELWP 2017, 'VEFMAP stage 6 project update 2017. Fish study southern Victorian rivers', Melbourne, Victoria.

VEFMAP Stage 5

The Stage 5 sampling period coincided with hydrological extremes across Victoria, including the millennium drought (1996–2010) and the major statewide floods of 2010–11. The final sampling period occurred before the winter/spring floods of 2016.[141] Across all sampling periods, seasonal and interannual variation influenced the abundance and biodiversity of all fish populations.

Monitoring outcomes reported 45 fish species across Victoria, of which 28 were native species that regularly inhabit inland aquatic ecosystems. Sampling included 127,646 individual fish with their weight equating to more than 15 tonnes. The native species catch was dominated by two species that are flow and habitat generalists: 36% Australian smelt and 15% flathead gudgeon.[142] (See Table B.10 for a full list of common and species names for inland aquatic fish reported in this indicator). Non-native fish dominated fish community composition. Non-native carp comprised on average 75% of the fish biomass, and up to 92% of the biomass in some rivers.[143] Eleven native fish species of conservation significance were collected: Macquarie perch, Murray cod, silver perch, golden perch, trout cod, freshwater catfish, Yarra pygmy perch, variegated pygmy perch, obscure galaxias, flat-headed galaxias and Australian grayling.[144]

141 DELWP 2018, 'Victorian environmental flows monitoring and assessment program – stage 5 report', Melbourne, Victoria.
142 Ibid
143 Ibid
144 Ibid

Table B.10 Common and species names for all native and non-native fish taxa reported in VEFMAP Stage 5 and 6 results

Native Victorian species	
Common name	**Species name**
Australian smelt	*Retropinna semoni*
Flathead gudgeon	*Philypnodon grandiceps*
Macquarie perch	*Macquaria australasica*
Murray cod	*Maccullochella peelii*
Silver perch	*Bidyanus bidyanus*
Golden perch	*Macquaria ambigua*
Trout cod	*Maccullochella macquariensis*
Freshwater catfish	*Tandanus tandanus*
Yarra pygmy perch	*Nannoperca obscura*
Variegated pygmy perch	*Nannoperca variegate*
Southern pygmy perch	*Nannoperca australis*
Estuary perch	*Percalates colonorum*
Obscure galaxias	*Galaxias oliros*
Flat-headed galaxias	*Galaxias rostratus*
Common galaxias	*Galaxias maculatus*
Australian grayling	*Prototroctes maraena*
Murray River rainbowfish	*Melanotaenia fluviatilis*
Carp gudgeon	*Hypseleotris spp.*
Mountain galaxias	*Galaxias olidus*
Unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*
Short-finned eel	*Anguilla australis*
Long-finned eel	*Anguilla reinhardtii*
River blackfish	*Gadopsis marmoratus*
Australian bass	*Percalates novemaculeata*
Short-headed lamprey	*Mordacia mordax*
Tupong	*Pseudaphritis urvillii*
Non-native species	
Common name	**Species name**
Carp	*Cyprinus carpio*
Gambusia	*Gambusia spp.*
Goldfish	*Carassius auratus*
Redfin	*Perca fluviatilis*
Oriental weatherloach	*Misgurnus anguillicaudatus*
Common roach	*Rutilus rutilus*

Statewide results found that the native fish community is degraded, with 24 of the 28 species caught comprising less than 5% of the total catch. At the landscape scale, Wimmera, Loddon and Campaspe native fish communities showed little signs of recovery, apart from Murray River rainbowfish.[145] Fish population trends varied across each regulated river system, but a common trend across all systems was non-native carp dominating the mean sampled catch. The Thomson had the highest native fish species richness (*n*=19) and the Campaspe had the lowest (*n*=9). Detailed results for each water system follow.

- **Broken:** Non-native fish dominated the sampling catch, with non-native carp comprising 20% of the mean annual catch, gambusia 10% and goldfish 9%. Carp gudgeon dominated the native fish catch, representing 30.6% of the mean annual catch followed by Murray River rainbowfish 9.6% and Australian smelt 5.6%.
- **Goulburn:** The native catch was strongly dominated by native Australian smelt (50% of the mean annual catch), followed by native carp gudgeon (16%). This was followed by non-native carp (15%). Four other non-native species were caught in relatively low numbers (≤ 1% of the mean annual catch).
- **Campaspe:** Native flathead gudgeon and carp gudgeon dominated the native catch (24% and 20% of the mean annual catch, respectively). Murray River rainbowfish comprised 6.7% of the mean annual catch and Australian smelt 3%. Of each non-native fish, carp represented 23% of the mean annual catch, redfin and gambusia 9% and goldfish 4%. As with many of the other rivers, fish biomass was dominated by non-native carp, which represented 85% of the mean biomass.
- **Loddon:** Native flathead gudgeon (21%) and carp gudgeon (12%) dominated the native fish mean catch. The non-native fish community was dominated by carp (28% of the mean catch) Gambusia, redfin, goldfish and oriental weatherloach were also collected (10%, 10%, 7% and 1% of the mean catch respectively). Non-native carp represented 74% of the mean total biomass catch.
- **Wimmera:** Flathead gudgeon and Australian smelt dominated the native catch (26% and 4% of mean catch respectively). Golden perch represented 2.7% of the mean annual catch (a maximum of 75 were caught in 2015–16) while relatively few carp gudgeon, silver perch, Murray cod, freshwater catfish, common galaxias and mountain galaxias were caught. No unspecked hardyhead and Murray River rainbowfish were caught in the monitoring period. Of the non-native species, carp were dominant, representing 29% of the mean catch, followed by gambusia (15%), redfin (11%) and goldfish (3%). Notably the Wimmera was the only inland catchment where native freshwater catfish were detected. Non-native Carp dominated the fish biomass in the Wimmera River representing 77% of the mean biomass.
- **Thomson:** Fish species richness was the highest compared to all other river systems. Australian smelt were dominant, representing 72% of the mean catch, followed by short-finned eels (3.4%). Native tupong and long-finned eels were also common (3% and 1.3% of the mean catch respectively). There were low catch numbers of river blackfish, Australian bass, short-headed lamprey and Australian grayling. Non-native carp and gambusia were abundant (8.7% and 3.7% of the mean catch, respectively). Non-native carp strongly dominated the fish biomass, representing 91% of the mean biomass.
- **Glenelg:** Species richness was also high in this river system. Flathead gudgeon dominated the native catch (31.4% of mean catch), followed by gambusia (30.6%). Variegated pygmy perch (10% of mean catch), river blackfish (5.9%) and southern pygmy perch (5.2%) were also reasonably common. There were lower catch numbers of common galaxias, obscure galaxias and estuary perch. With the exception of gambusia there were relatively low numbers of non-native fish. Carp comprised 36% of the mean fish sample biomass.

145 Ibid

- **Macalister:** Australian smelt strongly dominated the native catch (58% of the mean catch). Other native fish such as short-finned eels, tupong and long-finned eels were reasonably common – each representing 2% of the mean catch. There were low catch numbers of Australian bass, Australian grayling, common galaxias, estuary perch, river blackfish, short-headed lamprey and southern pygmy perch. Of the non-native fish, carp, gambusia and redfin were common at 16%, 9% and 4% of the mean catch, respectively. Carp comprised 92% of the mean fish sample biomass.
- **Yarra:** Australian smelt were strongly dominant, representing 49% of the mean catch, followed by short-finned eels (7.5%). Macquarie perch and common galaxias were also reasonably common, representing 7% and 5% of the mean catch respectively. There were low catch numbers of Australian bass, Australian grayling, river blackfish, short-headed lamprey and southern pygmy perch. Of the non-native fish species, carp were caught in large numbers and comprised 13% of the mean catch, followed by roach (8%) and redfin (4%).
- **Additional note on Glenelg, Thomson–Macalister and Yarra Rivers:** There was freshwater range expansion of native coastal river fish populations with a diadromous life-history (that is, they make obligatory movements between the sea/estuary and freshwater) due to improved connectivity and environmental flows, including:

  Glenelg – estuary perch and tupong

  Thomson–Macalister and Yarra – Australian grayling and tupong.

VEFMAP Stage 5 case studies focused on Australian grayling, silver perch and golden perch, with results informing future planning and management of water flows. Case study results found that:

- Longer-duration, moderate environmental flow events (for example, over five days) can change river hydrodynamics. This can potentially result in increased spawning of Australian grayling.
- Australian grayling spawning migration in the Bunyip, Thomson and Yarra systems was in response to environmental flow variations from prevailing conditions rather than flow events of a specific magnitude, indicating that even low flows can trigger downstream spawning movements. For fish species higher in the catchment, flow durations may need to be extended to enable fish to reach downstream spawning habitats.
- Bank-full spring flows, and flows within river channels, can lead to successful golden perch spawning without the need for over-bank flows in the Goulburn system. Low, stable flows do not result in golden perch spawning.
- Trends from a 20+ year dataset of the Torrumbarry Weir fishway demonstrated that juvenile golden perch and silver perch responded to small increases in summer river height by migrating upstream of the Murray system. There is potential for water managers to stimulate summer water rises in the Campaspe, Gunbower, Loddon and Goulburn to attract and enhance regional native fish communities.

Data quality was an issue with VEFMAP Stage 5 monitoring and assessment. Due to equipment operation, there was inconsistency in sampling techniques throughout the program, with marked variation in sampling techniques used across years, rivers and sites.[146] Future procedures will be required to ensure high-quality data is collected, as per the Sustainable River Audit protocols.[147]

Data was not analysed or modified to account for detection efficiency, differences between field teams, hydrological conditions or fieldwork timing. There were also numerous data entry errors and inconsistencies. For the Stage 5 analyses, these errors were subsequently corrected as much as possible by the VEFMAP database system administrator. Data quality and database reliability was an ongoing problem throughout VEFMAP Stage 5 and greater planning and resources have been addressed for VEFMAP Stage 6.[148]

146 Ibid
147 Ibid
148 Ibid

VEFMAP Stage 6

Surveys in 2016–17 investigated species population immigration, dispersal and distribution and recruitment across regulated rivers, as follows:

- immigration – the lower reaches of the Barwon, Werribee, Bunyip, Tarwin, Murray (Torrumbarry Weir fishway), Campaspe and Goulburn Rivers and Cardinia Creek (October–December 2016)
- dispersal – Glenelg River (January–March 2017), Loddon River Catchment and fishway trapping at The Chute, Kerang Weir and Box Creek fishlock (March–April 2017)
- distribution and recruitment – Glenelg and Thomson Rivers (February–March 2017)
- population Demography – Broken, Campaspe, Goulburn, lower Loddon and Little Murray Rivers and Pyramid Creek (March–May 2017).

Coastal Rivers

Cardinia Creek is regulated but does not have a seasonal watering plan or environmental flow targets. The Tarwin River is unregulated and has been included in VEFMAP Stage 6 to provide response data on natural fluctuations in freshwater discharge that may attract juvenile diadromous fish from marine into freshwater environments.[149] During this study, rain events occurred from September to December 2016, resulting in a number of natural flow peaks in all coastal rivers. The Werribee River experienced an environmental flow release in late 2016. Rainfall events and base flow environmental flow releases were experienced in the Glenelg River during 2017, with a summer fresh environmental flow release resulting in a discharge peak in mid-March 2017.

Immigration survey results found that over 130,000 fish were captured across the five coastal rivers. Juvenile diadromous galaxias comprised the bulk of the catch at approximately 95%. Two threatened diadromous species, Australian grayling (*Prototroctes maraena)* and Australian mudfish (*Neochanna cleaveri*) were collected.

149 Ibid

Other diadromous species collected were tupong and short-finned eels (*Anguilla australis*).[150,151] The highest catch rates of galaxias in Cardinia Creek and the Bunyip and Werribee rivers occurred early in the spring sampling period following multiple relatively large natural discharge pulses. Whether this was due to higher volumes of water or time of year will be investigated over the next two years. In the Werribee River, an increase in young-of-year (less than one year old) galaxias occurred during the peak of an environmental flow release, providing evidence that it was effective in attracting fish from the estuary into freshwater.

Dispersal survey results of the Glenelg River found a total of 99 tupong and 383 common galaxias (*Galaxias maculatus*). A total of 20 tupong were detected between January and May 2017, with most close to their initial tagging location. At five of the six river sites, higher catch rates occurred during the peak of the summer fresh release. No tagged tupong migrated upstream, although because few were subadults there was a limited ability to assess the role of environmental flows in promoting dispersal of subadults upstream. Two large adults moved downstream on a large discharge pulse in late April, which is expected as part of their autumn/winter spawning migration.

Distribution and recruitment surveys in the Thomson River found that a total of 1,531 fish of 14 species (10 native and 4 exotic) were captured, including 5 diadromous species: 69 short-finned eels, 14 long-finned eels (*Anguilla reinhardti*), 36 Australian bass (*Macquaria novemaculeata*), 18 Australian grayling and 174 tupong. Australian smelt (*Retropinna semoni*) and gambusia (*Gambusia affinis*) were the most abundant species. The catch rate of tupong indicated strong recruitment for the 2016–17 season (the highest observed in 13 years of VEFMAP sampling in this river). The 2007, 2011 and 2012 year classes of tupong were also detected, indicating a combination of successful spawning, immigration into freshwater and dispersal upstream. No trend in year classes for Australian grayling was detected, but this may be the result of low abundance and low detectability in the Thomson River.

Distribution and recruitment surveys in the Glenelg River captured a total of 1,000 fish made up of 12 species (9 native and 3 exotic), including 2 diadromous species: 19 common galaxias and 71 tupong. Flathead gudgeon (*Philypnodon grandiceps*) and gambusia were the most abundant species. Small tupong dispersed as far as 40 km upstream of Dartmoor. Some of this movement may have been stimulated by the summer fresh release. Environmental water was used to maintain river connectivity during summer 2017, allowing fish to migrate throughout the summer.

Northern Rivers

Environmental water was delivered to the Murray, Goulburn and Campaspe rivers in December 2016 and late February 2017 as small flow events (that exceed the baseflow and last for up to several weeks). Environmental water was delivered to the downstream end of the Loddon River in April 2017. There were also two natural rainfall events which resulted in elevated flows in the lower Loddon River in late April and mid-May 2017.[152]

Immigration survey results found a total of 41 subadult silver perch and 23 golden perch were captured at Torrumbarry Weir fishway and tagged with acoustic transmitters. 39 of the subadult silver perch were acoustically detected, moving upstream across 50–150 km in the Murray River from late February to early March 2017. Upstream movement coincided with the Murray River environmental watering event. Approximately half of the tagged silver perch moved from the Murray River into tributaries, coinciding with the environmental flows into tributary rivers. Approximately 70% of these tagged silver perch remained in a tributary, with some returning to the Murray River as the tributary receded.[153]

150 Ibid
151 DELWP 2017, 'VEFMAP stage 6: Do environmental flows enhance immigration and dispersal of diadromous fishes in Victorian coastal rivers? 2016/17 survey results', Melbourne, Victoria.

152 DELWP 2017, 'VEFMAP stage 6: Project update 2017. Fish study – northern Victoria rivers', Melbourne, Victoria.
DELWP 2017, 'VEFMAP stage 6: Monitoring fish response to environmental flow delivery in northern Victorian rivers, 2016/17', Melbourne, Victoria.
153 Ibid

Of the acoustically tagged golden perch, 22 were detected. These exhibited a diversity of movements locally, across a long-distance and within mainstem-tributaries, where elevated river flows promoted movement.[154]

Dispersal surveys across the Loddon River Catchment found a total of 12 fish species (7 native, 5 exotic) were captured during fishway sampling. There were 4 native fish species collected prior to environmental watering and 7 during water release during March and April 2017. With the exception of bony bream, Catch Per Unit Effort (CPUE) of native fish recorded in fishway trapping (and electrofishing) increased during the flow release at The Chute fishway and the Kerang Weir. Issues associated with the Box Creek fishway operation during the surveys prevented an assessment of environmental flow delivery.[155]

During this same dispersal survey, 34 golden perch were acoustically tagged and 22 were recorded. Acoustic results suggested that movement of golden perch was related to a water increase at the beginning of the environmental flow in early April in Pyramid Creek. Two fish tagged downstream of Kerang Weir moved substantial distances upstream through the fishway during peak environmental flow release.[156]

Population demography surveys revealed the following:[157]

- **Broken River:** A total of 526 fish were recorded (8 native and 4 exotic species), with Murray cod, carp and Murray River rainbowfish the most abundant. Temporal trends in CPUE for Murray cod and golden perch showed a decrease from 2008 to 2011, followed by an increase to the highest recorded levels in the system in 2016 and 2017. Murray River rainbowfish showed a similar pattern, although their numbers peaked in 2015.
- **Campaspe River:** A total of 4,745 fish were recorded (9 native and 6 exotic species) with Murray River rainbowfish, carp, Australian smelt and gambusia the most abundant. A total of 25 Murray cod and 48 golden perch were collected, with size structure differing between reaches. There were 12 juvenile silver perch recorded, and Murray River rainbowfish occurred at all sites. There has been an increasing trend in CPUE of Murray cod, golden perch and Murray River rainbowfish across different reaches. Silver perch was detected for the first time since the inception of the VEFMAP program in 2007.
- **Goulburn River**: A total of 2,974 fish were recorded (10 native and 4 exotic species) with Australian smelt, carp and Murray River rainbowfish the most abundant. Trends in CPUE for golden perch, Murray cod, Murray River rainbowfish and silver perch declined from 2008 to 2011, and then increased until 2017. A similar trend was detected for Murray cod, golden perch and Murray River rainbowfish. CPUE for trout cod and silver perch was low throughout the monitoring period, although silver perch CPUE increased significantly in 2017.
- **Loddon system:** A total of 6,273 fish were recorded (8 native and 4 exotic species) with Australian smelt, bony bream and carp the most abundant. Murray River rainbowfish were captured in all sites except Pyramid Creek. There was a decline in CPUE for golden perch from 2008 to 2016, followed by an increase in golden perch and Murray River rainbowfish in 2017.

At a broad level, Stage 6 VEFMAP data suggests a general increase in abundance and distribution for most priority native species in rivers that received environmental flows since the millennium drought (1996-2010). Results highlight that improved flow conditions – including environmental water – have potentially facilitated this recovery. However, further ongoing monitoring and assessments in response to environmental flows are needed to determine the different influences that are faciliting native fish species recovery.

154 Ibid
155 Ibid
156 Ibid
157 Ibid

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:14 Distribution and abundance of waterbirds in the Murray Darling Basin Data custodian DELWP			 DATA QUALITY Fair

The Eastern Australian Waterbird Survey has collected and analysed waterbird data annually since 1983, with the latest available report dated 2017.[158] This large-scale biodiversity dataset monitors change in the distribution and abundance of 50 waterbird species, including threatened species, and the health of rivers and wetlands. Waterbird abundances are strongly related to river flows and rainfall. Within Victoria, this survey is limited to the Murray–Darling Basin and coastal Ramsar sites (the latter is discussed in the Marine and Coastal Environments chapter).

There have been ecological impacts to the Murray–Darling Basin's rivers and floodplains due to reductions in cumulative annual flows extracted by water resource development.[159] Although waterbird abundances were highly variable over the 35-year survey period, a reduction in water flow has contributed to a long-term decline in the total abundance, as well as in functional response groups (ducks, grebes, herbivores, large wading birds and piscivores (fish-eaters)) and in individual species of waterbird at the basin, river and wetland scales. Ecosystem level change has impacted three Ramsar-listed sites including Lower Lakes, Coorong and Murray Mouth.[160]

The 2012 Wetland Connectivity study[161] recorded 145 waterbird species across Victorian wetlands. This figure excludes pelagic (ocean-going) seabirds and a small number of land birds associated with saltmarsh habitats. Of the 145 species, 83 breed in Victoria and the remainder are regular migrants (29 species) or rare vagrants which are seen far outside their expected breeding, wintering or migrating range (29 species). Some of the migrants breed in New Zealand, but most of them travel longer distances to breed in arctic or subarctic regions of northern Asia or Alaska.[162] As this study focused on wetland connectivity for birds, rather than being a pure bird population survey, there is no trend analysis to identify how bird numbers are influenced by international drivers or how wetland water availability across Victoria and Australia governs where birds choose to feed and breed.

Populations of waterbirds utilise multiple habitats over varying spatial scales (including wetlands, rivers and estuaries) to moult, roost, breed and forage.[163] Wetland water regimes strongly influence waterbird populations. Floods trigger breeding in many species, and wetland systems that are flooded after a dry period support large numbers of waterbirds compared to permanently flooded sites.[164]

Some waterbirds that occur in Victoria are common, occupying a range of habitats. Other species have more specialised requirements and only occupy habitats with certain levels of aquatic vegetation cover and salinity. Some of the less common species tend to be associated with large and complex wetlands that provide a range of habitat resources.[165]

158 Kingsford RT, Bino G, Porter JL 2017, 'Continental impacts of water development on waterbirds, contrasting two Australian river basins: global implications for sustainable water use', *Global Change Biology*, pp.1-12.
159 There are 240 large dams and annual diversions of approximately 6,800GL due to water resource use in the Murray–Darling Basin system.
160 Kingsford RT, Bino G, Porter JL 2017, 'Continental impacts of water development on waterbirds, contrasting two Australian river basins: global implications for sustainable water use', *Global Change Biology*, pp.1-12.
161 Morris K 2012, 'Wetland connectivity: understanding the dispersal of organisms that occur in Victoria's wetlands', Arthur Rylah Institute for Environmental Research Technical Report Series No.225, Heidelberg, Victoria.
162 Ibid
163 Ibid
164 Ibid
165 Ibid

The geographical arrangement of wetlands in the landscape and the dispersal capacity of waterbirds influence the dynamics of waterbird populations. Although there is some information about the dispersal capacity of waterbirds over large scales, there is little information on the frequencies or patterns of waterbird movements between wetlands over small spatial and temporal scales. Knowledge of these finer-scale movements, particularly during critical life stages, is needed to identify the landscapes elements required to sustain waterbird populations.[166]

166 Ibid

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
B:15 Distribution and abundance of macroinvertebrates	○	○	●	○	→	DATA QUALITY
Data custodian EPA Victoria						Fair

Inland aquatic macroinvertebrates are widely used in Australian assessments of ecosystem condition. The RiverMAP Long Term Sites (LTS) Project provides trends in aquatic macroinvertebrate biodiversity across 66 sampling sites. Sampling of inland aquatic macroinvertebrates has taken place since 1990. Between 1990 and 2012, the number of sampled sites, years sampled and total samples have varied. Therefore, trends reported here are heavily weighted towards more frequently sampled sites.

EPA Victoria and DELWP selected and agreed on 66 sites on initiation of the RiverMAP program. Of the 66 LTS, 39 are in DELWP's high priority locations and 15 are from EPA Victoria's long-term monitoring sites (sites that have been sampled since the 1990s), which simultaneously maximises coverage across SEPP defined bioregions (Table B.11). The remaining 12 sites were included to add analytical strength to detect change in macroinvertebrate condition at both statewide and SEPP region scales. While reasonably representative of conditions within a bioregion, the LTS do not represent the full range of environmental variability within a bioregion and therefore trends presented here are not indicative of long-term conditions for all stream types within a bioregion.

Table B.11 A description of the 5 SEPP WoV bioregions applied to the LTS Project[167]

SEPP Bioregion	Description
Highlands (B1)	This region is in the high country of Victoria, with streams often on steep slopes, generally above 1,000 m and subject to high rainfall. The vegetation tends to be native forest, woodland and grassland. Riparian shading varies from moderate to low cover, depending on the course of streams through forested or grassland areas, respectively.
Forests A (B2)	Six separate areas form this region, comprising upland reaches in the Upper Murray, Mitta Mitta, Kiewa, Goulburn, Yarra, Latrobe and Thomson catchments, and rivers and streams in the Grampians, Strzeleki Ranges, Wilsons Promontory and far East Gippsland. Although not all are geographically connected, they share similar environmental and biological characteristics. The streams are generally located on moderately steep slopes at much lower altitudes than the Highlands Region, but at moderately high altitudes relative to the remaining regions. The region receives moderate to high rainfall. Tall forests and woodlands are the typical vegetation cover, with some forestry and grazing activities. Streams generally have considerable shading from the riparian zone, and tend to be further from their source with a greater upstream catchment area than the Highlands Region. Cool waters with very low alkalinity, turbidity and salinity characterise the region, except in the Grampians where there is low to moderate salinity. Streams typically have both riffle and edge habitat with moderately coarse substrate, and very low macrophyte cover and diversity.
Forests B (B3)	The Forests B Region incorporates the upland reaches in the Ovens, Broken, Goulburn, Macalister, Mitchell, Tambo and Snowy catchments, and rivers and streams in the Otway Ranges. This discontiguous region generally covers an area similar in altitude to the Forests A Region, but stream slopes are less steep. Rainfall is slightly less in this region than in Forests A Region, and supports tall open forests. A greater degree of clearing for forestry, grazing and some intensive agriculture occurs in this region compared with the Highlands Region and Forests A Region. This results in a lower level of riparian shading. Streams are further from their source, with more than double the catchment area of streams in Forests A Region. Alkalinity of the cool waters typical of this region is slightly elevated relative to the Highlands Region and Forests A Region, but still remains low compared to the rest of the state along with turbidity and salinity. Stream habitat is characterised by the presence of riffles and edges, with very coarse substrate and high macrophyte diversity and cover.

167 EPA Victoria 2004, 'Information bulletin biological objectives for rivers and streams – ecosystem protection', Melbourne, Victoria.

SEPP Bioregion	Description
Cleared Hills and Coastal Plains (B4)	The urban area of Melbourne divides this region, which is characterised by coastal plains in the south and inland plains and low foothills in the north and east. This region includes upper reaches in the Campaspe, Loddon, Avoca, Wimmera and Hopkins catchments, midreaches in the Ovens, Broken and Goulburn catchments, lowland reaches in the Barwon, Yarra, Latrobe, Thomson, Macalister, Mitchell, Tambo and Snowy catchments, all reaches in the Curdies, Moorabool, Werribee, Maribyrnong and Western Port catchments, and river and stream reaches in South Gippsland. Streams flow through an undulating landscape of low altitude with little gradient and relatively low rainfall. The region has been substantially cleared for intensive agriculture including dryland pasture and some irrigated pasture, resulting in poor riparian shading. Warm stream waters with high alkalinity and low to moderate turbidity and salinity characterise the region. The edge habitat is more developed and extensive, and riffles are less common. The substrate tends to be composed of moderate to fine particles, and there is a very high diversity and moderate cover of macrophytes.
Murray and Western Plains Region (B5)	This region incorporates the west and north of the state and covers an area of low altitude plains with very little topographical relief and low rainfall. This region includes lowland reaches in the Kiewa, Ovens, Broken, Goulburn, Campaspe, Loddon, Avoca, Wimmera, Glenelg, and Hopkins catchments, the entire Corangamite catchment and the Portland and Millicent Coast basins. The region has been generally cleared for dryland and irrigated pasture, and broad-acre cropping. It also includes some patches of Mallee woodland. Riparian shading is, therefore, typically very poor. The waters are warm and slow, often seasonally intermittent, tending towards pond-like waterways with high alkalinity, and moderate to high turbidity and salinity. The very fine substrate of the streams means that the principal habitat is along edges, with the high diversity and cover of macrophytes and woody debris being the dominant habitat for invertebrates. Riffles are uncommon.
North-west Victoria	Because of insufficient data in the north-west area of Victoria, and a very different aquatic environment, no specific biological objectives have been set for water bodies in this region. If required, the objectives from the Murray and Western Plains Region (B5) can be used as interim objectives where streams are present.

The analysis explored relationships between trends and environmental variables and applied four macroinvertebrate metrics:[168]

- total number of different macroinvertebrate groups (total richness)
- total number of specific macroinvertebrate family groups, specifically Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa
- stream invertebrate grade number average level (SIGNAL2) which is a grading system ranging between 1 and 10 that represents water-quality sensitivities[169] of macroinvertebrates
- an indicator of community composition, Australian River Assessment System observed/expected index (AUSRIVAS O/E).[170]

At the statewide scale, the overall condition of inland aquatic macroinvertebrates across Victoria's 66 long-term monitoring sites is stable.[171,172] Forest and riparian cover were all strongly positively correlated with the condition of macroinvertebrates,[173] whereas rainfall, streamflow and land use all influenced the differences found in macroinvertebrate assemblages across all SEPP bioregions.[174]

Macroinvertebrate trends varied at the SEPP bioregional scale. The Cleared Hills and Coastal Plains and Murray and Western Plains bioregions (Figure B.6) had low numbers of sensitive taxonomic macroinvertebrate groups (EPT taxa) and low SIGNAL2 scores indicating poor stream health compared to Highlands and Forests A and B. Cleared Hills and Coastal Plains had comparatively low SIGNAL2 scores which is partially attributed to streamflow and potentially other variables such as higher proportions of land use.

168 EPA Victoria 2016, 'RiverMAP long term sites project final report', Melbourne, Victoria.
169 Note: water-quality sensitivities includes: water temperatures, turbidity, electrical conductivity, alkalinity, pH, dissolved oxygen, total nitrogen and total phosphorus, in: Chessman B 2003, 'New sensitivity grades for Australian river macroinvertebrates', *Marine and Freshwater Research*, 54, pp.95-103.
170 Note: the AUSRIVAS O/E is a standardised protocol for the assessment of river physical and chemical condition incorporating in-stream physical habitat, catchment geomorphology, riparian condition and water quality, in: Parsons M, Ransom G, Thoms M, Norris R, 2002, 'Australian river assessment system: AusRivAS physical and chemical assessment Module', Monitoring River Heath Initiative Technical Report no 23, Commonwealth of Australia and University of Canberra, Canberra.
171 Ibid
172 EPA 2016, 'River monitoring and assessment program (RiverMAP): river health modelling project technical report', Melbourne, Victoria.
173 Ibid
174 EPA Victoria 2016, 'RiverMAP long term sites project final report', Melbourne, Victoria.

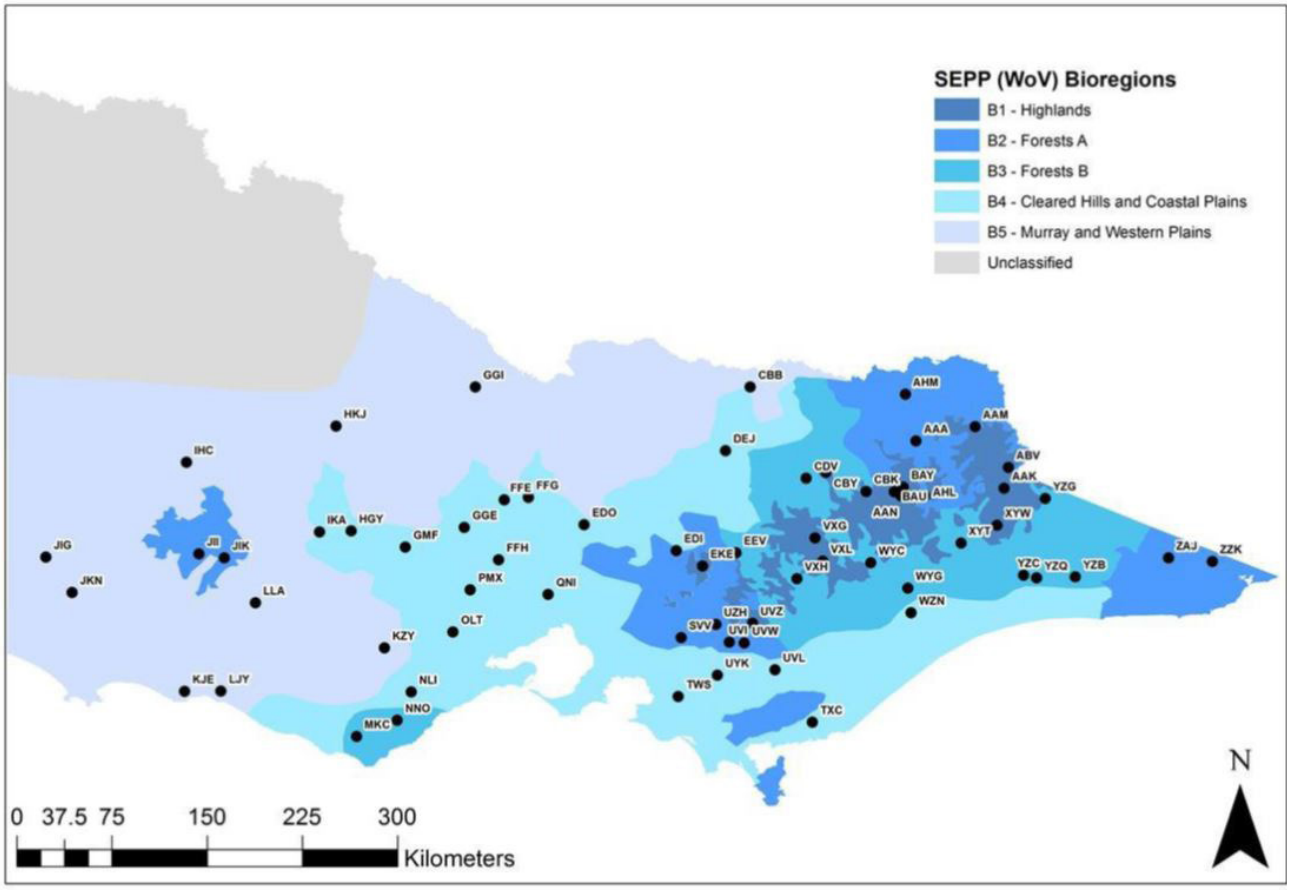


Figure B.6 The 66 sampled sites across SEPP bioregions for the RiverMAP long-term sites monitoring project[175]

175 Ibid

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:16 Wetland extent and condition		?	 DATA QUALITY
Data custodian DELWP			Poor

Wetlands are defined as natural, modified or artificial areas subject to permanent or temporary inundation that hold static or very slow-moving water and develop – or have the potential to develop – biota adapted to inundation and the aquatic environment.[176] The naming convention for inland (freshwater) wetland types was revised in the *Victorian Wetland Classification Framework 2014*.[177] There are two types of freshwater wetlands:

- lacustrine wetlands categorised by less than 30% vegetation cover such as lakes
- palustrine wetlands categorised by greater than 30% vegetation cover and divided into the following types:
  - swamps (wetlands dominated by woody vegetation)
  - marshes/meadows (wetland dominated by non-woody emergent vegetation)
  - high country peatlands.

Water sources for lacustrine and palustrine wetlands can include groundwater, river or those that are artificially filled and have permanent or periodically inundated water regimes, for example seasonal, intermittent or episodic water availability.[178] Marine and estuarine wetlands are assessed in the Marine and Coastal Environments chapter.

The 2014 inventory of Victoria's wetlands recorded 23,739 natural wetlands covering 604,322 hectares and 11,060 artificial wetlands covering 170,613 hectares.[179] More than a quarter of Victoria's wetlands have been lost since European settlement.[180] Of the 149 wetland EVCs, nearly all are threatened in at least one Victorian bioregion and over 75% of all wetland EVCs across Gippsland Plains, Glenelg Plain, Otway Plain, Victorian Riverina, Victorian Volcanic Plain and Warrnambool Plan are considered endangered and vulnerable.[181] There have been no further statewide assessments on wetland condition using the Index of Wetland Condition[182] since the release of the SoE 2013 report.[183]

DELWP is currently developing a statewide wetland monitoring and assessment program for environmental watering (WetMAP). WetMAP represents a short-to-medium term intervention approach and will monitor a subset of Victoria's wetlands, from each CMA region, before and after environmental water delivery. This long-term program aims to evaluate the effectiveness of wetland management by monitoring and assessing responses to different management approaches.[184]

176 DELWP 2018, 'Wetlands', https://www.water.vic.gov.au/waterways-and-catchments/rivers-estuaries-and-waterways/wetlands Accessed 9 September 2018.
177 DELWP 2016, 'The Victorian wetland classification framework 2014', Melbourne, Victoria.
178 Ibid
179 Ibid
180 Ibid
181 VEAC 2017, 'Statewide assessment of public land supplementary paper', Melbroune, Victoria.
182 Papas P, Moloney P 2012, 'Victoria's wetlands 2009–2011: statewide assessments and condition modelling', Arthur Rylah Institute for Environmental Research Technical Report Series No. 229, Heidelberg, Victoria.
183 CES 2013, 'Victoria: State of the Environment Report Science Policy People', Melbourne, Victoria.
184 DELWP 2017, 'VEFMAP Stage 6 Part A: program context and rationale', Arthur Rylah Institute for Environmental Research, Heidelberg, Victoria.

Cropping in Wetlands

The last Index of Wetland Condition found that cropping occurred in 7.5% of the 8,489 wetlands assessed (Figure B.7). An examination of key attributes for wetlands where cropping was recorded found that cropping appears most likely to occur in palustrine, fresh, periodically inundated wetlands with an episodic or seasonal water regime. The nationally, critically endangered ecological community of Seasonal Herbaceous Wetlands (Freshwater) of the Temperate Lowland Plains is an example of a wetland community that occurs in Victoria in wetlands with these attributes. This data indicates that cropping in wetlands is reasonably common and that certain types of wetlands are more vulnerable than others to the impacts of cropping.

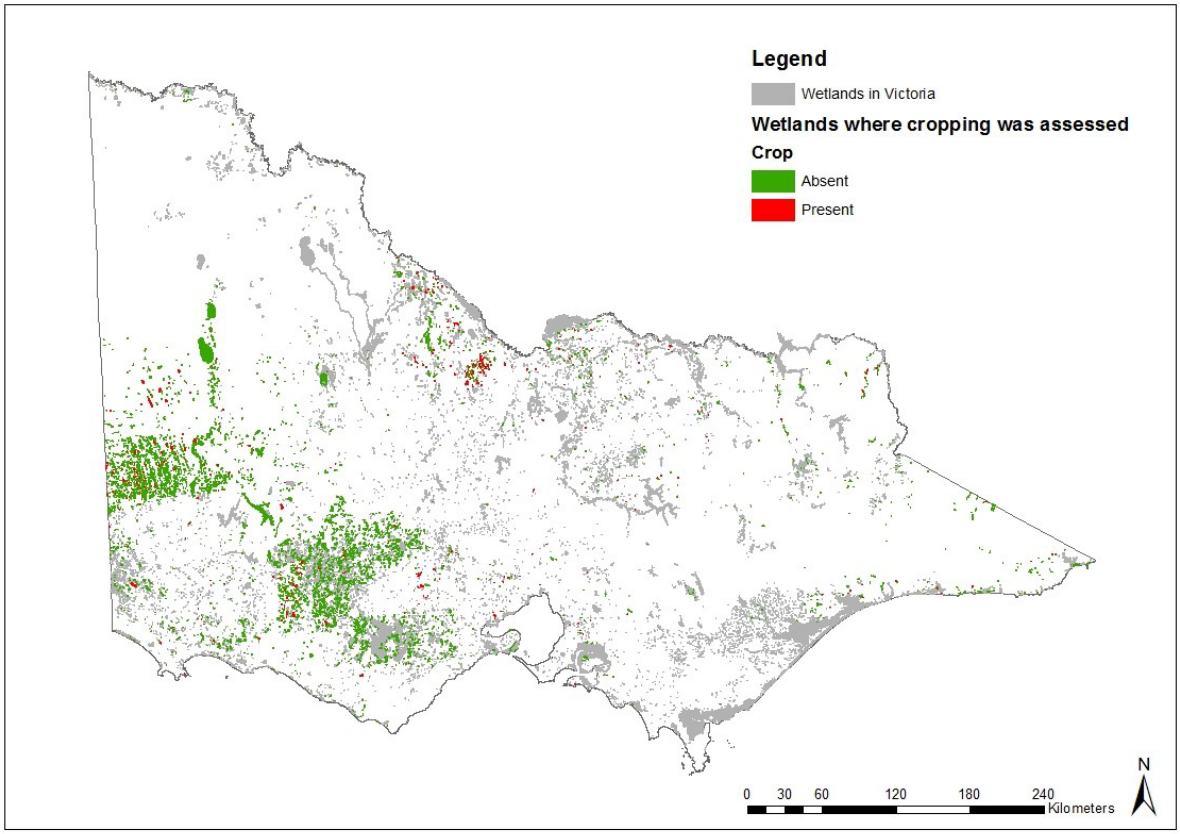


Figure B.7 Locations where wetland cropping occurs, based on results from the last Index of Wetland Condition.

Note: Cropping is marked in red.

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:17 Health and status of Ramsar wetlands in Victoria		?	 DATA QUALITY
Data custodian DELWP			Poor

Victoria has 11 Ramsar sites, of which 6 are inland and cover 98,623 hectares (Table B.12).[185] As part of the Ramsar Convention, management agencies are to maintain the ecological character description for each site. The 2016 Victorian Auditor-General's Office report *Meeting Obligations to Protect Ramsar Wetlands* found limited evidence that ecological character descriptions for each site were being maintained. The status of the ecological character of some sites cannot be fully determined due to limitations such as a lack of data. Therefore, trends in ecological health and status cannot be reported here. Where information is available, it shows that some Ramsar sites are not being effectively managed and protected from ecological decline. These declines are attributed to changed water regimes, water quality, recreational use, agricultural use, invasive species and climate change.[186]

Biodiversity 2037 Indicators

This theme will report on indicators that have been developed for *Biodiversity 2037*. These indicators include: Change in suitable habitat, Landscape scale change and Net gain in extent and condition of native vegetation. These indicators are assessed through new methodologies and will provide baselines for future status and trend analysis. Due to these new methodologies, it is not possible to continue previous trend analysis provided in SoE 2008 and 2013 reports. Trend analysis reported for *Biodiversity 2037* indicators are based on time-period data provided by the Data custodian, which varies across each indicator.

Table B.12 Inland aquatic Ramsar sites in Victoria[187]

Ramsar site	Area (ha)	Ramsar primary manager
Barmah Forest	29,305	Parks Victoria
Gunbower Forest	20,218	Parks Victoria and DELWP
Hatta-Kulkyne Lakes	977	Parks Victoria
Lake Albacutya	5,659	Parks Victoria
Kerang Wetlands	9,793	Parks Victoria and Goulburn–Murray Water
Western District Lakes	32,671	Parks Victoria

185 VAGO 2016, 'Meeting obligations to protect Ramsar wetlands', Melbourne, Victoria.
186 Ibid
187 Ibid

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
B:18 Net Gain in Extent and Condition of Native Vegetation	○	●	○	○	↘	DATA QUALITY Good

Data custodian DELWP

This indicator combines the following biodiversity indicators from previous Victorian SoE reports:

- Habitat Condition – measured as change in the extent and quality of vegetation by EVC categories
- Habitat Extent – measured as fragmentation of native vegetation
- Native Vegetation Extent – assessed as change in the extent of vegetation by EVCs
- Quality, Condition and Fragmentation of Victoria's native vegetation – provided as overall condition of native vegetation using modelled quality assessments.

These historical indicators are now reported here under the new *Biodiversity 2037* key performance indicator, 'Net gain in extent and condition of native vegetation'. This measure provides estimates of the overall rate of change in extent and quality of native vegetation on public and private land in Victoria. It should be noted that DELWP is currently designing a 'net gain' key performance indicator for freshwater and marine habitats.

Previous 'net gain' results, reported in 2008, were based on a once-off modelled overall rate of change in extent and quality of native vegetation on Victorian public and private land in 2007.[188] These results were based on a range of assumptions regarding specific transactions (such as investment, permitted clearing, management actions and offsets) and broad changes (based on imagery and data taken at regular intervals for comparison over time). Results were subject to high variability and poorly quantified levels of uncertainty.

The updated 'net gain' methodological approach applied to this indicator keeps the core modelling change categories, but adjusts the assumptions based on collated evidence. Change categories include:

- gain activities – government investment, general management, voluntary actions, improved security
- loss activities – entitled uses, exemptions, controlled management regimes on public land
- neutral activities – permits and offsetting, wildfire, forest harvesting and regeneration.

The impact of controlled management regimes is included as a loss where recent planned burns have resulted in native vegetation being below the tolerable fire interval.[189] While planned burns may provide some benefits for native vegetation extent and condition, this relationship needs further investigation and is not included in this report's calculations. Controlled management decisions on public land are made in the context of many factors including community health and safety. These decisions and their trade-offs are not within the scope of any 'net gain' calculations.

There has been a loss in native vegetation on public and private land between 2008 and 2014 (Table B.13). The largest contributors to net loss in native vegetation on private and freehold land are entitled uses (for example, grazing and removal of trees and fallen logs for personal use), unmanaged threats beyond legislative obligations (for example, environmental weeds) and clearing that is exempt from requiring a permit (such as fences and fire

188 DSE 2008, 'Native vegetation net gain accounting. First approximation report', Melbourne, Victoria.

189 Tolerable fire interval is defined as the minimum or maximum recommended time intervals between successive fire disturbance events at a site or defined area for a particular vegetation community. It guides how frequent fires should be in the future to allow the persistence of all species at the site or defined area, in: Cheal D 2010, 'Growth stages and tolerable fire intervals for Victoria's native vegetation data sets', Fire and Adaptive Management Report No.84, Melbourne, Victoria.

protection)[190] (Figure B.8). There is also limited data available on some native vegetation losses, such as permitted clearing through local government approvals, exemptions and illegal clearing.[191] It should be noted that native vegetation removal regulations and offsets for the removal of native vegetation will also influence future 'net gain' results and should be carefully assessed in all calculations.

Table B.13 Six-year trend in 'net gain' calculations on Victorian public and private land

	Public Land (habitat ha/yr)		**Private Land (habitat ha/yr)**	
	2008	**2014** (a)	**2008**	**2014**
Gains subtotal	+ 8,760	+10,500	+ 4,560	+3,100
Losses subtotal	- 2,860	- 8,400	- 14,550	- 13,400
'Net gain' outcome (b)	+ 5,900	+ 2,100	- 9,990	-10,300

(a) The 2014 calculations contain information that was not included in the 2008 Net Gain First Approximation Report.

(b) Due to significant uncertainties associated with underlying assumptions and availability of site specific data, these figures may be under or over estimates, possibly up to 20%.

(Data source: DELWP, 2018)

There has been no acquisition of new imagery for vegetation condition data since 2008. Updated data provided by DELWP (see B:19) will apply Landsat imagery together with resources required to resample previous monitoring sites across the state to model vegetation condition.[192] This will inform new monitoring sites that sample the native vegetation 'space' based on type, extent and other factors. DELWP has developed a framework and standards for monitoring native vegetation to inform management effectiveness studies and to help test assumptions.[193]

190 DELWP 2015,' 2015 qualitative update of the 2008 net gain accounting first approximation report', Melbourne, Victoria.
191 Ibid
192 Ibid
193 Ibid

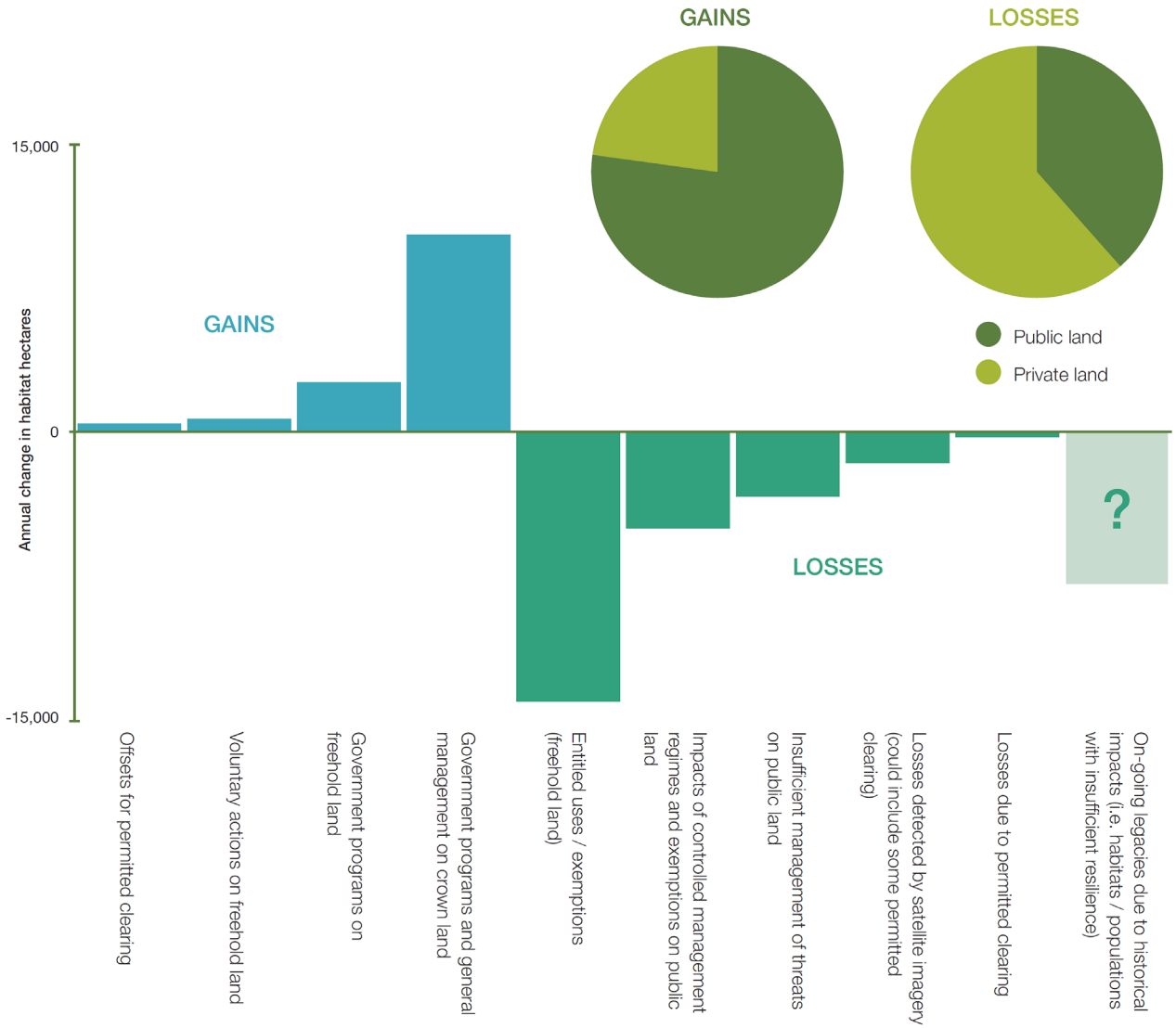


Figure B.8 Relative changes in native vegetation in 2014 estimated using the 'net gain' accounting approach[194]

194 DELWP 2016, 'Draft protecting Victoria's environment – Biodiversity 2036', Melbourne, Victoria.

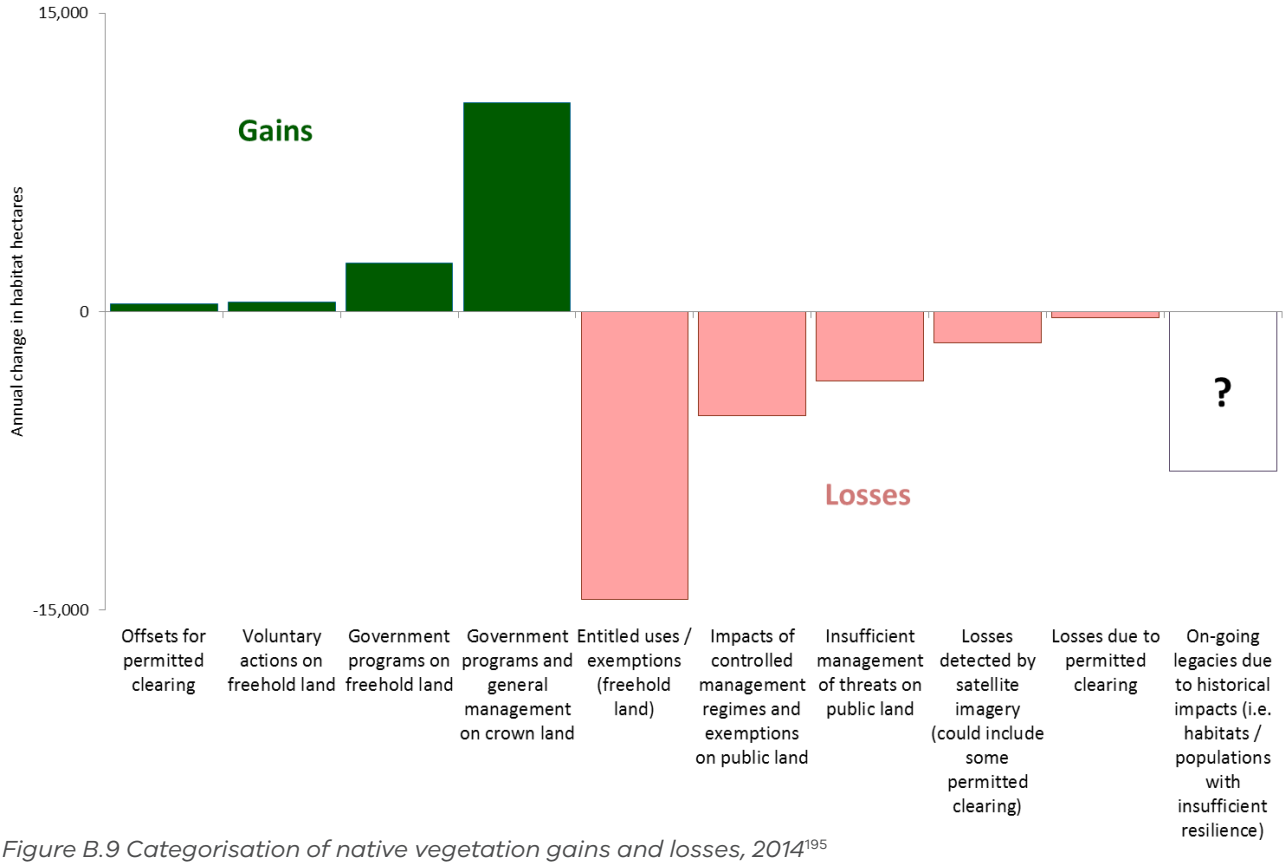


Figure B.9 Categorisation of native vegetation gains and losses, 2014[195]

Please note, the question mark in this figure denotes a lack of data to accurately measure on-going legacies.

195 DELWP 2015, '2015 qualitative update of the 2008 net gain accounting first approximation report', Melbroune, Victoria..

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:19 Landscape Scale Change		↘	DATA QUALITY: Fair

Data custodian DELWP

Landscape scale change is a new *Biodiversity 2037* indicator. Results provide new information on trends in native vegetation extent and land use from 1987 to 2015. Broken into six time epochs, Landscape scale change will be assessed on five-year groupings. The acquisition of Landsat (satellite) imagery, together with existing (and a small amount of new) training data, will provide a basis for modelling the distribution of native vegetation from a range of variables derived from satellite datasets. Training data is used to predict the relationship between the satellite imagery and native vegetation extent. This methodology will enable the quantification of how vegetation extent (measured as hectares) has changed across Victoria since 1987.

Analysis of landscape scale change shows an increase in landscapes associated with human-based activities and an overall decrease in native vegetation and intermittent and seasonal wetlands not of a marine water source.[196] The urban landscape, most notably in Melbourne's western suburbs and some regional areas such as Bendigo, has increased from 193,200 hectares in 1990 to 270,547 hectares in 2015, representing a 40% increase (Table B.14 and Figure B.10). This urban expansion has resulted in a loss of native grasslands and increased pressures on surrounding native vegetation in terms of asset protection from fire.[197] The built-up landscape, often associated with urban expansion, has also increased from 10,180 hectares to 13,089 hectares (29% increase) for the same time period. Additional landscape type increases between the years 1990 and 2015 include:

- hardwood plantations from 51,084 hectares to 243,609 hectares (377% increase)
  dryland cropping from 4,382,138 hectares to 5,145,877 hectares (17% increase) – specifically around the vicinity of Lake Bolac, Mallee, Mooroopna and Melbourne's western suburbs[198]
- native grasslands and herblands specifically in Kerang, most likely attributed to climate change due to variable rainfall resulting in drought and wet years[199]
- irrigated horticulture from 460,525 hectares in 1990 to 585,312 hectares in 2015 (27% increase) – specifically expansions in Robinvale[200]
- exotic woodlands from 77,137 hectares in 1990 to 109,837 hectares in 2015 (42% increase) – most notably around Lake Eppalock.

There have been decreases for the following landscape types between the years 1990 and 2015:

- native grasslands and herblands from 2,282,992 hectares to 1,820,093 hectares (20% decrease) – most notably around the vicinity of Lake Bolac, due to the expansion of dryland cropping and non-native pastures. This is also causing pressure on intermittent and seasonal wetlands and in Melbourne's western suburbs due to urban expansion and dryland cropping.
- native scattered trees from 542,201 hectares to 393,147 hectares (27% decrease)
- native shrubs from 165,262 hectares to 116,620 hectares (29% decrease)
- intermittent and seasonal wetlands, 47,286 hectares to 42,133 hectares 2015 (11% decrease) and 418,611 hectares to 342,955 hectares (18% decrease) respectively.

196 Note: definition of wetlands in the biodiversity chapter applies the Victorian wetland classification framework 2014. DELWP 2016, 'The Victorian wetland classification framework 2014', Melbourne, Victoria.
197 DELWP 2018, Data Analysis.
198 Ibid
199 Ibid
200 Ibid

Table B.14 Landscape scale change disaggregated to landscape type across 6 time epochs, 1990–2015[201]

Landscape name	1990		1995		2000		2005		2010		2015	
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
Built-up	10,180	100	10,975	108	11,562	114	12,336	121	13,452	132	13,089	129
Disturbed Ground	25,555	100	25,756	101	23,558	92	25,900	101	28,381	111	25,353	99
Dryland Cropping	4,382,138	100	4,673,019	107	4,793,679	109	4,978,979	114	5,035,536	115	5,145,877	117
Exotic Woody	77,317	100	74,668	97	95,930	124	91,825	119	88,649	115	109,837	142
Hardwood Plantation	51,084	100	66,513	130	73,400	144	164,109	321	201,594	395	243,609	477
Irrigated Horticulture	460,525	100	574,821	125	463,421	101	444,881	97	405,604	88	585,312	127
Mangrove	5,887	100	6,217	106	6,291	107	6,325	107	6,386	108	6,706	114
Native Grass Herb	2,282,992	100	2,083,245	91	1,944,463	85	2,124,330	93	2,222,795	97	1,820,093	80
Native Scattered Trees	542,210	100	454,371	84	492,556	91	467,682	86	446,289	82	393,147	73
Native Trees	7,822,316	100	7,935,448	101	7,912,706	101	7,916,538	101	7,917,106	101	8,000,382	102
Native Shrub	165,262	100	138,990	84	156,291	95	135,752	82	118,125	71	116,620	71
Natural Low Cover	101,448	100	92,462	91	90,162	89	98,925	98	97,689	96	96,063	95
Pasture Not Native	5,954,067	100	5,727,331	96	5,848,345	98	5,429,390	91	5,334,092	90	5,324,753	89
Pine Plantation	207,713	100	217,611	105	223,771	108	227,169	109	227,853	110	232,058	112
Saltmarsh	11,327	100	11,863	105	11,388	101	11,427	101	11,756	104	12,055	106
Urban	193,200	100	221,729	115	227,292	118	245,303	127	253,738	131	270,547	140
Water	1,527,070	100	1,526,788	100	1,509,181	99	1,504,251	99	1,500,232	98	1,506,213	99
Wetland Intermittent	47,286	100	47,869	101	40,191	85	41,851	89	34,265	72	42,133	89
Wetland Seasonal	418,611	100	397,106	95	361,999	86	359,225	86	342,651	82	342,955	82

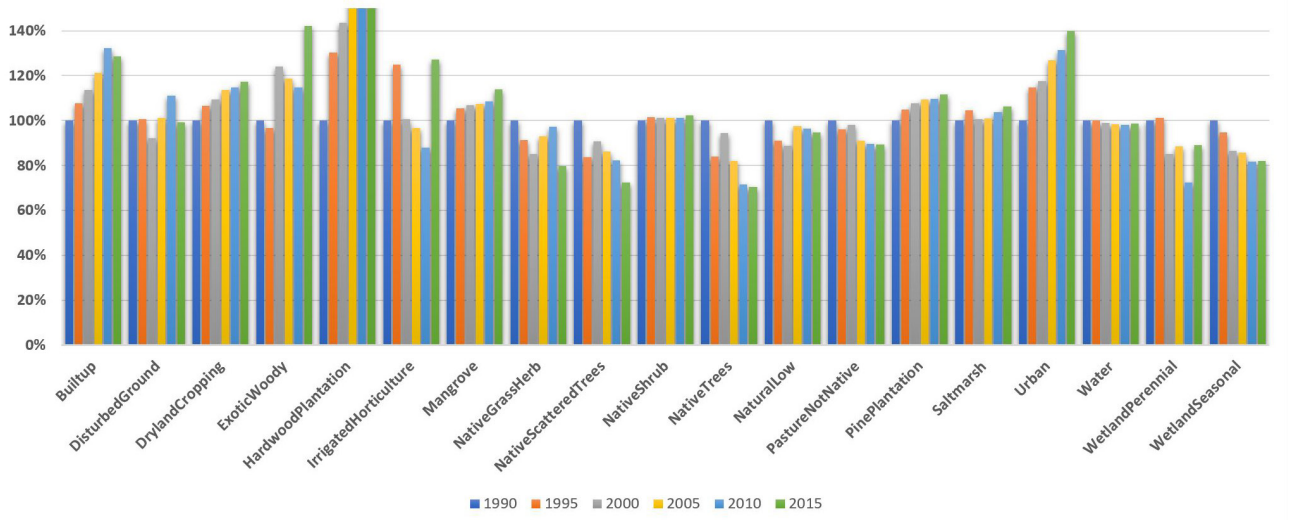


Figure B.10 Landscape Scale Change for each landscape type across 6 time epochs, 1990–2015[202]

201 DELWP 2018, Data Analysis.
202 Ibid

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
B:20 Change in Suitable Habitat	○	○	●	○	→	DATA QUALITY: Good
Data custodian DELWP						

The previous Victorian SoE biodiversity indicator, Biodiversity Information, which assesses the comprehensiveness of biodiversity information required for effective management, is reported here under the new indicator title, Change in suitable habitat (CSH), which will be included in future SoE reporting.

CSH is the Victorian Government's new key performance indicator (KPI) through which it will measure progress towards the targets in *Biodiversity 2037*. This indicator's aim is to provide a practical measure for estimating net improvement in suitable habitat and the most effective options for improving the future of native species across the state under climate change.[203] The indicator's target is a 100% net positive change (on average) in suitable habitat for threatened species in 50 years.

The methodology considers the type, extent and configuration of habitat for a species and the factors that influence how much a species can make use of this habitat. This measure allows comparisons to be made between species, places and actions and is a shift from considering threatened species individually to securing the greatest overall benefit for all threatened and native species, taking account of cost-effectiveness. It compares the relative benefits that can be expected for different species from diverse management interventions. CSH can be calculated for one species and can be combined across many species.

Biodiversity 2037 states that achieving the 100% change (on average) in suitable habitat target will require the establishment and maintenance of management actions and associated targets identified in the Strategic Management Prospects (SMP) tool. The contributing management actions and targets identify priority areas that need to achieve the CSH, as soon as possible, and its maintenance over the life of the management plan. If effort slows or stops, for even a short time, the gains made over the preceding years of management effort could be lost. The faster the management actions are implemented and sustained to deliver their contributing targets, the more likely the statewide target, 100% net positive change (on average) in suitable habitat for threatened species in 50 years, can be achieved. The contributing management actions and targets will be reviewed every five years to ensure they are contributing to the statewide target.

To track and identify each management plan's actions and efforts in meeting this indicator's statewide target, DELWP has established five-yearly milestone targets for each management plan. Milestone targets identify whether the expected management actions and efforts in priority locations, from existing and proposed activities, align with the management plan's target and the statewide target. Milestone targets will also consider that some management actions and efforts, such as deer control, are still subject to adaptive management approaches.

For each management plan, CSH measures the increase in the likelihood that a species will persist at a priority location at a future time (for example, in 50 years) in response to sustained management of relevant threats. It is expressed as the proportional increase (percentage) in hectares of suitable habitat a species has received under a sustained management regime, compared with no management.

203 DELWP 2017, 'Protecting Victoria's Environment – Biodiversity 2037', Melbourne, Victoria.

The calculation for CSH is:

$$CSH \text{ (for a species)} = (action^1 - action^0) \div action^0$$

where:

$action^0$ is the likelihood of persistence of the species with no action in the analysis

$action^1$ is the likelihood of persistence of the species with actions, adjusted based on the standard of work applied.

Management actions at sites included in the analysis are based on the activity data (DELWP standard outputs) reported by organisations delivering on-ground works to control terrestrial pest plants and animals (Figure B.11). The current analysis includes on-ground management actions from 2015–16 and 2017–18, in addition to any permanent protection agreements.

Results found that the average percentage CSH in 50 years for all native species is 5.24% (Table B.15). For threatened species, the average percentage CSH in 50 years is 5.3%, based on the on-ground management actions taken. For some species, the percentage CSH was much higher than the average. For example:

- 6 species had CSH greater than 100%
- 89 species had a CSH greater than 20%
- 431 species had a CSH greater than 10%.

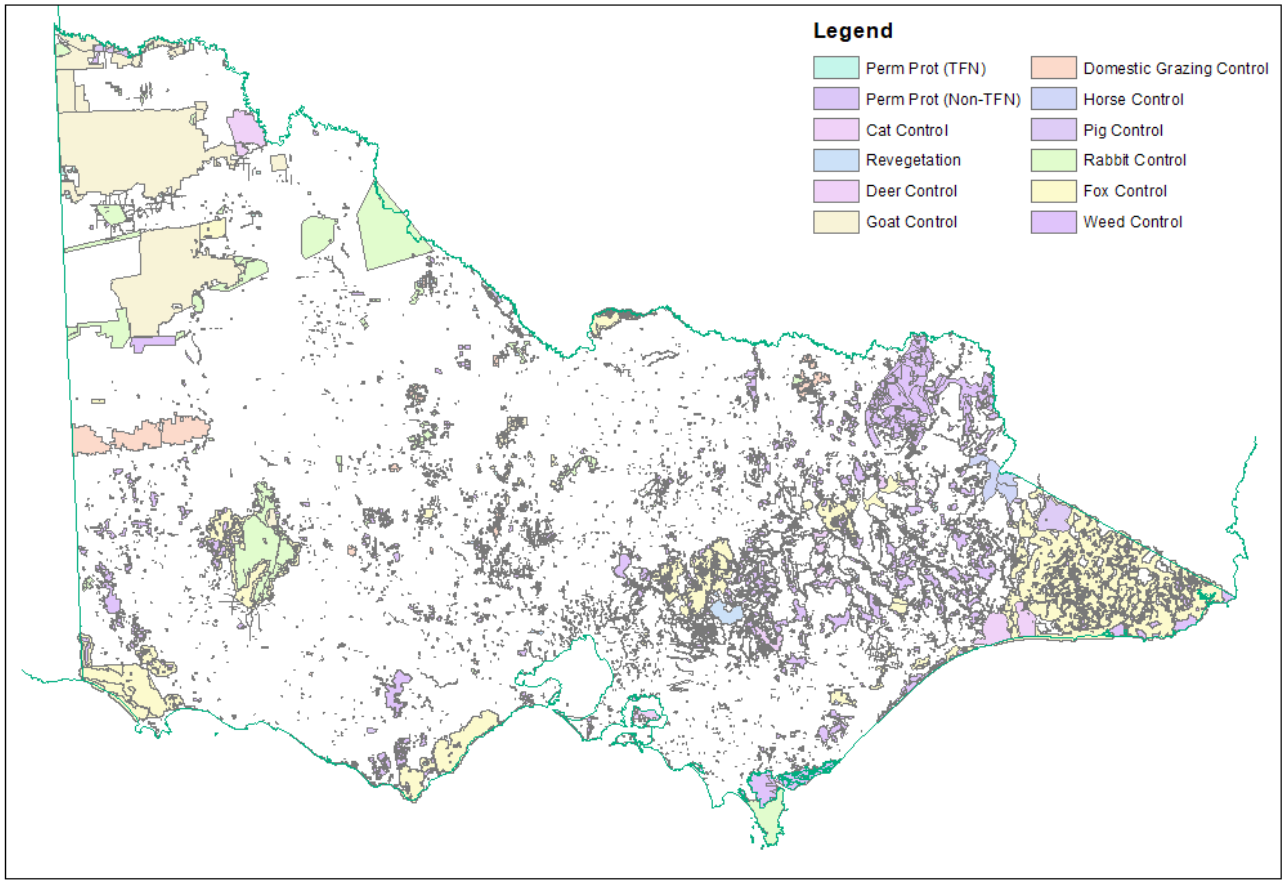


Figure B.11 Map of reported on-ground management actions across Victoria and applied to assess CSH assessment

(Source: DELWP 2018)

Table B.15 CSH for all native species in 50 years

Parameter	Target net positive CSH in 50 years for all species (%)	(on average) % net CSH in 50 years (%)
All species	(on average) 100	5.24
Birds		2.56
Frogs		3.45
Mammals		27.11
Plants		4.33
Reptiles		19.02
Threatened species	n/a	(on average) 5.3

(Data source: DELWP 2018)

A key assumption of these calculations is that the actions are continued for the next 50 years at the best practice standard. The relatively low predicted percentage net change (on average) in suitable habitat in 50 years may be due to the following factors:

- the short time frame over which reporting and recording of key management actions has occurred
- a lack of alignment of key management actions with priority locations
- evidence of only partial control of the threat due to the lack of a fully integrated management plan or implementation of partial treatments of a particular threat (Figure B.11). For example, management actions such as pest predator and herbivore controls in priority locations require an integrated approach to fully manage these threats. All pest herbivore species must be adequately controlled in a location for a beneficial management outcome. In practice, controlling all pest herbivore species is rarely done, and in many cases, only one or two species are targeted for control at a management location. While there is a large amount of pest herbivore control occurring in priority management locations across Victoria (Table B.16), analysis of management actions indicate that the benefits are not being fully realised in terms of percentage increase in suitable habitat as not all pest herbivore species are being adequately controlled in those priority locations (for example, there is a need for integrated feral horse, deer and pig control in the Victorian Alps).
- a relatively large number (over 100) of flora species that received negative benefits from predator control management actions, due to the increase of herbivore species (such as rabbits) from reductions in predation without the corresponding pest herbivore control, therefore increasing total grazing pressure. Such negative benefits could be avoided by an increase in integrated ecosystem management, such as considering the potential flow-on effects of predator control by restoring or mirroring the function of predators through other management.
- the need for further management action through increased investment
- missing spatial data for management actions completed or being undertaken that may impact on CSH, particularly for threatened species (for example, species-specific actions) or actions implemented by community groups, volunteers, conservation efforts on private land and gaps for individual CMAs and other organisations who manage environmental assets that have not been recorded and reported to DELWP.

Caveats and assumptions for implementing and measuring CSH include:

- The values provided here assume that the reported management actions were done to best practice, and that they will be sustained for 50 years. Any estimated benefits do not apply if a management action is not sustained for the 50-year time horizon. Therefore, when calculating benefits, management actions will be counted for a location if they are current (either newly established or continuing from previous years).
- The location across which management actions were implemented for each individual species targeted contributes to the overall management target, even when the location of the management action or the management action itself overlaps.
- he benefit and area data are calculated on the assumption that a management action is implemented across the full extent of the polygons reported, and therefore may be overestimated in some cases. Efforts were applied to refine polygons where better information was available, however, data for some actions (such as weed control) may still be an overestimate due to spatial data that overvalues the actual area of management action. Future reporting against these targets requires refinement of reporting data to reduce this uncertainty and associated overestimates.
- In instances, some polygons of reported management action did not intersect with action benefit models in the SMP tool. This was due to some threat models underestimating the true distribution of a threat, and therefore, locations where management action is required. This results in an optimistic CSH value.
- The figures detailed here apply to the information provided by the current (v1.2) SMP analysis. As the SMP develops and improves over time, and includes accurate data for effective treatment area and standard of works, the CSH values will vary. It will be possible in the future to back cast the SMP models and data to provide trend information through time.

Case Studies

Potoroos

The Long-footed Potoroo (*Potorous longipes*) and Long-nosed Potoroos (*Potorous tridactylus*) are both expected to have a net positive CSH of 127% and 98.6%, respectively, over the next 50 years under their reported management regimes. This is largely due to large-scale predator control programs (e.g. Southern Ark) operating in East Gippsland.

Anglesea Grevillea

The Anglesea Grevillea (*Grevillea infecunda*) will experience a positive CSH by approximately 4.1% over the next 50 years under the reported management plans. This positive change is due to weed control efforts across its distribution range. Important threats to the Anglesea Grevillea include: physical disturbance by humans and inappropriate fire regimes. Management of these threats are not captured in this assessment. Future inclusion of these management actions, and others, in this assessment might result in an increase in the expected positive CSH for Anglesea Grevillea.

Button Wrinklewort

The Button Wrinklewort (*Rutidosis leptorhyncoides*) is expected to have roughly a 1.3% positive CSH over the next 50 years under the reported management plans, due to weed control efforts. Other key management actions for this species including management of fire regimes and species' genetic diversity management across its distribution range, are not captured in this assessment. Increasing the coverage and inclusion of management actions specific to this endangered species, such as genetic rescue, might result in an increase in the expected positive CSH for Button Wrinklewort.

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:21 Area of Management in Priority Locations			 DATA QUALITY Fair
Data custodian DELWP			

This indicator sets out targets for hectares of management in priority locations, including restoration of habitat, which includes:

- 4 million hectares of herbivore control in priority locations by 2037
- 1.5 million hectares of pest predator control by 2037
- 1.5 million hectares of weed control in priority locations by 2037
- 200,000 hectares of revegetation in priority areas for connectivity between habitats by 2037
- 200,000 hectares of new protected areas on private land by 2037

A priority location refers to areas identified within the top 20% cost-effective actions in the SMP. SMP helps to integrate and compare information on the expected benefits and indicative costs of conservation actions across species and locations. It allows us to compare management options, or the effectiveness of individual management actions in different places.

SMPs will help conservation managers make decisions across Victoria, including both investment in actions to strengthen biodiversity, and guidance in the application of statutory responsibilities and regulatory controls. SMP helps to integrate and compare information on the expected benefits and indicative costs of conservation actions across species and locations. It allows us to compare management options, or the effectiveness of individual management actions in different places.[204]

The SMP focuses on the benefit of action (representing best options for gains) and so contains a mix of values, noting some high-value areas may not be included because they may not have a relevant action in the analysis, the actions are not particularly cost-effective, or the needs of that species have been met by other actions in other places. Increasing the alignment of these actions to sit in the top 20% cost-effective actions, as indicated in the SMP analysis outputs,[205] could yield greater biodiversity benefit per unit cost.

On-ground management works are progressing towards Victorian priority location *Biodiversity 2037* targets (Table B.16 and Figure B.12). Caveats and assumptions for implementing and measuring change in area of management in priority locations include:

- Measures include the effective treatment area over which the management action was undertaken. For example, herbivore control in an area with introduced herbivores such as, deer, rabbits, goats, horses and stock. Pigs were controlled by culling, other animals were removed or restricted, shot, trapped, excluded (seasonal or permanent) or a changed grazing regime was introduced. It recognises the area where the target species is located and treatment is applied. It does not include the search area.

204 DELWP 2018, 'Strategic Management Prospectus', Melbourne, Victoria http://delwp.maps.arcgis.com/apps/MapJournal/index.html?appid=e0289e3fe12f436490ef63d4444a05df# Accessed 2 October 2018.

205 Ibid

- This assessment assumes on-ground management actions were completed to an appropriate standard (such as DELWP's *Biodiversity 2037* Monitoring, Evaluation and Reporting Framework, DELWP Output Delivery Standards and Output Data Standard).[206] A discount rate was applied where a lower level of standard has been applied to the work, where only a portion of the area has been treated or where there is insufficient information provided on the delivery standard. Given this dataset is preliminary in nature, any of these discount rate scenarios are likely to have occurred. Discount rates were 50% of the estimated total biodiversity benefit for the actions where the discount was applied. Weed control and revegetation had a 50% discount applied to each as both actions are rarely done to the standard that is the basis of the benefit estimate in SMP. The spatial data provided for weed control appeared to overestimate the area controlled (in areas such as Murray-Sunset, Grampians and East Gippsland). Weed control, for example, assumes that all high threat weeds are controlled in an area, not just a single or subset of species. Revegetation assumes that it is done to the ecological vegetation class standards, rather than just selected overstorey and understorey species.
- Priority locations in the SMP contain a mix of area values, where some high value areas may not be included due to the following:

  - They lack a relevant management action in the analysis.

  - The management actions are not particularly cost-effective.

  or

  - The needs of that species have been met by management actions in other locations.

Increasing the alignment of these management actions to the top 20% cost-effective management actions in the SMP could yield greater biodiversity benefit per unit cost.

206 Note: see Biodiversity 2037 Monitoring, Evaluation and Reporting Framework, DELWP Output Delivery Standards, DELWP Standard Outputs.

Table B.16 Measuring progress from on-ground management actions in achieving *Biodiversity 2037* targets for priority locations across Victoria applying DELWP's Standard Output Data

Management action	Contribution of actions to Biodiversity 2037 targets		Actions across the State
	Hectares of action in priority locations (ha)	**Target hectares of actions in priority locations by 2037 (ha)**	**Total hectares of action in priority and other locations across the state (ha)**
Herbivore control	1,572,725	4,000,000	6,979,935
Pest predator control	705,590	1,500,000	2,475,713
Weed control	1,916,350	1,500,000	4,223,328
Restoration	359	200,000	65,217
Hectares of newly protected area on private land	2,204 (a)	200,000	137,270 (b)

(a) Priority location does not apply to this management action.

(b) Total area of permanently protected area on private land in Victoria

(Data source: DELWP 2018)

Some management plans and projects may occur in locations where it would be beneficial to conduct a particular management action. However, each management action is competing with all other management actions across Victoria in the SMP Analysis. This means that not all locations where it is beneficial to conduct a particular management action will be in a 'priority location' within the SMP analysis or where that management action is the most cost-effective. Further progress towards targets could be made by increased alignment of management actions in priority locations (including a combination of actions) through increased funding.

Further progress towards targets could be made by increased alignment of management actions in priority locations (including a combination of management actions). An audit of management sites is planned to determine how management and data standards are being interpreted and applied in DELWP's Standard Output Data. This will feed into a review of the standards to ensure reporting accurately reflects on-ground management action and progress towards priority location targets.

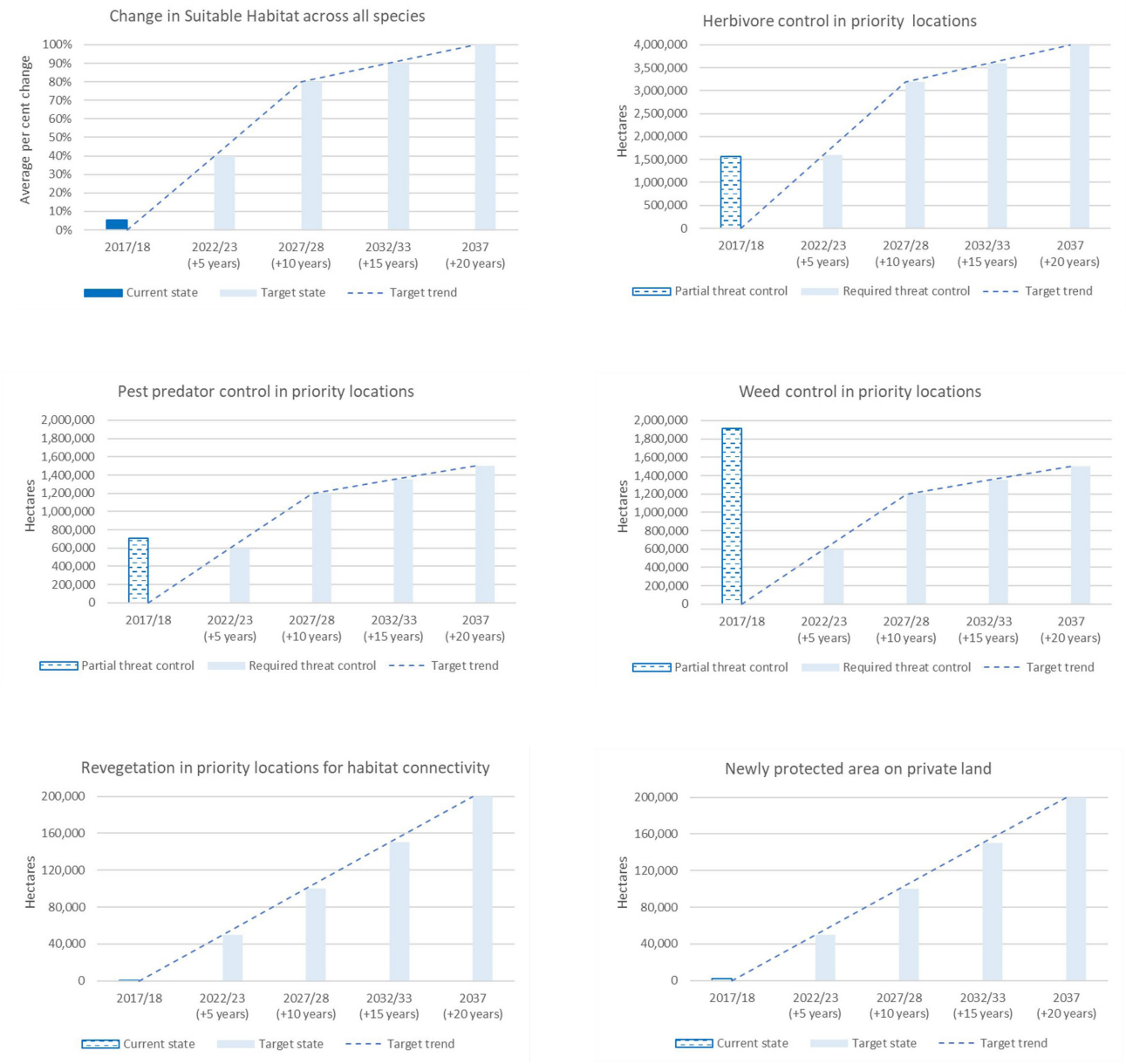


Figure B.12 Measuring progress from on-ground management actions in achieving Biodiversity 2037 targets for priority locations across Victoria

(Data source: DELWP 2018)

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:22 Victorians value nature		?	 DATA QUALITY
Data custodian DELWP, Parks Victoria, CMAs			Poor

There is an estimated number of 100,000 Victorians participating in environmental volunteering each year across diverse volunteer groups and mostly structured programs.[207] These include citizen science programs, marine and coastal volunteers, water programs, Landcare, friends groups, parks volunteers, outdoor enthusiasts groups, Zoos Victoria, climate change and sustainability networks, gardening, wildlife programs, corporate volunteering, not-for-profits, and local government and government agency programs. The majority of environmental volunteer groups are based in regional and rural Victoria.[208] There is a lack of culturally and linguistically diverse communities involved in environmental volunteering.[209]

'Victorians value nature' (VVN) is a key objective for the Victorian Government's *Biodiversity 2037*. This objective aims to understand and assess how Victorians are connecting with the natural environment, how this improves their health and wellbeing and how people are protecting Victoria's natural environment for current and future generations.[210] An underlying assumption here is that an increased connection with nature will lead to greater value placed on the environment and more Victorians acting to support biodiversity. This indicator describes the relationship between people's interaction with nature (how they value it and act to protect or enhance biodiversity) and the ways they use it to improve their health and wellbeing. Targets for VVN include:

- all Victorians connecting with nature
- five million Victorians acting to protect the natural environment
- all Victorian Government organisations that manage environmental assets contributing to achieving the above two targets.

To meet these targets, DELWP has developed the Victorians Volunteering for Nature – Environmental Volunteering Plan. This plan has four key foci areas:

- sustain – to sustain existing environmental volunteering programs and networks
- expand – to regenerate environmental volunteering and encourage more Victorians to act for nature
- value – to value and recognise the contributions of environmental volunteers
- understand – to understand the diverse needs of the environmental volunteering sector.

To implement this plan, DELWP is currently developing the Victorians Valuing Nature Conceptual Framework, which includes the Victorians Valuing Nature Foundations Survey and Structured Decision Making Process for Victorians Valuing Nature. The Victorians Valuing Nature Conceptual Framework will assist in conceptualising the work and creating measures to meet the above targets to be included in the next iteration of the *Biodiversity 2037* Monitoring, Evaluation and Reporting Framework in mid-2019. This will include the development of KPIs and related outcomes for the VVN goal, together with a description of the outputs and the types of standard outputs data required for reporting. As a new *Biodiversity 2037* indicator, baseline figures to assess and inform future state and trend of how Victorians value nature and their experience with nature is currently being collated by DELWP.

207 DELWP 2018, 'Victorians volunteering for nature environmental volunteering plan', Melbourne, Victoria.
208 Ibid
209 Ibid
210 DELWP 2017, 'Protecting Victoria's Environment – Biodiversity 2037', Melbourne, Victoria.

Parks Victoria visitor data can also contribute to understanding how Victorians value nature through visitor numbers. In 2013–14, approximately 4.3million day trips were taken to natural areas by Victorian domestic nature-based visitors.[211] During 2016–17, there were 449 licensed tour operators which increased to 494 licensed tour operators in 2017–18 with active licences working across Parks Estate, highlighting visitor interest.[212] It is estimated that visits to parks saves Victoria between $80 to $200 million per year from avoidance of disease, mortality and lost productivity.[213] Aboriginal cultural tourism is also expanding to meet the growing demand for Aboriginal cultural experiences and products.[214] ParkConnect is Park Victoria's online volunteer management system. The largest demographic registering to volunteer on ParkConnect is the 18 to 35-year old age group with the highest percentage indicating their employment status as 'full-time'. The largest proportion of volunteer activities are focused on habitat restoration followed by environmental research, historic heritage conservation then gardening. Since the implementation of ParkConnect there has been a significant shift in demographics of new volunteers with the highest percentage of volunteers previously over 65.[215]

Citizen Science Contribution to Understanding and Managing Victoria's Biodiversity

Under VVN there is an opportunity for citizen science data to complement science research data for evidence-based biodiversity planning and management decisions. The following indicators can be considered for future reporting of citizen science data:

- the actual data, and its quality, that contribute to management decisions
- the number and types of citizen science programs contributing data for informing real-time on-ground management decisions
- the number of volunteers involved in citizen science programs and the economic value of volunteers' time
- social benefits – for example social cohesion, level of environmental stewardship and health and wellbeing benefits – as outcomes from volunteers engaging in citizen science.

211 DELWP 2016, 'Protecting Victoria's Environment – Biodiversity 2036. Supporting technical supplement', Melbourne, Victoria.
212 PV Data 2018.
213 PV 2015, 'Valuing Victoria's Parks. Accounting for ecosystems and valuing their benefits: Report of first phase findings', Melbourne, Victoria http://parkweb.vic.gov.au/about-us/news/valuing-victorias-parks Accessed 27 July 2018.
214 Tourism Victoria 2014, 'Aboriginal tourism: market profile year ending June 2014', Melbourne, Victoria. http://www.tourism.vic.gov.au/research/domestic-and-regional-research/product-segment-market-profiles.html Accessed 27 July 2018.
215 PV Data 2018.

Indicator	Status UNKNOWN POOR FAIR GOOD	Trend	Data Quality
B:23 Number of Victorian Government organisations that manage environmental assets that contribute to DELWP Standard Output Data Data custodian DELWP		?	 DATA QUALITY Poor

This indicator's target is to have 100% of Victorian Government organisations that manage environmental assets contributing to DELWP Standard Output Data.

To date, 12% of Victorian Government organisations who manage Victoria's natural assets have contributed some data. In most cases this data is not complete and does not reflect all on-ground works those organisations have delivered or funded. Further work, funding and resourcing is needed to support all Victorian Government organisations who manage natural assets to contribute activity data, and ensure they include as requirement for programs including any grant agreements.

Future Focus

Improve Victoria's biodiversity outcomes on public land

As this report demonstrates, the data and science available to answer many of the critical questions about biodiversity condition and extent in Victoria, is inadequate. This fragmented evidence base is an impediment to adaptive management and improving biodiversity outcomes. This fragmentation has three overarching causes.

Firstly, various investment programs across multiple land management groups have created different and inconsistent data sources and terminologies for reporting on the state of biodiversity, land and forest assets in Victoria. These inefficiencies impact on the ability to present a coherent and integrated evidence base to improve management interventions and ultimately, biodiversity outcomes. Streamlining its approach to land-management to reduce inefficiencies will assist DELWP to deliver a well-coordinated and coherent approach.

Secondly, these measures will require complementary investment in improving data capability to routinely monitor progress towards biodiversity outcomes. This will result in improved accessibility and utility of data in more meaningful timeframes for biodiversity, land and water decision-making. Improved data capability has been recognised as an 'enabler' in DELWP's Science Statement for increasing connectivity and discoverability of science across the department, with partners, stakeholders and the community.

Finally, Victoria's biodiversity science and data capability, although underpinned by world-class scientists and research institutions (including DELWP's Arthur Rylah Institute), is diminished by a lack of coordination and strategy in approach to investing in critical research to enable better and more timely decision-making and policy interventions. This is a critical theme that links many of the recommendations presented in this report – and the broader narrative of addressing knowledge gaps and improving the evidence base for environmental management.

This report highlights the need for improved functionality of biodiversity science across the Victorian Government environment portfolio to improve the collection, coordination, curation and interpretation of biodiversity science. Perhaps most critical is the need to integrate biodiversity science to inform solutions to complex problems, cumulative threats (climate change, fire, drought, flood, heatwave, invasive pests, development) and cumulative challenges (forests, water, marine and coastal management).

A chief biodiversity scientist for Victoria would provide the leadership that is missing in Victoria to improve investment and coordination in biodiversity science and research. The chief biodiversity scientist would report directly to the Secretary of DELWP, complement the current roles of EPA Victoria's Chief Environmental Scientist, Parks Victoria's Chief Conservation Scientist and Victoria's Lead Scientist, and provide the DELWP Secretary and the Minister for Environment with esteemed counsel on biodiversity, threatened species and the impacts of climate change, invasive pests and extreme events on biodiversity values and assets. This science leadership role would also extend to advising on the development of the biodiversity targets that the Victorian Government has committed to establishing in *Biodiversity 2037*. A key function of this role would be to ensure that biodiversity research investment by the Victorian Government is targeted to management and policy priorities across the portfolio, and that the science is better curated, coordinated and tailored to improve the collective research impact of the investment on adaptive management.

The chief biodiversity scientist would be equipped with the authority to provide esteemed counsel on the Victorian Government's collective biodiversity research effort and on enhancing biodiversity outcomes consistent with the objectives of *Biodiversity 2037*.

Recommendation 5: That DELWP streamline the governance and coordination of investment in the science and data capability of all government biodiversity programs and improve the coherence and impact of the publicly-funded, scientific endeavour. Further, that DELWP establish the position of the chief biodiversity scientist to oversee this coordinated effort and provide esteemed counsel to the DELWP Secretary and the Minister for Environment to improve the impact of investment in biodiversity research across the Victorian environment portfolio.

Improve Victoria's biodiversity outcomes on private land

The rate of biodiversity loss on private land requires greater focus and effort by government. Victoria has nearly 23 million hectares of land: public land accounts for 37% and private land 63%.[216] Private land conservation through permanent protection has been increasing across the state. However, it occurs at a slower rate than biodiversity loss and needs to be addressed as a priority over the next decade.

The recommended chief biodiversity scientist would, in consultation with stakeholders across the portfolio, provide esteemed counsel to the DELWP Secretary and the Minister for Environment on the science that underpins private land conservation and on enhancing biodiversity outcomes on private land consistent with the objectives of *Biodiversity 2037*.

Recommendation 6: That DELWP improve biodiversity outcomes on private land by accelerating private land conservation. This will require resourcing permanent protection measures that focus on high-priority ecosystems and landscapes, and investing in local government capability to enforce the existing *Guidelines for the Removal, Destruction or Lopping of Native Vegetation and the Invasive Plants and Animals Policy Framework*.

216 VEAC, 2016. Statewide Assessment of Public Land Discussion Paper. Victorian Environmental Assessment Council, East Melbourne, Victoria.

Accounting for the Environment

Biodiversity plays an essential role in supporting economic and social wellbeing through maintaining functioning ecosystems that produce ecosystem services. Environmental–economic accounting provides a framework to measure and link biodiversity and the ecosystem services it supports that underpin economic activity and wellbeing.

The impact of healthy or degraded biodiversity already appears to some extent in Victoria's traditional economic accounts (the System of National Accounts (SNA)) that record goods and services such as tourism and agricultural production, which are often supported by biodiversity. However, traditional accounts do not identify the proportion of economic activity that can be attributed to biodiverse ecosystems. The System of Environmental–Economic Accounting (SEEA) extends the SNA by including environmental and ecosystem assets. For example, in 2015, Victorian parks were found to support $1.4 billion per year in visitor expenditure and generate $1 billion gross value added for the Victorian economy.[217] Biodiversity is a key part of the visitor experience attraction of parks.

Biodiversity accounts can help illustrate the relationship between biodiversity and economic activity and wellbeing by reporting data in a spatially explicit and consistent and comparable manner. By comparing trends in biodiversity against measures such as land use, energy use, or residual pollutants such as carbon emissions or nitrogen loads it may be possible to link key drivers and pressures contributing to biodiversity loss. Biodiversity accounts have the potential to play an important role in evaluating the efficiency and effectiveness of government and community management actions to protect and enhance Victoria's biodiversity.

In experimental ecosystem accounting, biodiversity is typically considered as a characteristic of ecosystems which can be strongly linked to the ecosystem services they provide. In this context, falling biodiversity (as measured, for example, by reductions in the number of species in a given area) will generally correspond to declining ecosystem condition. A measure of biodiversity could be a relevant condition metric for ecosystem assets discussed in other chapters of the SoE 2018, such as forests or marine and coastal environment.

Biodiversity accounting is a complex and evolving area of environmental–economic accounting. Its measurement is a specialist field, and different methods for assessing biodiversity provide varying levels of accuracy and precision. Biodiversity accounting is advancing but remains less defined than other areas of environmental–economic accounting such as land, water or carbon accounting.

Species Accounts

As a component of biodiversity, species form the biotic elements of ecosystems and have an important role in how ecosystems function and deliver ecosystem services that support economic activity and human wellbeing.

Specific species can also contribute directly to economic activity and wellbeing. For instance, some species are important for providing food or medicines used by local communities and in commercial activities. Others may contribute to wellbeing due to their charismatic and iconic nature – valued on the basis of aesthetics, characteristics and behaviour – or because of the cultural status given to them.

Species accounts may support the following analytical uses:

comparing trends in species status with information on economic activities and other drivers of species loss

- organising the information required to support trend analysis – for instance, via interpolation (new data points in an existing set) or forecasting

217 Varcoe T, Betts O'Shea H, Contretas Z 2015, 'Valuing Victoria's parks: Accounting for ecosystems and valuing their benefits', Melbourne, Victoria.

- organising information on species for aggregation and communication across all scales
- communicating the relationships between species, ecosystems and the supply of ecosystem services
- providing objective statistics to report on policies related to species and ecosystems
- exploring future trade-offs by organising species information required to support scenario modelling
- informing cost–benefit or ecological return on investment analyses
- supporting expert judgement on species status and trends by organising available information on the observations of species.

Australian Capital Territory Butterfly Accounts

Due to the complexities of biodiversity measurement, the focus is often placed on selected indicators of biodiversity rather than accounting for all aspects of biodiversity.

Butterflies can be used as indicators of environmental condition and change. The Australian Capital Territory (ACT) has recently prepared a set of novel SEEA butterfly accounts[218] aiming to use accounting for butterflies as a metric of ecosystem condition to identify problems and guide management of ecosystems. The ACT butterfly accounts include:

1. number of butterfly species at different scales (ACT, Australia and global) at one point in time
2. snapshot of species by family with breakdown by breeding category (endemic or introduced) and specialisation (generalists able to survive in a wide range of conditions or specialists that are more localised with specific needs for survival)
3. snapshot of species focusing in classifying in a way to enable links between species and ecosystem condition and climate change (by identifying those which rely on habitats in the ACT to breed)
4. account bringing together the information in points two and three above over two periods of time, showing 9 species added over 40 years.

Lessons learned from the butterfly accounts include that, while conservation status is important, a number of other classifications are useful for understanding the management needs of species, or strategies for conservation of species. In particular, classifications of species as specialists or generalists in terms of habitat needs as well as by area of distribution and movement is important. Having these classifications standardised in future will be useful. The ACT is also planning to compare measures of ecosystem condition from remote sensing data with the butterfly accounts.

The ACT is aiming to eventually use butterfly accounts covering species presence and abundance by habitat type and season each year and between two points in time, species area of distribution by habitat and a land cover account.

218 Bond S, Vardon M 2018, 'Moonlight Jewels to Common Browns: Butterfly Accounts for the ACT, Canberra', Australian Bureau of Statistics and Australian National University. https://seea.un.org/sites/seea.un.org/files/lg_24_d_16b.pdf Accessed September 2018.

LAND (L)

SCIENTIFIC ASSESSMENTS Part III

Commissioner *for* Environmental Sustainability Victoria



Land

This chapter includes assessments of Victoria's land health across four key themes: land use, soil health, contaminated sites and land management. The land use theme looks at current land use and land-use changes over time as well as greenfield versus infill development. The soil health theme incorporates soil carbon content, salinity, acidification and erosion. The contaminated sites theme contains a single indicator on that topic, while the land management theme includes assessments of land-management activities, participation in natural resource management activities, use of best practice on agricultural land and the proportion of the agricultural area under productive and sustainable agriculture.

Background

Victoria's land is used for a variety of purposes, including residential and business use, agricultural lands for production of food and fibre, and conservation areas to protect biodiversity. Maintaining the viability of the agricultural sector while also protecting and enhancing biodiversity is a key challenge for land managers.

The SoE 2013 reported that land development for urban and agricultural uses has resulted in declines in the condition of land, water and biodiversity. Many of the environmental challenges facing Victoria are the result of decisions about land use and land management. Land-use change is driven by a range of social, economic and environmental pressures. Preference for living in coastal or rural areas close to Melbourne has an impact on natural ecosystems and agricultural land, and threat to biodiversity. However, the main drivers of agricultural land-use change are climate (for example, water availability), commodity prices, supporting infrastructure and land capability (for example, soil type, terrain, susceptibility to flooding and inundation). These factors determine the type of farming that can be carried out, as well as those types that will maximise returns.[1]

Few long-term datasets exist to inform our knowledge of Victoria's statewide land health, and those datasets that do exist are often limited in extent, impairing our ability to comprehensively understand environmental condition. This lack of land-health data was a key observation of the Victorian Catchment Management Council's (VCMC) *Catchment Condition and Management Report 2017*.[2]

New and emerging technology is helping to improve the data capture and understanding of Victoria's land health. Remote sensing is one example, with satellite and aerial imagery capable of identifying areas subject to climate stress. However, remote sensing only has a limited ability to identify specific land-management types. Despite this limitation, remote sensing is rapidly improving with more investment in the sector (including by Digital Earth Australia and the Australian National University).[3,4]

More frequent drought and fires will reduce vegetation cover, and more severe storms and extreme rainfall events are also likely.[5] These conditions will create great potential for severe erosion and reductions in soil nutrients and carbon.[6]

The critical challenges facing Victoria's land-health management now and in the future include:

- ensuring on-ground monitoring is undertaken to understand changing land-management practices
- enhancing the ability of technology such as remote sensing to identify land areas subject to climate stress
- mitigating the effect of climate change on soil degradation

1. 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.
2. Victorian Catchment Management Council 2017, 'Catchment Condition and Management Report 2017', East Melbourne, Victoria, http://www.vcmc.vic.gov.au/pdf/CCMR_Report_2017.pdf Accessed 3 December 2018.
3. Geosciences Australia 2017, 'Digital Earth Australia', Canberra, Australia http://www.ga.gov.au/__data/assets/pdf_file/0008/49490/Prospectus.pdf Accessed 3 December 2018.
4. Australian National University, 'Projects', Canberra, Australia http://wald.anu.edu.au/ Accessed 3 December 2018.
5. Commissioner for Environmental Sustainability 2012, 'Climate Change Victoria: the science, our people and our state of play', Melbourne, Victoria.
6. Ibid

- increasing, and then maintaining, soil carbon. Decomposing organic matter is the most useful soil carbon for farming and is very susceptible to deterioration during drought.
- proactively identifying and remediating legacy land contamination
- ensuring that environmental implications are a primary consideration in land-use decision-making, including providing land users and managers with timely information on land condition.

Current Victorian Government Settings: Legislation, Policy, Programs

In May 2016, a Ministerial Advisory Committee (MAC) completed its inquiry into Environment Protection Authority Victoria (EPA Victoria). One of the MAC's recommendations was for Department of Environment, Land, Water and Planning (DELWP) to 'develop a comprehensive database of contaminated sites'.[7] The Victorian Government supported this recommendation and asserted that 'a public database providing consistent and easily accessible, statewide site history information will be developed to assist with the identification of potentially contaminated sites'.[8] More information on the progress of this database is provided in indicator L:09 (Contaminated sites).

Relevant audits within the land-health sector have been completed during the past decade by the Victorian Auditor-General's Office. The audit topics were Soil Health Management (October 2010) and Enhancing Food and Fibre Productivity (August 2016).[9,10] The 2010 audit recommended the development of agreed soil-health indicators and monitoring programs to assess soil-health status and trends. The Soil Health Strategy released by DELWP in July 2012 responded to the 2010 audit. This strategy included an action to identify key performance indicators that effectively and pragmatically measure the impact against departmental and regional priority environmental assets, using monitoring programs to collect the data required.[11]

7. MAC 2016, 'Independent inquiry into the Environment Protection Authority', http://www.epa-inquiry.vic.gov.au/__data/assets/file/0008/336698/Inquiry-report-EPA_June.pdf Accessed 3 December 2018.
8. DELWP 2017, 'Andrews Labor Government Response to the Independent Inquiry into the Environment Protection Authority', East Melbourne, Victoria https://www.environment.vic.gov.au/__data/assets/pdf_file/0025/49741/Andrews-Labor-Government-Response-to-the-Independent-Inquiry-into-the-Environment-Protection-Aut.pdf Accessed 3 December 2018.
9. VAGO 2010, 'Soil Health Management', Melbourne, Victoria https://www.parliament.vic.gov.au/papers/govpub/VPARL2006-10No378.pdf Accessed 3 December 2018.
10. VAGO, 'Enhancing Food and Fibre Productivity', Melbourne, Victoria https://www.audit.vic.gov.au/report/enhancing-food-and-fibre-productivity Accessed 3 December 2018.
11. Department of Sustainability & Environment 2012, 'Soil Health Strategy 2012', Melbourne, Victoria https://teamspace.cenitex.vic.gov.au/LotusQuickr/landhealthprogram2013-2017/Main.nsf/h_Toc/1B9120B62D5E6597CA257BDB0017203D/%24FILE/DSE-Soil-Health-Strategy.doc Accessed 3 December 2018.

The 2016 audit recommended that the Department of Economic Development, Jobs, Transport and Resources (DEDJTR) develop or utilise external performance measures to provide assurance that changes in agricultural practices and productivity are not affecting the long-term sustainability of the natural resources base. In its response to the audit, DEDJTR agreed to seek to incorporate indicators of the long-term sustainability of the state's natural resource base as part of the agriculture-industry component of the DEDJTR-wide Outcomes Framework.

To address the challenges associated with measuring statewide changes to soil health, Agriculture Victoria is working with the Cooperative Research Centre for High Performing Soils to ascertain key soil properties that could form the basis for soil performance indicators.[12] In alignment with this, Agriculture Victoria has recently completed work to update its data systems for improved data sharing and accessibility. Another project designed to improve access to both public and private data includes the Soil and Landscape Grid of Australia (funded by the Terrestrial Ecosystem Research Network and the National Research Infrastructure for Australia).[13]

The Australian Government has invested $1 billion in the National Landcare Program over four years from 2014–15 to 2017–18. The program is designed to address problems such as loss of vegetation, soil degradation, the introduction of pest weeds and animals, changes in water quality and flows, and changes in fire regimes. Over the coming five years, from 2018–19 to 2022–23, the Australian Government will invest more than $1 billion in a second phase of the National Landcare Program.[14]

In 2017, Agriculture Victoria released the *Agriculture Victoria Strategy*. The strategy noted the agriculture sector was continuing to make a major contribution to Victoria's economic and employment growth, even though the nature of farming has changed dramatically in recent decades.[15] This strategy is a reform framework, articulating Agriculture Victoria's priorities to enhance the global competitiveness, innovation and resilience of the state's agriculture.[16]

Parks Victoria works with Traditional Owners to manage parks and reserves. The Managing Country Together framework provides both practical and symbolic recognition of Traditional Owner rights, underpins enduring partnerships with Traditional Owners and strengthens sector capacity in joint protected area and cultural heritage management.[17]

12. Soil CRC, 'Current Projects', https://www.soilcrc.com.au/projects/ Accessed 3 December 2018.
13. Terrestrial Ecosystem Research Network, 'Soil and Landscape Grid of Australia', http://www.clw.csiro.au/aclep/soilandlandscapegrid/index.html Accessed 3 December 2018.
14. National Landcare Program, 'National Landcare Program Phase Two', Canberra, Australia http://www.nrm.gov.au/national-landcare-program Accessed 3 December 2018.
15. DEDJTR 2017, 'Agriculture Victoria Strategy', Melbourne, Victoria http://agriculture.vic.gov.au/__data/assets/pdf_file/0011/385949/Agriculture-Victoria-Strategy_FINAL.pdf Accessed 3 December 2018.
16. Parks Victoria, 'Managing Country together', http://parkweb.vic.gov.au/park-management/aboriginal-joint-management Accessed 3 December 2018.
17. Ibid

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.

Poor
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

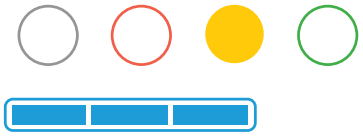
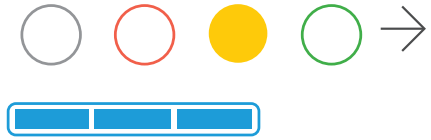
Data quality

Poor
Evidence and consensus too low to make an assessment

Fair
Limited evidence or limited consensus

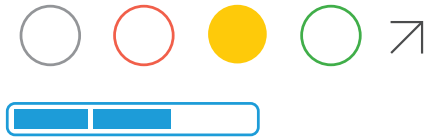
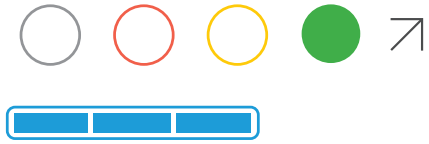
Good
Adequate high-quality evidence and high level of consensus

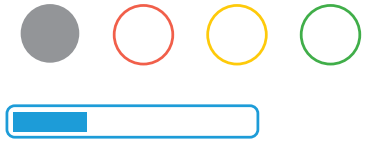
LAND

	Summary	Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **L:01** Land use types in Victoria **Region** Victoria **Measures** Percentage of Victoria's area classified by each type of land use class **Data custodian** AV, DELWP	Slightly more than half of Victoria's land is used for primary production. The overall mix of land use across Victoria is viewed as having a limited and variable impact on environmental health across Victoria. *For trend refer to L:02 and text explanation	 DATA QUALITY Good	N/A
Indicator **L:02** Changes in major land uses in Victoria **Region** Victoria **Measures** Changes in Victoria's land use over time **Data custodian** AV, DELWP	There were no significant shifts in Victorian land use from 2012-17. *For status refer to L:01 and text explanation	 DATA QUALITY Good	
Indicator **L:03** Changes in land tenure **Region** Victoria **Measures** Percentage of Victoria's area classified as public or private land **Data custodian** AV, DELWP	There were no significant shifts in Victorian land tenure from 2012-17.	 DATA QUALITY Good	

	Summary	Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **L:04** Greenfield versus infill development **Region** Victoria **Measures** (i) Housing development and greenfield development in Melbourne (ii) Population change in growth LGAs (iii) Urban area of Melbourne **Data custodian** DELWP	Melbourne's population is growing more than twice as quickly in growth areas on the urban fringes than it is in established areas.	 DATA QUALITY Good	
Indicator **L:05** Soil carbon content **Region** Victoria **Measures** Victorian Soil Total Organic Carbon at various depths **Data custodian** AV	There is an extremely wide range of soil organic carbon stocks across Victorian cropping and pasture soils, with most of the variation attributable to climate.	 DATA QUALITY Fair (detailed baseline data for all private land except the north east of Victoria – however unable to assess changes in soil carbon and statewide raster (grid) data)	
Indicator **L:06** Area affected by salinity **Region** Victoria **Measures** Percentage of Victoria's area classified as public or private land **Data custodian** AV, DELWP	Fewer bores are being found with an increasing salinity threat in the catchments that drain to the Murray River.	 Improving for the river catchments that drain to the Murray River and Unclear elsewhere DATA QUALITY Fair (for the river catchments that drain to the Murray River and Poor elsewhere (monitoring has largely ceased beyond the river catchments that drain to the Murray River))	

	Summary	Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **L:07** Soil acidification **Region** Victoria **Measures** Victorian soil pH ($CaCl^2$) at various depths **Data custodian** AV	Soil acidity and acidification is an issue for the high rainfall agriculture regions in the south west and east of Victoria.	 DATA QUALITY Fair (there is baseline statewide soil pH data but no suitable data to assess the pH change (acidification))	?
Indicator **L:08** Soil erosion **Region** Victoria **Measures** Dryland area with 30-100% bare soils **Data custodian** AV	Victoria's dryland area at risk of erosion has steadily increased to 37% in 2016 from a low of 13% in 2011.	 DATA QUALITY Poor (only case study data and no current statewide information)	↘
Indicator **L:09** Contaminated sites **Region** Victoria **Measures** (i) Number of environmental audits completed in Victoria (ii) Number of sites on EPA's Priority Sites Register **Data custodian** EPA Victoria, DELWP	More than 600 contaminated sites have been improved between 2013-17 to be suitable for more sensitive land use. However, it is unclear how many sites have become contaminated during that time.	 DATA QUALITY Fair (the current knowledge only pertains to a subset of contaminated sites, databases and regions)	?

	Summary	Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **L:10** Land management activities **Region** Victoria **Measures** The area of land managed for conservation **Data custodian** CMAs	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)	
Indicator **L:11** Participation in natural resource management activities **Region** Victoria **Measures** (i) Number of volunteers (ii) Amount of volunteer hours (iii) Community co-contribution in economic terms **Data custodian** CMAs, Landcare, PV	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	
Indicator **L:12** Use of best practice on agricultural lands **Region** Victoria **Measures** Area of land with improved agricultural practices in Victoria **Data custodian** CMAs	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.	 DATA QUALITY Poor (no statewide comprehensive data; data isn't granular)	

	Summary	Status	Trend
Indicator **L:13** Proportion of agricultural area under productive and sustainable agriculture **Region** Victoria **Measures** Proportion of agricultural area under productive and sustainable agriculture **Data custodian** AV, CMAs	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. There is no statewide data on sustainable agriculture.	 DATA QUALITY Poor (limited examples from two CMAs)	?

Land Use

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
L:01 Land use types in Victoria	○	○	●	○	N/A	DATA QUALITY
Data custodian AV, DELWP						Good

Land use across Victoria is shown in Figure L.1 and Table L.1, with data sourced from the Victorian Land Use Information System (VLUIS). The most up-to-date version of VLUIS contains data for 2016–17. The data in VLUIS has been categorised according to the Australian Valuation Property Classification Codes, which categorise land use into nine broad categories and many more subcategories.[18]

51.8% of Victoria's land use is defined as primary production, with most of that area used for mixed farming and grazing (23.2% of the state). Agriculture cropping (16.5%) and livestock grazing (8.4%) are other primary production land uses that take up significant portions of the state.[19] Another 39.8% of the state comprises national parks, conservation areas and forest reserves.[20,21] Urban areas – such as residential and commercial properties, industrial facilities and built-up areas – and roads make up 7% of Victoria's land.

18. Australian Bureau of Agricultural and Resource Economics and Sciences 2011,' Guidelines for land use mapping in Australia: principles, procedures and definitions 4th edition', Canberra, Australia.
19. DEDJTR, 'Victorian Land Use Information System 2016/17', Melbourne, Victoria https://www.data.vic.gov.au/data/dataset/victorian-land-use-information-system-2016-2017 Accessed 3 December 2018.
20. Ibid
21. Note that the terminology in the Australian Valuation Property Classification Codes for the categorisation of 'National Parks, conservation areas, forest reserves and natural water reserves' should be considered in the Victorian context to include national parks, conservation areas and State forest.

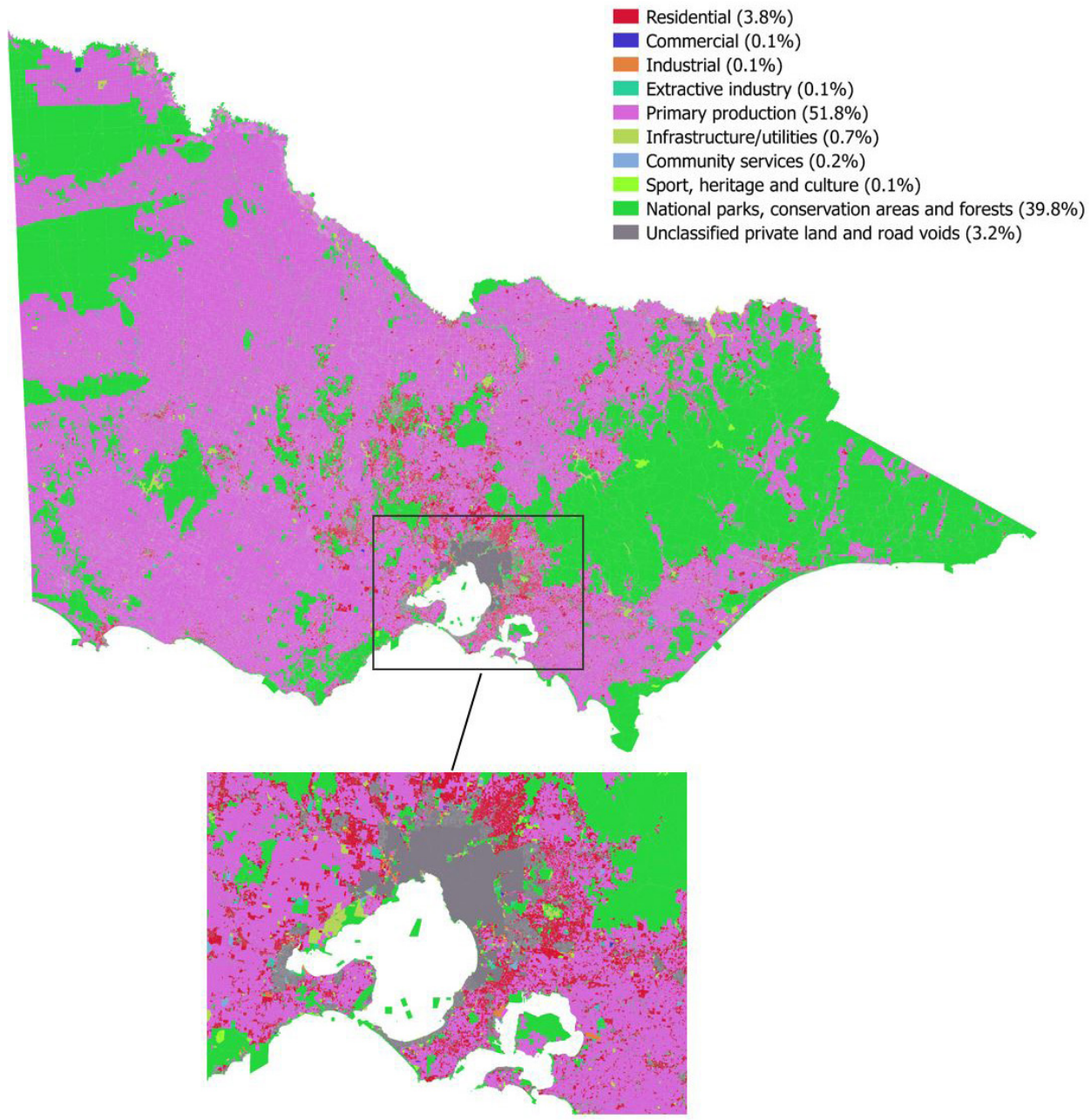


Figure L.1 Major land-use classes in Victoria

(Data source: VLUIS 2016–17)

Table L.1 Major land-use classes in Victoria, with selected subcategories included

Land-use type	Proportion of Victoria's area %
Primary production	
Mixed farming and grazing	23.2
Agriculture cropping	16.5
Livestock grazing and production	8.4
Softwood and hardwood plantations	2.1
Other	1.6
Total primary production	51.8
National parks, conservation areas and forest reserves	39.8
State forest	12.7
National park - land	11.5
Nature reserves	9.8
Other	5.7
Total national parks, conservation areas and forest reserves	39.8
Residential	3.8
Unclassified Private land and road voids	3.2
Infrastructure and utilities	0.7
Community services	0.2
Sport, heritage and culture	0.1
Extractive industries	0.1
Industrial	0.1
Commercial	0.1

(Data source: VLUIS 2016–17)[22,23]

22. DEDJTR, 'Victorian Land Use Information System 2016/17', Melbourne, Victoria https://www.data.vic.gov.au/data/dataset/victorian-land-use-information-system-2016-2017 Accessed 3 December 2018.
23. Total area of Victoria in VLUIS 2016/17 is 25.5 million hectares.

At a regional level, land use varies significantly between catchments. Approximately three-quarters of the land in the western catchments of Glenelg Hopkins, Wimmera and North Central is used for primary production. These areas in western Victoria are typically flatter and more accessible for agricultural production than other parts of Victoria. Conversely, the eastern and north-eastern catchments predominantly comprise national parks, conservation areas and forests. More than 20% of land in the Port Phillip and Westernport catchment is residentialThis is a much greater percentage of residential land than any other catchment and demonstrates the specific environmental pressures of the region.

Irrigated agriculture can require large volumes of water and needs careful management to ensure water quality and water resources are not adversely impacted. Even though it accounts for just over 1 million hectares (less than 5% of Victoria's land), irrigated agriculture is responsible for 78% of the state's surface-water consumption (see indicator WR:07 (Percentage of waterways and groundwater areas, subject to water extraction, exceeding sustainable yields)) and contributes $4.2 billion (30%) of Victoria's total gross value of $14 billion of agricultural production.[24] Because of its heavy water usage, irrigated agriculture is impacting flow regimes by reversing the seasonality of natural flows, with large volumes of water released for irrigation during the dry season (see indicator WR:03 (Condition of flow regimes)). As detailed in indicator WR:09 (Percentage of agricultural land with improved irrigation), some improvements have been made to irrigation efficiency in Victoria.

The status of this indicator has been assessed as Fair because the overall mix of land use across Victoria is viewed as having a limited and variable impact on environmental health across Victoria.

24. Australian Bureau of Statistics 2018, '4610.0.55.008 - Gross Value of Irrigated Agricultural Production, 2016-17', Canberra, Australia http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/4610.0.55.008Main+Features12016-17?OpenDocument Accessed 3 December 2018.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
L:02 Changes in major land uses in Victoria	N/A				→	DATA QUALITY
Data custodian AV, DELWP						Good

Land-use change is driven by a range of social, economic and environmental pressures. For example, population growth is a key driver of urban land-use change, leading to urban expansion in Melbourne's fringe areas and parts of regional Victoria (see indicator L:04 (Greenfield versus infill development)). As stated in the SoE 2013, urban land use is also strongly affected by social pressures through the property market, which drives land use towards the highest values (for example, housing in fringe areas).[25] In addition, preference for living in coastal or rural areas close to Melbourne is resulting in the loss of natural ecosystems and agricultural land. Such losses threaten biodiversity and promote more intensive agriculture to compensate for reductions in the availability of productive land.[26]

The agricultural landscape in northern Victoria has changed markedly in recent years with the introduction of a water market. The ability to trade and move water has provided increased opportunities for certain subsectors, including high-value horticulture.

The data for this indicator is sourced from the VLUIS dataset for 2012–13, which aligns with the release of the previous SoE report, and the most recent VLUIS dataset (2016–17).[27, 28] There were no significant shifts in Victorian land use from 2012–13 to 2016–17.

25. 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.
26. Ibid
27. DEDJTR, 'Victorian Land Use Information System 2012/13', Melbourne, Victoria https://www.data.vic.gov.au/data/dataset/victorian-land-use-information-system-2012-2013 Accessed 3 December 2018.
28. DEDJTR, 'Victorian Land Use Information System 2016/17', Melbourne, Victoria https://www.data.vic.gov.au/data/dataset/victorian-land-use-information-system-2016-2017 Accessed 3 December 2018.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
L:03 Changes in Land Tenure	○	○	●	○	→	DATA QUALITY: Good

Data custodian AV, DELWP

Public land is mainly divided between parks and reserves, managed under the *National Parks Act 1975*, and state forests, managed under the *Forests Act 1958*. State forests are managed for multiple purposes, including timber harvesting, conservation, recreation and water production.

Similarly to indicator L:02 (Changes in major land uses in Victoria), the data for this indicator is sourced from the VLUIS dataset for 2012–13, which aligns with the release of the previous SoE report and the most recent VLUIS dataset (2016–17).[29,30]

For 2016–17, 57.6% of Victoria's land was privately owned (Figure L.2), which remained stable from 2012–13 when 57.3% of the state's land was recorded as privately owned. Private land can exert more pressure on the environment; however, the effect of changing land tenure does not necessarily mean a change in environmental pressure – the effect of land-use management is the driving force. Consequently, more information on land-use management associated with land tenure is required to determine if the move of private land to public land is resulting in more secure management. Private land is predominantly used for primary production, which accounts for half of Victoria's total area. Residential areas are another form of private land use, making up 3.8% of the state's total area. Melbourne occupies less than 5% of Victoria's land area but is home to more than 75% of Victoria's population, illustrating the land-health pressures that exist in the state's capital.[31,32]

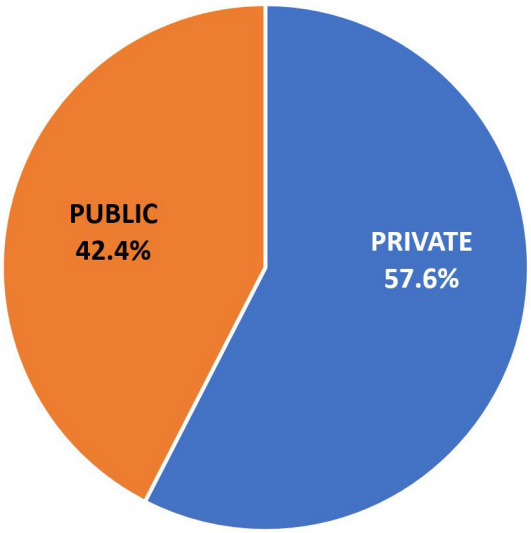


Figure L.2 Land tenure in Victoria, 2016–17

(Data source: VLUIS 2016–17)[33]

29. DEDJTR, 'Victorian Land Use Information System 2012/13', Melbourne, Victoria https://www.data.vic.gov.au/data/dataset/victorian-land-use-information-system-2012-2013 Accessed 3 December 2018.
30. DEDJTR, 'Victorian Land Use Information System 2016/17', Melbourne, Victoria https://www.data.vic.gov.au/data/dataset/victorian-land-use-information-system-2016-2017 Accessed 3 December 2018.
31. Australian Bureau of Statistics , 'Greater Melbourne (GCCSA) (2GMEL)', Canberra, Australia http://stat.abs.gov.au/itt/r.jsp?RegionSummary&region=2GMEL&dataset=ABS_REGIONAL_ASGS2016&geoconcept=ASGS_2016&datasetASGS=ABS_REGIONAL_ASGS2016&datasetLGA=ABS_REGIONAL_LGA2017&regionLGA=LGA_2017&regionASGS=ASGS_2016 Accessed 3 December 2018.
32. Australian Bureau of Statistics , 'Victoria (STE) (2)', Canberra, Australia http://stat.abs.gov.au/itt/r.jsp?RegionSummary&region=2&dataset=ABS_REGIONAL_ASGS2016&geoconcept=ASGS_2016&datasetASGS=ABS_REGIONAL_ASGS2016&datasetLGA=ABS_REGIONAL_LGA2017&regionLGA=LGA_2017&regionASGS=ASGS_2016 Accessed 3 December 2018.
33. DEDJTR, 'Victorian Land Use Information System 2016/17', Melbourne, Victoria https://www.data.vic.gov.au/data/dataset/victorian-land-use-information-system-2016-2017 Accessed 3 December 2018.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
L:04 Greenfield versus infill development	○	○	●	○	→	DATA QUALITY: Good

Data custodian DELWP

As Victoria's population continues to grow, so will construction of residential, commercial and industrial properties to meet demand. The construction increase comes in the form of two types of development: the utilisation of previously developed land for urban and other development (infill), and previously undeveloped land (greenfield). The data included in this indicator provides background information on land-use pressures for a range of issues, including biodiversity.

Housing development increased at record levels across Melbourne in the five years to 2016. In established areas of Melbourne, 10,000 more dwellings were constructed in 2016 than 2012 – the majority being apartment developments.[34] As these are most commonly intensifying existing residential uses or urban-renewal projects, this has not increased the urban area of Melbourne. The City of Melbourne has seen a population increase of nearly 50,000, with its urban land intensified or existing urban uses transformed.[35]

Greenfield development has also been at record levels and has delivered approximately 30% of housing development across the five years.[36] Greenfield development and associated infrastructure increased the urban area of Melbourne by approximately 7,400 hectares from 2012 to 2016.[37]

The local government areas (LGAs) of Wyndham and Casey have seen the most growth over the five years, with increases in population of 60,000 and 50,000 respectively.[38] The urban areas of both LGAs has increased by approximately 1,500 hectares between 2012 and 2016.[39]

Figure L.3 shows that Melbourne's population is growing more than twice as quickly in growth areas on the urban fringes than it is in established areas.[40] This increases the pressure on biodiversity in Melbourne's urban fringes. Figure L.4 shows that Melbourne's urban area has increased by at least 1,000 hectares each year since 2012.[41] Melbourne's urban fringes also contain areas known as 'green wedges' that host a mix of agriculture and low-density activities such as:

- major infrastructure that supports urban areas, including Melbourne and Moorabbin airports
- the western and eastern water treatment facilities
- major quarries used in the building industry
- cultural heritage sites
- biodiversity conservation areas
- water catchments.[42]

With the expanding populations in green wedge LGAs, the importance of green wedges to protect environmental values is increasing.

34. Australian Bureau of Statistics 2018, '8731.0 - Building Approvals, Australia, May 2018', Canberra, Australia http://www.abs.gov.au/ausstats/abs@.nsf/mf/8731.0 Accessed 3 December 2018.
35. Australian Bureau of Statistics 2018, '3218.0 - Regional Population Growth, Australia, 2016-17', Canberra, Australia http://www.abs.gov.au/ausstats/abs@.nsf/mf/3218.0 Accessed 3 December 2018.
36. Australian Bureau of Statistics 2018, '8731.0 - Building Approvals, Australia, May 2018', Canberra, Australia http://www.abs.gov.au/ausstats/abs@.nsf/mf/8731.0 Accessed 3 December 2018.
37. DELWP, 'Rural urban fringe GIS layer', East Melbourne, Victoria.
38. Australian Bureau of Statistics 2018, '3218.0 - Regional Population Growth, Australia, 2016-17', Canberra, Australia http://www.abs.gov.au/ausstats/abs@.nsf/mf/3218.0.
39. DELWP, 'Rural urban fringe GIS layer', East Melbourne, Victoria.
40. Ibid
41. Ibid
42. DELWP, 'Green wedges', East Melbourne, Victoria https://www.planning.vic.gov.au/policy-and-strategy/green-wedges Accessed 3 December 2018.

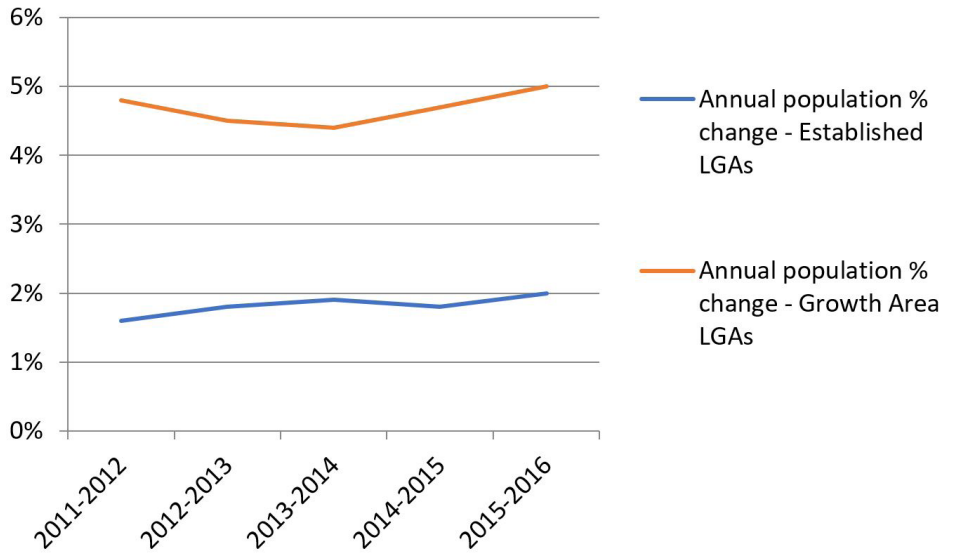


Figure L.3 Annual percentage change in population for LGAs in Melbourne, 2011–12 to 2015–16

Note: Growth area LGAs are Cardinia, Casey, Hume, Melton, Whittlesea and Wyndham

(Data source: ABS, 2016)[43]

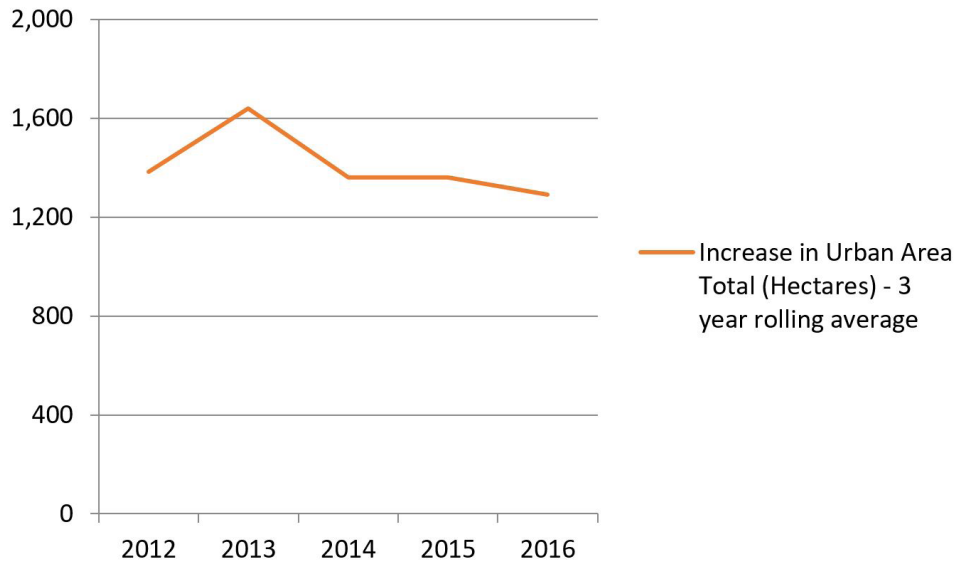


Figure L.4 The increase in urban area land (hectares) shown as a three-year rolling average, 2012–2016

(Data source: DELWP)[44]

43. Australian Bureau of Statistics 2018, '3218.0 - Regional Population Growth, Australia, 2016-17', Canberra, Australia http://www.abs.gov.au/ausstats/abs@.nsf/mf/3218.0 Accessed 3 December 2018.
44. DELWP, 'Rural urban fringe GIS layer', East Melbourne, Victoria.

Soil Health

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
L:05 Soil carbon content	●	○	○	○	?	DATA QUALITY
Data custodian AV						Fair

Increasing the organic carbon content in soils may help to mitigate rising greenhouse gas emissions, while sustaining agricultural productivity and environmental conditions.[45, 46] A benchmarking study undertaken between 2010 and 2012 at 615 sites on farms across western and south-eastern Victoria determined how much soil organic carbon (SOC) was present in Victoria's agricultural lands (Figure L.5).[47] The results of the study were published in 2016 and have been used as part of the assessment for this indicator. Data has also been sourced from the Soil Grids of Victoria that were published in 2017.[48] The methodology used to develop the Soil Grids of Victoria is based on the Australian Soil and Landscape Grid, and the new maps are most appropriately used for assessments of regional to statewide trends of soil properties.

The amount of carbon stored in soil is the balance between inputs (mainly from plants) and losses (decomposition, erosion or removal at harvest).[49] These processes are influenced by environmental factors such as climate and topography, as well as by physical, chemical and biological soil properties. Inputs of carbon could also be manure or compost on a minority of farms.

45. Lal R, Follett RF 2009, 'Soil carbon sequestration and the greenhouse effect', Soil Science Society of America, Madison, WI, USA.
46. Swift RS 2001, 'Sequestration of carbon by soil', *Soil Science*, 166, 858–871.
47. Robertson F et al 2016, 'Soil organic carbon in cropping and pasture systems of Victoria, Australia', *Soil Research*, 54(1), pp. 64-77.
48. DEDJTR, 'SOIL_TOTAL_ORGANIC_CARBON', Melbourne, Victoria http://services.land.vic.gov.au/SpatialDatamart/dataSearchViewMetadata.html?anzlicId=ANZVI0803005804&extractionProviderId=2 Accessed 3 December 2018.
49. Robertson F et al 2016, 'Soil organic carbon in cropping and pasture systems of Victoria, Australia', *Soil Research*, 54(1), pp. 64-77.

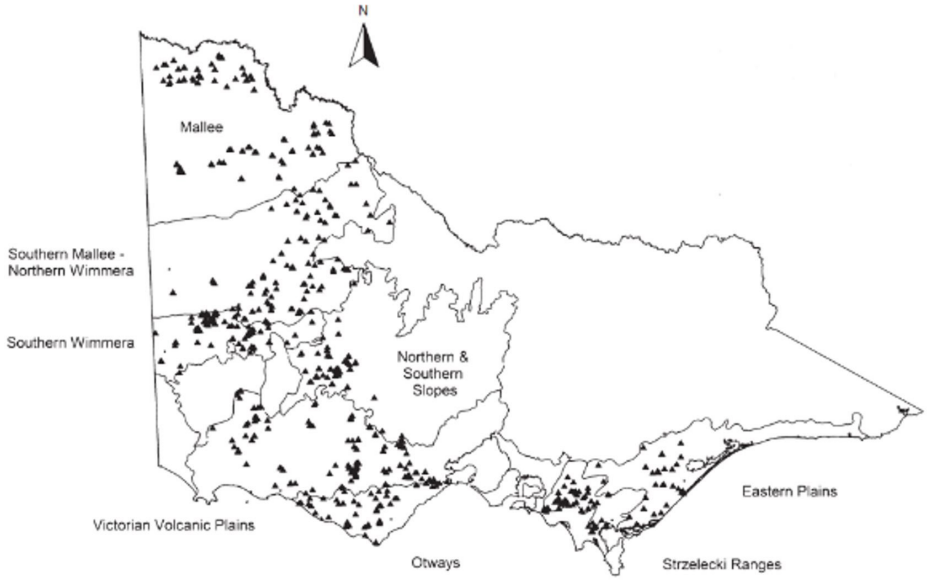


Figure L.5 Map of Victoria showing approximate location of sampled sites within each region[50]

Note: The regions are the primary production landscape of Victoria.[51]

The results of the study found an extremely wide range in SOC stocks across Victorian cropping and pasture soils.[52] Results from the study outlined four key factors assessed for their impact on soil carbon content:

- **Climate** – Most of the variation in SOC was attributable to climate, with nearly 80% of the differences in SOC stocks across the state explained by local patterns of annual rainfall or vapour pressure deficit.[53]
- **Texture-related soil properties** – Silicon and clay explained a further small amount of variation in SOC.[54]
- **Management classes (continuous cropping, crop-pasture rotation, sheep or beef pasture, and dairy pasture)** – After accounting for climate and soil properties, differences in SOC between management classes were small and often not significant.[55]
- **Management practices (stubble retention, minimum cultivation, perennial pasture species, rotational grazing and fertiliser inputs)** – These were also not significantly related to SOC stock.[56] These results were consistent with a 2013 study that concluded the potential to increase carbon through changes to management practices is quite limited.[57]

SOC stocks were generally greatest in the Strzelecki Ranges, Eastern Plains, Victorian Volcanic Plains and the Otways, while SOC was less abundant in the Mallee and Wimmera (areas of less rainfall).

Data from the Soil Grids of Victoria supports these findings, with Figure L.6 showing the raster maps of SOC as taken from the Spatial Datamart Victoria and displayed on the Australian Digital Soil Mapping website OzDSM.[58,59]

50. Ibid
51. MacEwan R, Robinson N, Imhof M, Rees D, Sposito V 2008, 'Primary Production Landscapes of Victoria', Paper presented at the 14th Agronomy Conference, Adelaide, South Australia, 21–25 September 2008.
52. Robertson F et al 2016, 'Soil organic carbon in cropping and pasture systems of Victoria, Australia', *Soil Research*, 54(1), pp. 64-77.
53. Ibid
54. Ibid
55. Ibid
56. Ibid
57. Robertson F, Nash D 2013, 'Limited potential for soil carbon accumulation using current cropping practices in Victoria, Australia', Agriculture, Ecosystems & Environment, 165, pp. 130-140.
58. DEDJTR, 'SOIL_TOTAL_ORGANIC_CARBON', Melbourne, Victoria http://services.land.vic.gov.au/SpatialDatamart/dataSearchViewMetadata.html?anzlicId=ANZVI0803005804&extractionProviderId=2 Accessed 3 December 2018.
59. OzDSM, 'Australian digital soil mapping', Ballarat, Victoria http://www.ozdsm.com.au/ozdsm_map.php Accessed 3 December 2018.

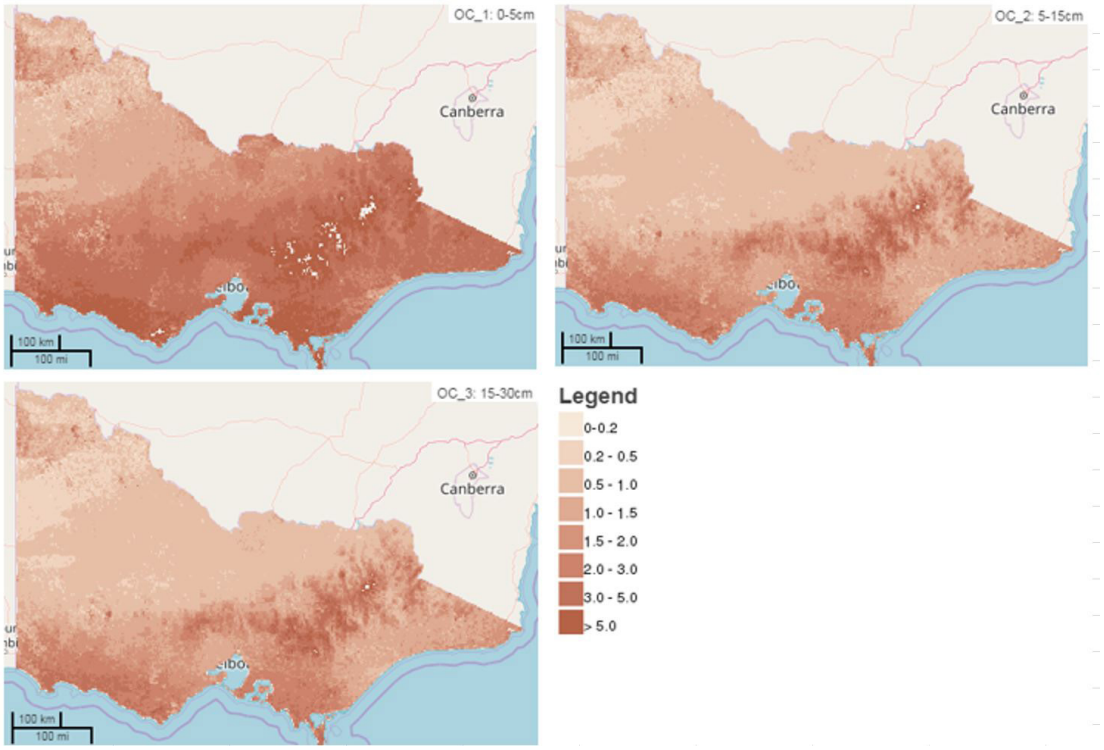


Figure L.6 Victorian Soil Total Organic Carbon (%) at various depths.[60,61]

The status of this indicator has been assessed as Unknown due to the absence of available standards to determine suitable SOC stocks.

60. DEDJTR, 'SOIL_TOTAL_ORGANIC_CARBON', Melbourne, Victoria http://services.land.vic.gov.au/SpatialDatamart/dataSearchViewMetadata.html?anzlicId=ANZVI0803005804&extractionProviderId=2 Accessed 3 December 2018.
61. OzDSM, Ballarat Victoria http://www.ozdsm.com.au/ozdsm_map.php Accessed 3 December 2018.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
L:06 Area affected by salinity						
			Improving for the river catchments that drain to the Murray River and Unclear elsewhere			DATA QUALITY Fair
Data custodian AV, DELWP						

A statewide update on the area of land affected by salinity cannot be provided due to the absence of current data. Dryland salinity occurrence has not been systematically remapped since the millennium drought. In SoE 2013, it was estimated that 2% of the total area of dryland agriculture in Victoria was affected by dryland salinity.[62] Some small areas of soil salinity occurrence were remapped in research areas after the drought, and this work showed that a contraction of discharge areas occurred after 2010. On top of the salinity mitigation benefits of the lower rainfall years, improved land-management practices reduced salinity severity in many landscapes by lowering groundwater recharge and protecting groundwater discharge areas from further damage. These improved practices arose out of community, state and federal salinity management programs that commenced in the late 1980s. The effects of irrigation-induced salinity tend to be more seasonal than for dryland areas and are defined by the extent of high water tables associated with each irrigation area.

Salinity remains a threatening process in many parts of Victoria. One means by which this threat is now monitored is looking at trends in groundwater level in observation bores. For the five river catchments that drain to the Murray River, the Basin Salinity Management 2030 strategy requires a review of groundwater levels every five to ten years to identify trends.[63] Recently completed reviews in three of these catchments (the Campaspe, Ovens and Kiewa Rivers) provide an indication of the salinity threat relative to earlier decades. The analysis found fewer bores with a rising trend across all landscape positions monitored.[64, 65, 66] Most bores had declining or flat trends, and for those few bores still rising, the trends were smaller than those seen in previous reviews. Figure L.7 provides an illustration of the trends seen from 57 bores in the Campaspe catchment. In the Below Mount Camel Ranges subset, groundwater levels are still rising, albeit at a slower rate than prior to 2000.[67]

62. 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.
63. Murray-Darling Basin Ministerial Council 2015, 'Basin Salinity Management 2030 (BSM2030)', Canberra, Australia https://www.mdba.gov.au/sites/default/files/pubs/D16-34851-basin_salinity_management_strategy_BSM2030.pdf Accessed 3 December 2018.
64. Cheng X 2017, 'Draft Technical Report - 2017 Campaspe Catchment Register B Five-year Review', prepared for DEDJTR, Melbourne, Australia.
65. Ibid
66. Ibid
67. Ibid

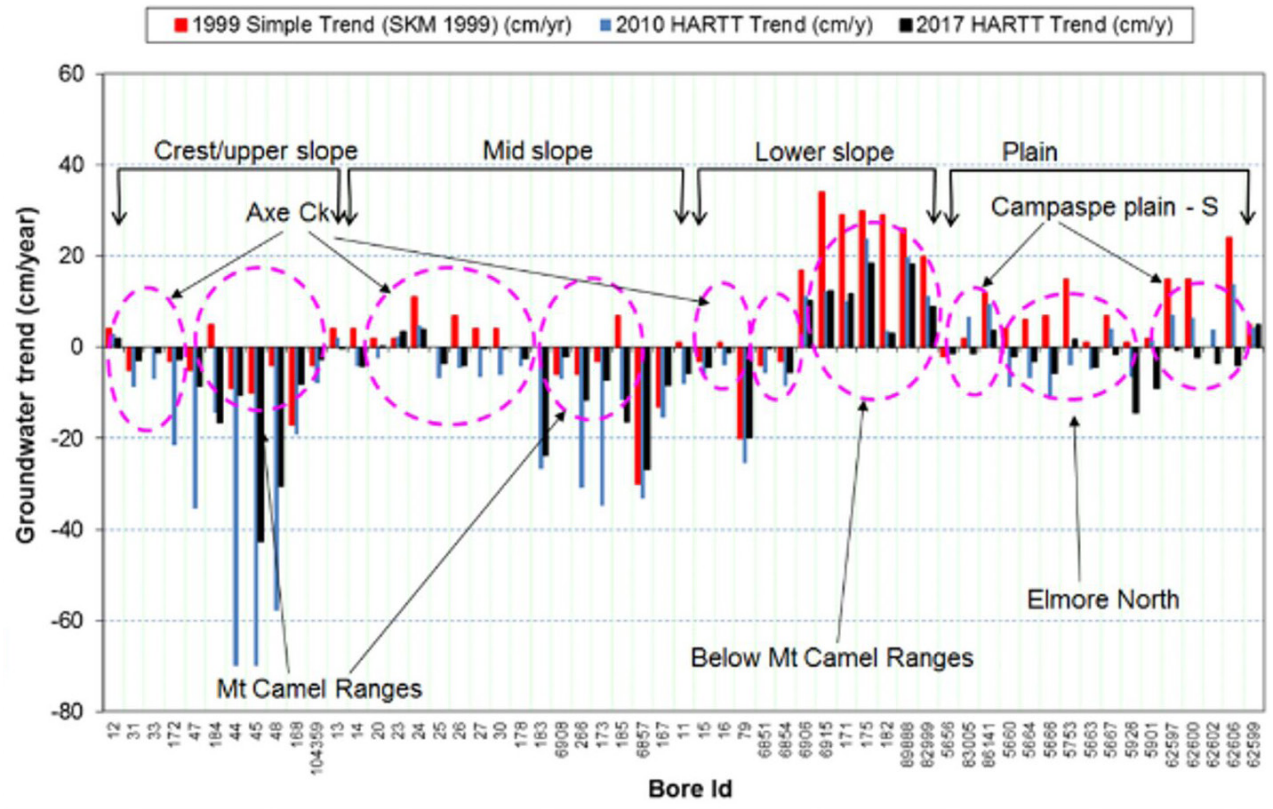


Figure L.7 Dryland salinity observation bore trends from the 2017 review[68]

Note: The bars above the line shows bores with a rising level; bars below show a falling trend.

For parts of the state outside the five northern river basins that flow into the Murray River, monitoring of salinity has largely ceased (except for the Macalister Irrigation District in Gippsland). However, salinity can be a threatening process to parts of all Victorian landscapes, including in areas where water trade is moving to support new irrigation developments, and land-use change compromises past salinity management work, or in land close to sea level where the water table is permanently close to the surface. Dryland salinity data in southern Victoria is currently well understood; however, our knowledge will decrease in the absence of data collection.

While not a direct measure of the area affected by salinity, the depth to shallow groundwater is a close proxy for area threatened by salinity. This is particularly the case in irrigated areas where there is ongoing monitoring and annual production of groundwater maps. DELWP maintains a statewide layer showing the depth to the watertable and (Figure L.8). Further detail on groundwater salinity, indicator WR:11 (Groundwater quality).

68. Ibid

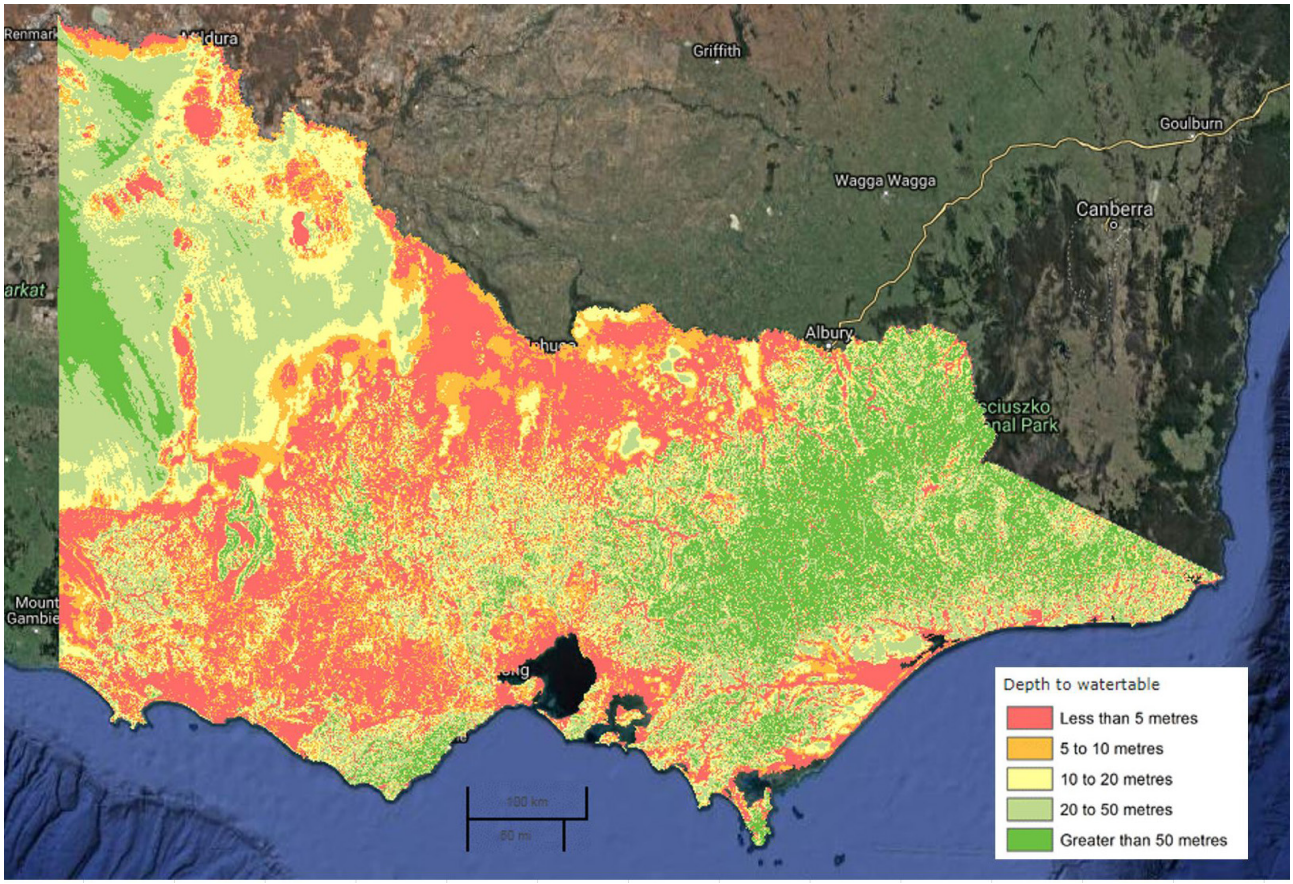


Figure L.8 Depth to watertable in Victoria [69, 70]

69. Visualising Victoria's Groundwater, 'Visualising Victoria's Groundwater', Ballarat, Victoria http://maps.cerdi.com.au/vvg.php Accessed 3 December 2018.
70. DELWP, 'Victorian Aquifer Framework (VAF) 3D Surfaces', East Melbourne, Victoria https://www.data.vic.gov.au/data/dataset/victorian-aquifer-framework-vaf-3d-surfaces Accessed 3 December 2018.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
L:07 Soil acidification	●	○	○	○	?	DATA QUALITY
Data custodian AV						Fair

Soil acidification refers to a decrease in soil pH over time, while soil alkalinisation describes the process of soil pH increasing over time. Soils that are too acidic or too alkaline present problems for many crops and pastures. In acidic soils, the availability of several nutrients is generally reduced and the solubility of elements toxic to plants is greater. Soil acidification impacts farming when the acidity of surface soil and/or subsurface soil limits crop or pasture choices, or detrimentally affects productivity and ground cover. In turn, this can increase the risk of soil erosion and the potential of losing nutrients to groundwater and/or surface waters. In 2014, the cost of lost productivity due to soil acidity and acidification in Victoria was estimated at $470 million per year.[71]

The most comprehensive dataset on Victorian soil pH was collated from farming paddocks between 1973 and 1994.[72] The study found that the pH of Victoria's soils ranged from extremely acidic to extremely alkaline, although such extremes in soil pH were rare and only occurred in a minority of Victoria's agricultural land. Spatial modelling of this data indicated that 29% of Victoria's agriculturally productive soils were affected by soil acidity and were expected to have a pH of less than 4.8, which was an increase from 23% of soils in the 1970s. These results show that areas of Victoria acidified from the 1970s to the 1990s.

The Soil Grids of Victoria published in 2017 and used as part of the assessment for indicator L:05 (Soil carbon content) have also been used for the assessment of this indicator. Soil acidity and acidification is an issue for the higher rainfall agriculture regions in the south-west and east of Victoria, whereas soil alkalinity is an issue for agriculture in the lower rainfall north-western region of the state. Figure L.9 shows soil pH across Victoria as taken from Spatial Datamart Victoria and displayed on the Australian Digital Soil Mapping website OzDSM.[73,74]

71. Parliament of Victoria Environment and Natural Resources Committee 2004, 'Inquiry on the impact and trends in soil acidity', Melbourne, Victoria https://www.parliament.vic.gov.au/images/stories/FINAL_REPORT_Inquiry_into_Impacts_and_Trends_in_Soil_Acidity.pdf Accessed 3 December 2018.
72. Marchant BP, Crawford DM, Robinson NJ 2014, 'What can legacy datasets tell us about soil quality trends? Soil acidity in Victoria', *IOP Conference Series: Earth and Environmental Sciences*, 25, pp. 1–15.
73. DEDJTR, 'SOIL_pHcacl2', Melbourne, Victoria http://services.land.vic.gov.au/SpatialDatamart/dataSearchViewMetadata.html?anzlicId=ANZVI0803005795&extractionProviderId=2 Accessed 3 December 2018.
74. OzDSM, http://www.ozdsm.com.au/ozdsm_map.php Accessed 3 December 2018.

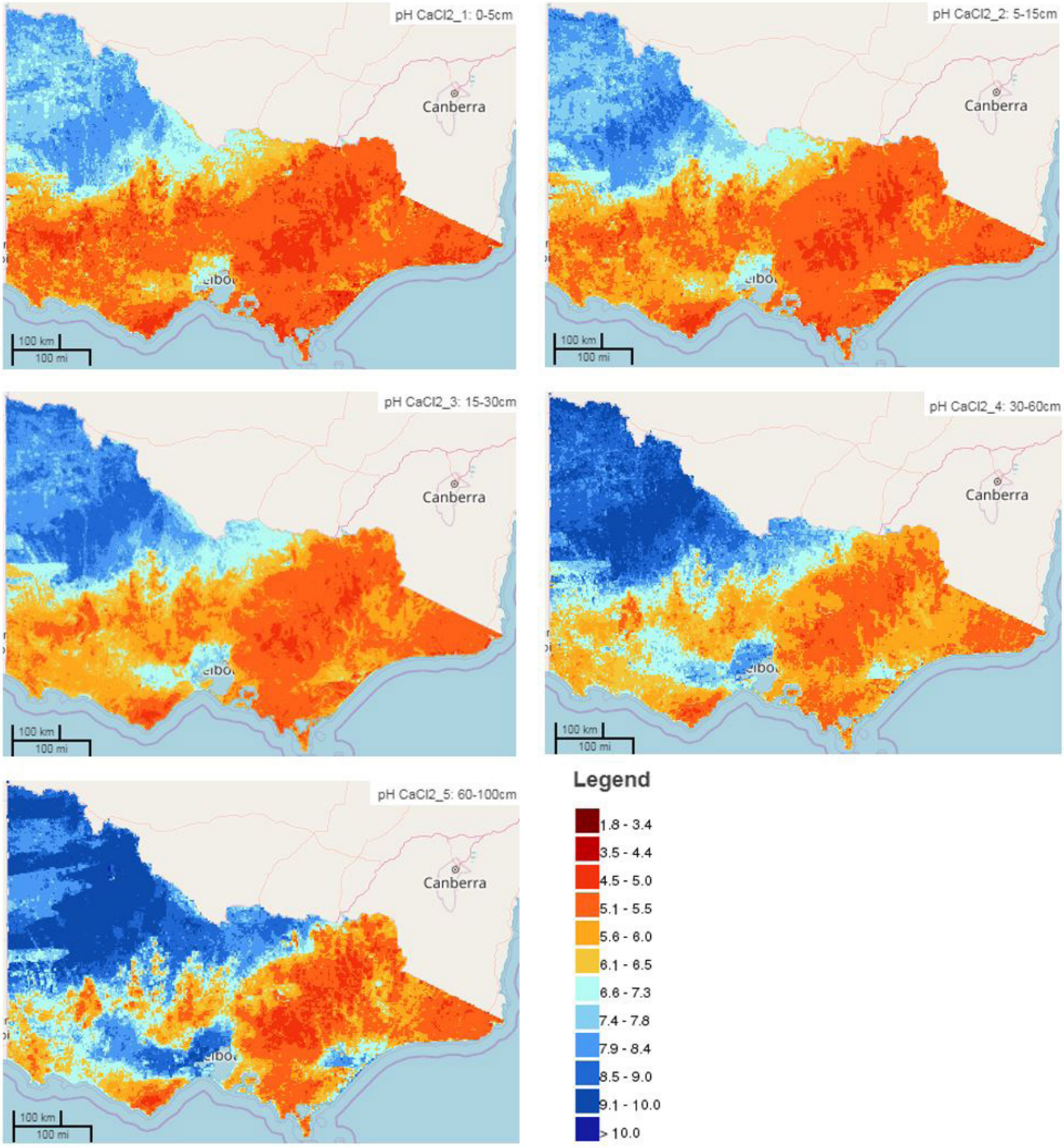


Figure L.9 Victorian Soil pH ($CaCl^2$) at various depths [75, 76]

75. DEDJTR, 'SOIL_pHcacl2', Melbourne, Victoria http://services.land.vic.gov.au/SpatialDatamart/dataSearchViewMetadata.html?anzlicId=ANZVI0803005795&extractionProviderId=2 Accessed 3 December 2018.
76. OzDSM, http://www.ozdsm.com.au/ozdsm_map.php Accessed 3 December 2018.

Soil pH naturally changes as soil weathers and forms, both decreasing in pH (acidification) and increasing pH (alkalinisation). Changes take place very gradually in undisturbed ecosystems and occur in both surface soil and subsoil. These changes can be accelerated by agriculture, particularly in surface soil. Importantly for Victoria, it has been found that many surface soils that were once slightly or moderately acidic are now more acidic since the land has been cleared and used for agriculture. In some soils, subsurface acidification has occurred but much less data is available on this soil degradation issue.

In the past, detailed analysis was undertaken to look at soil acidification under both pastures and crops, with faster acidification rates under crops, particularly those where nitrogen fertilisers are applied and where legumes are included in the rotation. However, this research was conducted in association with a range of farming systems that are not used as prevalently today (such as conventional cultivation, ley farming). There is little data available to understand soil acidification under current farming systems, while there has been almost no research on the extent and severity of soil acidification in horticulture or irrigated broad-acre agriculture.

The use of nitrogen-based fertilisers is recognised as a profitable management practice in horticulture, dairying and cropping. The risk of soil acidification increases in areas where land use changes from low nitrogen-use pastures (usually under meat and wool production) to high nitrogen-use cropping or other more intensive farming systems.

Limited data exists to understand current practices for managing soil acidity. Up until 2012–13, the Australian Bureau of Statistics (ABS) regularly surveyed farm businesses on a range of issues, including soil testing. From 2013–14, the question on soil testing was no longer asked. The 2012–13 data showed soil pH testing was infrequent, with only 16% of agricultural businesses testing their soil in the previous 12 months.[77]

Precision agriculture tools, such as variable-rate liming and digital mapping of soil pH, are now available to more efficiently manage soil pH. Adoption of variable-rate fertiliser application is mainly being taken up in cropping, although the uptake has been limited with just over 10% of the area under crop being applied with variable rates of fertiliser.[78]

A significant number of landholders are managing acidification using lime, although there is great potential to increase lime application in Victoria. In 2016–17, published ABS data showed lime was only applied to 4% of land used for agricultural production.[79] The ABS data also displayed the average rate of lime application at 1.7 tonnes per hectare, which is below the general minimum recommendations of 2.5–7.5 tonnes per hectare.[80]

No overall status assessment has been provided for this indicator due to the lack of current information on soil acidification across the state. The current knowledge is mostly based on data that is now more than a decade old.

77. Australian Bureau of Statistics 2014, '4267.0 - Land Management and Farming in Australia, 2012-13, 'Rural Environment and Agricultural Commodities Survey', Canberra, Australia http://www.abs.gov.au/ausstats/abs@.nsf/ProductsbyReleaseDate/59575E628C99F1ECCA257E-92001B14A1?OpenDocument Accessed 3 December 2018.

78. Australian Bureau of Statistics 2016, '4627.0 - Land Management and Farming in Australia, 2014-15, 'Rural Environment and Agricultural Commodities Survey', Canberra, Australia http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/4627.0Main+Features102014-15?OpenDocument Accessed 3 December 2018.

79. Australian Bureau of Statistics 2018, '4267.0 - Land Management and Farming in Australia, 2016-17', Canberra, Australia http://www.abs.gov.au/ausstats/abs@.nsf/mf/4627.0 Accessed 3 December 2018.

80. Tasmanian Department of Primary Industries, Parks, Water and Environment 2014, 'Soil pH & Liming', https://dpipwe.tas.gov.au/agriculture/land-management-and-soils/soil-management/soil-ph-liming Accessed 3 December 2018.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
L:08 Soil erosion	○	○	●	○	↘	DATA QUALITY
Data custodian AV						Poor

Soil erosion and structure decline is a natural process, determined by factors such as soil type and slope. However, it can be accelerated by human activities, including vegetation clearing, some cropping activities (for example, cultivation, sowing, harvesting, burning of crop residues), soil compaction from farm traffic and livestock, forestry activities (such as heavy vehicle compaction), mining, and the development of land for residential and other purposes.[81]

Ground-cover management can be used as a surrogate for soil health, but particularly for soil erosion. Ground cover assists in: protecting the soil from wind and water erosion, slowing and reducing runoff, improving water retention and infiltration into the soil, maintaining soil structure and preserving soil carbon. Improvements in ground-cover management have occurred through the provision of government funds to enable farmers to set up stock containment areas that protect soil and pasture resources during adverse seasons. In 2017, Agriculture Victoria announced that 550 stock containment areas would be built in Victoria.

The best available Victorian data on soil erosion was published in the VCMC's *Catchment Condition and Management Report 2017*.[82] The report contained information on Victoria's dryland area with 30–100% bare soils (i.e. the area at higher risk of erosion). Victoria's dryland area at risk of erosion is greatest during prolonged periods of dry weather, which is shown in Figure L.10 by the higher erosion risk during the end period of the millennium drought (2007–09). The dryland area at risk of erosion has steadily increased to 37% in 2016 from a low of 13% in 2011. This low was associated with increased rainfall after the millennium drought.

The spatial pattern of erosion risk is linked with annual average rainfall. Relatively wet catchments, such as West and East Gippsland, have the lowest dryland erosion risk in the state, while more arid regions (such as Mallee) have a much greater erosion risk.

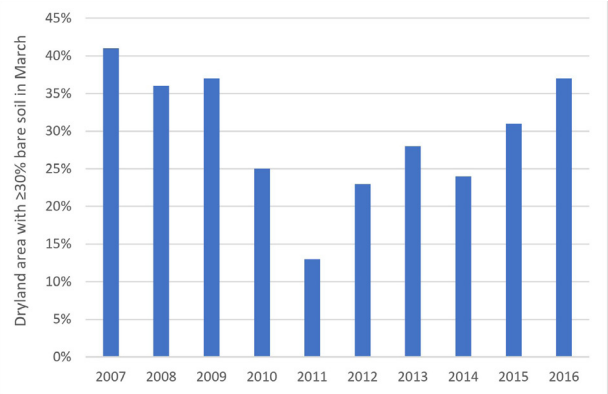


Figure L.10 Dryland area with 30–100% bare soils (higher risk of erosion) in March, 2007–16[83]

Advances in remote sensing to create seasonal Fractional Ground Cover (FGC) estimates offer the opportunity to improve data supporting grazing management and cropping practices that protect soil resources. However, the practical application of FGC data in the Victorian agricultural-management context indicates that FGC data must be combined with contextual information on land management and landscape condition. There are important differences in the management of agricultural systems that influence the ground cover across regions and throughout seasons. Future reporting will require the development of a method that uses a range of features to contextualise the measured FGC and then monitor soil protection.

81. 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.
82. Victorian Catchment Management Council 2017, 'Catchment Condition and Management Report 2017', East Melbourne, Victoria, http://www.vcmc.vic.gov.au/pdf/CCMR_Report_2017.pdf Accessed 3 December 2018.
83. Ibid

Contaminated Sites

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
L:09 Contaminated sites	●	○	○	○	?	DATA QUALITY
Data custodian EPA Victoria, DELWP						Fair

Like other economies with a significant history of settlement and industrial activity, Victoria has a legacy of waste and pollution. Contaminated sites range from old mines and industrial sites to petrol stations and dry-cleaning operations.[84]

No complete database of contaminated sites exists for Victoria, although DELWP and EPA Victoria are partnering to develop an online mapping system. This system will bring together relevant information on potential land and groundwater contamination (for example, groundwater quality restricted-use zones, environmental audits, Victorian Landfills Register and historical business listings). When completed, the availability of this data will improve access to information that will strengthen management and awareness of legacy contamination. As this mapping system develops, it will be easier to report on the extent and trend of site contamination in Victoria.

As part of the assessment of the indicator in this report, data on contaminated sites was sourced from EPA Victoria's 53X audits and Priority Sites Register.

A 53X audit is an environmental audit that verifies that potentially contaminated land can be used for a specific purpose (industrial, commercial or residential).[85] The number of completed 53X audits shows how many contaminated sites have been improved to be suitable for a more sensitive land use, and can be used to show the scale of land quality improvement at contaminated sites across Victoria. There were 603 53X audits completed in the state from 2013 to 2017, with a peak of 142 audits in 2015. The number of audits has dropped during the past two years.

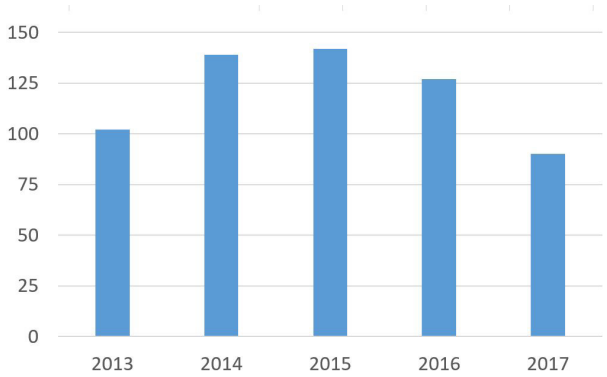


Figure L.11 53X Audits completed in Victoria, 2013–2017

(Data source: EPA Victoria, 2018)

Priority sites are sites for which EPA Victoria has issued a clean-up notice or pollution abatement notice due to land and/or groundwater pollution. The condition of these sites is not compatible with the current or approved use of the site without active management to reduce the risk to human health and the environment. Such management can include clean-up, monitoring and/or institutional controls.[86] The number of sites on EPA Victoria's Priority Sites Register has remained reasonably stable from June 2013 to June 2018, at 230 and 300 respectively (Figure L.12).[87]

84. MAC 2016, 'Independent inquiry into the Environment Protection Authority', http://www.epa-inquiry.vic.gov.au/__data/assets/file/0008/336698/Inquiry-report-EPA_June.pdf Accessed 3 December 2018.
85. EPA, 'Types of environmental audit', Carlton, Victoria https://www.epa.vic.gov.au/our-work/environmental-auditing/types-of-environmental-audit Accessed 3 December 2018.
86. EPA, 'Priority Sites Register', Carlton, Victoria https://www.epa.vic.gov.au/your-environment/land-and-groundwater/priority-sites-register Accessed 3 December 2018.
87. EPA, communication dated 04/10/2018 ("PSR_summary_delwp.xlsx").

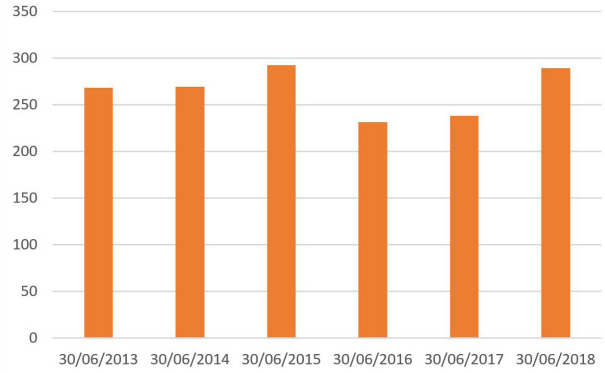


Figure L.12 Number of sites on EPA Victoria's Priority Sites Register as at the end of June, 2013–2018

(Data source: EPA Victoria, 2018)

Some chemicals are emerging as threats for site contamination, including per-and poly-fluoroalkyl substances (PFAS). An example of the increasing focus on PFAS is the investigation EPA Victoria is coordinating into potential environmental contamination, including soil, surface water and groundwater pollution, from the historical use of PFAS in firefighting foam by the Country Fire Authority (CFA).[88] In addition to the investigation of PFAS pollution at CFA sites, EPA Victoria has collaborated with industrial groups to identify the likely major industries in Victoria that would use PFAS.

The major industrial sources of PFAS were found to be:

- the oil and gas industry
- firefighting
- bulk storage facilities for flammable products
- chemical manufacturing
- metal plating.[89]

In 2018, RMIT University released a publicly available database and interactive map of ambient background soil concentrations and other soil characteristics for four Victorian regions (Ballarat, Greater Geelong, Greater Melbourne and Mitchell).[90] The key factors that influenced ambient background variability of As, Cu, Cr, Ni, Pb and Zn in the surveyed soils of those Victorian regions are summarised below by Mikkonen et al.[91]:

- Arsenic enrichment was attributed to erosion and landscape transfer of mineralised (gold bearing) soils, including alluvial and aeolian deposition and accumulation of As with Fe during lateritic weathering.
- Nickel enrichment occurred in soils overlying basalt and was associated with the weathering of olivine, and influence of illuviation, resulting in Ni enrichment in B horizon soils.
- Chromium enrichment occurred in highly weathered soils and was likely to have developed during lateritic weathering, due to immobilisation with Fe.
- Copper concentrations were negatively correlated with weathering and precipitation and likely to be influenced by clay content.
- Lead concentrations in soil were found to be influenced by multiple factors including co-accumulation with Fe in the highly weathered environments, topography and possibly diffuse contamination from urban areas.
- Zinc concentrations were negatively correlated with weathering and precipitation, but were indicated to be influenced by biological cycling, resulting in enrichment in surface soils compared to subsurface soils.

No overall status assessment has been provided for this indicator due to the lack of information of contaminated sites across the state. The current knowledge only pertains to a subset of contaminated sites. The trend is unclear, because even though there is evidence of environmental audits taking place that lead to improved land use, it is unclear how many sites have become contaminated during that time and what the overall change in the number of contaminated sites has been.

88. EPA, 'CFA regional training centres', Carlton, Victoria http://www.epa.vic.gov.au/our-work/current-issues/water-quality/cfa-regional-training-centres Accessed 3 December 2018.
89. EPA, 'Interim position statement on PFAS', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1669%202.pdf Accessed 3 December 2018.
90. Mikkonen HG, Bentley PD, Barker AO, Dasika R, Wallis CJ, Clarke BO, Reichman SM 2018, 'Victorian Background Soil Database, Version 1.0', RMIT University, Melbourne, Australia https://soilexplorer.eres.rmit.edu.au/soil-explorer/ Accessed 3 December 2018.
91. Mikkonen HG, Dasika R, Drake JA, Wallis CJ, Clarke BO, Reichman SM 2018, 'Evaluation of environmental and anthropogenic influences on ambient background metal and metalloid concentrations in soil', *Science of The Total Environment*, 624, pp. 599-610.

Land Management

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
L:10 Land management activities	○	○	●	○	↗	DATA QUALITY
Data custodian CMAs						Fair

Most Catchment Management Authorities (CMAs) are now reporting on the area of land managed for conservation in their annual reports. The Corangamite, Glenelg Hopkins, North Central, North East, West Gippsland and Wimmera CMAs all reported this data in their 2016–17 annual reports.[92,93,94,95,96,97]

The six CMAs reporting on the area of land managed for conservation had a combined total of approximately 43,000 hectares of land covered by Trust for Nature covenants, which increased by nearly 1,500 hectares from the previous year. The purpose of these covenants is to permanently conserve and protect the natural, cultural or scientific values of the land. The reporting CMAs also entered into management agreements with landholders to improve and conserve a further 8,000 hectares of land, increasing the total area of landholder agreements by nearly 10% on the previous year. The Glenelg Hopkins CMA was responsible for the greatest additional areas of land managed for conservation in 2016–17 across both landholder agreements and Trust for Nature covenants (Figure L.13). There were no additions to the public reserve system in any of the reporting CMAs.

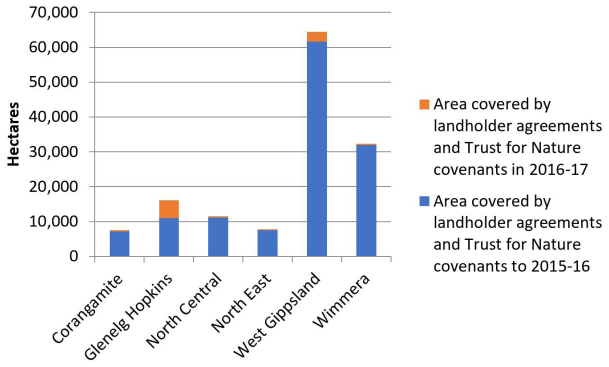


Figure L.13 Area of land covered by landholder agreements and Trust for Nature covenants

Note: Area is shown in hectares.

(Data source: 2016–17 CMA annual reports)

This indicator would ideally include statewide data and a detailed trend analysis, and be complemented with a more comprehensive quantitative analysis of the outputs and benefits associated with land-management activities; however, this type of data is not collated or published.

In addition to the work at the CMA level, the *Traditional Owner Settlement Act 2010* provides for certain Crown land sites to be granted to the Traditional Owner corporation in Aboriginal title, and then for that land to be jointly managed with the state. Joint management recognises the ongoing connection of Traditional Owners to their land and enables the knowledge and culture of the Traditional Owner group to be incorporated in the management of that land. Traditional Owners and the state work together in equal partnership to manage the natural and cultural values of parks and reserves under Aboriginal title.

92. Corangamite Catchment Management Authority 2017, 'Annual Report 2016-2017', Colac, Victoria.
93. Glenelg Hopkins Catchment Management Authority 2017, 'Annual Report 2016-2017', Hamilton, Victoria.
94. North Central Catchment Management Authority 2017, 'Annual Report 2016-2017', Huntly, Victoria.
95. North East Catchment Management Authority 2017, 'Annual Report 2016-2017', Wodonga, Victoria.
96. West Gippsland Catchment Management Authority 2017, 'Annual Report 2016-2017', Traralgon, Victoria.
97. Wimmera Catchment Management Authority 2017, 'Annual Report 2016-2017', Horsham, Victoria.

Aboriginal title is a highly modified freehold grant to the Traditional Owners. Under Aboriginal title, the right to occupy, use, control and manage the land is transferred back to the state, including the authority to issue leases and licences. Transfer of parks or reserves to Aboriginal title does not affect existing use and access, which will continue to be managed under the relevant land act. Table L.2 shows current Traditional Owner organisations and corporation(s) with native title and settlement negotiations, while Table L.3 shows the current Traditional Owner corporation(s) in settlement negotiations with the state under the *Traditional Owner Settlement Amendment Act 2016*.

Table L.2 Current Traditional Owner Corporations with native title and settlement determinations

Current Traditional Owner Corporations	Region
Dja Dja Wurrung Clans Aboriginal Corporation	North Central Region
Gunaikurnai Land and Waters Aboriginal Corporation	Gippsland Region
Gunditj Mirring Traditional Owners Aboriginal Corporation	Barwon South West Region
Yorta Yorta Nation Aboriginal Corporation	Hume Region
Barengi Gadjin Land Council	Grampians Region

Table L.3 Current Traditional Owner Corporations in settlement negotiations with the State of Victoria under the *Traditional Owner Settlement Amendment Act 2016*

Current Traditional Owner Corporations	Region
Taungurung Clans Aboriginal Corporation	Hume Region
Eastern Maar Aboriginal Corporation	Barwon South West Region
Barengi Gadjin Land Council	Grampians Region
Gunditj Mirring Traditional Owners Aboriginal Corporation	Barwon South West Region

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
L:11 Participation in natural resource management activities						 DATA QUALITY Good
Data custodian CMAs, Parks Victoria, Landcare						

This indicator assesses community participation in natural resource management (NRM) activities, which includes volunteers who are involved in 'Friends of' and community groups, Landcare and citizen science programs across terrestrial, inland aquatic, coastal and marine ecosystems. Community participation can improve environmental stewardship, connect people to nature and improve physical, mental and emotional health and wellbeing. In the future, this indicator can potentially be used to assess the progress of Priority 5, 'Increase opportunities for all Victorians to act to protect biodiversity' in the new plan, *Biodiversity 2037 – Protecting Victoria's Environment*. An assessment of citizen science programs by DELWP found 34 active programs across Victoria.[98] These programs run across all Victorian ecosystem types, including terrestrial, rivers, estuaries, wetlands, coasts and marine waters, and are led by government, non-government and academic organisations.

Parks Victoria engages an extensive community network that provides 281,776 volunteering hours with 37,200 volunteer attendees across 167 parks. This network includes 234 volunteer (or volunteer-involving) organisations that partner with Parks Victoria to engage and facilitate practical volunteering outcomes. Parks Victoria's volunteer network has provided over $10 million of in-kind support in 2017–18. This is the highest ever recorded figure for Parks Victoria.

Parks Victoria has continued to implement the first online volunteer management system for a state park agency. ParkConnect enables staff and volunteer groups to collaboratively plan, manage and report on volunteer activities. It makes volunteering more accessible and promotes volunteer opportunities broadly across Victoria. There have been over 1,500 new volunteer registrations with over 65% attending one or more of the 573 activities planned within the system. The largest demographic registering to volunteer has been 18 to 35-year-olds in full-time employment. The largest proportion of volunteer activities are focused on habitat restoration, followed by environmental research, historic heritage conservation and gardening.

The VCMC estimated that Victorian communities co-contributed approximately $116 million in 2015–16 to catchment management across all Victorian CMA regions.[99] Although this estimate was based on a simple calculation, and therefore should be treated with caution, this value is potentially equivalent to both national and state government investment in NRM, as well as investment from other sources.[100] This figure does not take into account the intangible benefits to the community of participation in catchment management, including: physical and mental wellbeing, social capital, and engaged and resilient communities.[101] Two essential components of the work coordinated by CMAs to successfully manage natural resources in their regions are: actively engaging the many stakeholders (such as private landholders, community groups and local councils), and understanding their local issues.

Participation at CMA natural resource management engagement events has increased each year since data was first reported in 2013–14 (Figure L.14).[102,103] Engagement events have included field days, seminars and farm

98. Data supplied by DELWP in 2018.

99. Victorian Catchment Management Council 2017, 'Catchment Condition and Management Report 2017', East Melbourne, Victoria, http://www.vcmc.vic.gov.au/pdf/CCMR_Report_2017.pdf Accessed 3 December 2018..
100. Ibid
101. Ibid
102. 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, Bairnsdale, Hamilton, Shepparton, Irymple, Huntly, Wodonga, Frankston, Traralgon, Horsham, Victoria.
103. 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.

inspections. There were nearly 35,000 participants at engagement events in 2013–14, which has grown to more than 93,000 participants in 2016–17, although it should be noted that the 2013–14 report captured only state-funded outputs.[104] The data from 2014–15 onwards provides a better comparison as it consistently contains State and Commonwealth funding sources. Participation at engagement events has increased by nearly 70% since 2014–15, indicating a more engaged and informed stakeholder cohort.

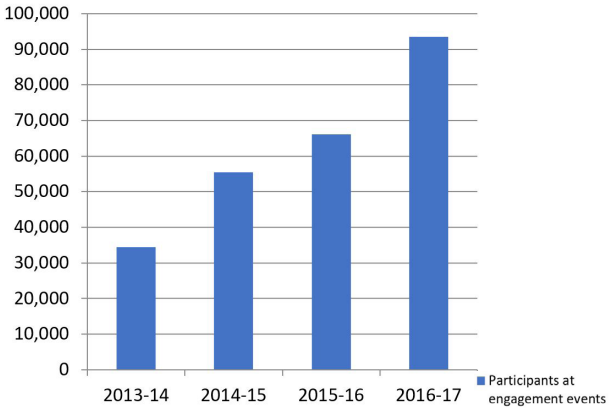


Figure L.14 Participation at CMA organised natural resource management engagement events

(Data source: CMA Actions and Achievements report, 2015-16 and 2016-17) [105,106]

The Goulburn Broken CMA recorded the greatest participation at engagement events in 2015–16 and then doubled this in 2016–17. This is reflective of a regional area with local communities, Traditional Owners, partner organisations, farmers and other individuals that are an active presence in decision-making and take actions to improve their local environments.[107]

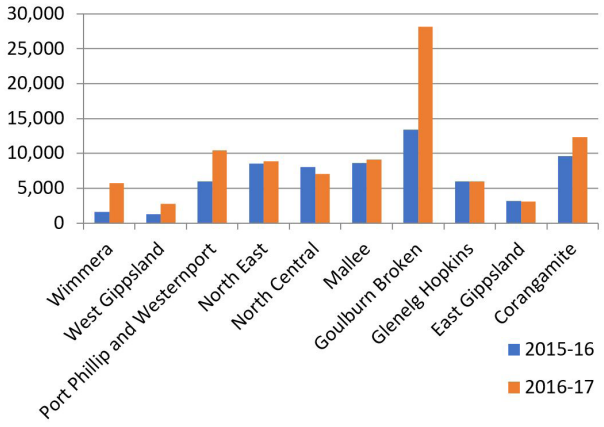


Figure L.15 Participation at organised natural resource management engagement events by CMA, 2015–16 and 2016–17

(Data source: CMA Actions and Achievements reports, 2015–16 and 2016–17).[108,109]

Landcare is a vital community-based volunteer movement that facilitates and coordinates actions to care for the environment. Among the wide variety of on-ground activities undertaken by Landcare are: rejuvenation and repair of habitats, restoration of waterways, improvements to farmland, and addressing of land-management issues such as erosion and pest plants and animals.[110] There are around 600 Landcare groups and 64 networks in Victoria that cover 65% of the state (82% of private land and 32% of public land).[111,112] Landcare volunteers reported

104. Ibid
105. 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, Bairnsdale, Hamilton, Shepparton, Irymple, Huntly, Wodonga, Frankston, Traralgon, Horsham, Victoria.
106. 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.
107. Goulburn Broken Catchment Management Authority 2017, 'Annual Report 2016-2017', Shepparton, Victoria.
108. 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, Bairnsdale, Hamilton, Shepparton, Irymple, Huntly, Wodonga, Frankston, Traralgon, Horsham, Victoria.
109. 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.
110. DELWP, 'Landcare', East Melbourne, Victoria https://www.environment.vic.gov.au/landcare Accessed 3 December 2018.
111. Ibid
112. Landcare, communication dated 02/10/2018 ("Landcare Total Coverage – Groups & Networks.pdf").

contributing 375,000 hours in 2016–17 to land, water and biodiversity protection across Victoria, providing a value of $11.2 million.[113] The reported Landcare contributions in 2016–17 varied from 2015–16, when the Victorian Landcare Program estimated that volunteers contributed $20 million worth of hours.[114]

Traditional Owner participation is another vital component of NRM. Traditional Owners have strategies for their participation in NRM detailed within a Natural Resource Agreement (as part of their Recognition & Settlement Agreements). For more information refer, to indicator L:10 (Land-management activities).

Research from 2015 shows the importance of combining social and environmental values in NRM.[115] The research develops a Valued Attributes of Landscape Scale to help bridge the divide between theoretical understandings of value in psychology, which have largely focused on the core values held by people, and values as understood by NRM professionals, which have largely focused n valuing the environment.[116]

113. 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, Bairnsdale, Hamilton, Shepparton, Irymple, Huntly, Wodonga, Frankston, Traralgon, Horsham, Victoria.
114. 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.
115. Kendal D, Ford RM, Anderson NM, Farrar A 2015, 'The VALS: a new tool to measure people's general valued attributes of landscapes', *Journal of Environmental Management*, 163, pp. 224-233.
116. Ibid

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
L:12 Use of best practice on agricultural lands	●	○	○	○	?	DATA QUALITY
Data custodian CMAs						Poor

As discussed in indicator L:01 (Land use types in Victoria), half of Victoria's land use is defined as primary production. Therefore, it is critical that agricultural land is managed well for multiple outcomes. This indicator is designed to assess the area of land managed using best-practice techniques that maintain and improve land and ecosystem health.

No data currently exists to determine whether each parcel of agricultural land is operated under best practice. The available statewide data that most closely relates to this indicator is the area of land with improved agricultural practices – defined as the area over which agricultural practices have been established, modified, maintained or removed (this may include retaining ground cover, changes in cropping practices or nutrient management).[117] This has been annually reported by CMAs for the three years from 2014–15 to 2016–17. During that three-year period, the area of land with improved agricultural practices has increased each year, with an extra 335,325 hectares of agricultural land operating under improved management.[118]

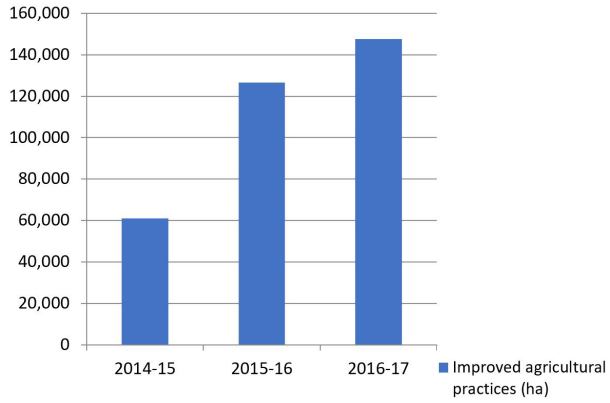


Figure L.16 Area (hectares) of improved agricultural practices in Victoria, 2014–15 to 2016–17

Note: Area is shown in hectares

(Data source: CMA Actions and Achievements reports for 2016–17)

More than 93,000 hectares of improved agricultural practices during 2016–17 were federally funded through the National Landcare Program. These improved practices were focused on the grains and grazing industries, and included work coordinated by the West Gippsland CMA that saw landholders develop: 60 nutrient and effluent management plans; 21 irrigation plans; 14 grazing, soil and nutrient management plans; and 5 soil erosion management plans.[119]

The current data does not enable statewide status or trend assessments. There is information to suggest best practice on agricultural land is becoming more prevalent in Victoria; however, a trend cannot be determined without baseline data on the use of best practice on agricultural land.

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

118. 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, Bairnsdale, Hamilton, Shepparton, Irymple, Huntly, Wodonga, Frankston, Traralgon, Horsham, Victoria.

119. 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.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
L:13 Proportion of agricultural area under productive and sustainable agriculture					?	 DATA QUALITY
Data custodian AV, CMAs						Poor

This indicator arises from the United Nations Sustainable Development Goals (SDGs), specifically Target 2.4 that aims to ensure sustainable food production systems and implement resilient agricultural practices by 2030. Achievement of this aim will: increase productivity and production; help maintain ecosystems and strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters; and progressively improve land and soil quality.[120]

The definition of sustainable agriculture used for this indicator is based on the definition provided by the Food and Agriculture Organization of the United Nations in 1988: 'the management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such development conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable.'[121]

Agriculture Victoria coordinates a Land Health Program that delivers a range of activities including whole-farm planning, grazing management workshops and general soil extension. These activities assist farmers to improve their skills in assessing land capability and land class, empowering them to modify management practices to increase long-term sustainability. This program influenced and 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, from 2013–14 to 2015–16.

Qualitative information relating to this indicator is also captured as part of the two transect surveys Agriculture Victoria conduct each year with the CMAs in the Glenelg Hopkins and Wimmera catchments. The transect surveys monitor land-management practices and ground cover in autumn and spring across the Wimmera and South West regions. The surveys cover approximately 83,000 hectares across the two catchments, with a much larger area covered in the Wimmera catchment, which is split into a northern and southern region.[122,123,124] The most recent available transects were conducted in autumn 2018, following a dry summer that appears to have had a significant impact on land practices and increased the risk of soil loss through erosion in southern Wimmera.

The transect surveys have found that northern Wimmera farmers have increasingly adopted conservation farming practices that minimise the risk of topsoil erosion, rather than the more traditional farming methods that were prevalent during the first survey observations from 1996. Less promisingly, recent surveys have observed more variable stubble retention practices in the northern Wimmera that can cause an increase in chemical fallow and legume stubbles, which increase the risk of soil erosion in the lead-up to crop establishment, or if dry conditions continue.

In the Glenelg Hopkins catchment, it was found that nearly all livestock were being fed supplementary hay and grain. It was evident that there was insufficient pasture available to sustain them. The common observation was that the livestock grazing those paddocks were in predominantly barer paddocks than usual.[125]

120. United Nations, 'SDG Indicator 2.4.1 - Agricultural sustainability', http://www.fao.org/sustainable-development-goals/indicators/241/en/ Accessed 3 December 2018.
121. Food and Agriculture Organization of the United Nations 1988, 'Report of the Council of FAO', Ninety-fourth Session, Rome, 15-26 November 1988. http://www.fao.org/docrep/meeting/011/t0087e/t0087e00.htm Accessed 3 December 2018.
122. Agriculture Victoria, 'Northern Wimmera Cropland Management Transect Survey – Autumn 2018'.
123. Agriculture Victoria, 'Southern Wimmera Cropland Management Transect Survey – Autumn 2018'.
124. Agriculture Victoria, 'Glenelg Hopkins Catchment Land Use and Land Management Transect – Land cover Autumn 2018'.
125. Ibid

Agricultural industries are undertaking a range of processes to improve their sustainability. An example is the dairy industry, with Dairy Australia establishing its own sustainability framework in 2012.[126] The framework includes four environmental goals to be achieved by 2020:

- Improve nutrient, land and water management
- Reduce consumptive water intensity of dairy manufacturers by 20%
- Reduce greenhouse gas emissions intensity by 30%
- Reduce waste to landfill by 40%.

To meet each of these goals, the framework contains targets that need to be achieved. In the 2016 report, most of the measured targets showed environmental improvements from 2012 to 2016.[127]

The information from the Land Health Program, the transect surveys and the information on improved practices on agricultural land tell a story of an agricultural sector that appears to be becoming more productive and sustainable.

However, overall status and trend assessments could not be provided at the time of this report due to the absence of baseline data on where sustainable agriculture is being operated in Victoria. It is anticipated that the SDGs will become increasingly central to Victorian environment reporting, therefore it is intended this indicator will be reported in future SoEs and drive the collection of more suitable data for future assessments.

126. Dairy Australia Limited 2013, 'Australian Dairy Industry Sustainability Framework Progress Report 2013', Melbourne, Victoria.
127. Dairy Australia Limited 2017, 'Australian Dairy Industry Sustainability Report 2016', Melbourne, Victoria.

Future Focus

Improve understanding of soil and land conditions and threats

To manage Victoria's land health during a time of climate change, it is essential that a long-term plan is created for the collection, consolidation, reporting and assessment of land data across the state. It may be a decade before the benefits of this plan are realised, but it is critical that responsible agencies commence work now so that adequate assessments of land health can be used to drive statewide improvements in land-health condition across Victoria.

The main challenges to soil monitoring are the inherently high variability of soils (the changes are minor and occur over decades), and that measuring soil characteristics can be expensive. These are national issues. New collaboration and funding models linking public and private databases and federated data could provide greater opportunity for soil-health monitoring. Alignment of these new models with the work undertaken by the Cooperative Research Centre for High Performing Soils to develop and measure soil-health indicators for the future could be the foundation for a state soil and land condition monitoring program.

Further analyses of the threats and impacts of land use and land-use change would also improve policy development and decision-making across a variety of sectors, including agriculture, planning and water management. An analysis of the tools that support ongoing land-use assessments, including the Victorian Land Use Information System, and the optimum frequency for updating land-use datasets and maps would be required.

Recommendation 7: That Agriculture Victoria lead the design and delivery of a state soil and land condition monitoring program, that includes analysis of the threats and impacts of land use and land-use change, to improve decision-making across a variety of sectors including agriculture, planning and water management.

Note: This recommendation complements recommendation 6: Improve biodiversity outcomes on private land. The investigation of the threats and impacts of land use and land-use change would determine the impact of private land on Victoria's ecosystems and inform actions to maintain and improve biodiversity on private land.

Accounting for the Environment

Land accounts are at the core of environmental–economic accounting. Land accounts can be used to assess changes in tenure, impacts of urbanisation, intensity of crop and animal production, deforestation and other direct and indirect uses. Land accounts are also very relevant to many levels of governance including local, regional, catchment and state. While broad assessment of the changing shares of different land use and land cover within the state may provide useful indicators of change, increasingly the power of the land accounts is reflected in the use of mapping technologies that can pinpoint areas of change. The UN SEEA describes land as:

A unique environmental asset that delineates the space in which economic activities and environmental processes take place and within which environmental assets and economic assets are located.[128]

The use of any given parcel of land determines the suite of ecosystem services it may provide. For instance, a native forest provides water purification, carbon sequestration and habitat services. By contrast land used for farming, such as wheat production, is generally limited to providing provisioning services in the form of wheat for feed. There are many other instances where a unit of land can provide multiple ecosystem services, and it is government policy and economic activity that determine land use and in turn the suite of ecosystem services.

A key feature of land accounts is the ability to disaggregate them for specific and targeted spatial analysis and decision-making. For instance, biodiversity-related services are highly dependent on specific types of land or ecosystem assets, including Ecological Vegetation Classes (EVCs), wetlands and rivers. Further, many species require specific types of ecosystem assets in a condition that allows for them to exist and breed.

Land accounts alone are not sufficient and there is generally a need to have them connected to accounts that can report on ecosystem services and benefits. The decision to use land should include an analysis of the potential changes in both services and benefits, noting that some benefits may not be monetary and so not all land-use decisions are driven or motivated by economic returns.

For example, forests are a type of land account. Forest asset accounts can be linked to the natural inputs and ecosystem services they produce which have benefits for the economy and society. (This is discussed further in the Forests chapter).

Land accounts are linked to soil resources. Soil is an important environmental asset that provides services and benefits, but it can be degraded. The services provided by soil are linked to land accounts, as the way land is used and managed impacts on the condition of soil, and the condition of soil affects land-use decisions. Soil assets can be managed to improve or maintain their condition. For example, soil acidification can be reversed with the application of lime, and soil erosion can be managed by maintaining ground cover that protects soil from wind and water erosion.

Land also has an important role to play in climate change. For instance, land may be inundated in coastal areas or contain ecosystem assets that will be impacted by changing climatic conditions. Changes are already being observed in the allocation of land to different agricultural enterprises in response to changes in climate and weather patterns. Land accounts could be used to forecast potential impacts on land and how that may impact on economic and social wellbeing for planning and government policies and programs.

128. United Nations 2014, 'System of Environmental-Economic Accounting 2012: Central Framework'.

Victorian Land Accounts

The ABS provided land accounts for Victoria showing the rateable value of land (see Figure L.17), and the distribution of the native vegetation from 1750 that was remaining in 2006 (see Figure L.18 and Figure L.19).

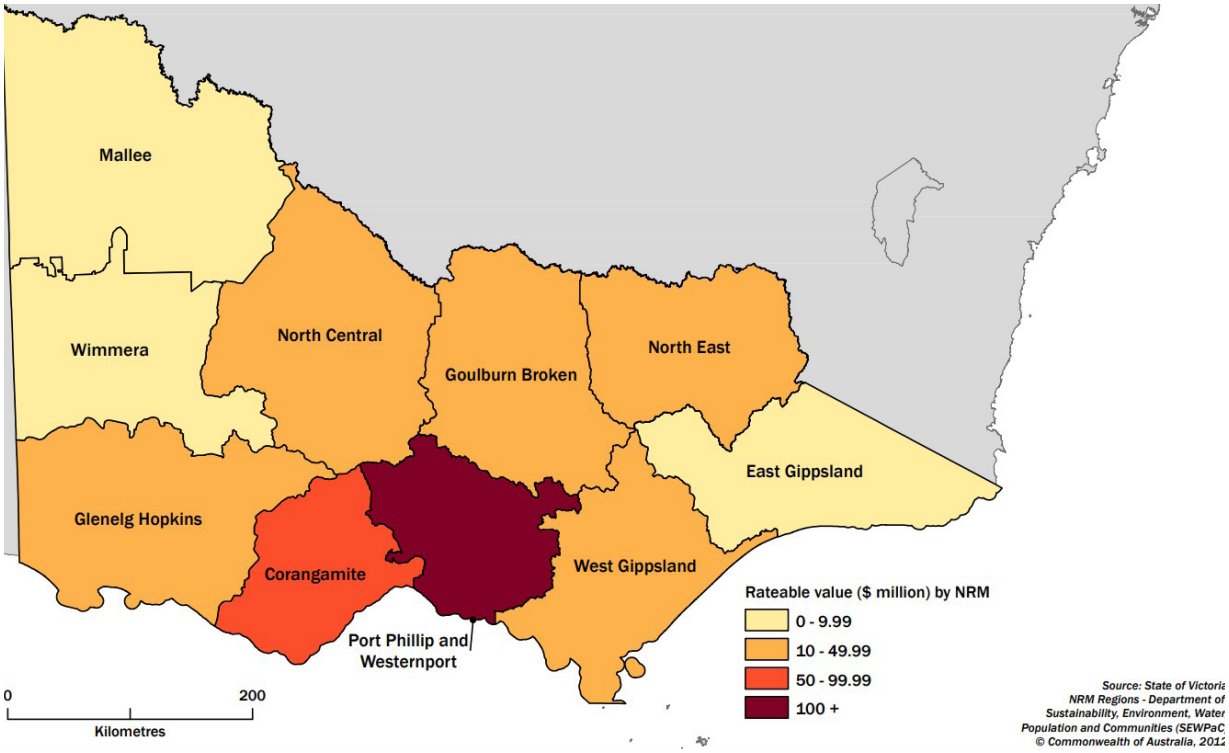


Figure L.17 Total rateable value of land by natural resource management area, 2012

(Data source: 4609.0.55.002 - Land Account: Victoria, Experimental Estimates, 2012)

A particular feature of land accounts is that they can be tailored to analyse of specific areas in the state. For example, Figure L.18 shows the distribution of native vegetation by NRM area whereas Figure L.19 reports the same information but for Interim Biogeographic Regionalisation for Australia (IBRA) regions. Further specific analysis can be done to show the links between economic activity and the state of the environment for any area of interest.

Ecosystem accounts as a special case of land accounts are important because they can be used to show the change in extent of EVCs, and can be linked to economic activity and investments by government to improve or maintain the condition of the ecosystems (spatial condition accounts). Both extent and condition accounts can then be linked to Habitat Distribution Models (HDMs) to demonstrate how the maintenance and improvement of key ecosystems can contribute to species preservation (see the Forests chapter for an example of links to HDMs and rare and threatened species).

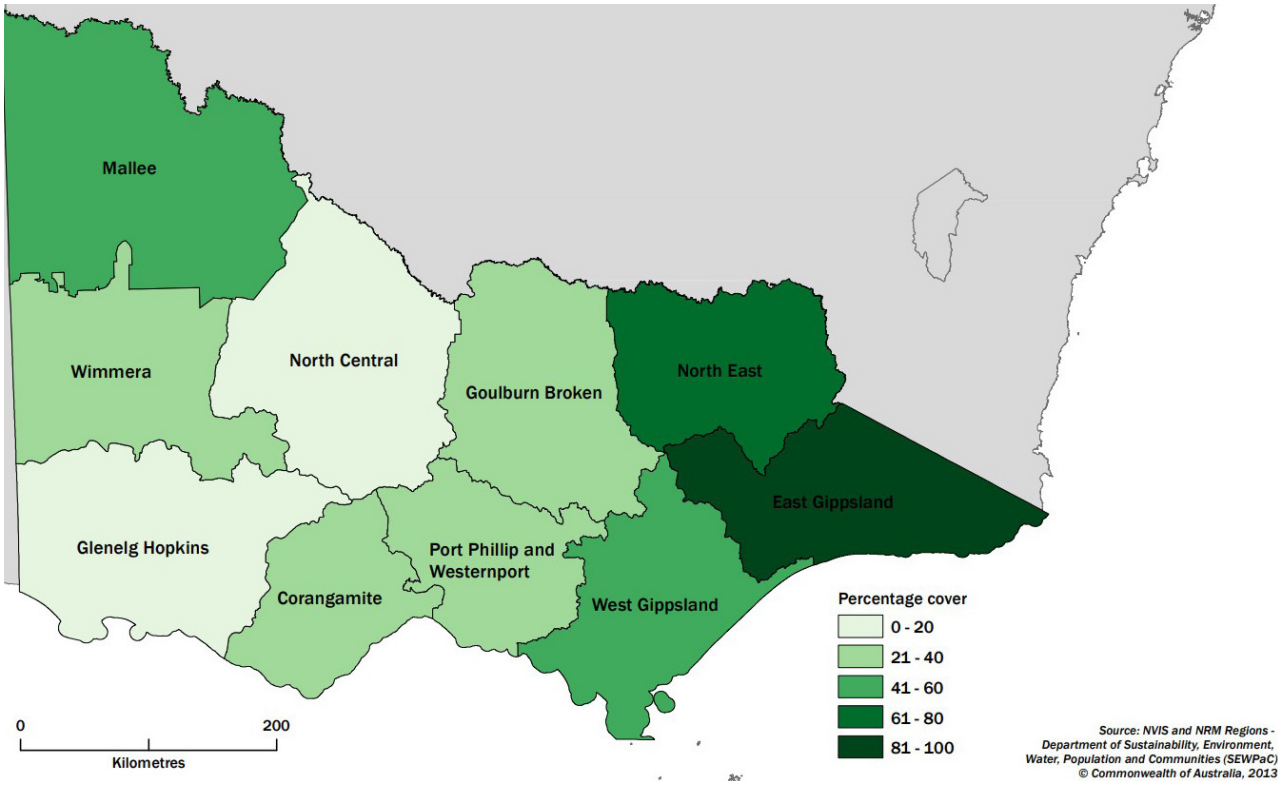
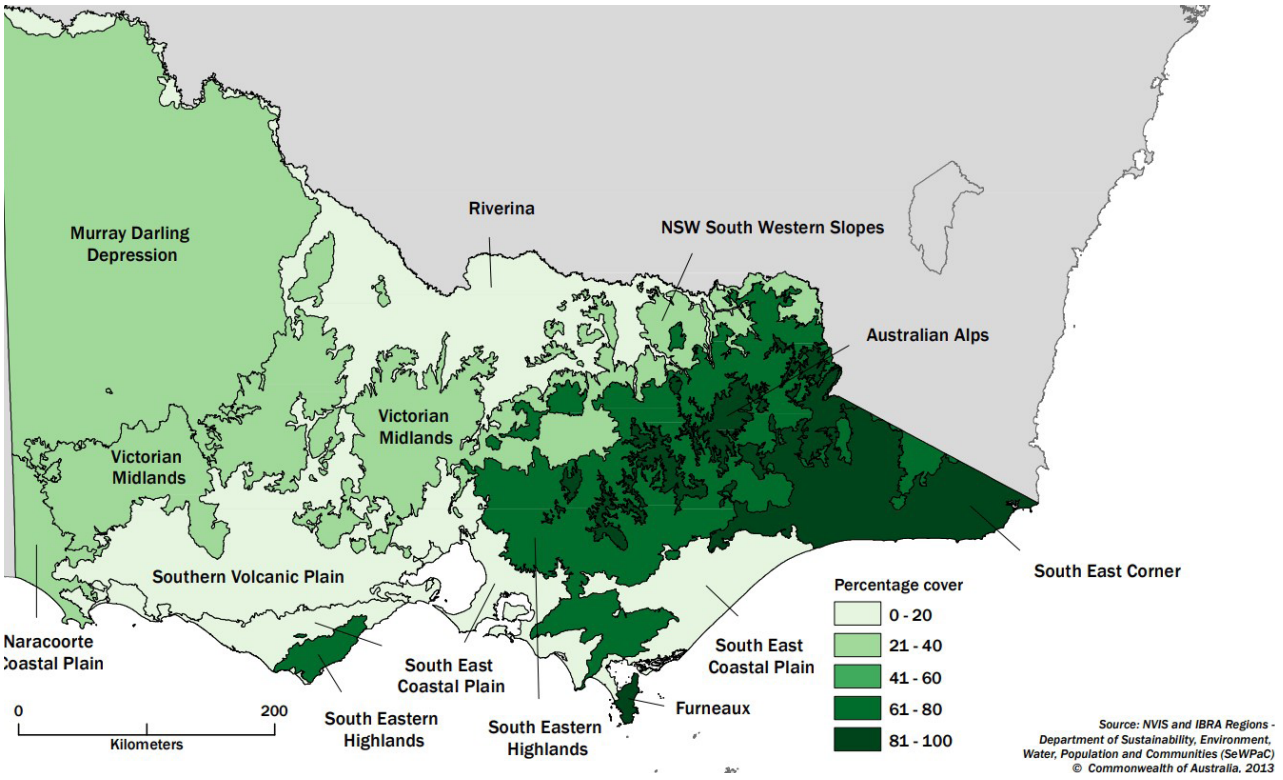


Figure L.18 Percentage of 1750 native vegetation cover remaining in 2006 by NRM area

(Data source: 4609.0.55.002 - Land Account: Victoria, Experimental Estimates, 2012)



zzFigure L.19 Percentage of 1750 native vegetation cover remaining in 2006, by IBRA

(Data source: 4609.0.55.002 - Land Account: Victoria, Experimental Estimates, 2012)

There are several measurement and reporting requirements for the regular production of land accounts. These requirements include:

- regular and ongoing collection of land use and land cover data, rather than ad hoc project-based work
- spatial standards for the collection and collation of spatial data to ensure government agencies can aggregate the data to undertake integrated analysis
- clarity on the classification of land for different purposes and consistent use across government agencies for integrated decision-making
- systems in place to report on changes in land condition and the services the land is providing
- systematic reporting on the spatial location of land and its contribution to economic and social wellbeing.



FORESTS (Fo)

SCIENTIFIC ASSESSMENTS Part III

Commissioner *for* Environmental Sustainability Victoria

Forests

The Forests chapter has 21 indicators divided across eight themes: 1) Ecosystem Diversity, 2) Genetic Diversity, 3) Species Diversity, 4) Ecosystem Health, 5) Carbon Cycles, 6) Productive Capacity, 7) Legal, Institutional and Economic and 8) Socio-economic Benefits.

In terms of biodiversity, the Genetic Diversity and Species Diversity themes discuss forest-dependent species using the limited available information. Several threatened species are discussed in relation to their risks and potential consequences of timber production activities. This chapter does not discuss soil and water resources in Victorian forests and several socio-economic aspects, which will be included in the State of the Forests (SoF) 2018 report. This chapter does not provide comprehensive discussions about climate change and fire, as these are discussed in the respective chapters.

Background

Forests and the services they provide are essential for the health and wellbeing of all Victorians. Forests maintain Victoria's water quality, purify the air and store carbon, stabilise and nourish soil, assist agriculture, and support economies vital for regional communities and businesses. Forests have also been an essential part of history and culture for Victoria's Traditional Owners and Aboriginal Victorians. The definition of 'forest' used by Australia's National Forest Inventory, established in 1988, is:

> an area, incorporating all living and non-living components, that is dominated by trees having usually a single stem and a mature or potentially mature stand height exceeding 2 metres and with existing or potential crown cover of overstorey strata about equal to or greater than 20 per cent. This includes Australia's diverse native forests and plantations, regardless of age. It is also sufficiently broad to encompass areas of trees that are sometimes described as woodlands.[1]

Victoria has 7.9 million hectares of public land (excluding marine and coastal areas). Parks and Reserves, and State Forest, account for 3.7 million and 3.2 million hectares of land respectively and both have approximately 3 million hectares of forest cover. Other crown land, which accounts for the remaining 1 million hectares of public land, has 0.4 million hectares of forest cover, bringing the total area of forest across the public land estate to 6.4 million hectares (Figure Fo.1)[2]. Since European settlement, more than 14 million hectares (60%) have been cleared, mainly for agriculture and settlements.[3] Victoria's population growth and subsequent urban expansion will increase the pressure on Victorian forests through elevated water demand from forest catchments and timber harvesting.[4] In managing these forests, a range of actions are identified to achieve the principles of sustainable forest management.

This was defined in 1993 at the Ministerial Conference on the Protection of Forests in Europe as:

> the stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems.[5]

1. Australian Department of Agriculture and Water Resources ABARES, 'Australia's forests', Canberra, Australia http://www.agriculture.gov.au/abares/forestsaustralia/australias-forests Accessed 3 December 2018.
2. Forest and land area statistics are provided by DELWP in 10 January 2019, using public land management datasets (PLM25)..
3. Commissioner for Environmental Sustainability 2013, 'State of the Environment report 2013', Melbourne, Victoria http://www.ces.vic.gov.au/sites/default/files/publication-documents/2013%20SoE%20report%20full.pdf Accessed 3 December 2018.
4. Lindenmayer DB, Sato C 2018, 'Hidden collapse is driven by fire and logging in a socioecological forest ecosystem', *Proceedings of the National Academy of Sciences*, 115, pp. 5181-5186.
5. Second Ministerial Conference on the Protection of Forests in Europe 1993, 'Resolution H1: general guidelines for the sustainable management of forest in Europe', Helsinki, Finland https://www.foresteurope.org/docs/MC/MC_helsinki_resolutionH1.pdf Accessed 3 December 2018.



Figure Fo.1 Victorian state forest, and parks and reserves

(Data source: DELWP, 2018)

The current literature identifies several major issues for long-term sustainable forest management in Victoria:

- Climate change – There is considerable scientific evidence predicting damage to the vitality and health of Australia's forests due to climate change.[6,7,8,9] Forests are an important element of the global carbon cycle; therefore, monitoring carbon stocks in forests is an essential part of sustainable forest management.
- Changing fire regimes – more frequent and severe fires as a result of changing climate are expected to cause tree mortality, regeneration and seed viability in the fire-sensitive forest types,[10] including eucalypt forests (such as *Eucalyptus pauciflora*[11] and *Eucalyptus delegatensis subsp. Delegatensis*[12]).
- Biodiversity – In Victoria, nearly 250 fauna species are listed as 'threatened' in the *Flora and Fauna Guarantee Act 1988 (FFG Act)*. Of these, approximately 20% are forest-dependent species. While disturbance and regeneration are fundamental to

6. Madsen T, Ujvari B, Shine R, Olsson M 2006, 'Rain, rats and pythons: climate-driven population dynamics of predators and prey in tropical Australia', *Austral Ecology*, 31(1), pp. 30-37.
7. Donohue RJ, McVicar TR, Roderick L 2009, 'Climate-related trends in Australian vegetation cover as inferred from satellite observations, 1981-2006'.*Global Change Biology*, 15(4), pp. 1025-1039.
8. Johnson BJ, Miller GH, Fogel ML, Magee JW, Gagan MK, Chivas AR 1999, '65,000 years of vegetation change in central Australia and the Australian summer monsoon'. *Science*, 284(5417), pp. 1150-1152.
9. Hughes L 2003, 'Climate changes and Australia: trends, projections and impacts'. *Austral Ecology*, 28(4), pp. 423-443.
10. Fairman T, Nitschke CR, Bennett LT 2016, 'Too much, too soon? A review of the effects of increasing wildfire frequency on tree mortality and regeneration in temperate eucalypt forests'. *International Journal of Wildland Fire*, 25(8), pp. 831-848.
11. Fairman, TA, Bennett LT, Tupper S, Nitschke CR 2017, 'Frequent wildfires erode tree persistence and alter stand structure and initial composition in a fire-tolerant sub-alpine forest'. *Journal of Vegetation Science,* 28(6), pp. 1151-1165.
12. Doherty MD, Gill AM, Cary GJ, Austin MP 2017, 'Seed viability of early maturing alpine ash (Eucalyptus delegatensis subsp. delegatensis) in the Australian Alps, south-eastern Australia, and its implications for management under changing fire regimes'. *Australian Journal of Botany*, 65, pp. 517-523.

forest maintenance, significant shifts in the frequency, scale and intensity of these processes can disrupt the health of forests.[13]

- Fragmentation – Forest-dwelling fauna species, including endangered species, are impacted by the fragmentation of native forests.[14] This loss of forest connectivity eventually leads to the geographic isolation of a species' population and impacts on the species' genetic diversity. This has significant implications for the survival of many iconic and forest-dependent species.
- Economy – Forests provide a resource for several economically significant industries in Victoria. These include forest products, agriculture (agroforestry) and tourism. The forest products industry alone provides an estimated 15,696 jobs, of which 14,475 are directly related[15] to forests. Victoria has the largest total area of plantations in Australia, compared to other states and territories, with 433,000 hectares of commercial hardwood and softwood plantations in 2013–14, up 13% from 2003–04.[16] Successful management of Victoria's forest/timber resources is vital to the state's economy.
- Legal framework – Management of Victoria's forests is delivered within a complex legal and policy framework. Relevant legislation includes the *Sustainable Forests (Timber) Act 2004*, *National Parks Act 1975* and *Forests Act 1958*.[17]

13. Keenan R J and Nitschke C 2016, 'Forest management options for adaptation to climate chance: a case study of tall, wet eucalypt forests in Victoria's Central Highlands region'. *Australian Forestry,* 79(2), pp. 96-107.
14. Riitters KH, Wickham JD, O'Neill R, Jones B, Smith E 2000, 'Global-scale patterns of forest fragmentation'. *Conservation Ecology*, 4(2), pp. 3.
15. Schirmer J, Mylek M, Magnusson A, Yabsley B, Morison J 2018, 'Socio-economic impacts of the forest industry Victoria (exc. The Green Triangle)'. *Forest & Wood Products Australia,* Melbourne, Victoria https://www.fwpa.com.au/resources/reports/other/1631-socio-economic-impacts-of-the-forest-industry-victoria-exc-the-green-triangle.html Accessed 3 December 2018.
16. VAFI 2015, 'Industry review 2015', Melbourne, Victoria, http://www.vafi.org.au/wp-content/uploads/2015/12/VAFI015-Victorian-Forest-Industry-Review-2015-FINAL.pdf Accessed 3 December 2018.
17. VEAC 2017, 'Conservation values of state forests: assessment report', Melbourne, Victoria http://www.veac.vic.gov.au/documents/Complete%20report%20for%20web%20page.pdf Accessed 3 December 2018.

Critical challenges for sustainable forest management in Victoria, now and in the future, include:

- establishing long-term monitoring of key aspects of forest conditions, such as loss of species population and genetic diversity due to fragmentation of native forests
- understanding the changes in patterns of natural disturbances including fire, flood and drought, and any increase in variability and intensity of these disturbances due to climate change
- understanding the impacts of altered disturbance patterns on forest productivity and forest-related biophysical and social values
- understanding Victoria's forest carbon cycle and increasing the carbon storage capacity of forests
- improving complex and outdated forest management legislation that cause inconsistencies, overlaps and gaps, and lead to confusion for land managers and communities
- managing forests for a range of social, cultural, economic and ecological values and uses
- enhancing the protection and management of forests with attributes important to ecological conservation and carbon storage[18]
- characterising the optimal restoration targets (location, maturity stages) in post-fire and/or logged regrowth forests to reduce fire proneness[19]
- achieving sustainable native-timber production while protecting threatened species such as Leadbeater's possum
- defining forest-logging to fire-severity relationships as mediated by regrowth stage, tree abundance and density
- being consistent, multi-tiered and multi-valued in monitoring approaches and data acquisition strategies for sustainable forest management.

18. Lindenmayer DB, Blair D, McBurney L, Banks S 2015, 'Mountain Ash: fire, logging and the future of Victoria's giant forests', CSIRO Publishing, Melbourne, Victoria.
19. Ibid

Current Victorian Government Settings: Legislation, Policy, Programs

Victoria's forests are managed in accordance with Victorian legislation, including the *National Parks Act 1975*, *Forests Act 1958*, *Conservation, Forests and Land Act 1987*, *Flora and Fauna Guarantee Act 1988*, *Crown Land (Reserves) Act 1978*, *Land Act 1958*, and *Sustainable Forests (Timber) Act 2004*, along with related regulations, codes of practice, management plans and policy initiatives.[20] The system undertakes to balance management of the multiple values of Victoria's forests, including environmental values.

Recent policy measures that address or overlap with the issues above include:

- *Protecting Victoria's Environment – Biodiversity 2037 (Biodiversity 2037)* which sets out a 20-year vision and goals for biodiversity in Victoria
- review of the *Flora and Fauna Guarantee Act 1988* (FFG Act), so that it can more effectively protect Victoria's biodiversity in the face of existing and emerging threats
- amendments to regulation of native vegetation with the aim of providing for better consideration of biodiversity elements in decision-making, including habitat for rare or threatened species, large trees, endangered ecological vegetation classes (EVCs), sensitive wetlands and coastal areas.

In 2017, the Victorian Environmental Assessment Council (VEAC) recommended the following be undertaken within five years:

- state forests be administered under one Act
- the *National Parks Act 1975* be expanded to include revised categories of national parks, conservation parks, nature reserves, marine protected areas, and other categories and overlays classified as protected areas, to become the 'National Parks and Conservation Reserves Act'
- a new public land Act be developed to replace the current *Land Act 1958, Crown Land (Reserves) Act 1978* and *Forests Act 1958*.

The Victorian Government has accepted these recommendations.

Elements of Victoria's forest management framework are accredited by the Commonwealth under five Regional Forest Agreements (RFAs).[21] The RFAs were a key outcome of the *National Forest Policy Statement (1992)* through which the federal, state and territory governments committed to the sustainable management of all Australian forests.

RFAs endeavour to maintain a comprehensive, adequate and representative reserve system, to manage forests on an ecologically sustainable basis, and provide for the long-term stability of forests and forest industries. All five Victorian RFAs are due to expire in March 2020.

The Victorian Government endorsed a program to modernise Victoria's RFAs. Over the next two years, the Department of Environment, Land, Water and Planning (DELWP) has committed to engaging with Victorian communities on how they value Victoria's forests. DELWP will also complete assessments of forest values, including environmental values, indigenous heritage values, economic values, social values and principles of ecologically sustainable management.

It is anticipated that the outcomes of the engagement and assessments processes will inform the modernisation of Victoria's RFAs and the planning and regulatory frameworks they accredit.

20. Turner J, Flinn D, Lambert M, Wareing K, Murphy S 2011, 'Management of Victoria's Publicly-owned Native Forest for Wood Production', *Forest & Wood Products Australia*, Melbourne, Victoria. http://www.fwpa.com.au/images/resources/PRC174-0910_Research_Report_Native_forest_project.pdf Accessed 3 December 2018.

21. DELWP 2018, 'Modernising Victoria's regional forest agreements', Melbourne, Victoria https://www.forestsandreserves.vic.gov.au/forest-management/regional-forest-agreements Accessed 3 December 2018.

Indicator Assessments

The Montreal Process

The Montreal Process is a voluntary agreement between nations to monitor and report on agreed criteria and indicators for the conservation and sustainable management of forests. Australia has accepted the criteria and developed indicators that best represent Australia's unique forest conditions in the *Framework of Regional (Sub-National) Level Criteria and Indicators of Sustainable Forest Management in Australia* (the framework).

Victoria has developed 45 indicators under the framework for reporting on Victoria's forest management.[22] To ensure accurate and consistent performance reporting against the criteria, since 2003, DELWP has produced three iterations of Victoria's SoF report every five years. Through the reporting process, a range of key challenges have been identified that are necessary to achieve sustainable forest management. Through discussions with relevant stakeholders, the Office of the Commissioner for Environmental Sustainability (OCES) has selected 20 indicators from six criteria relevant for the Montreal Process to be discussed in this chapter. A complete version of the OCES analysis, including all 45 framework indicators, will be presented in SoF 2018.

Victorian Forest Monitoring Program

The main data source for the Forests chapter is the Victorian Forest Monitoring Program (VFMP), which has informed 9 of the 21 forest-related indicators in this report.

DELWP's Victorian Forest Monitoring Program (VFMP) was stablished in 2011. It measures and monitors landscape-level trends in forest ecosystems in the Victorian public land estate, and is the only broad-scale forest-monitoring process operating in Australia.[23] It aims to provide relevant information for the Montreal Process, and contribute to policy development and decision-making related to carbon, biomass and ecosystem-service accounting, water-yield modelling, habitat structure, forest health and productivity, and the impacts of disturbances such as fire.

The VFMP comprises a network of 786 permanent ground plots, which are stratified (or grouped) into 21 distinct regions, according to Victoria's 11 bioregions (Table Fo.1 and Figure Fo.3)[24] and by public tenure ('state forests' and 'parks and conservation reserves'). The field measurement process achieved 84% (662 plots) of the 786 ground plots, with the remaining plots not measured due to various constraints such as accessibility or other hazards (Table Fo.1).

The results of the VFMP's first full cycle of measurements, completed in November 2015, are reported here. The second measurement cycle is to be completed in 2020.

22. Department of Sustainability and Environment 2007, 'Criteria and indicators for sustainable forest management in Victoria: guidance document', Melbourne, Victoria https://www.forestsandreserves.vic.gov.au/__data/assets/pdf_file/0022/30865/Vic_Indicators_for_SFM_Guidance.pdf Accessed 3 December 2018.

23. Haywood A, Thrum K, Mellor A, Stone C 2017, 'Monitoring Victoria's public forests: implementation of the Victorian Forest Monitoring Program'. *Southern Forests*, 2620, pp. 1–10.

24. Australian Department of the Environment and Energy, 'Australia's bioregions (IBRA)', Canberra, Australia http://www.environment.gov.au/land/nrs/science/ibra Accessed 3 December 2018.

Note that comparison of results between this report and SoF 2013 is limited due to changes to data collection, and improvements in data quality. For example, when SoF 2013 was prepared, only 337 plots (or approximately 50%) had been measured (Table Fo.1). While important, increased sample sizes and improved accuracy have introduced analytical 'noise'. More accurate trend analysis for all VFMP metrics will be possible from 2020 onwards, once two full measurement cycles have been completed.

VFMP evaluates its performance against a quality assurance and quality control (QA/QC) protocol.[25] The protocol involves a training and audit program that assesses a minimum 15% of plots per year – an increase of 7 percentage points from the previous report.[26] The QA/QC program is important to avoid any bias from data interpretation for evaluating natural and human-induced disturbance and the efficacy of management actions and policy decisions about public forests.

SoF reports prior to 2013 were produced based on data sources with varying spatial and temporal scales and a bias towards commercial state forests in eastern Victoria.[27] The VFMP is intended to help DELWP improve its forest monitoring activities with a more consistent and comprehensive monitoring approach across tenure (state forest/national park). However, the program has limitations, which have been acknowledged by its design team.[28] A relatively low sample size (786 at the time of the evaluation), determined by the available budget, means the program must leverage a three-tiered remote-sensing approach to improve its forest-area estimates. Consequently, the program's application to finer-scale or discrete metrics is not recommended. Rather, the program is designed to observe broad-scale, long-term trends in forest health and condition. It could be improved by investments in separate but complementary monitoring activities specific to important/relevant sites.

Note that DELWP has increased the sample size by 73 plots (from 786 to 859) since the evaluation was conducted, as a result of tenure change in the Riverina and improvements to spatial data accuracy.

Continuous improvement is necessary for the program to remain a useful tool to assist public land managers to observe the influence of tenure-specific management interventions (across national parks and state forests) at the bioregion level.

25. DELWP 2017, 'Standard operating procedures field guide (v2.1.0): Victorian Forest Monitoring Program', Melbourne, Victoria.
26. Haywood A, Thrum K, Mellor A, Stone C 2017, 'Monitoring Victoria's public forests: implementation of the Victorian Forest Monitoring Program'. *Southern Forests: Journal of Forest Science,* 80(2), pp. 185–194.
27. Ibid
28. Ibid

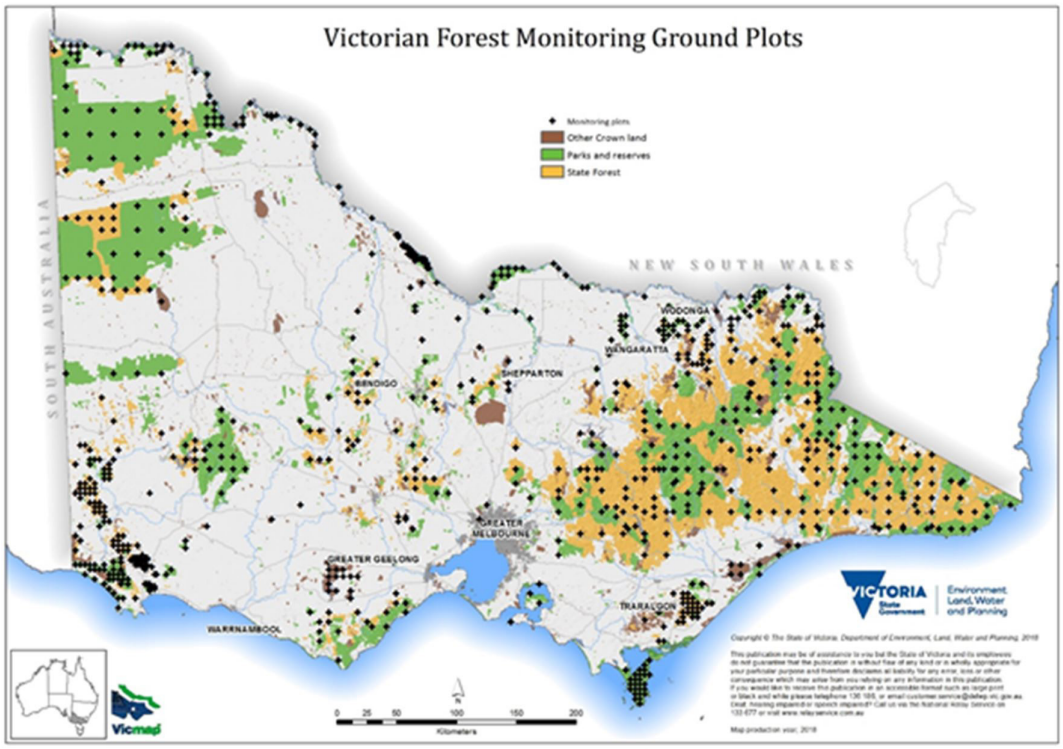


Figure Fo.2 Location of sampling units for VFMP

(Data source: DELWP, 2018)

Table Fo.1 Number of VFMP permanent sample plots per bioregion

Bioregion	2013 VFMP plots	2018 VFMP plots
Australian Alps	61	76
Flinders	9	19
Murray–Darling Depression	21	58
Naracoorte Coastal Plain	32	79
NSW South Western Slopes	27	65
Riverina	27	69
South East Coastal Plain	24	40
South East Corner	29	66
South Eastern Highlands	50	74
Victorian Midlands	36	66
Victorian Volcanic Plain	21	50
Total	**337**	**662**

(Data source: DELWP 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.

Poor
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

Poor
Evidence and consensus too low to make an assessment

Fair
Limited evidence or limited consensus

Good
Adequate high-quality evidence and high level of consensus

FORESTS

	Summary	Status	Trend
		UNKNOWN POOR FAIR GOOD	

Indicator

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

Region

Victoria

Measures

Forest canopy cover

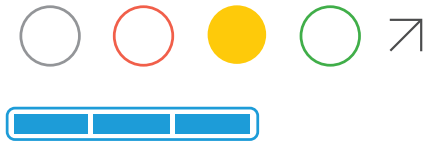
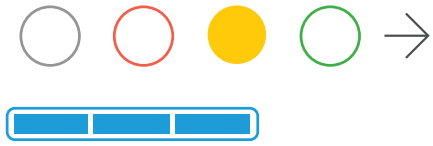
Data custodian

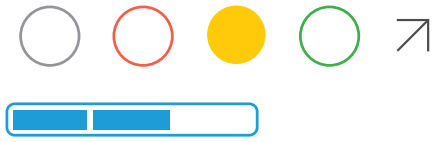
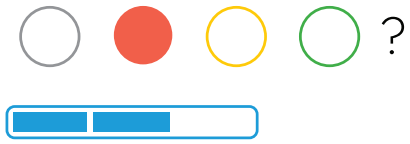
DELWP

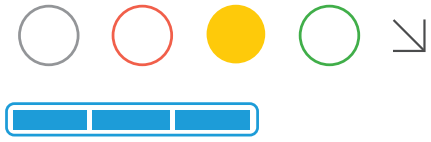
Maps of forest cover in Victoria are based on satellite data. Although the 2008–13 data can provide the change in forest cover, the trends have not been demonstrated for this report, but will be included in future reports.

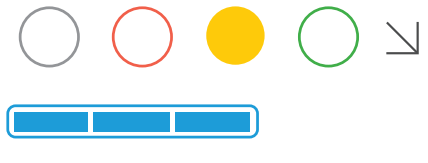
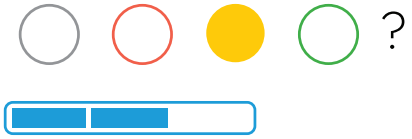
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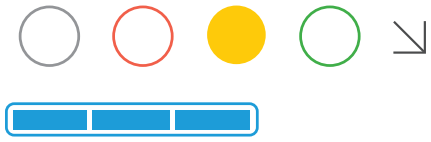
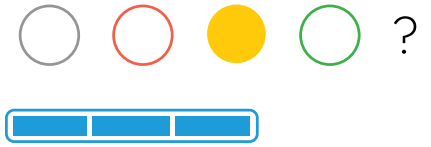
Poor

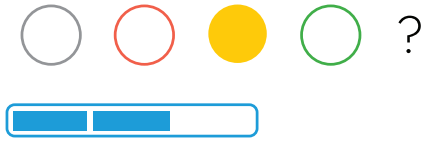
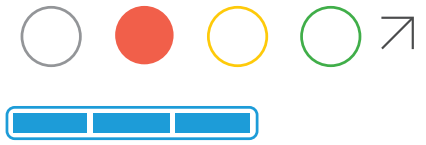
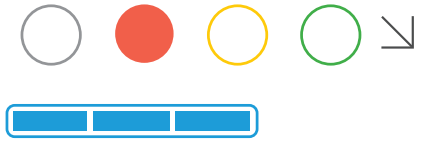
	Summary	Status UNKNOWN POOR FAIR GOOD	Trend
Fo:01B Area of forest by type and tenure-forest type **Region** Victoria **Measures** Forest area on public lands **Data custodian** DELWP	Forest extent in Victoria was heavily affected by the 2009 'Black Saturday' bushfires. But a decrease in the areas where classified as 'Forest unclassified (burnt)' demonstrates tree regrowth from previously burnt forest, largely concentrated in the Mallee.	 DATA QUALITY Good	
Indicator **Fo:01C** Area of forest by type and tenure-plantation forest **Region** Victoria **Measures** Plantation area (hectare) New plantation establishment per year **Data custodian** ABS	Plantation area in private land had little change since 2009-10. This is due to a significant decline in new plantation establishment in Victoria (none since 2012-13).	 DATA QUALITY Good	
Indicator **Fo:02** Area of forest type by growth stage **Region** Victoria **Measures** Forest area by growth stage **Data custodian** DELWP	This indicator reports the growth stage by broad forest type which provides an indication of diversity and balance of growth stages across Victoria's forest estate. Comparison of two datasets captured in different years indicates that forest area in different types increased both in State forest, parks and reserves but it is still difficult to determine current status.	 DATA QUALITY Good	

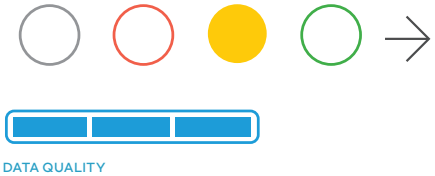
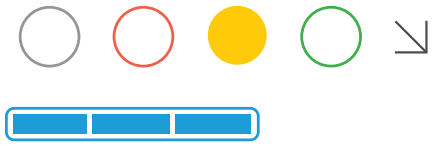
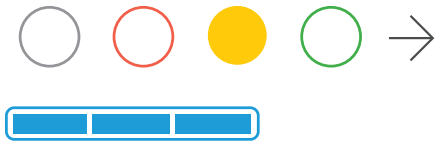
	Summary	Status	Trend
Indicator **Fo:03** Area of forest type by growth stage distribution in protected zones **Region** Victoria **Measures** IUCN and PV protected area Implications of changes in IUCN and PV protected area for threatened species **Data custodian** DELWP, PV	Overall IUCN protected area increased between 2004 - 2016, and PV managed formal protected area (parks and reserves) also increased between 1956 - 2016. While this is anecdotally a positive outcome for conservation of forest systems, there is limited evaluation of the effectiveness of the protected area network in providing better protection of biodiversity assets such as threatened species.	 DATA QUALITY Fair	
Indicator **Fo:04** Fragmentation of native forest cover **Region** Victoria and regional locations **Measures** Forest fragmentation: edge, interior, patch, perforated and transitional area by bioregion **Data custodian** DELWP	The presented data demonstrates a map of forest fragmentation in Victoria. As this is a snapshot of forest fragmentation in 2018, no trend analysis is available. Peer-reviewed journal papers have found that several threatened species are at risk due to forest fragmentation.	 DATA QUALITY Fair	

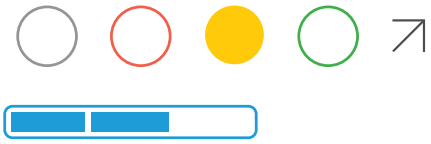
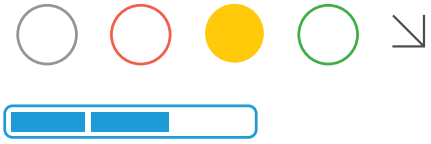
	Summary	Status	Trend
Indicator **Fo:05** Number of in-situ and ex-situ conservation efforts for forest dependent species **Region** Victoria **Measures** in-situ and ex-situ conservation activities on forest dependent threatened species Quantifiable conservation efforts **Data custodian** DELWP	In 2013, a method change occurred, making it difficult to determine benefits from management activities, and making trend analysis unachievable. The data presented has been provided by on-ground managers.	 DATA QUALITY Poor	
Indicator **Fo:06** The status of forest dependent species at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment **Region** Victoria **Measures** Conservation status: numbers of rare or threatened forest dependent species **Data custodian** DELWP	Since 2013, the only species group to be updated is vascular plants, in 2014. However, assessing changes in DELWP's advisory list related to plants can be misleading due to the frequent changes in botanical nomenclature. Except for the 36 species that were added, the status of the other 461 species has not been changed. Vascular plants represent by far the greatest proportion of these species. This might be due to greater knowledge and awareness of vascular plants within the scientific community, and their relative ease of detection. Since 2007–08, no changes have been observed in the number of rare or threatened amphibians.	 DATA QUALITY Good	

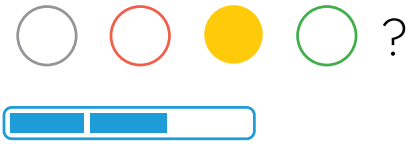
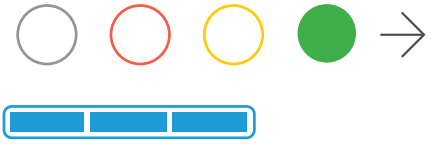
	Summary	Status	Trend
Indicator **Fo:07** Degree of disturbance to native forest species caused by invasive species **Region** Victoria **Measures** Scale and impact of invasive species on native forests, plantation and urban/farm forests **Data custodian** DELWP	For most identified pathogens and insect agents in Victoria, damage during the reporting period has stabilised or decreased. But a few species, including Red Gum basket lerp, *Dothistroma* needle blight, Mycosphaerella leaf disease, Cypress canker and *Phytophthora cinnamomi* have expanded their distribution and impact.	 DATA QUALITY Good	
Indicator **Fo:08A** Scale and impact of agents and processes affecting forest health and vitality – mortality, dieback, canopy health sub-section **Region** Victoria **Measures** Degree of leaf damage based on mortality, crown dieback, crown defoliation **Data custodian** DELWP, BoM	Robustness of previous datasets is weaker than current dataset, preventing comparison of current and past data. Across all Victorian bioregions, the average percentage of areas showing mortality, crown dieback and canopy health impacted are 14.3%, 20.3% and 23.3 % respectively.	 DATA QUALITY Fair	

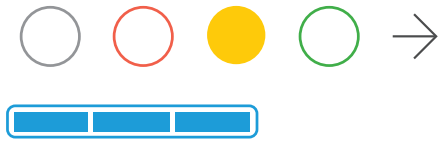
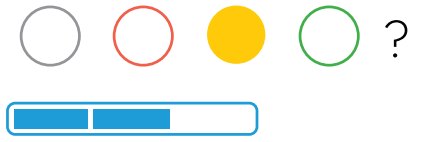
	Summary	Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **Fo:08B** Scale and impact of agents and processes affecting forest health and vitality – bushfire affected area and climate sub-section **Region** Victoria **Measures** Bushfire affected area (hectare) Annual mean temperature by year Number of unusually warm days by year **Data custodian** DELWP, BoM	Between 2013 and 2018, The most damaging bushfire on record is the Wye River-Jamieson Track fire, instigated by lightning on 19 December 2015. The fire exceeded control lines on Christmas Day under extreme weather conditions, burning 2,520 hectares of national park and private properties, with an estimated 160 houses. Between 2013 and 2014, Victoria experienced its most significant fire season since 2008, which challenged emergency services and Victorian communities. Across the season, Victoria had 19 days of Extreme and Severe Fire Danger Rating, and 16 days of Total Fire Ban. More than 463,000 hectares of public and private land was burnt, and 80 residences destroyed. Bushfire-affected area has been decreasing since 2003. Annual mean temperature and number of unusually warm days are increasing. This could reverse this trend in the future.	 DATA QUALITY Good	
Indicator **Fo:09A** Area and type of human-induced disturbance – Planned burns **Region** Victoria **Measures** Annual planned burn area **Data custodian** DELWP	Following the 2010 final report by the 2009 Victorian Bushfires Royal Commission, the Victorian Government committed to expand its planned-burning approach by aiming to reduce fuel hazards and protect human life. But in 2016, based on recommendations by the Inspector-General for Emergency Management, the government began to shift from a hectare-based approach to a risk-based approach to bushfire management. This focuses on areas where the likelihood of a bushfire starting, spreading and impacting on people, property and the environment is greatest, based on fire-modelling results. The government is developing a system of bushfire management strategies to reduce risk, to be delivered by 2020. A strategic change in planned-burning targets prevents trend analysis.	 DATA QUALITY Good	?
Indicator **Fo:09B** Area and type of human-induced disturbance – grazing **Region** Victoria **Measures** Number of licences issued for grazing activities **Data custodian** DELWP	License numbers and payments for rent or other activities on Crown land in the reporting period were stable. However, it is difficult to assess status, as the relationship between license numbers and environmental impact is unknown. No information on the size of grazing area has been identified.	 DATA QUALITY Poor	

	Summary	Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **Fo:10** Total forest ecosystem biomass and carbon pool by forest type, age class and succession all stages **Region** Victoria **Measures** Total carbon distribution per bioregion, tenure and type **Data custodian** DELWP	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	?
Indicator **Fo:11** Contribution of forest ecosystems to the global greenhouse gas balance **Region** Victoria **Measures** Carbon dioxide emissions by sector **Data custodian** DELWP	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	
Indicator **Fo:12** Area and percentage of forest and net area of forest available and suitable for wood production **Region** Victoria **Measures** Area and percentage of forest and net area of forest available and suitable for wood production **Data custodian** VicForests, DELWP	The Resource Outlook from VicForests has reduced the available timber production area in State forests. The Resource Outlook defines the volume of hardwood timber products from native forests made available to the market, separating the species groups of timber supply into two groups: ash and mixed-species. The reduction in availability of sawlog resource in areas such as the Central Highlands of Victoria can be attributed to the effects of fire in estimates of sustained yield. The trend indicates that less timber production in state forests will occur in the future and more emphasis will be on other values including species conservation and carbon sequestration issues.	 DATA QUALITY Good	

	Summary	Status	Trend
Indicator **Fo:13** Area of native forest harvested **Region** Victoria **Measures** Area available for native timber harvesting **Data custodian** VicForests, DELWP	Allocation Order shows that the area available to harvest for ash timber will decrease dramatically, whereas that for mixed species will increase. The overall area available for timber harvesting is stable.	 Good	
Indicator **Fo:14** Annual production of wood products from State forests compared to sustainable harvest levels **Region** Victoria **Measures** Annual production of wood products from State forest **Data custodian** VicForests, DELWP	Total timber annual production from state forests has been gradually decreasing. Decreasing sawlog production, seen over the past 20 years, has continued. Production fell by more than 50% between 1996-97 and 2016-17. Pulpwood has followed a similar trend. This will deteriorate further, as age class distribution of ash forests are highly imbalanced.	 Good	
Indicator **Fo:15** Proportion of timber harvest area successfully regenerated by forest type **Region** East Victoria **Measures** Net native forest area regenerated **Data custodian** VicForests	Between 2011–17, 2,059 hectares more have been harvested than regenerated. This does not indicate that sustainable harvest has not been achieved, according to DEDJTR. The figures show the area harvested in a specified five-year period, and the area regenerated in the same five-year period. This needs to be carefully monitored to ensure successful post-harvest timber harvest is fully achieved. A VAGO 2013 audit report found that the harvest manager, VicForests, was meeting the required regeneration standards, but recommended better alignment of harvesting and regeneration reports. .	 Good	

	Summary	Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **Fo:16** Extent to which the legal framework (laws, regulations, guidelines) supports the conservation and sustainable management of forests **Region** Victoria **Measures** Impact of legislations on conservation and sustainable management of forests **Data custodian** DELWP	There are currently 33 legislations that regulate forest management in Victoria. VEAC provided its *Statewide Assessment of Public Land Final Report* to government in May 2017, including several recommendations to reform the complex public land legislative framework. The Victorian Government has accepted, or accepted in principle or in part, all recommendations made by VEAC, including committing to rewriting the Crown land legislation over the next four years.	 DATA QUALITY Fair	
Indicator **Fo:17** Extent to which the institutional framework supports the conservation and sustainable management of forests **Region** Victoria **Measures** The overall assessment result of compliant and non-compliant audit **Data custodian** DELWP	Audits since 2014 have targeted elements of the regulatory framework that have been assessed as having a 'high risk' of causing environmental harm. While the 'high risk' elements have been targeted, VicForests have indicated a high level of compliance with lower risk prescriptions for timber production harvesting and coupe closure activities throughout the reporting period. The major environmental impact of timber production harvesting and coupe completion operations has been increasing.	 DATA QUALITY Fair	

	Summary	Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **Fo:18** Extent to which the economic framework supports the conservation and sustainable management of forests **Region** Victoria **Measures** Description of economic framework in Victoria to quantify and evaluate all relevant aspects for the conservation and sustainable management of forests **Data custodian** DELWP	The overall assessment result of compliant and non-compliant audit elements by different environmental impact categories since 2014 for native timber harvesting activities is described in this indicator. VicForests has indicated a high level of compliance with lower risk prescriptions for timber production harvesting and coupe closure activities throughout the reporting period. Some coupes that were harvested between 2014-15 and 2015-16 were assessed to have major environmental risk. A number of these coupes have been increasing which must be identified and investigated in the future.	 DATA QUALITY Fair	?
Indicator **Fo:19** Capacity to conduct and apply research and development aimed at improving forest management, including development of scientific understanding of forest ecosystem characteristics and functions **Region** Victoria **Measures** Number of full-time equivalent employees by research activity for government agencies, private companies and academia **Data custodian** DELWP	Although the overall number of Full-time equivalent (FTE) employees remained unchanged, FTE employees in academia increased by around 4 FTE in fire behaviour and forest hydrology when comparing 2011-17. Conversely, the FTEs in government agencies decreased the same amount in fire and flora ecology. For both years, topics related to fire, ecology and hydrology accounted for 80% of overall FTE employees. DELWP indicates that current budget allocation for R&D is based on identification and prioritisation of research directions. The organisation also explained that the expected impact of the research activities on management actions or policy change has been documented.	 DATA QUALITY Good	→

	Summary	Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **Fo:20** Investment and expenditure in forest management **Region** Victoria **Measures** Expenditure on forest management **Data custodian** DELWP	Expenditure for forest fire management was reduced to $269.9 million in 2016–17. Prior to this, it fluctuated, including up to $396.5 million in 2015–16. Reported expenditure on conservation and recreation increased significantly between 2014-15 and 2016-17 to $369.8 million. This may reflect increased Victorian Government focus on conservation and recreational values in state forests, parks and reserves.	 DATA QUALITY Good	
Indicator **Fo:21** Value ($) of forest derived ecosystem services **Region** Victoria **Measures** ($) Value of forest derived ecosystem services **Data custodian** DELWP	Forest ecosystems provide a suite of ecosystem services, including climate regulation, water supply, and filtration and habitat services. There is no state-scale approach that quantifies the value ($) of forest-derived ecosystem services in Victoria. Existing regional-scale approaches could be expanded to work on a state-scale.	 DATA QUALITY Fair	?

Ecosystem Diversity

	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
Fo:01 Area of forest by type and tenure	●	○	○	○	?	DATA QUALITY Poor

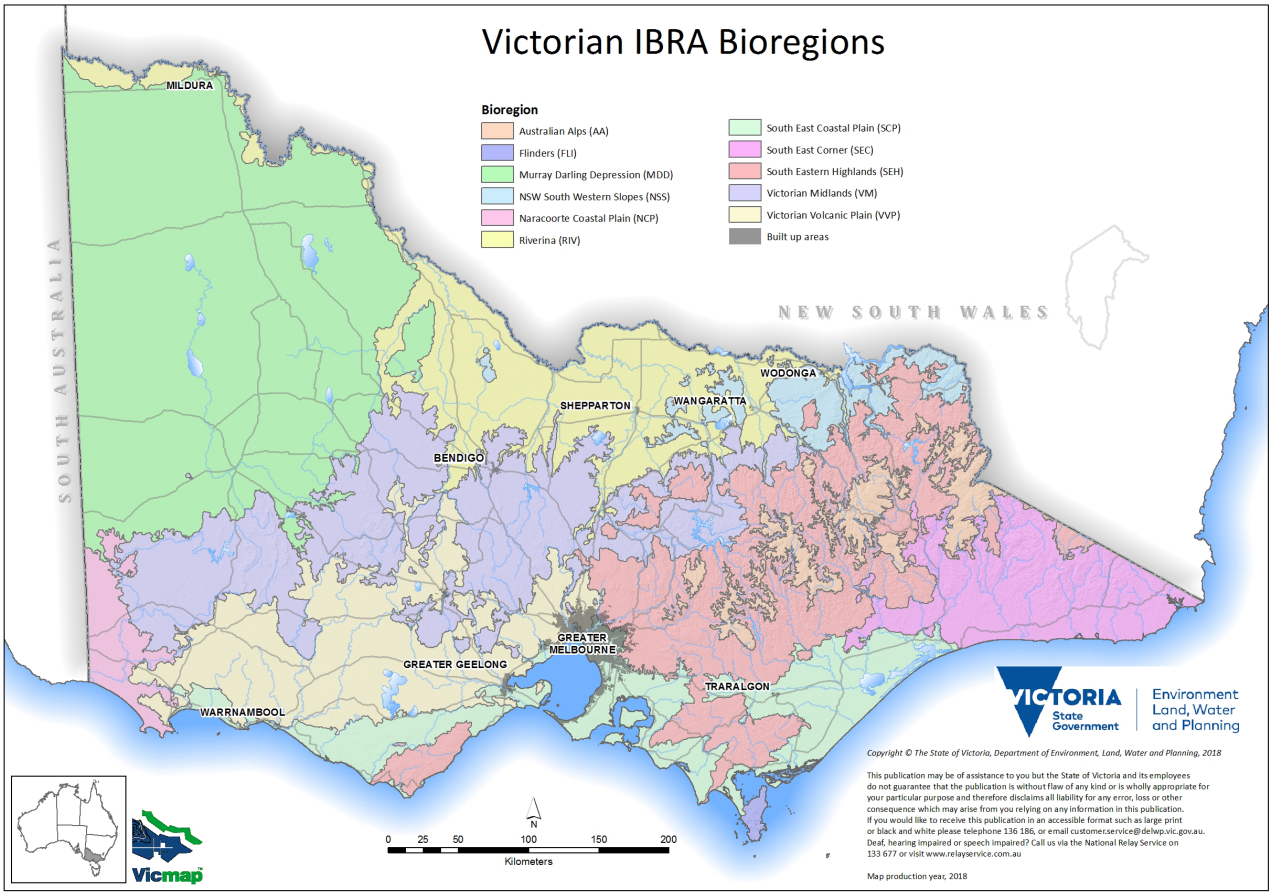


Figure Fo.3 Interim Biogeographic Regionalisation for Australia bioregions in Victoria

(Data source: DELWP, 2018)

To effectively manage Victorian forests, it is necessary to understand forest area by type, as it provides a broad measure of forest ecosystem and biodiversity maintenance. Changes in forest area and structure over time also provide an indicator for the impact of environmental disturbances and extreme events on forest ecosystems (such as bushfires).

Bioregions are the major geographic stratification unit for the VFMP, with 11 bioregions located within Victoria (Figure Fo.3). Within each bioregion, further divisions are made based on public land tenure. In Victoria, state forests and parks and reserves are the two major tenures of interest for this report.[29] State forests are primarily managed for conservation and recreation, with small portions of areas for native-timber harvesting. Parks and conservation reserves are managed for conservation outcomes as well as recreation and tourism. Intensive recreation takes place in some areas, such as alpine parks.

This indicator provides information on the area of forest by broad forest type and tenure, as well as change in forest extent (forest cover) over time. Forest types, including height and canopy-cover classes, are defined according to Australia's National Forest Inventory (NFI) definitions. Information about area of forest by forest type and tenure is reported for public forests and plantations on private land.

29. Department of State Development, Business and Innovation, 'Public land management (PLM25)', Melbourne, Victoria https://www.data.vic.gov.au/data/dataset/public-land-management-plm25 Accessed 3 December 2018.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:01A Area of forest by type and tenure- forest canopy cover	●	○	○	○	?	DATA QUALITY: Poor

Data custodian DELWP

Forest canopy cover is derived from the freely available Landsat archive, with a baseline year of 2013. (This is consistent with the five-year interval used in SoF 2013, which presented a 2008 baseline year.) A binary (forest/non-forest) classification is applied. The identified forest area is used as the extent for the direct expansion method, from which the aspatial forest type estimates described above are derived (Figure Fo.4).

Comparison of this product to national and global forest-cover products[30] suggests this process is relatively accurate for state-level reporting, with a global error of +/– 15% variable across the state. It is even more accurate for public land, which provided the source of validated, ground-truthed data.

Analysis demonstrates that forest-cover confidence is lowest in the Mallee and some coastal regions, particularly in national and global forest-cover products. Although the 2008–13 data can provide the change in forest cover, the trends have not been analysed for this report due to time constraints, but will be included in future reports.



Figure Fo.4 Victorian forest cover, 2018

(Data source: DELWP, 2018)

30. Soto-Berelov M, Jones SD, Haywood A 2018, 'Assessing large area forest cover products derived from the same imaging source across Victoria, Australia', *Ecological Management & Restoration*, 19(1), pp. 66-75.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:01B Area of forest by type and tenure-forest type	○	○	●	○	↗	DATA QUALITY: Good
Data custodian DELWP						

'Forest' is defined by Australia's National Forest Inventory as an area greater than 0.5 hectares of native forest, with a dominant vegetation height of greater than 2 m and canopy cover greater than 20%. Areas that meet this definition are assigned a land cover classification based on the species they are home to, dominant height and canopy cover, as well as the level of disturbance experienced. Forest types are based on the relative abundance of eucalypt species (eucalypt, mallee or mixed) and divided into height classes: low (2–10 m), medium (11–30 m) and tall (>30 m).

Forest-area estimates are derived from a network of 2 km x 2 km high-resolution aerial photographs taken above each VFMP plot. The photographs have been interpreted by trained practitioners and provide information describing the boundaries of different forest and land regions using the classifications of broad forest type, canopy cover and height, as described above.

A direct expansion method[31] was used to inform area and uncertainty estimates. This method has been found to be practical for land-cover-type mapping.[32] It incorporates digitised representative sample units through mathematical functions, enabling unbiased, landscape-scale land-cover interpretation of estimates with minimal sampling size.[33] (Information about forest type on private land is not reported under this methodology; however, some estimates are provided in the section on Forest Canopy Cover.[34]

The VFMP estimates forest extent with the help of remote-sensing technology. In 2013, the forest area estimates were derived from imagery from a five-year period (2003–07) and modelled to a baseline year of 2008. The forest-area estimates in this report were derived from a 5-year period (2008–12) and modelled to 2013.

The forest-area estimates report the land-cover types of Victoria's major vegetation types based on predominant height.[35]

The area of most forest types has increased. A notable exception is the 'forest unclassified (burnt)' type. This increased dramatically after the February 2009 'Black Saturday' fires (Table Fo.2 and Table Fo.3), but has decreased as forest areas recover (Figure Fo.5 and Figure Fo.6).

Note that methodological uncertainty may contribute to observed variation. For example, the dataset from 2018 is more comprehensive, with 15 additional Aerial Photo Interpretation (API) plots. Another potential source of error is the improved resolution of DELWP's corporate public land management spatial layer, which has improved from 100 m resolution in 2008 to 25 m resolution in 2013. Manual interpreters, with the aid of higher-resolution images, may make different decisions about forest types.

31. Deppe F 1998, 'Forest Area Estimation Using Sample Surveys and Landsat MSS and TM Data', *Photogrammetric Engineering and Remote Sensing*, 64(4), pp. 285-292.
32. Kamaruzaman JHj, Hasmadi IM 2008, 'Mapping and quantification of land area and cover types with Landsat TM in Carey Island, Selangor, Malaysia', *Modern Applied Science*, 3(1), pp. 42.
33. Ibid
34. Farmer E, Jones S, Clarke C, Buxton L, Soto-Berelov M, Page S, Mellor A, Haywood A 2013, 'Creating a large area landcover dataset for public land monitoring and reporting', In C. Arrowsmith, C. Bellman, W. Cartwright, S. Jones, & M. Shortis (Eds.), Progress in Geospatial Science Research (pp. 85–98). Publishing Solutions, Melbourne, Victoria.
35. Farmer E, Jones S, Clarke M, Soto-Berelov M, Mellor A, Haywood A 2011, 'Semi-Automated API for Large Area Public Land Monitoring and Reporting'. *Proceedings of the GSR_1 Research Symposium*, Melbourne, Australia, 12-14 December 2011, pp. 1–12.

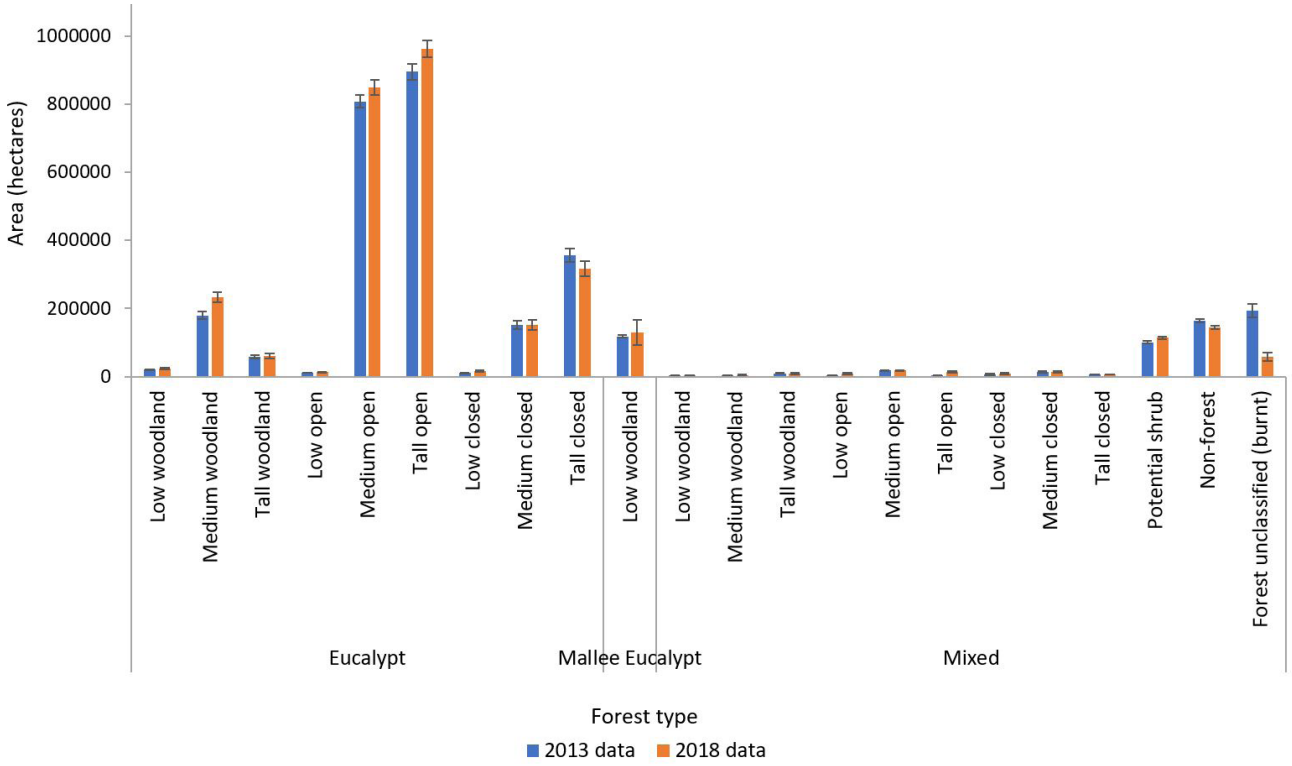


Figure Fo.5 Area of forest by broad forest type, height and canopy cover in state forest

(Data source: DELWP, 2018)

Table Fo.2 State forest area estimates

Forest type/land cover	Cover	2013		2018	
		Area (ha)	C.I. (95%)	Area (ha)	C.I. (95%)
Eucalypt	Low woodland	19,895	8.3	23,313	12.5
	Medium woodland	179,929	6.5	233,037	6.2
	Tall woodland	58,281	7.9	60,647	10.6
	Low open	11,492	6.5	12,559	6.2
	Medium open	808,105	2.4	849,327	2.7
	Tall open	895,140	2.6	962,058	2.6
	Low closed	10,301	15.2	16,805	15.7
	Medium closed	151,501	8.2	152,784	9.7
	Tall closed	356,340	5.3	317,722	7.0
Mallee Eucalypt	Low woodland	117,872	2.8	128,802	28.5
Mixed	Low woodland	3,683	4.0	3,381	6.7
	Medium woodland	4,601	5.5	4,766	6.3
	Tall woodland	9,637	17	9,531	28.3
	Low open	3,582	13.7	8,504	19.9
	Medium open	17,859	7.4	17,592	9.4
	Tall open	3,750	30.5	13,802	18.7
	Low closed	6,266	29.5	7,756	28.6
	Medium closed	14,055	16.3	14,027	20.7
	Tall closed	6,533	10.6	6,429	15.3
Potential shrub		100,658	3.8	113,566	3.6
Non-forest		163,719	2.5	143,794	3.1
Forest unclassified (burnt)		194,257	10.1	57,935	21.5

Note: C.I. = confidence interval

(Data source: DELWP, 2018)

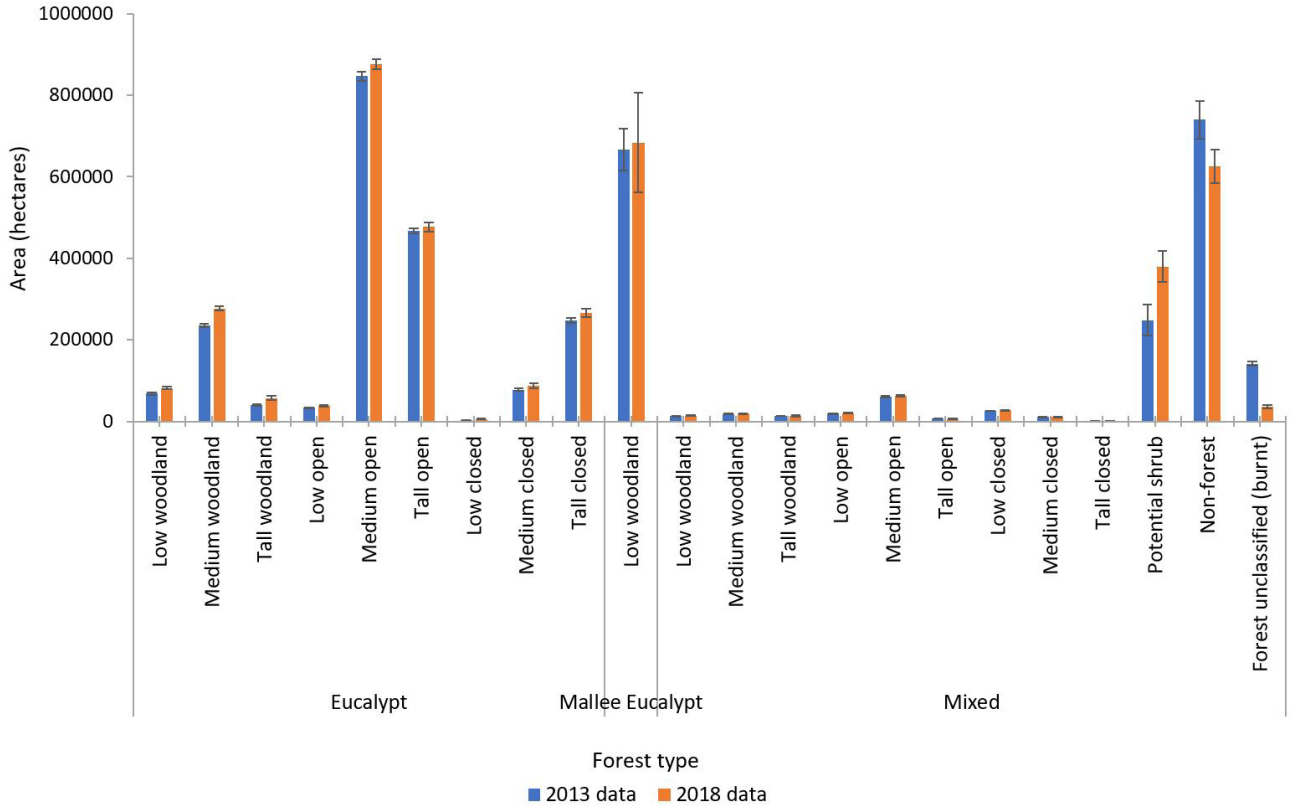


Figure Fo.6 Area of forest by broad forest type, height and canopy cover in parks and reserves

(Data source: DELWP, 2018)

Table Fo.3 Parks and reserves area estimates

Forest type/land cover	Cover	2013		2018	
		Area (ha)	C.I. (95%)	Area (ha)	C.I. (95%)
Eucalypt	Low woodland	68,001	4.8	81,773	4.1
	Medium woodland	234,369	1.7	277,013	2.0
	Tall woodland	39,830	5.4	57,193	9.4
	Low open	33,105	5.4	38,337	5.2
	Medium open	846,636	1.4	875,429	1.4
	Tall open	467,166	1.4	476,742	2.2
	Low closed	2,877	8.5	5,933	9.1
	Medium closed	77,993	3.1	87,878	6.8
	Tall closed	246,887	2.4	265,896	3.7
Mallee Eucalypt	Low woodland	665,686	7.7	683,707	17.8
Mixed	Low woodland	12,399	4.9	13,734	7.3
	Medium woodland	18,410	5.0	18,711	7.6
	Tall woodland	13,131	5.8	13,165	16.1
	Low open	19,418	5.3	20,478	5.3
	Medium open	60,099	2.7	62,466	2.6
	Tall open	6,784	8.3	6,069	23.7
	Low closed	25,599	1.9	27,210	3.4
	Medium closed	10,520	2.2	10,336	5.1
	Tall closed	241	12.8	241	39.3
Potential shrub		247,927	15.3	379,715	9.9
Non forest		739,807	6.3	625,948	6.6
Forest unclassified (burnt)		141,083	3.9	35,814	9.2

Note: C.I. = confidence interval

(Data source: DELWP, 2018)

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:01C Area of forest by type and tenure-plantation forest	○	○	●	○	→	DATA QUALITY: Good
Data custodian ABS						

Victoria's plantation forests provide export and domestic timber products, including both hardwood and softwood. Plantation forests are almost all privately owned (99%).

The most recent statistics, from 2015to 2016, show Victoria has the largest total area of plantations in Australia.[36] Victorian plantations account for approximately one-fifth of Australia's total plantation forest estate. Each year, plantation areas are harvested extensively, and some are not replanted and possibly left fallow. (Note that in this report, 'plantation' describes land use: both planted and fallow land may be referred to as 'plantation').

In 2016–17, there were 421,700 hectares of industrial hardwood and softwood plantations in Victoria (Figure Fo.7). Over the past 18 years, commercial softwood plantation areas have been stable at between 212,000 and 226,000 hectares. By contrast, commercial hardwood plantation areas doubled in the 10 years since the 1999–2000 financial year, from 101,500 to 203,000 hectares. (This increase was mainly due to managed investment schemes, popular in the early 2000s. A number of high-profile agri-business managed investment schemes collapsed, resulting in substantial losses for many investors).

Since the 2010–11 financial year, plantation areas have gradually decreased by approximately 11,200 hectares (Figure Fo.7). This is due to a decrease in the rate of new plantation establishments since 2000.

Newly established plantation areas in Victoria have decreased sharply from a peak of approximately 38,000 hectares in 1999–2000 (Figure Fo.8). No new plantation areas have been established since the 2012–13 financial year. Victoria pledged $110 million in the 2017–18 budget to assist plantation establishment in the Latrobe Valley, to support the long-term sustainability of Victoria's timber-harvesting industry.[39]

36. Australian Department of Agriculture and Water Resources ABARES, 'Australian plantation statistics 2017 update', Canberra, Australia https://data.gov.au/dataset/pb_aplnsd9abfe20170503/resource/477323a0-11dd-4276-a765-dc8e19fdeb49 Accessed 3 December 2018.

39. Victorian Department of Treasury and Finance 2017, 'Getting on with the job: Victorian Budget 17/18 overview', Melbourne, Victoria https://www.dtf.vic.gov.au/sites/default/files/2018-02/state-budget-overview-2017-18.pdf Accessed 4 December 2018.

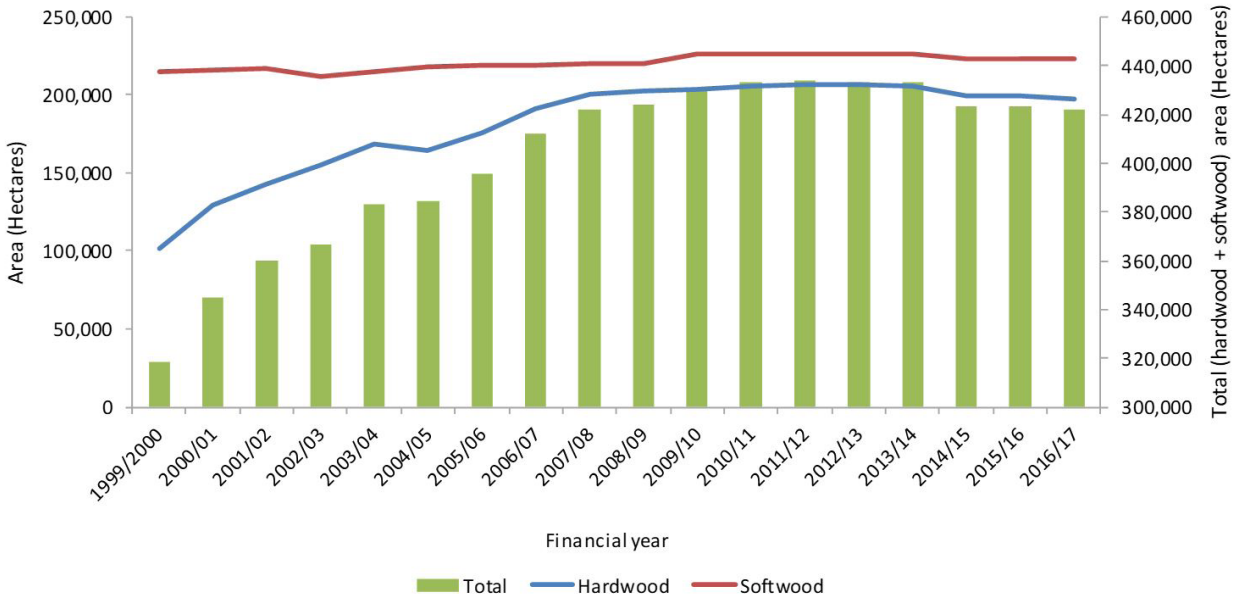


Figure Fo.7 Plantation areas in Victoria, 1999–2000 to 2016–17 [37, 38]

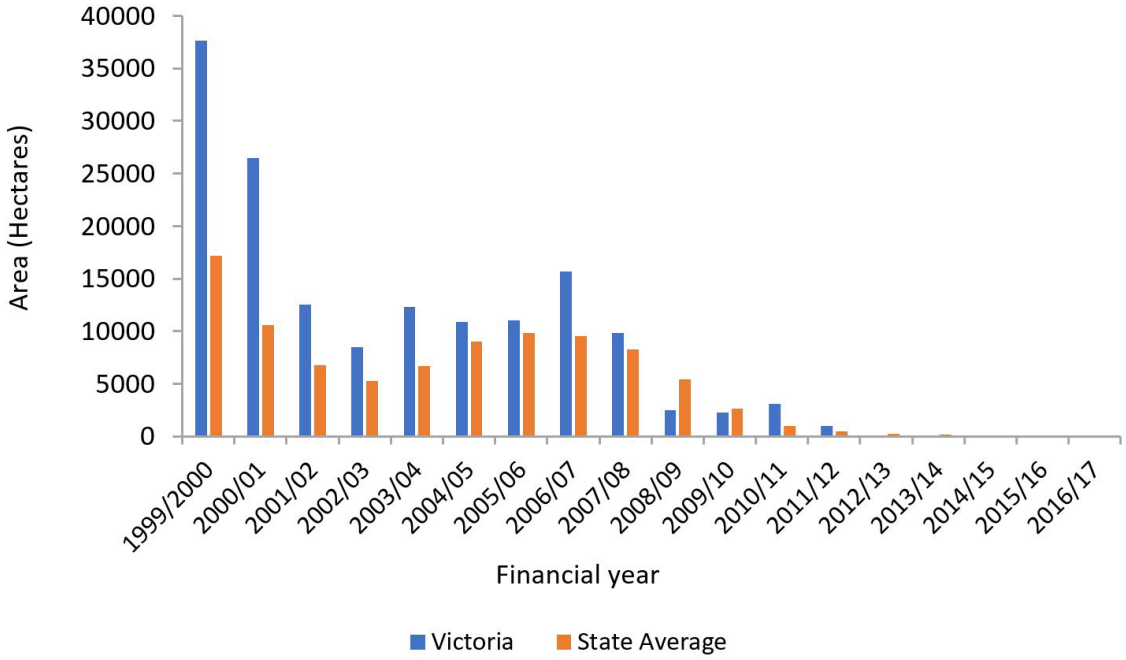


Figure Fo.8 Area of new plantation establishment in Victoria, 1999–2000 to 2016–17[40]

37. Australian Department of Agriculture and Water Resources ABARES 2018, 'Australian forest and wood products statistics: September and December quarters 2017', Canberra, Australia http://data.daff.gov.au/data/warehouse/9aaf/afwpsd9abfe/afwpsd9abfe20180524/AFWPSOverview_Sep-Dec_2017_v1.0.0.pdf Accessed 4 December 2018.

38. Australian Department of Agriculture and Water Resources ABARES 2007, 'Australian forest and wood products statistics: September and December quarters 2006', Canberra, Australia http://data.daff.gov.au/data/warehouse/pe_abare99001363/afwps06.2_sept__dec06.pdf Accessed 4 December 2018.

40. Australian Department of Agriculture and Water Resources ABARES 2018, 'Australian forest and wood products statistics: September and December quarters 2017', Canberra, Australia http://data.daff.gov.au/data/warehouse/9aaf/afwpsd9abfe/afwpsd9abfe20180524/AFWPSOverview_Sep-Dec_2017_v1.0.0.pdf Accessed 4 December 2018.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:02 Area of forest type by growth stage	○	○	●	○	↗	DATA QUALITY
Data custodian DELWP						Good

Understanding the previous and current growth stages of forests in Victoria is important for sustainable forest management. Forest dynamics, and particularly species succession, can be drastically altered by natural and human-induced disturbances, which are increasing. Knowledge of growth stages, and subsequent forest-recovery conditions, is thus critical for decision-making by land managers to mitigate any ecological losses.[41]

This indicator provides information on the area and extent of forest ecosystem types, including successional stage, age class and the nature of tenure or ownership. Reporting the growth stage by broad forest type provides an indication of the diversity and balance of growth stages across Victoria's forest estate.

In this report, forest area is classified by height, which is considered a growth-stage indicator. Height is classified according to the NFI[42] forest definition into three types, depending on stand height:

- low: 2–10 m
- medium: 11–30 m
- tall: > 30 m

The total area of all forest types, except 'non-forest' (describing a traditional forest area that currently has no trees due to disturbances including fire damage), increased between the two assessments.

Recovery of forests following the 2009 Black Saturday bushfires explains the large reduction in 'non-forest' areas compared with SoF 2013, which has a baseline year of 2008. Fire-affected areas that regrew post-2008 are likely to have been reclassified from 'non-forest' to 'forest' or 'forest potential shrub'.

Medium and tall eucalypt forests make up 63% of the native forests across Victoria's state forests, parks and conservation reserves, covering an area of 4.6 million hectares. While the total area of medium and tall forest has increased since 2013, the relative proportion of these types has declined by approximately 15% due to an increase in low eucalypt, low mixed/other forest and forest potential shrub with a decrease of non-forest area. This is predominately due to residual mallee regrowth from fires that occurred during the 2002-03 summer bushfire season. For a description of the method used to calculate areas and associated uncertainty estimates indicator Fo:01 (Area of forest by type and tenure)

41. Franklin JF, Lindenmayer DB, MacMahon JA, McKee A, Magnusson J, Perry DA, Waide R, Foster DR 2000, 'Threads of continuity: ecosystem disturbances, biological legacies and ecosystem recovery', *Conservation Biology in Practice*, 1, pp. 8-16.
42. Australian Department of Agriculture and Water Resources ABARES, 'Australia's national forest inventory', Canberra, Australia http://www.agriculture.gov.au/abares/forestsaustralia/australias-national-forest-inventory Accessed 3 December 2018.

Table Fo.4 Broad forest types by estimated area in State forest and Parks and conservation reserves

Forest type and height class	State forests				Parks and conservation reserves			
	2013		2018		2013		2018	
	Area (ha)	C.I.	Area (ha)	C.I.	Area (ha)	C.I.	Area (ha)	C.I.
Low Eucalypt	41,688	6.1	52,677	7.4	103,983	3.6	126,042	3.1
Medium Eucalypt	1,139,535	1.8	1,235,148	1.9	1,158,997	1.1	1,240,319	1.1
Tall Eucalypt	1,309,761	1.8	1,340,426	1.8	753,883	1.0	799,832	1.7
Mallee Eucalypt	117,872	2.8	128,802	28.5	665,686	7.7	683,707	17.8
Low mixed/other* forest	13,530	15.6	19,641	15.7	57,416	2.6	61,421	2.5
Medium mixed/other forest	36,514	7.6	36,385	9.5	89,029	2.7	91,513	2.6
Tall mixed/other forest	19,920	11.9	29,762	11.6	20,156	6.1	19,475	15
Forest potential shrub†	100,658	3.8	113,566	3.6	247,927	15.3	379,715	9.9
Non-forest	359,003	5.5	203,421	5.6	881,388	5.4	662,277	6.2

C.I. = Confidence Interval (95%)

†Forest potential shrub: previously forested land cover which has undergone significant disturbance (such as short-interval bushfire) or clearance (such as by clearfell logging), but which is known to be regenerating as 'forest' (according to NFI definition).

** Mixed/other forest types include casuarina, callitris, acacia, melaleuca, rainforest and mangrove. Eucalypt forests comprise the vast majority of Victoria's public forests. As a result, other forest types are underrepresented in the land cover map ecause sampling and obtaining reliable area estimates is difficult. For this analysis, these forest types are aggregated into a 'mixed and other forest types' class. Based on data presented in SoF 2008, other forest types make up less than 10% of Victoria's total native forest area.*

(Data source: DELWP, 2018)

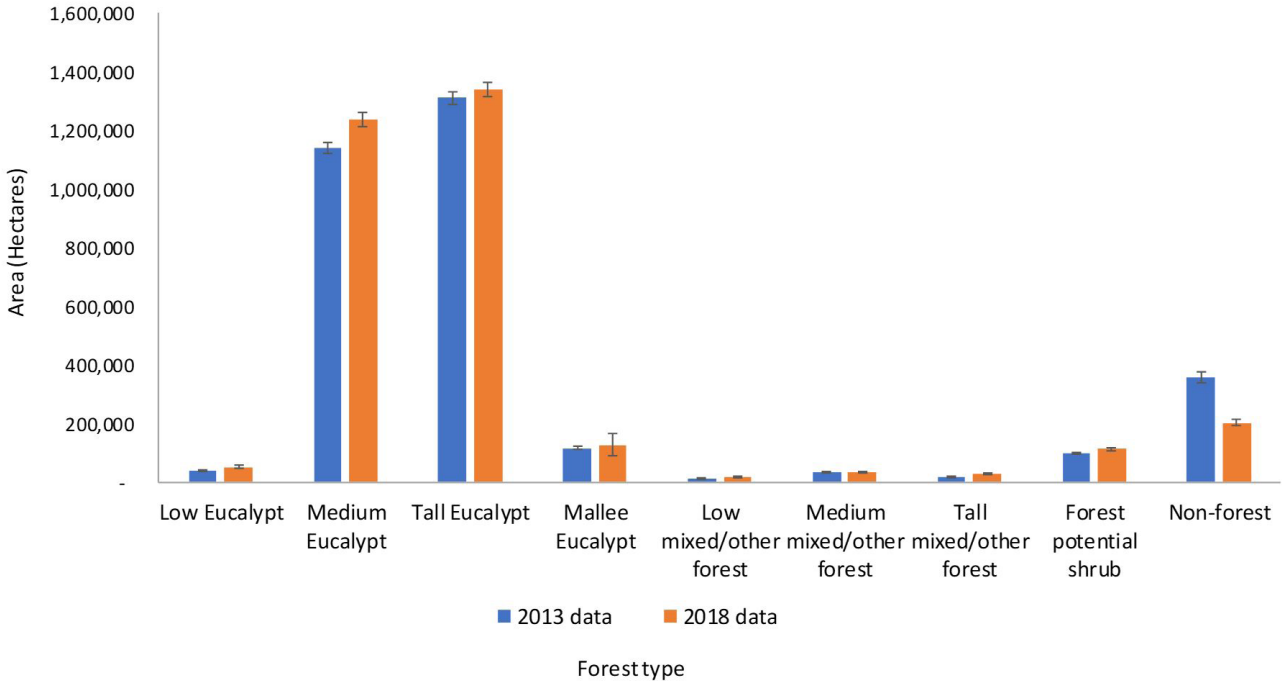


Figure Fo.9 Area of state forest by forest type, 2013 and 2018

(Data source: DELWP, 2018)

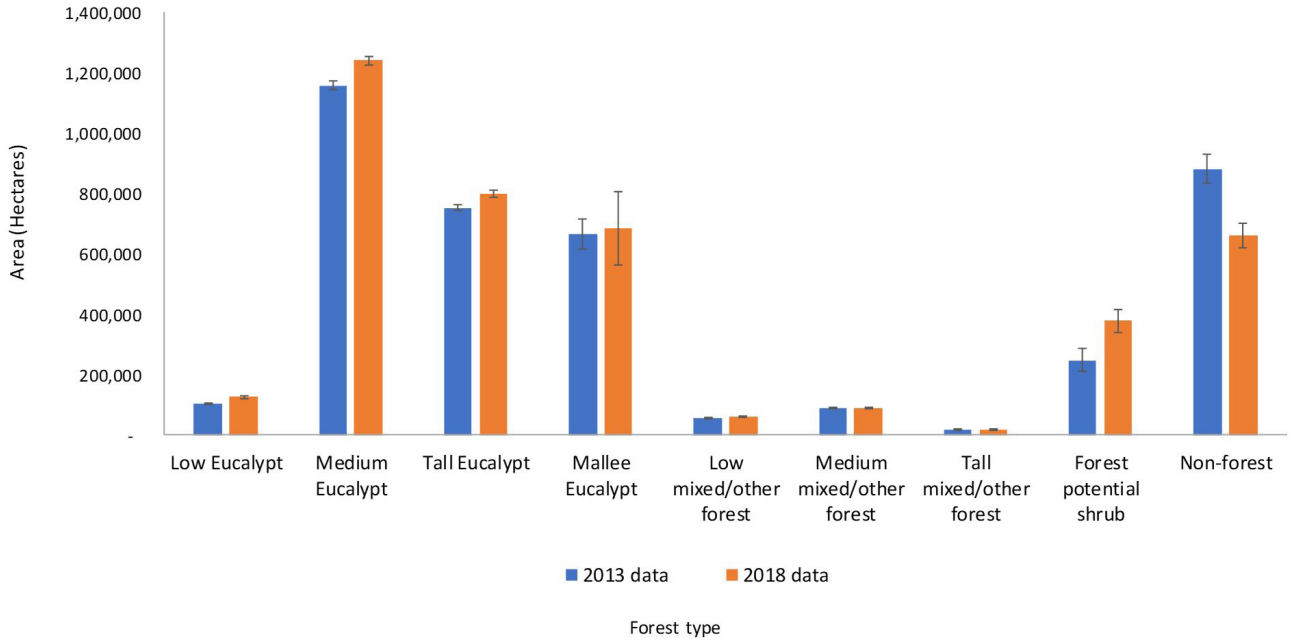


Figure Fo.10 Area of parks and reserves by forest type, 2013 and 2018

(Data source: DELWP, 2018)

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:03 Area of forest type by growth stage distribution in protected zones	○	○	●	○	↗	DATA QUALITY: Fair

Data custodian DELWP, Parks Victoria

The protection of biodiversity to sustain forest ecosystems and the species that inhabit them is fundamental to Victoria's approach to forest conservation. It is also a key objective of sustainable forest management.

The management of forests in Australia is guided by the 1992 *National Forest Policy Statement* (NFPS): a set of broad goals agreed to by Commonwealth, state and territory governments. The goals undertake to embed the concept of ecologically sustainable development. The aim is to manage Australia's native forests to conserve biological diversity, heritage, and cultural values, while at the same time developing an internationally competitive forest products industry based on native forests that are managed sustainably.

Major elements of the NFPS include a commitment to the development of a comprehensive, adequate and representative (CAR) reserve system, and implementation of strategies to protect old-growth forests and wilderness as part of the reserve system. The CAR reserve system is based on three principles:

- including the full range of vegetation communities (comprehensive)
- ensuring the level of reservation is large enough to maintain species diversity (adequate)
- conserving the diversity within each vegetation community, including genetic diversity (representative).

The system identifies the forested areas based on 'JANIS'[43] criteria to protect nature conservation reserves.[44]

The CAR reserve system contains two categories, formal and informal reserves, defined as follows:

- formal reserve: including Crown land formally reserved where environmental protection that provides legislated prohibition on timber harvesting is required – such as forest parks, national parks, state parks, nature conservation reserve and other conservation reserve
- informal reserve: including public land where public authorities are assigned to achieve conservation values while excluding timber harvesting.

The proportion of Victorian land assigned formal protection status has risen from less than 1% in the 1950s to 17% in 2016 (Figure Fo.11). Between the late 1970s and early 1990s, the addition of more than 3,000 protected areas significantly increased the total formal protected area. Much of this increase was due to changes to the *National Parks Act 1975* and *Crown Land (Reserves) Act 1978*.

Between 2000 and 2014, the total area of parks and conservation reserves increased by around 400,000 hectares. Since 2014, additional land parcels have been added as a result of improvements and clarifications to Crown land records, changes of the on-ground manager (for example, land has moved from Parks Victoria to Water Authority/VicTrack[45]) and the purchasing and reserving of land.

43. Australian Department of Agriculture and Water Resources, 'Protecting our forest environment', Canberra, Australia http://www.agriculture.gov.au/forestry/policies/rfa/about/protecting-environment Accessed 3 December 2018.
44. Australian Department of Agriculture and Water Resources, 'Conservation of Australia's forests', Canberra, Australia http://www.agriculture.gov.au/forestry/australias-forests/forest-mgnt/conservation Accessed 3 December 2018.
45. VicTrack is a state-owned enterprise which owns all railway and tram lines.

Details of significant additions to reserves are described in Table Fo.5. (Note that the addition of land to Great Otway National Park was not captured in the 'land assigned formal protection status' prior to its surrender to the Crown. The assignment of 6,367 hectares in 2017 was not included in the Parks Victoria (PV) managed estate reported in annual reports and budget papers tabled in Victorian Parliament.)

There was a net addition of approximately 5,800 hectares to the area that PV manages between July 2014 and July 2017.

Table Fo.5 Significant additions to formal protection area, July 2014 to July 2017

Significant additions	Area (ha)
Belfast Coastal Reserve – addition of tidal areas	34
Red Gum Swamp, Jallumba Wildlife Reserve – previously freehold	73
Great Otway NP – addition of Anglesea Heath (ALCOA lease)	6,367
Truganina South Nature Conservation Reserve – previously freehold	38
Western Grassland Nature Conservation Reserve – purchased freehold	1,200
Mount Ridley Nature Conservation Reserve – previously freehold	44
Plenty Gorge Parklands Park (addition) – purchased freehold	42
Woowookarung Regional Park – previously Reserved Forest (previously known as Canadian Regional Park)	640

(Data source: Parks Victoria, 2018)

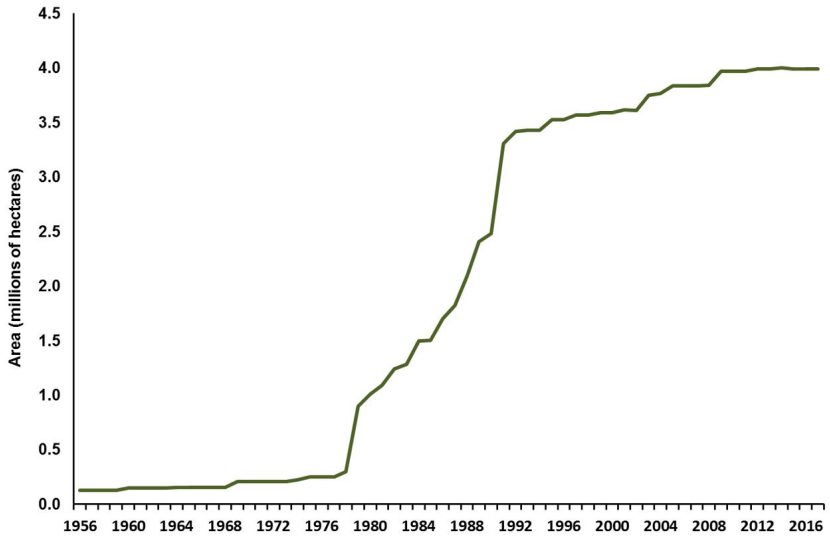


Figure Fo.11 Change in Victoria's formal protected area (parks and conservation reserves), 1956–2016

(Data source: Parks Victoria, 2018)

IUCN protected areas

The International Union for Conservation of Nature (IUCN) is the global authority on the status of the natural world. IUCN defines a protected area as 'a clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values'[46].

Australia compares favourably against other countries with respect to forest conservation.[47]

Under *Australia's Strategy for the National Reserves System 2009–2030*, all state and territory governments have agreed to adopt IUCN international standards for defining and reporting areas of protected area management.

All Victorian formal reserves are assigned an IUCN protected area category based on protection status and primary land management. Victorian terrestrial IUCN protected areas is described in Figure Fo.12. The IUCN assigned area categories may be refined occasionally. Informal reserves are not assigned an IUCN protected area category.

There was an increase of about 13% in IUCN protected areas overall between 2004 and 2016 (Table Fo.6), indicating better protection of Victoria's forests.

Type V (protected landscape/seascape) and Type VI (protected area with sustainable use of natural resources) areas increased most, by more than 200% each. Type Ia (strict nature reserve) and Type III (natural monument or feature) areas increased gradually. (Type Ia area is protected for biodiversity and strictly controlled to avoid any intervention. Type III area is to protect a specific natural monument such as a cave.)

Significant changes have been made to the network of protected areas, including the expansion of Great Otway National Park, additions to conservation parks and reserves (Table Fo.6), and more accurate GIS mapping, and clarifications and changes from on-ground managers.

46. The International Union for Conservation of Nature, 'Australia', Suva, Fiji https://www.iucn.org/theme/protected-areas/about Accessed 11 January 2019.
47. The International Union for Conservation of Nature, 'Australia', Suva, Fiji https://www.iucn.org/regions/oceania/get-involved/members/australia Accessed 4 December 2018.

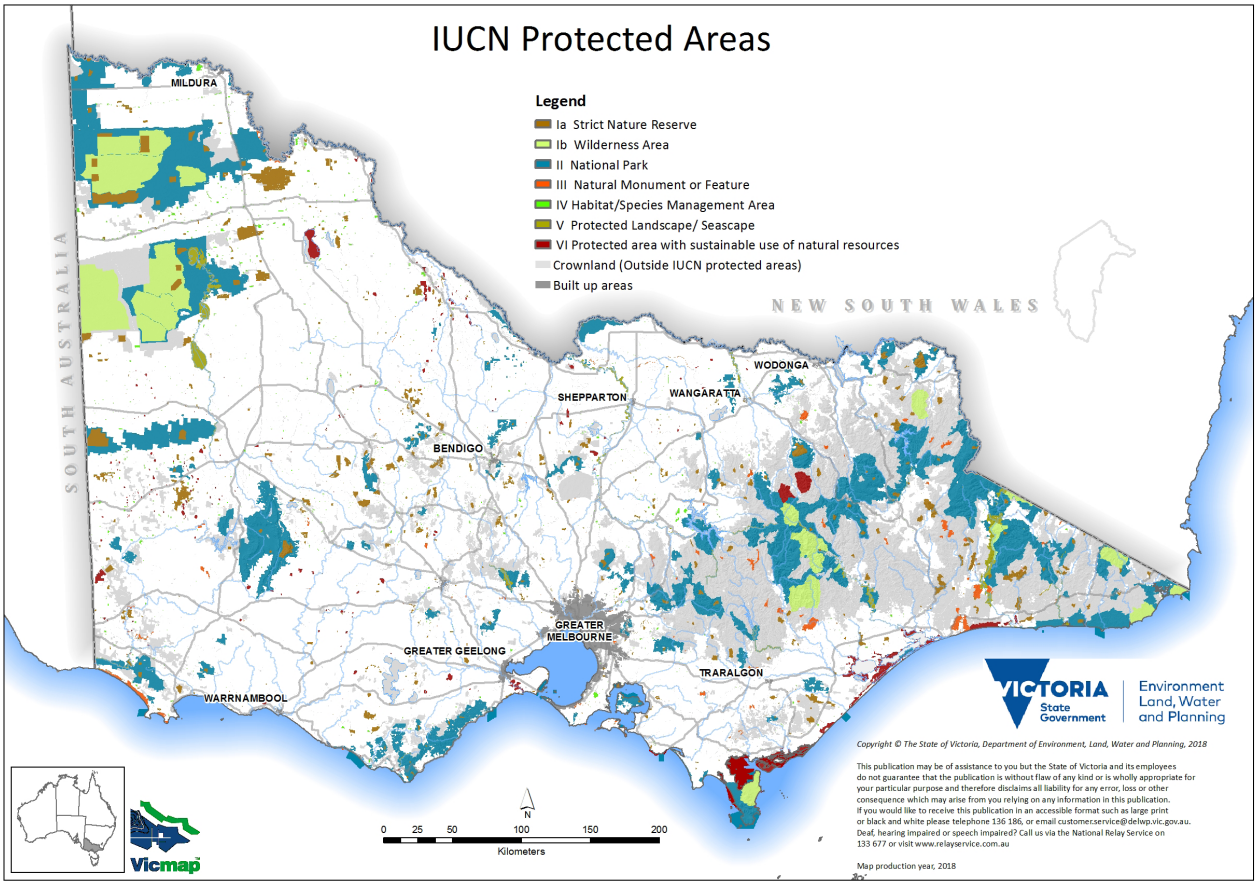


Figure Fo.12 Victorian terrestrial IUCN protected areas, 2018

(Data source: DELWP, 2018)

Table Fo.6 Victorian protected areas by IUCN category and informal Special Protection Zone reserves, 2004–2016

Formal protection IUCN Category	Area (hectares)							Proportion of forest cover (%) (a)
	2004	2006	2008	2010	2012	2014	2016	
Ia	356,300	366,200	381,900	380,700	388,600	421,600	421,500	83.37
Ib	815,500	815,300	815,700	815,700	815,500	740,900	740,900	78.50
II	2,128,600	2,182,400	2,224,200	2,309,700	2,371,300	2,374,400	2,373,700	83.89
III	55,000	48,900	49,500	51,300	78,000	75,500	75,600	73.68
IV	48,000	44,900	43,800	43,700	47,400	47,500	47,500	54.74
V	58,500	57,800	56,600	49,200	26,800	135,200	135,200	58.58
VI	91,100	89,200	94,500	85,100	130,600	208,300	206,200	23.13
All IUCN Protected Area	3,553,000	3,604,700	3,666,200	3,735,400	3,858,200	4,003,400	4,000,600	
Informal protection area								
Special protection zone (SPZ)	828,100	828,100	783,100	783,100	753,100	747,300	761,100	97.19
Total	**4,381,100**	**4,432,800**	**4,449,300**	**4,518,500**	**4,611,300**	**4,750,700**	**4,761,700**	**81.44**

(a) Proportion of forest cover refers to the proportion of this reserve class under forest

(Data source: DELWP, 2018)

Currently, there is little evidence on how well these classifications protect species. Detailed research is necessary to identify the benefits of different IUCN protected areas for target species, such as those on the IUCN Red List of Threatened Species.

A viability analysis has been completed for the ash-type forests of the Central Highlands of Victoria for the threatened species Leadbeater's possum (*Gymnobelideus leadbeateri*). Leadbeater's possum is listed on the IUCN Red List, and listed as threatened in the *FFG Act 1988*. The viability analysis indicates that the entire mountain ash resource needs to be protected from timber harvesting to achieve sustainable populations of Leadbeater's possum, and other species of possums, gliders and large forest owls in the medium term.[48,49]

To reflect this, DELWP established a 200-metre-radius timber-harvesting exclusion zone (THEZ) to gauge the impact of exclusion zones on the conservation of Leadbeater's possum.[50] Two years of intensive surveying found that the addition of 4,046 hectares (through an increase of the special protection zone in the Central Highlands from 30,520 to 34,566 hectares) resulted in the protection of 436 additional Leadbeater's possum colonies.[51] Nonetheless, the population in the protected area will be at a high risk of extinction if a single bushfire event is factored into the analysis.[52]

48. Todd CR, Lindenmayer DB, Stamation K, Acevedo-Catteneo S, Smih S, Lumsden LF 2016, 'Assessing reserve effectiveness: application to a threatened species in a dynamic fire prone forest landscape', *Ecological Modelling*, 338, pp. 90-100.
49. Taylor C, Cadenhead N, Lindenmayer DB, Wintle BA 2017, 'Improving the design of a conservation reserve for a critically endangered species', ***PLOS One***, 12, e0169629.
50. DELWP 2017 'A review of the effectiveness and impact of establishing timber harvesting exclusion zones around Leadbeater's Possum colonies', Melbourne, Victoria https://www.wildlife.vic.gov.au/__data/assets/pdf_file/0033/73869/eadbeaters-Possum-Review-Report-July-2017.pdf Accessed 4 December 2018.
51. Nelson JL, Durkin LK, Cripps JK, Scroggie MP, Bryant DB, Macak PV, Lumsden LF 2017, 'Targeted surveys to improve Leadbeater's Possum conservation', Arthur Rylah Institute for Environmental Research Technical Report Series No. 278. Department of Environment, Land, Water and Planning, Heidelberg, Victoria https://www.wildlife.vic.gov.au/__data/assets/pdf_file/0032/27896/Targeted-survey-report-2015_final-7Oct15r.pdf Accessed 4 December 2018.
52. Woinarski J 2017, 'Independent review report: assessment of the conservation benefit provided to Leadbeater's Possum by the establishment of timber harvesting exclusion zones'. Charles Darwin University, Darwin, Northern Territory https://www.wildlife.vic.gov.au/__data/assets/pdf_file/0025/73870/Independent-Review-of-LBP-Review-Report-Conservation-Benefits-Analysis.pdf Accessed 4 December 2018.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:04 Fragmentation of native forest cover	○	●	○	○	?	DATA QUALITY: Fair
Data custodian DELWP						

Forest fragmentation is a metric to describe forest quality. It assumes that the highest-quality forests are at the centre, and that the larger the area, the more resilient the forest is to disturbances.[53,54,55] Forest loss and the deterioration of forest health via increasing fragmentation pose significant threats to biodiversity, and endanger the sustainability of ecological goods and services from forested land.[56,57,58,59]

This indicator measures the loss of forest cover and the spatial configuration of that loss to show the level of fragmentation in Victoria's forests and the likely impacts on forest-dependent species.

Analysis of the satellite Landsat data captured in 2013 (Table Fo.7 and Table Fo.8) shows that on a state scale:

- On average, approximately 75% of Victoria's forest cover in each bioregion is classed as 'interior' (for example, core non-fragmented forest) and about 13% as 'edge area', with boundaries between interior forest and non-forest landcover (Table Fo.8). 25% of Victoria's total land area is interior forest, and about 4% is edge area (Table Fo.7).
- Bioregions with the highest proportion of interior forest are concentrated in Victoria's east. Main areas include the Australian Alps (91% interior forest), South East Corner (89% interior forest) and South Eastern Highlands (85% interior forest). Riverina is the most fragmented bioregion, and also has the highest proportion of forest patches (20%).
- Except for the Riverina bioregion, the most fragmented areas are on private land within each bioregion (Figure Fo.14). On average, about 85% of state forest (SF) and parks and reserves (PR) have interior areas. But on private land, the proportion of interior forest drops to one-third. Proportionally, the sum of 'edge', 'transitional' (deteriorating forest fragmentation from interior type to patch or edge) and patch (small and isolated remnant vegetation) areas in private land was six times greater than in SF and PR.
- In the South East Coastal Plain (SECP), PR appears more fragmented than SF; however, there is significantly more area of PR than SF. Moreover, a large area of SECP was transferred to PR when native-forest timber harvesting ceased in the Otway Ranges in the early 2000s.

A map of statewide forest fragmentation is provided in Figure Fo.13. Due to differences in mapping methodology and improvements in satellite imaging resolution, it is not possible to compare this data with that of previous years. This makes it difficult to assess overall trends in forest fragmentation in different bioregions and for different forest types.

53. Forman RTT, Godron M 1986, 'Landscape ecology', John Wiley, New York, USA.
54. Turner MG 1989, 'Landscape ecology: the effect of pattern on process', *Annual Review of Ecology and Systematics,* 20, pp. 171-197.
55. Levin SA 1992, 'The problem of pattern and scale in ecology'. *Ecology,* 73, pp. 1943-1967.
56. Harris LD 1984, 'The fragmented forest. Island biogeography theory and the preservation of biotic diversity', University of Chicago Press, Chicago, Illinois, USA.
57. Lovejoy TE, Bierregaard RO, Rylands AB, Malcolm JR, Quintela CE, Harper LH, Brown KS, Powell AH, Powell GVN, Schubart HOR, Hays MB 1986, 'Edge and other effects of isolation on Amazon forest fragments', In Soulé ME, editor. Conservation biology: the science of scarcity and diversity, Sinauer Associates, Sunderland, Massachusetts, USA.
58. Bierregaard RO, Lovejoy TE, Kapos V, dos Santos AA, Hutchings RW 1992, 'The biological dynamics of tropical rainforest fragments', ***BioScience***, 42, pp. 859-866.
59. Laurance WF, Laurance SG, Ferreira LV, Rankin-de Merona JM, Gascon C, Lovejoy TE 1997, 'Biomass collapse in Amazonian forest fragments', ***Science***, 278, pp. 1117-1118.

Fragmentation category	2018 (ha)	% of total state area
Non-forest	15,053,953	66.24
Patch	223,483	0.98
Transitional	273,889	1.21
Edge	979,423	4.31
Perforated	436,091	1.92
Interior	5,772,863	25.40
Undetermined	1,455	0.01
Total	**22,741,158**	**100**

Table Fo.7 Victorian forest fragmentation, 2018

(Data source: DELWP, 2018)

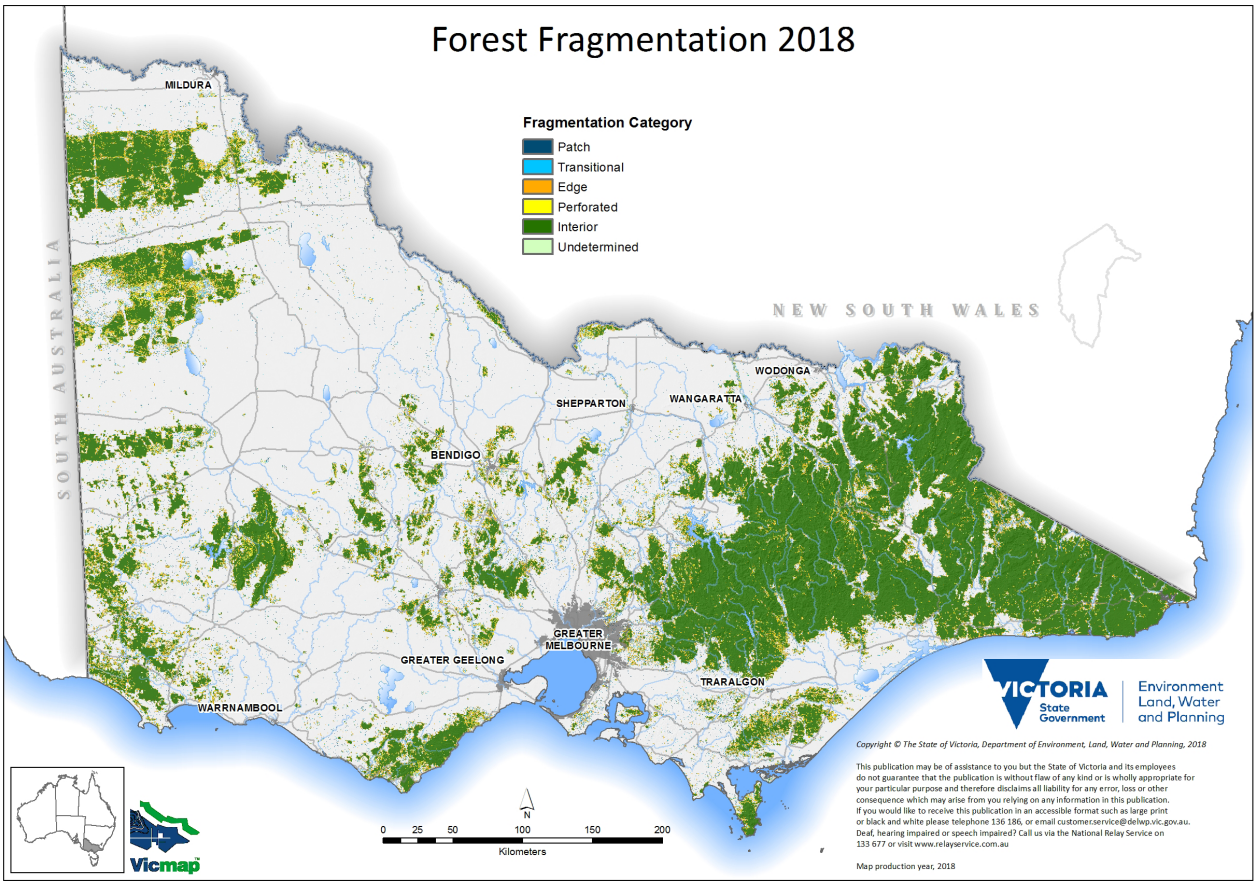


Figure Fo.13 Forest fragmentation in Victoria, 2018

(Data source: DELWP, 2018)

Table Fo.8 Proportion of forest fragmentation category by bioregion, 2018

Bioregion	Forest Cover Fragmentation category (% of bioregion total area)				
	Patch	Transitional	Edge	Perforated	Interior
Australian Alps	<1	1	5	4	91
Flinders	1	4	15	6	74
Murray–Darling Depression	4	5	16	10	64
Naracoorte Coastal Plain	2	4	19	9	67
NSW South Western Slopes	5	7	22	7	59
Riverina	20	16	28	13	22
South East Coastal Plain	8	9	26	9	48
South East Corner	1	1	6	3	89
South Eastern Highlands	1	2	8	3	85
Victorian Midlands	5	7	22	8	59
Victorian Volcanic Plain	11	9	24	7	49
Victoria (statewide)	**3**	**4**	**13**	**6**	**75**

(Data source: DELWP, 2018)



Figure Fo.14 Relative proportion of forest fragmentation categories by region and land type, based on % of total cover, 2018

(Data source: DELWP, 2018)

Long-term monitoring and detailed spatial research have been conducted at a regional scale to investigate the effects of fragmentation on native forests and biodiversity.

One example is the research conducted on mountain ash forests. These are fragmented by roads and logging coupes,[60] which work as barriers to the movement of animals such as Leadbeater's possum.[61,62] It has also been found that these barriers promote the rate of collapse of large old trees, which are key habitat for cavity-dependent fauna.[63,64] This disturbance is intensifying with the addition of more logging coupes under the Timber Release Plan.[65,66,67]

To compensate for this, DELWP Arthur Rylah Institute (ARI) surveyed 176 sites between September 2015 and April 2016 for presence of Leadbeater's possum in the Central Highlands.[68] Fifty-four of those sites were in areas designated for timber harvesting under the 2013–2016 Timber Release Plan; Leadbeater's possum was detected in 38 of the 54. THEZs were subsequently established in these areas to protect the species.

Intensification of forest fragmentation has been observed in other parts of Victoria, such as in the box-ironbark forests in Central Victoria, where greater abundance and widespread distribution of generalist egg predators of many bird species where observed, including the Regent honeyeater (*Anthochaera phrygia*).[69] State-scale assessments of threatened species need to be conducted, and intense management should be taken in areas where mitigation actions are required.

60. Lindenmayer DB, Blair D, McBurney L, Banks S 2015, *Mountain Ash: Fire, logging and the future of Victoria's giant forests to 'Mountain Ash: Fire, logging and the future of Victoria's giant forests'*, CSIRO Publishing, Melbourne, Victoria.
61. Blair D, McBurney L, Lindenmayer DB, Banks S, Blanchard W 2017, ***The Leadbeater's Possum review***, The Australian National University, Canberra.
62. Blair D, McBurney L, Lindenmayer DB 2018, 'Failing to conserve Leadbeater's Possum and its Mountain Ash forest habitat', *Australian Zoologist*, 39(3), pp. 442-448. Doi:https://doi.org/10.7882/AZ.2018.008.
63. Lindenmayer DB, Blanchard W, Blair D, McBurney L 2018, 'The road to oblivion – quantifying pathways in the decline of large old trees', *Forest Ecology and Management*, 430, pp. 259-264.
64. Lindenmayer DB, Blanchard W, Blair D, McBurney L, Stein J, Banks SC 2018, 'Empirical relationships between tree fall and landscape-level amounts of logging and fire', *PLOS One*, 13(2), e0193132.
65. VicForests, 'Timber release plan', Melbourne, Victoria http://www.vicforests.com.au/planning-1/timber-release-plan-1/timber-release-plan Accessed 4 December 2018.
66. Lindenmayer DB, Blanchard W, Blair D, McBurney L 2018, 'The road to oblivion – quantifying pathways in the decline of large old trees', *Forest Ecology and Management*, 430, pp. 259-264.
67. Lindenmayer DB, Blanchard W, Blair D, McBurney L, Stein J, Banks SC 2018, 'Empirical relationships between tree fall and landscape-level amounts of logging and fire', ***PLOS One***, 13(2), e0193132.
68. Nelson JL, Durkin LK, Cripps JK, Scroggie MP, Bryant DB, Macak PV, Lumsden LF 2017, 'Targeted surveys to improve Leadbeater's Possum conservation'. Arthur Rylah Institute for Environmental Research Technical Report Series No. 278. Department of Environment, Land, Water and Planning, Heidelberg, Victoria https://www.wildlife.vic.gov.au/__data/assets/pdf_file/0032/27896/Targeted-survey-report-2015_final-7Oct15r.pdf Accessed 4 December 2018.
69. Meney B, Cunningham S, Weston MA, Whisson DA 2018, 'Woodland birds and rural towns: artificial clutch survival in fragmented Box-Ironbark forests', *The Royal Society of Victoria*, 130, pp. 7-17.

Genetic Diversity

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:05 Number of in situ and ex situ conservation efforts for forest dependent species	●	○	○	○	?	DATA QUALITY Poor

Data custodian DELWP

Several conservation measures are being applied for sustainable forest management of locally and regionally adapted native species. These measures require a combination of in-situ and ex-situ approaches. In-situ conservation is conducted by declaring, as protected, areas such as parks, genetic and ecological conservation areas, and reserved stands. Ex-situ conservation measures include seed banks, long-term captive breeding, animal translocation and gene banks for the preservation of components of biological diversity outside of natural habitats.

Previous SoF reports used the Actions for Biodiversity Conservation (ABC) system to describe the extent of conservation efforts for native species.[70] However, the system was decommissioned in 2013, making comparisons with past data difficult. The data provided here has been collated by DELWP's regional implementation teams.

Table Fo.09 shows the level of management activity for each forest-dependent threatened species for eight action categories, as provided by DELWP's regional implementation teams. The categories are:

- community engagement
- policy and planning
- survey and monitoring
- habitat protection and restoration
- pest and weed control
- population manipulation
- captive management
- research.

The two levels of management activity provide a qualitative measure of conservation efforts in Victoria; however, it is difficult to evaluate whether the current approach has a strong impact on achieving positive species conservation status. The management activities need to be linked with state-scale monitoring programs to evaluate the effectiveness of in-situ and ex-situ conservation efforts.

70. DELWP, 'Actions for biodiversity conservation', Melbourne, Victoria https://www.environment.vic.gov.au/conserving-threatened-species/actions-for-biodiversity-conservation Accessed 11 January 2019.

Table Fo.09 Management activity for each forest-dependent threatened species, 2013–2017

Common name	Community engagement	Policy and planning	Survey and monitoring	Habitat protection and restoration	Pest and weed control	Population manipulation	Captive management	Research
Mammals								
Broad-toothed rat								
Brush-tailed phascogale								
Brush-tailed rock wallaby								
Eastern horseshoe bat								
Greater glider								
Grey-headed flying-fox								
Leadbeater's possum								
Long-footed potoroo								
Long-nosed potoroo								
Smoky mouse								
Spot-tailed quoll								
Squirrel glider								
Swamp antechinus								
White-footed dunnart								
Yellow-bellied glider								
Yellow-bellied sheathtail bat								
Birds								
Barking owl								
Brown treecreeper								
Chestnut-rumped heathwren								
Glossy black-cockatoo								
Grey goshawk								
Helmeted honeyeater								
Hooded robin								
Masked owl								
Powerful owl								
Regent honeyeater								
Sooty owl								
Speckled warbler								
Spotted quail-thrush								

Note: Yellow cells denote minor activity – routine or ad hoc. Green cells denote substantial activity – targeted or sustained. Blank cells denote no activity.

Common name	Community engagement	Policy and planning	Survey and monitoring	Habitat protection and restoration	Pest and weed control	Population manipulation	Captive management	Research
Birds								
Square-tailed kite								
Swift parrot								
Turquoise parrot								
White-bellied sea-eagle								
Reptiles								
Alpine bog skink								
Eastern she-oak skink								
Lace monitor								
Rosenberg's goanna								
Swamp skink								
Amphibians								
Baw baw frog								
Booroolong tree frog								
Brown toadlet								
Giant burrowing frog								
Green and golden bell frog								
Large brown tree frog								
Martin's toadlet								
Southern toadlet								
Spotted tree frog								
Fish								
Australian grayling								
Barred galaxias								
Cox's gudgeon								
Dwarf galaxias								
Empire gudgeon								
Flat-headed galaxias								
Macquarie perch								
Murray cod								
Trout cod								
Invertebrates								
Orbost spiny cray								

Common name	Community engagement	Policy and planning	Survey and monitoring	Habitat protection and restoration	Pest and weed control	Population manipulation	Captive management	Research
Plants								
Baw baw berry								
Blackfellow's hemp								
Brown guinea-flower								
Colquhoun grevillea								
Eastern pomaderris								
Elegant daisy								
Forest geebung								
Forest phebalium								
Forest sedge								
Gippsland stringybark								
Gully grevillea								
Leafless pink-bells								
Outcrop guinea-flower								
Oval fork-fern								
Oval-leaf grevillea								
Sandfly zieria								
Serpent heath								
Slender fork-fern								
Small fork-fern								
Smooth geebung								
Tall astelia								
Tasmanian wax-flower								
Toothed leionema								
Tree geebung								
Upright pomaderris								
Veined pomaderris								
Velvety geebung								

(Data source: DELWP, 2018)

Note: Yellow cells denote minor activity – routine or ad hoc. Green cells denote substantial activity – targeted or sustained. Blank cells denote no activity.

Species Diversity

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:06 The status of forest dependent species at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment	○	○	●	○	↘	DATA QUALITY Good

Data custodian DELWP

Identifying the conservation status of forest-dependent species at risk is an important initial step to developing action plans for successful protection. Current conditions of rare and threatened species are useful indicators for recognising species particularly at risk and the state of the forest communities. Changes in conservation status can be used to assess the effectiveness of biodiversity management and species recovery programs.

This indicator is reported based on information from DELWP's Threatened Species Advisory List, and the threatened species and communities listed under the FFG Act.

In 2018, Victoria signed the Intergovernmental Memorandum of Understanding Agreement on a Common Assessment Method for Listing of Threatened Species and Threatened Ecological Communities (CAM MoU).[71] The CAM MoU requires signatories to adopt the IUCN Red List categories and criteria through legislative reform to establish a single operational list of threatened species in each jurisdiction and to collaborate in the assessment and periodic review of the conservation status of native species in Australia.

The IUCN Red List of Threatened Species provides taxonomic, conservation status and distribution information on plants, fungi and animals that have been globally evaluated using the IUCN Red List categories and criteria.[72] The system is designed to determine the relative risk of extinction, with the main purpose of cataloguing and highlighting those plants, fungi and animals that are facing higher risk of global extinction. Following assessment, plants, fungi and animals are listed as either: critically endangered, endangered, vulnerable, near threatened, least concern, data deficient, not evaluated, extinct or extinct in the wild.[73]

DELWP is currently working on a project to reassess all listed Victorian rare and/or threatened species, according to the IUCN Red List categories and criteria, including species listed in the FFG Act Threatened List and the DELWP advisory list. In addition to yielding a single, comprehensive list of Victorian threatened species, this work will also provide the baseline for key targets in *Biodiversity 2037*. This new list will not be comparable to the current DELWP Advisory List, but will instead create a new baseline for trend reporting. An update on this new, comprehensive Victorian threatened species list will be made available in 2019.

At the time of writing, DELWP was also leading a review process for the FFG Act. This review process included public consultation to inform the development of reforms to the FFG Act. The Flora and Fauna Guarantee Amendment Bill was introduced into Victorian Parliament on 23 May 2018. The Bill was debated in the Legislative Assembly and passed without amendment. It was subsequently introduced into the Legislative Council, but was not debated before the final scheduled parliamentary sitting day of the 58th Parliament of Victoria.

71. Australian Department of the Environment and Energy 2015, 'Intergovernmental Memorandum of Understanding. Agreement on a common assessment method for listing of threatened species and threatened ecological communities', Canberra, Australia https://www.environment.gov.au/system/files/resources/36ece4ab-82dc-4de9-aac6-9cc54bd7a820/files/mou-cam.docx Accessed 4 December 2018.
72. International Union for Conservation of Nature 2000, 'IUCN Red List categories and criteria', Gland, Switzerland https://portals.iucn.org/library/sites/library/files/documents/RL-2001-001-2nd.pdf Accessed 4 December 2018.
73. International Union for Conservation of Nature Standards and Petitions Subcommittee 2014, 'Guidelines for using the IUCN Red List categories and criteria. Version 11', Gland, Switzerland https://cmsdata.iucn.org/downloads/redlistguidelines.pdf Accessed 4 December 2018.

Since 2013, the only species group to be updated is vascular plants, in 2014 (Table Fo.10).[74] (However, assessing changes in plant species on DELWP advisory list can be difficult. Frequent changes in botanical nomenclature means that apparently new plants may simply have been renamed.) The status of the 461 species listed in 2013 has not changed. Vascular plants represent by far the greatest proportion of these species (Figure Fo.15). This might be due to greater knowledge and awareness of vascular plants within the scientific community, and their relative ease of detection.

Since 2007–08, no changes have been observed in the number of rare or threatened amphibians. Conservation status of mammals is a concern, with approximately 40% of the species on the list close to extinct or already extinct in the wild. This suggests a deteriorating trend in some forest species groups at risk, though fair strategies are in place to monitor the current status.

Deterioration in the overall status of species has been observed in the Central Highlands. Between 1990 and 2015, the numbers of species listed under the IUCN Red List categories in the Central Highlands increased from 16 to 44. The increasing number of listed species in threatened species categories is also described in other studies.[75,76]

As recommended in Fo:03 Area of forest type by growth stage distribution in protected zones, results from viability analyses for key threatened forest-dependent taxa are important to adjust current management strategies to mitigate the risks of not being able to maintain viable breeding populations.

74. Victorian Department of Environment and Primary Industries 2014, 'Advisory list of rare or threatened plants in Victoria'. Melbourne, Victoria https://www.environment.vic.gov.au/__data/assets/pdf_file/0021/50448/Advisory-List-of-Rare-or-Threatened-Plants-in-Victoria-2014.pdf.
75. Keith H, Vardon M, Stein JA, Stein JL, Lindenmayer DB 2017, 'Ecosystem accounts define explicit and spatial trade-offs for managing natural resources', *Nature Ecology and Evolution*, 1, pp. 1683-1692.
76. Keith H, Vardon M, Stein JA, Stein JL, Lindenmayer DB 2017, 'Experimental ecosystem accounts for the Central Highlands of Victoria. Summary Report', The Australian National University and the Threatened Species Recovery Hub, Canberra, Australia.

Table Fo.10 Number of species by conservation status, 2018

Species group	Extinct in the wild	Extinct	Regionally extinct	Critically endangered	Endangered	Vulnerable	Near threatened	Data deficient	Total
Amphibians				7	3	2		3	15
Birds				4	15	17	15		51
Fish				2		3	1		6
Invertebrates				5	7	12	1	9	34
Mammals	1	8	9	2	7	6	14	2	49
Reptiles				5	7	8	7		27
Vascular plants					4	10			14
Other flora					92	165	6	1	264
Total	**1**	**8**	**9**	**25**	**135**	**223**	**44**	**15**	**460**

(Data source: DELWP, 2018)

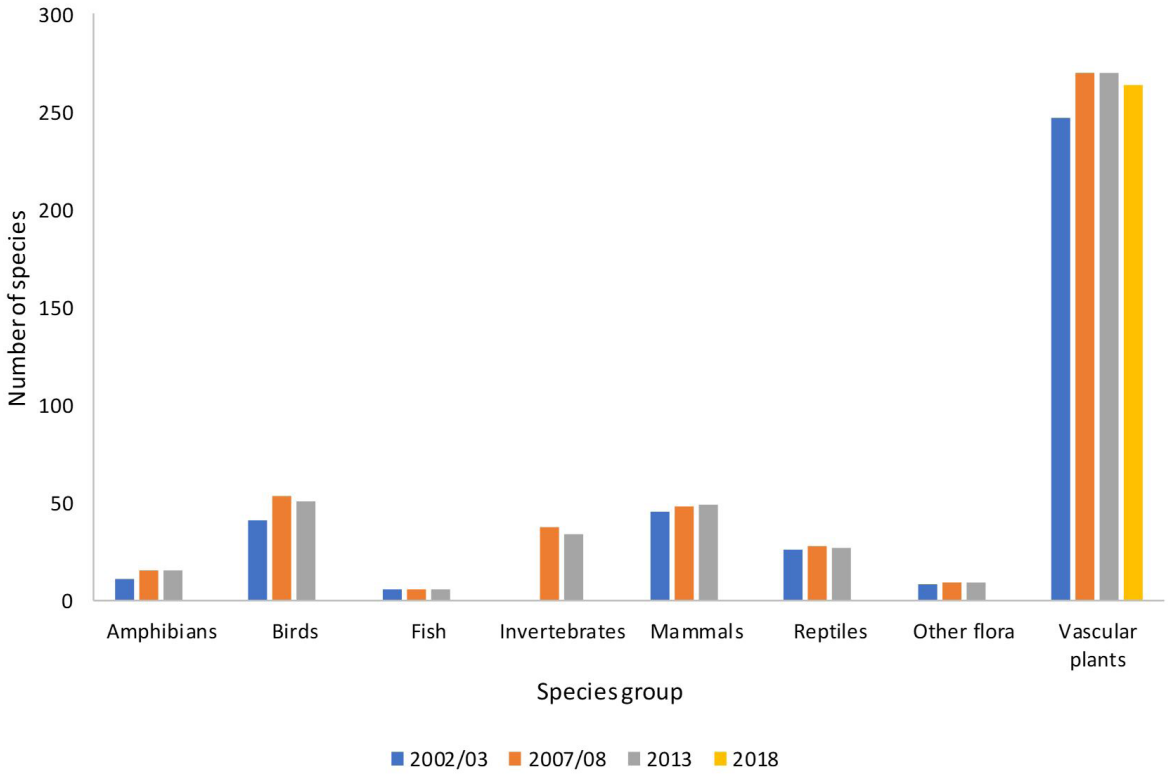


Figure Fo.15 Change in numbers of rare or threatened species on the advisory list, by reporting period

(Data source: DELWP, 2018)

The Victorian Environmental Assessment Council (VEAC) is responsible for conducting investigations that are requested by the Victorian Government relating to the protection and ecologically sustainable management of the environment and natural resources of public land.

VEAC's 2017 'Conservation values of state forests: assessment report' focuses on the state forests in the Central Highlands, North East, Gippsland and East Gippsland regions, where most commercial native-timber harvesting is in place, to identify forest-dependent species.[77] An identification process was conducted by a group of expert biologists convened by DELWP. Of 79 forest-dependent species identified, 35 were selected that could be adversely affected by native-timber harvesting. Of the 79 species, 28 are listed as critically endangered, endangered, or vulnerable in the *Environment Protection and Biodiversity Conservation Act 1999* 54 are listed as a threatened taxon under the FFG Act (see Appendix 2 in the VEAC report). Although a time-series trend analysis and status assessment were not conducted, this information is useful, as it provides a specific list of forest-dependent species in areas where most commercial native-timber harvesting has taken place.

The list of forest-dependent species used for this analysis was developed with DELWP expert opinion, and is consistent with previous SoF reports. However, as the list in Table Fo.10 has not been published and differs from other lists (such as that published in the VEAC report), there may be some ambiguities in future analyses. (Care should be taken, in particular, to avoid the inadvertent omission of species that require critical attention.) A formal and agreed list of forest-dependent species would assist the consistency and transparency of this analysis.

77. VEAC 2017, 'Conservation values of state forests: assessment report', Melbourne, Victoria http://www.veac.vic.gov.au/documents/Complete%20report%20for%20web%20page.pdf Accessed 3 December 2018.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:07 Degree of disturbance to native forest species caused by invasive species	○	○	●	○	↘	DATA QUALITY Good

Data custodian DELWP

Invasive species are defined here as any species that are non-native to a particular Victorian ecosystem, and whose introduction and spread causes adverse sociocultural, economic and/or environmental impact. As invasive species often do not have natural predators in Victoria's ecosystems (outside of their native range), they can spread, reproduce and compete for habitat, causing severe ecological degradation. Understanding the degree of disturbance caused by invasive species can provide an indication of the effectiveness of management/control actions, and assist with evaluation of policy responses.

Invasive species on public land in Victoria are managed by a biosecurity approach.[78] This approach focuses on asset-based protection measures that aim to minimise the impact of invasive species on the environment, economy and society. The Invasive Plants and Animals Policy Framework aims to protect Victoria's native flora, fauna and primary producers from harm caused by invasive species. The VFMP collects data on the presence and abundance of weed species across the state, including monitoring the impacts of weeds on native-forest species for the Victorian public forest estate. This data was collected for the first time between 2011 and 2012, and reported in SoF 2013. However, as the 2013 report was based on only 50% of the total plots measured, the information available for this report cannot be compared with previous data. The data in this indicator could be significantly different from that of the previous report.

The data shows that the proportion of weed species to total species is highest in the New South Wales Southwestern Slopes bioregion (24%) and the Riverina bioregion (20%). As shown in Fo:04 Fragmentation of native forest cover, the Riverina bioregion is the most highly fragmented bioregion and has the largest proportion of edge and patch areas.

Considering the cumulative effects of a high number of invasive weed species and fragmentation, the Riverina bioregion's capability to deliver long-term sustainable forest management is under threat. The edges of forest patches, such as roadsides, are highly susceptible to invasion by exotic species. In addition, forests in the Riverina bioregion have developed on active floodplains, and flooding could promote the abundance, proliferation and spread of weeds.

78. Victorian Department of Economic Development, Jobs, Transport and Resources, 'Protecting Victoria from pest animals and weeds', Bacchus Marsh, Victoria http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/protecting-victoria-from-pest-animals-and-weeds Accessed 4 December 2018.

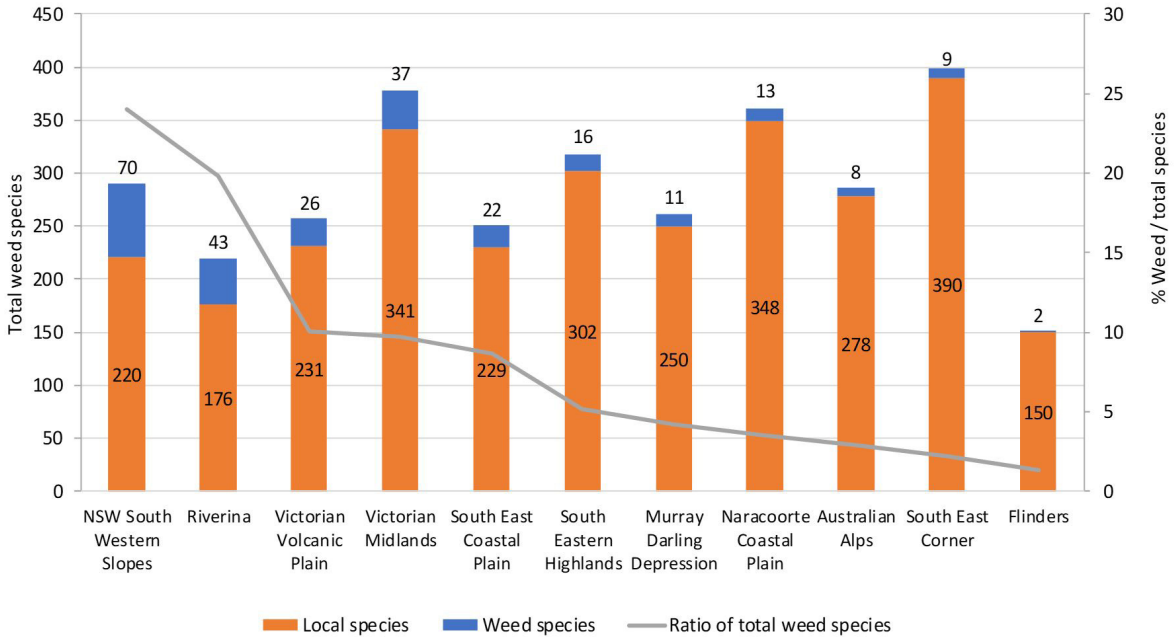


Figure Fo.16 Proportional distribution of weed species in bioregions, 2018

(Data source: DELWP, 2018)

The major insects and pathogenic agents found on public land are listed in Table Fo.12. Overall, damage by most identified pathogens and insect agents in Victoria during the reporting period stabilised or decreased. However, the distribution and destruction of a few species on native forests, plantations and urban/farm forests has increased. It is crucial to continue monitoring the impacts of insect and pathogen species, and also consider climate change impacts on these identified species, and the potential introduction of new insect and pathogenic agents in Victoria.

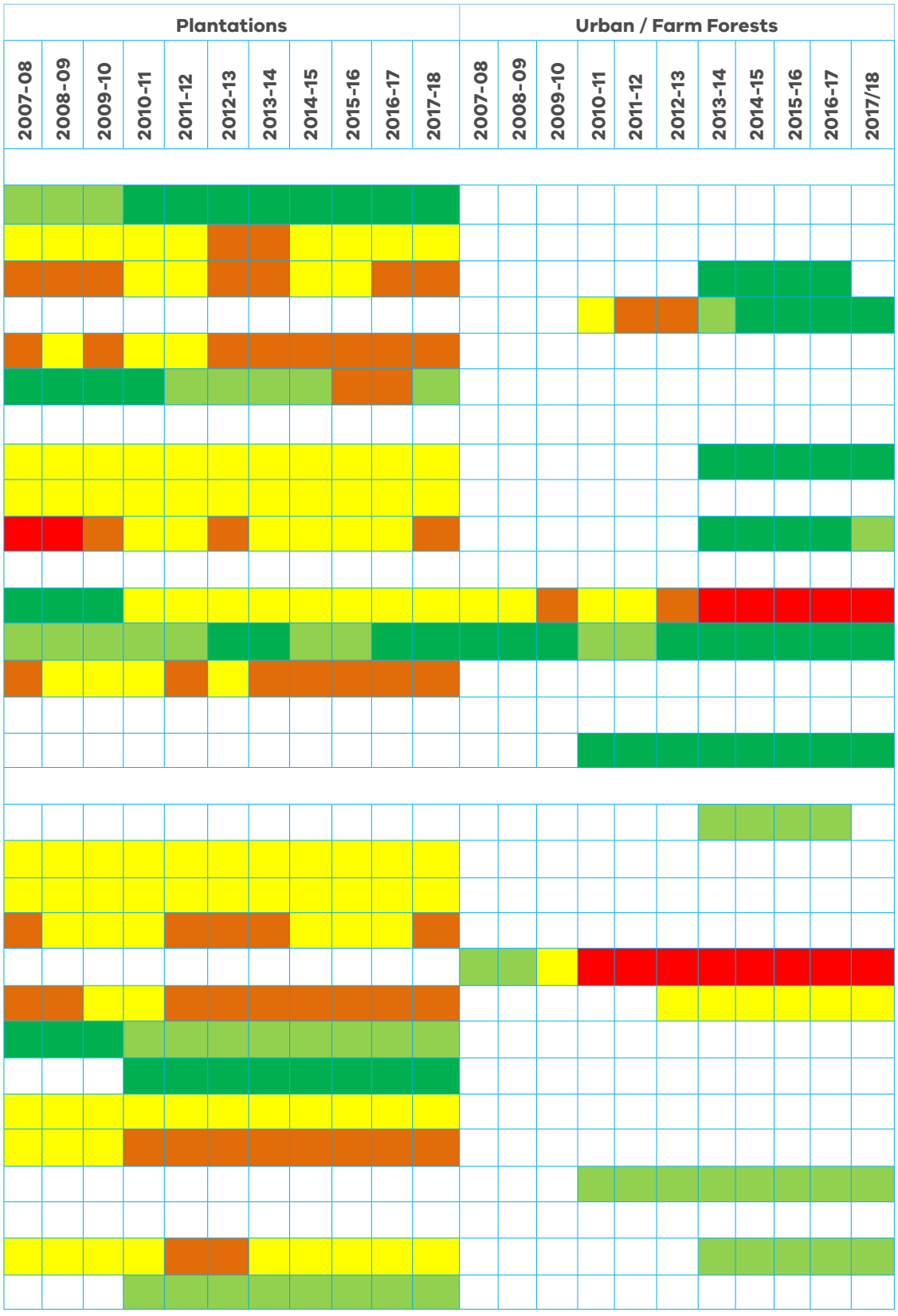
Table Fo.11 Colour code for Table Fo.12, indicating scale of distribution and impact of insects and pathogenic agents on native forests, plantation and urban/farm forest

Code	Scale of distribution	Impact
0	Does not occur, or not observed in assessment period	No impact
1	Restricted (<25%)	Minimal
2	Restricted (<25%)	Adverse
3	Widespread (>25%)	Minimal
4	Widespread (>25%)	Localised adverse
5	Widespread (>25%)	Widespread adverse

Table Fo.12 Common insect and pathogen agent, distribution and impact, 2007–08 to 2017–18

		Native forests										
Agent common	**Agent scientific**	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
Insects												
Autumn gum moth	Mnesampela privata											
Christmas beetle	Anoplognathus spp											
Chrysomelid leaf beetles	Chrysophtharta agricola											
Cup moth	Doratifera spp											
Five-spined bark beetle	Ips grandicollis											
Goldern-haired beetle	Hylurgus ligniperda											
Gum leaf skeletoniser	Uraba lugens											
Leaf blister sawfly	Phylacteophaga froggatti											
Longicorn borers	Phorocantha spp											
Monterey pine aphid	Essigella californica											
Mountain ash psyllid	Cardiaspina bilobata											
Red gum basket lerp	Cardiaspina retator Taylor											
Sawflies	Perga spp											
Sirex	Sirex noctilio											
Spurlegged phasmatid	Didymuria violescens											
Sycamore lace bug	Corythucha ciliata											
Pathogens												
Armillaria	Armillaria luteobubalina											
Corky leaf spot	Aulographina eucalypti											
	eucalypti											
Cyclaneusma needle cast	Cyclaneusma minus											
Cypress canker	Seridium sp											
Diplodia	Diplodia pinea											
Dothistroma needle blight	Dothistroma septosporum											
Eucalyptus canker	Holocryphia eucalypti											
Lophodermium	Lophodermium pinastri											
Mycosphaerella leaf disease	Mycosphaerella spp											
Myrtle rust	Uredo rangelii											
Myrtle wilt	Chalara australis											
Phytophthora	Phytophthora cinnamomi											
Septoria leaf blight	Kirramyces eucalpti											

(Continued following page)



(Data source: DELWP, 2018)

Public land management programs across Victoria are helping to reduce the impact of invasive species. Some of the key programs are:

- Weeds and Pests on Public Land Program – an ongoing program investing in weed, predator and herbivore control to protect Victoria's key biodiversity assets
- Peri-Urban Weed Management Partnership Initiative – a project to protect key biodiversity assets on public land in Melbourne's peri-urban areas from high-threat weeds
- Good Neighbour Program – a program to support public land managers to control weeds and pests at the interface of public and private land for the protection of private land values.

Figure Fo.17 shows the area of invasive species control by actions in Victoria since SoF 2013. The analysis excludes private land programs coordinated through the Department of Economic Development, Jobs, Transport and Resources (DEDJTR).

The Biodiversity chapter presents further assessments related to the management of invasive species, specifically indicators B:20 (Change in suitable habitat) and B:21 (Area of management in priority locations).

Action	Treated area (ha)
Feral cat control	66,054
Deer control	153,219
Fox control	2,409,659
Feral goat control	1,085,221
Feral pig control	91,576
Rabbit control	5,649,919
Weed control	4,223,328
Fencing	300,055
Total	13,979,031

Figure Fo.17 Area of invasive species control, by action, in public and private land between 2013–14 and 2017–18 financial year

(Data source: DELWP, 2018)

Note: Excludes private land programs coordinated through DEDJTR

Ecosystem Health

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:08A Scale and impact of agents and processes affecting forest health and vitality – mortality, dieback, canopy health sub-section Data custodian DELWP, BoM	○	○	●	○	?	DATA QUALITY Fair

Forest health and vitality are critically related to a variety of natural disturbances, which are strongly influenced by climate. In Victoria, natural disturbances can include fire, non-native species invasions, floods, disease outbreaks and climatic events such as windstorms, extreme temperatures and millennial drought events. All of these events influence the composition, structure and functions of forests.

The effects of such disturbances are not always negative. Rather, they can be an important part of natural processes essential to the long-term health of ecosystems. Forests have evolved to overcome and regenerate from certain natural disturbances. However, there have been major shifts recently in the frequency, scale and intensity of the agents and processes that can cause significant disruptions in forest ecosystems, resulting in a dramatic increase in the susceptibility of forest health and vitality. Capturing these shifts through monitoring programs is vital, as predictions indicate that forest ecosystems will be increasingly exposed to these events due to climate change.[79]

Condition of the forest canopy is used globally as an indicator of forest health.[80] This report presents three measures of tree-canopy quality: mortality, crown dieback and canopy health. Mortality is defined as the proportion of the stand basal area (m^2/ha) in dead trees. Basal area is the cross-sectional area of a tree's trunk, measured at 1.3 m above the ground. Crown dieback is the amount of withered branches within the canopy, often over a certain period. This is measured by the VFMP as the proportion of dominant branches in tree crowns lacking living foliage. The crown canopy impacted is a measure of canopy health through defoliation and discolouration, and this is gauged as the percentage of existing foliage over an estimated foliage volume. Due to the application of different methods from previous SoF reports, not all data for this indicator can be compared with previous reports for trend analysis.

Across all Victorian bioregions, the average percentage of areas showing mortality, crown dieback and canopy health impacted are 14.3%, 20.3% and 23.3%, respectively.

As a result of a wide confidence interval of the mortality rate in every forest tenure and in each bioregion (Figure Fo.18), it is difficult to identify significant differences between bioregions and between parks, reserves and state forests-except for the Victorian Volcanic Plains, where a higher mortality rate was identified in state forests.

On average, the crown dieback by bioregion was between 16% and 24% of the total large-tree basal area (Figure Fo.19). Bioregions with more than 20% crown dieback included the Australian Alps, Murray–Darling Depression, Riverina and Victorian Volcanic Plains. The eastern parts of Victorian bioregions (South East Coastal Plain, South East Corner and South Eastern Highlands) had lower dieback rates.

In the comparison of parks and reserves with state forests, Riverina had the highest difference: dieback rates in the parks and reserves area were about three times greater than in state forests. The Australian Alps and South East Corner bioregions also had a greater proportion of dieback rates in the parks and reserves than state forests category (about 10% greater). This may be due to a range of factors, including different site conditions, management history and current uses.

79. Ian F 2009, 'Fires, Forests and Futures: The ANU Westoby Lecture', *Australian Forestry*, 72(4), pp. 195-205.
80. Stone C, Haywood A 2006, 'Assessing canopy health of native eucalypt forests', *Ecological Management & Restoration*, 7, pp. S24-S30.

Figure Fo.20 summarises average canopy health affected for measured plots by bioregion. At the bioregion level, canopy condition was worst affected in the Naracoorte Coastal Plain and the western areas of the South East Coastal Plain (around Cape Otway) as well as in the pockets of the Victorian Volcanic Plain, Victorian Midlands, southern areas of the Mallee and eastern areas of the Australian Alps (Central Highlands).

Plot-derived canopy health data was interpolated across the state using the kriging method in ArcGIS software that is widely used for spatial analytics (Figure Fo.21). This method is a geostatistical technique that can predict certain status, in this case canopy health, based on a scattered set of spatial data points from field measurements through the VFMP. This method has been used internationally to estimate forest cover[81] and forest health.[82] Figure Fo.21 demonstrates that there are several Victorian bioregions where degree of leaf damage is more than the average of 30%: Naracoorte Coastal Plain, South Eastern Highlands (including the Otway region), Central Highlands, south of Murray–Darling Depression and Victorian Midlands.

The Australian Alps, which has experienced multiple fires over the past 10 years, has a high proportion of dead stems (Figure Fo.18). Data suggests a similar condition in the Riverina; however, these dead stems occur in isolated pockets, leading to significant variation across the bioregion.

Overall, it would be counterproductive to determine the current status of forest health and vitality in Victoria using tree mortality and dieback rate, as there is no comparative threshold. Although the data presented cannot be used for trend analysis, recent research has shown mortality-rate trends in mountain ash forests in the Central Highlands. Between 1997 and 2015, 25% of the measured population died on unburnt sites, while 61% died on burnt sites.[83] Monitoring trends that relate to forest health and vitality is critical to develop strategies and management actions to mitigate deterioration.

81. Dindaroğlu T 2014, 'The use of the GIS Kriging technique to determine the spatial changes of natural radionuclide concentrations in soil and forest cover', *Journal of Environmental Health Science and Engineering*, 12(1), pp. 130.
82. Conkling BL 2011, 'Forest health monitoring: 2007 national technical report', General Technical Reports SRS-147, Asheville, NC, US Department of Agriculture Forest Service, Southern Research Station, 147, pp. 1-59.
83. Lindenmayer DB, Blanchard W, Blair D, McBurney L 2018, 'The road to oblivion – quantifying pathways in the decline of large old trees', Forest Ecology and Management, 430, pp. 259-264.

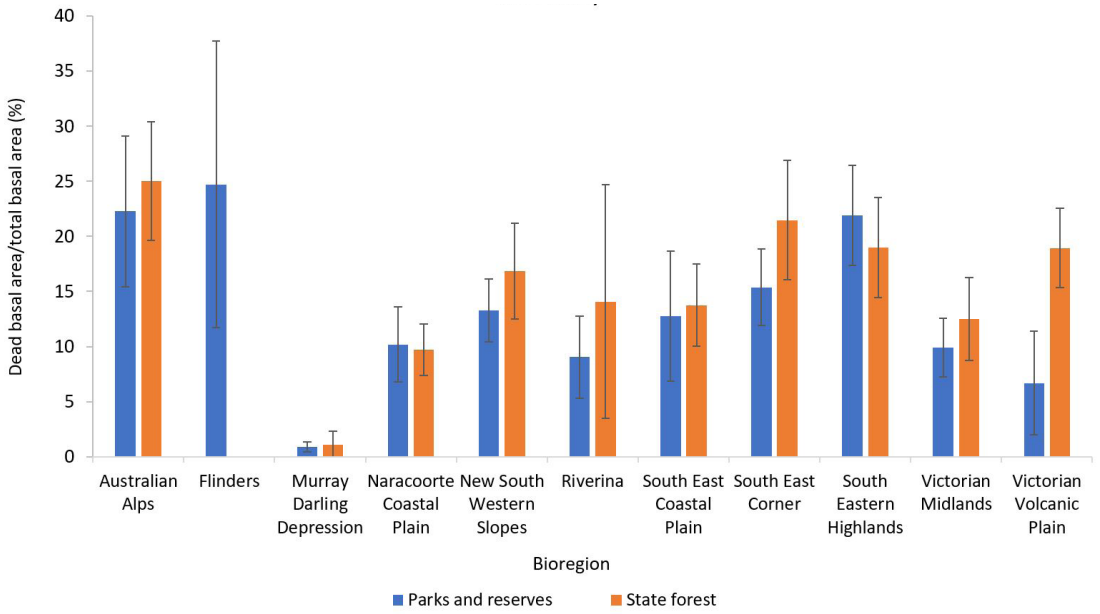


Figure Fo.18 Mortality by bioregion as a proportion of total dead basal area to total live basal area for large trees

Note: Number of plots by bioregion is described in Table Fo.1.

(Data source: DELWP, 2018)

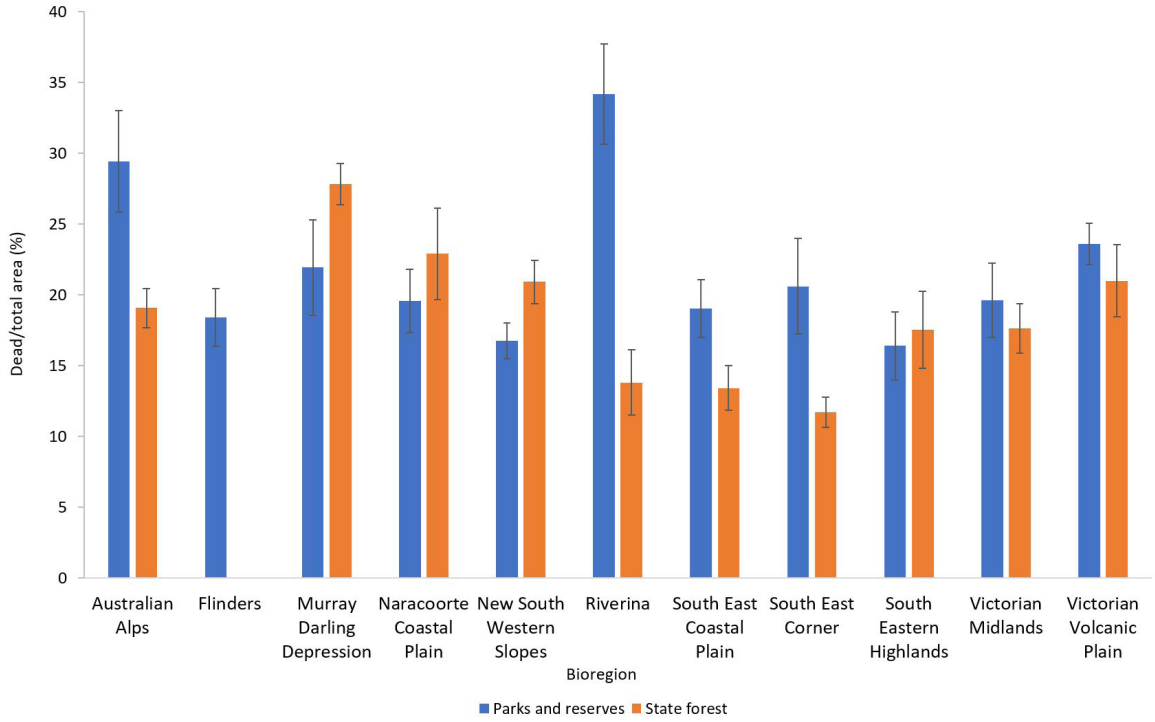


Figure Fo.19 Average canopy dieback and defoliation rates for measured plots by bioregion

Note: Number of plots by bioregion is described in Table Fo.1.

(Data source: DELWP, 2018)

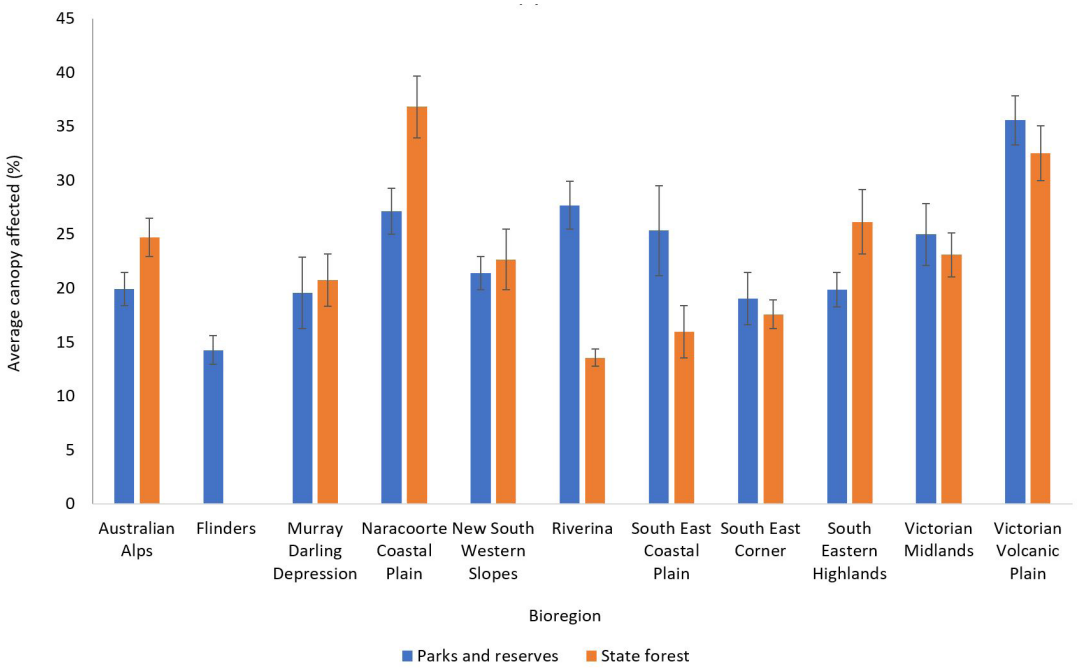


Figure Fo.20 Canopy health as characterised through discolouration and defoliation, by bioregion

(Data source: DELWP, 2018)

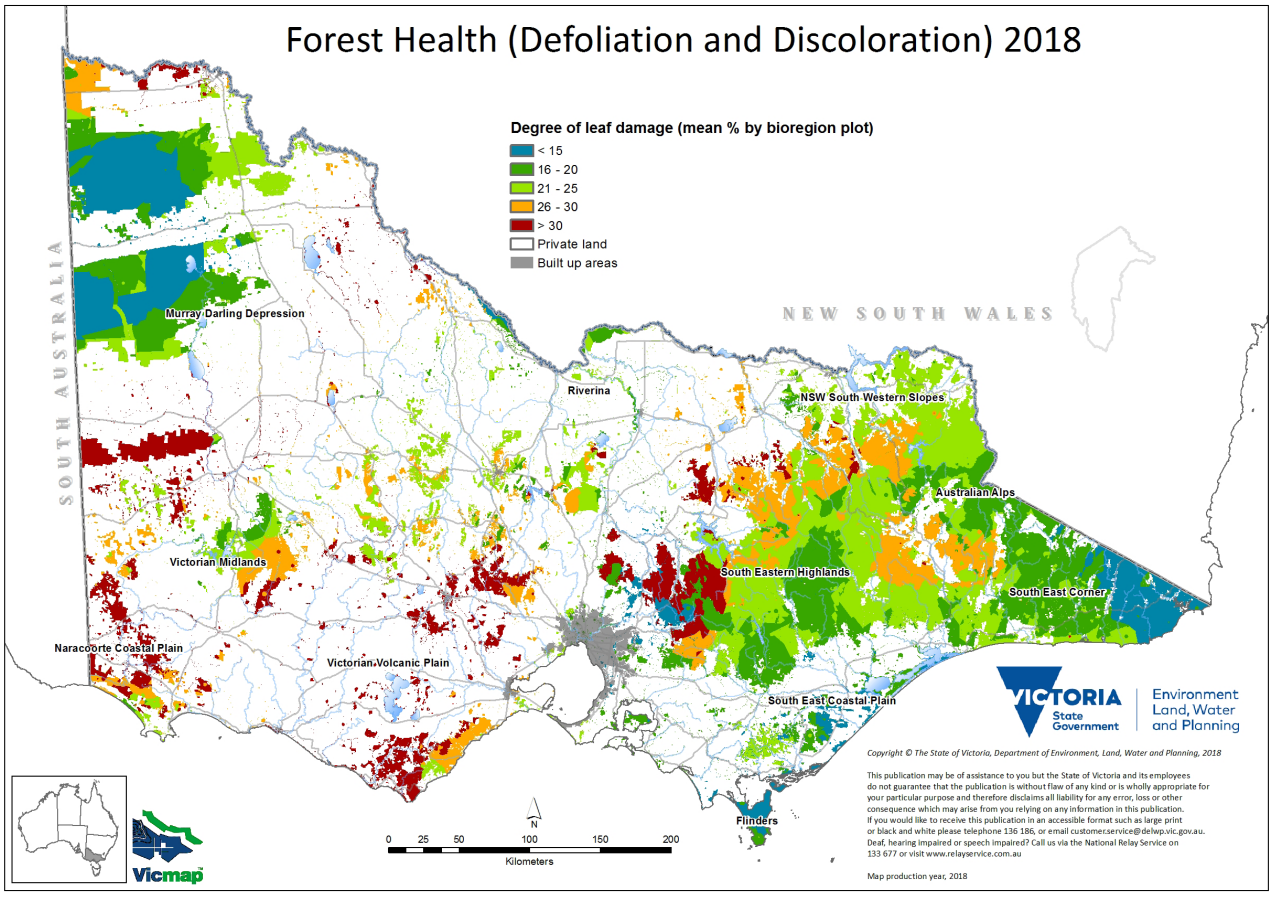


Figure Fo.21 Canopy health (defoliation and discolouration), 2018

(Data source: DELWP, 2018)

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:08B Scale and impact of agents and processes affecting forest health and vitality – Bushfire affected area and climate sub-section						 DATA QUALITY Good

Data custodian DELWP, BoM

Bushfire Affected Area

Native flora and fauna in Victoria evolved by adapting for bushfires of varying frequency and intensity. In fact, many native species have become dependent on natural fire regimes for health and survival. Fire regimes comprise four parameters: fire intensity, fire frequency (between-fire interval), seasonality of fire occurrence and type of fire (above or below-ground).[84]

The effects of fire on forest ecosystems are determined by fire intensity. 'Fire intensity' varies depending on the position of the periphery of the fire.[85] Victorian forests can experience very intense canopy fires during summer where warm, dry and windy weather conditions occur, and this can lead to large-scale replacement and regeneration of mature tree populations. Victorian mountain ash and alpine ash forests are especially susceptible to significant alterations, as the canopy-tree species are fire-sensitive, and can be replaced by acacia scrub if burnt by two fires at an interval less than the time it takes for the eucalypts to reach sexual maturity. The effects of intense, extensive fires also extend to long-term effects on streamflow, threatened species survival and subsequent invasions by exotic species. Therefore, it is important to understand fire-affected areas for sustainable forest management.

Unattended campfires constitute a large proportion of the fires reported on public land. Compliance concerning campfire use is managed by Parks Victoria, together with DELWP, Victoria Police and the Country Fire Authority (CFA). The most damaging bushfire on record is the Wye River-Jamieson Track fire, instigated by lightning on 19 December 2015. The fire exceeded control lines on Christmas Day under extreme weather conditions, burning 2,520 hectares of national park and private properties, including an estimated 160 houses.

Between 2013 and 2014, Victoria experienced its most significant fire season since 2008, which challenged emergency services and Victorian communities. Across the season, Victoria had 19 days of Extreme and Severe Fire Danger Rating and 16 days of Total Fire Ban. More than 463,000 hectares of public and private land was burnt, and 80 residences destroyed.[86]

The respective land management and fire agencies (including the CFA, Department of Environment and Primary Industries and their Networked Emergency Management partners, consisting of Parks Victoria, VicForests and Melbourne Water and the Metropolitan Fire Brigade) responded to more than 4,600 bushfires and grassfires over a five-month period. The years between 2015 to 2017 have seen relatively low fire activity.

84. Gill AM 1975, 'Fire and the Australian flora: a review' Australian Forestry, 38, pp. 4-25.
85. Ibid
86. Emergency Management Victoria 2013, 'Post season operations review: fire danger period 2013/14', Melbourne, Victoria http://files.em.vic.gov.au/EMV-web/Fire-Danger-Period-Operational-Review-2013-14.pdf Accessed 4 December 2018.

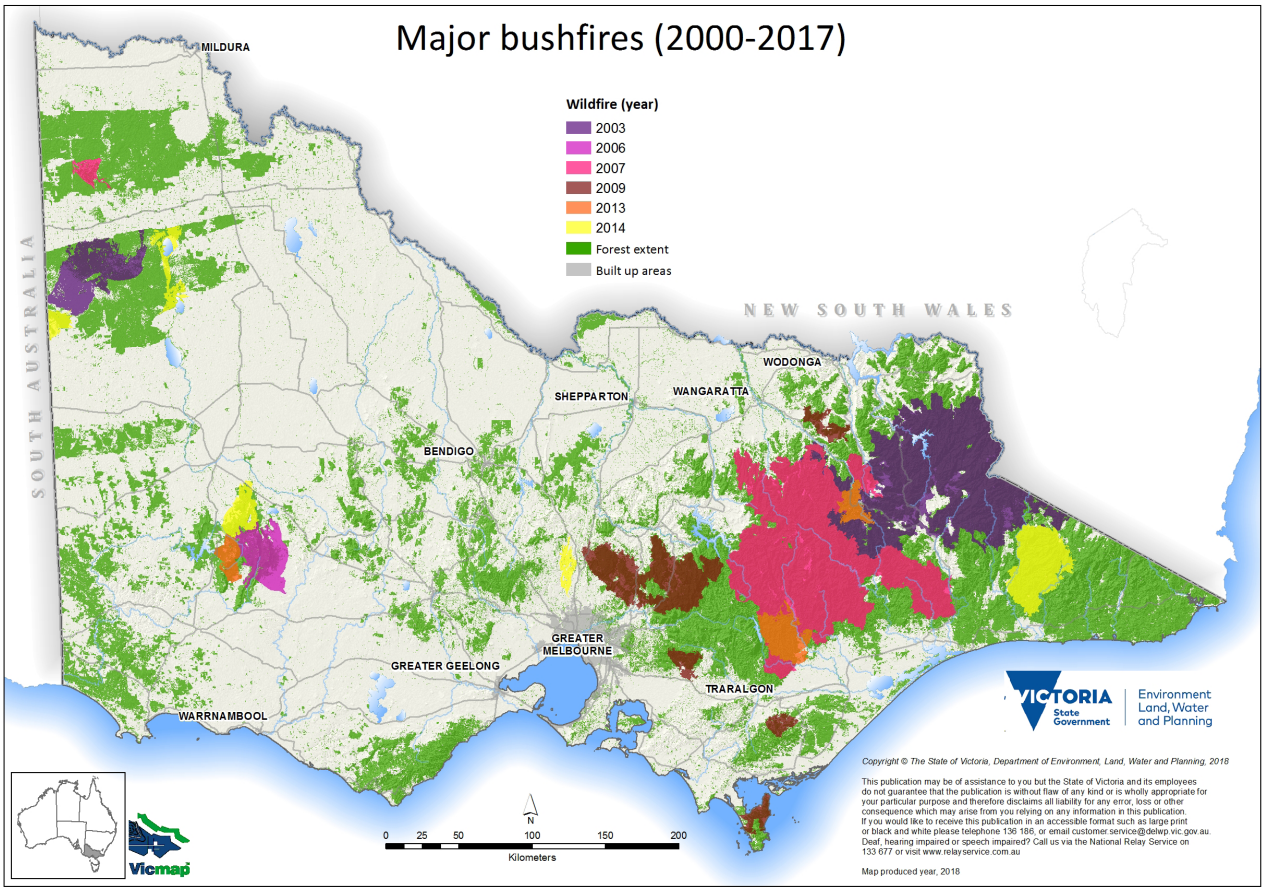


Figure Fo.22 Major bushfires in Victoria, 2000–17

(Data source: DELWP, 2018)

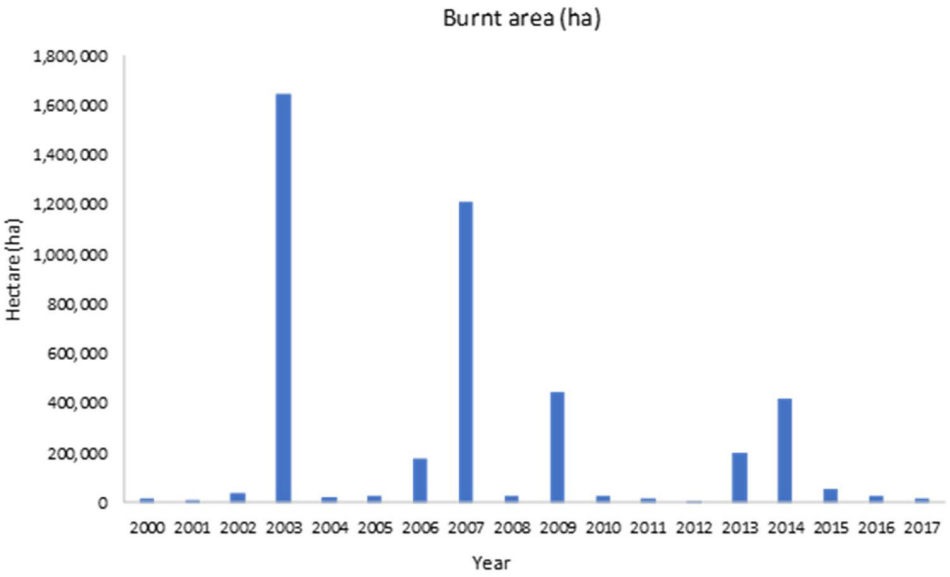


Figure Fo.23 Total area affected by bushfires, 2000–17

(Data source: DELWP, 2018)

Climate

The health and vitality of forests are critically related to climatic patterns and events. Forest health and vitality are affected by conditions such as rainfall deficit and extreme temperatures, with impacts on mortality, defoliation and withering in trees and their understorey, and reduced productivity, regenerative abilities and resources for forest-dependent species.

High temperatures and drought can also augment fire activity and degrade overall land condition. Forests under stress from drought are also more prone to infections and insect invasions. Recent events related to anthropogenic climate change have created an extreme climatic environment, in which it is becoming increasingly difficult to maintain healthy and vital forest ecosystems.[87] The native ecosystems in which species have evolved have been rapidly changing, and studies[88, 89] have indicated that the speed of the change could be too fast for some native species to adapt. This could lead to significant consequences, including species extinction.

The Victorian climate has been gradually warming since the 1950s (Figure Fo.24). Since SoE 2013, every year has been among the top-ten warmest in Victoria on record,[90] with 2014 the second-warmest year on record (behind 2007). The temperature increase is observed in both daytime (maximum) and overnight (minimum) temperatures, with the greatest degree of warming in summer (+0.14 °C per decade) and the smallest in winter (+0.06 °C per decade).

The temperature increase in Victoria was widespread, with the greatest increases in the central and southern parts of the state. A uniform increase in daytime temperature can be observed throughout the state, with the exception of parts of Gippsland, the far-west, and north-east of the state, where the increase was marginally slower. The southern coastal areas have experienced the greatest increases in overnight temperature, with a smaller degree of night-time warming in inland parts of Victoria. This could be a result of reduced rainfall and cloud cover in the cool season, which may have mitigated some effects of global warming in the central region.

A greater number of extreme heat events in Victoria are a consequence of the warmer climate, as indicated by an increase in the number of unusually warm days per year in Victoria (Figure Fo.25). Unusually warm days have been calculated based on average temperatures recorded each day from 1910 until 2015. Data for those 105 years was then used to calculate average temperature by month. This result is compared to the average temperature each day for 105 years of data: days in the top 1% for each month are counted as 'unusually warm'.

87. Keenan RJ 2015, 'Climate change impacts and adaptation in forest management: a review', Annals of Forest Science, 72(2), pp. 145-167.
88. Thuiller W 2007, 'Biodiversity: climate change and the ecologist', *Nature*, 448(2), pp. 550-552.
89. Dawson TP, Jackson ST, House JI, Prentice IC, Mace GM 2011, 'Beyond predictions: Biodiversity conservation in a changing climate', Science, 332, pp. 53-58.
90. Bureau of Meteorology, 'Heatwave Service for Australia', Melbourne, Victoria www.bom.gov.au/australia/heatwave Accessed 4 December 2018.

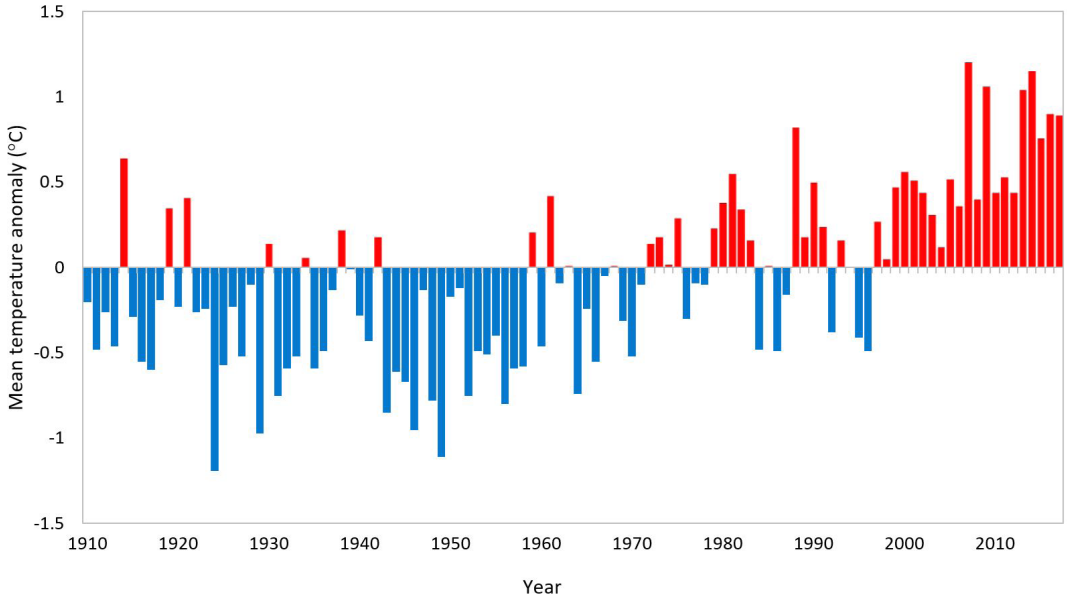


Figure Fo.24 Mean temperature anomaly in Victoria, 1910–2017

(Data source: BoM, 2018[91])

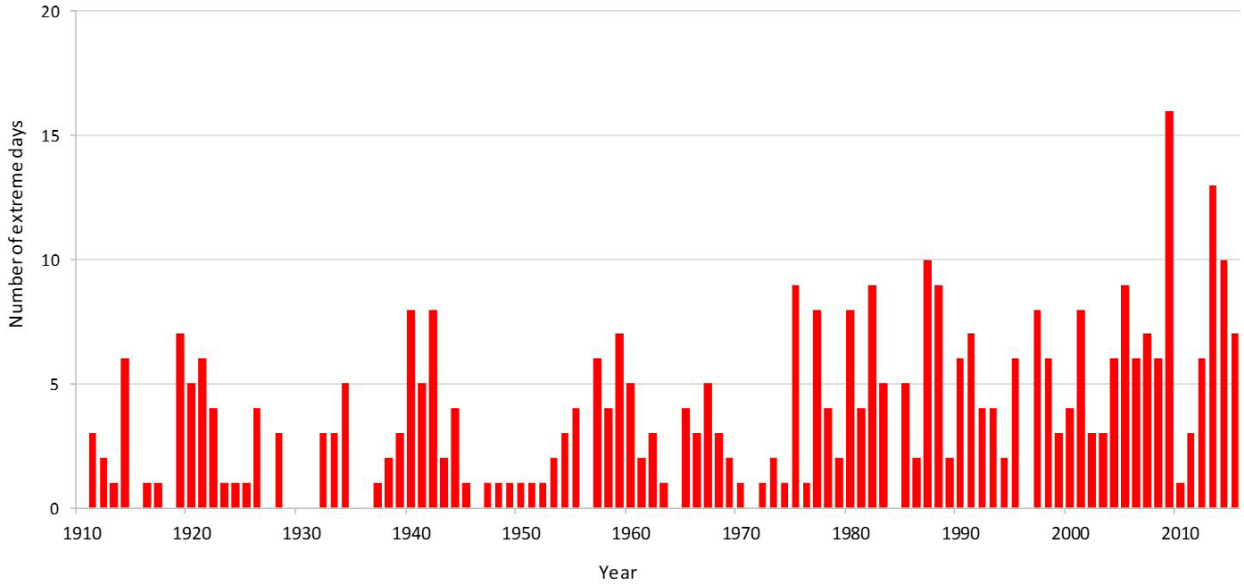


Figure Fo.25 Number of days annually when the Victorian area-averaged daily mean temperature is 'unusually warm', 1910–2015

Note: Extreme days are those above the 99th percentile for the month from 1910–2015.

(Data source: BoM, 2018[92])

91. Bureau of Meteorology, 'Climate change and variability', Canberra, Australia. http://www.bom.gov.au/climate/change/index.shtml#tabs=Tracker&tracker=timeseries Accessed 9 January 2019.
92. Bureau of Meteorology, 'Climate change and variability', Canberra, Australia. http://www.bom.gov.au/climate/change/index.shtml#tabs=Tracker&tracker=timeseries Accessed 13 January 2019.

Fo:09 Area and type of human-induced disturbance

Disturbance is the transition of a short-term change in environmental conditions to the long-term change of an ecosystem. The impacts of human-induced disturbances (intentional or unintentional) on forest ecosystems have been extensively reported throughout the world.[93] In Victoria, extensive planned fire activities, intensive grazing, and roads have been identified as factors that have great potential to affect forest ecosystem health. Observing the various forms and significance of these disturbances would allow better understanding of anthropogenic impacts on forest health, as well as help to formulate appropriate mitigation strategies. This report discusses two major causes of disturbances: planned burns and grazing.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:09A Area and type of human-induced disturbance – Planned burns	○	○	●	○	?	DATA QUALITY: Good
Data custodian DELWP						

Fuel management is an effective way to manage bushfire risk on large areas of public land. Fuel management reduces the amount of fuel available to a bushfire, which can reduce its intensity and rate of spread, thereby increasing opportunities for firefighters to suppress it. Victoria mainly manages fuel by planned burns, but also by mechanical treatment. Definition of planned and unplanned burns is provided in Table Fo.13. For fuel management purposes, Victoria has four fire management zones:

- Asset Protection Zone (APZ): an area around properties and infrastructure where fuel is intensively managed to provide localised protection to reduce radiant heat and ember attack on life and property in the event of a bushfire
- Bushfire Moderation Zone (BMZ): an area around properties and infrastructure where fuel is managed to reduce the speed and intensity of bushfires and to protect nearby assets, particularly from ember attack in the event of a bushfire
- Landscape Management Zone (LMZ): an area where fuel is managed to minimise the impact of major bushfires, to improve ecosystem resilience and for other purposes (such as to regenerate forests and protect water catchments)
- Planned Burning Exclusion Zone (PBEZ): an area where planned burning is avoided, mainly because ecological assets in this zone cannot tolerate fire.

DELWP conducts planned burns to meet the objectives of the relevant fire management zone and other site-specific objectives.

Following the 2010 final report by the 2009 Victorian Bushfires Royal Commission, the Victorian Government committed to expanding its planned-burning approach by aiming to reduce fuel hazards and protect human life.

But in 2016, based on recommendations by the Inspector-General for Emergency Management, the government began to shift from a hectare-based approach to a risk-based approach which to bushfire management. This focuses on areas where the likelihood of a bushfire starting, spreading and impacting on people, property and the environment is greatest, based on fire-modelling results. The government is developing a system of bushfire management strategies to reduce risk, which will be delivered by 2020. For further discussion, see the Fire chapter.

Due to the new approaches for planned burns since 2016–17, trend analysis could not be conducted.

93. Zamorano-Elgueta C, Cayuela L, Ray-Benayas MR, Donoso PJ, Geneletti D, Hobbs RJ 2014, 'The differential influences of human-induced disturbances on tree regeneration community: a landscape approach', Ecosphere, 5(7), pp. 90.

Table Fo.13 Definitions of planned and unplanned burns

Planned Fire	Unplanned Fire
Fire started in accordance with a fire management plan, or some other type of planned-burning program or wildfire response procedure. Usual reasons for such fires may include: • fulfilling the ecological requirements of flora and fauna • protecting of human life and property • maintaining and promoting sustainable production values • maintaining cultural resources and practices.	Fire started naturally, accidentally or deliberately, but not in accordance with planned fire management activities. Examples include: • lightning strikes • escaped campfires or barbeques • fires resulting from equipment or machinery • fires deliberately lit without the necessary permits or authority (and those lit with malicious intent) • escaped planned burns.

(Data source: DELWP, 2018)

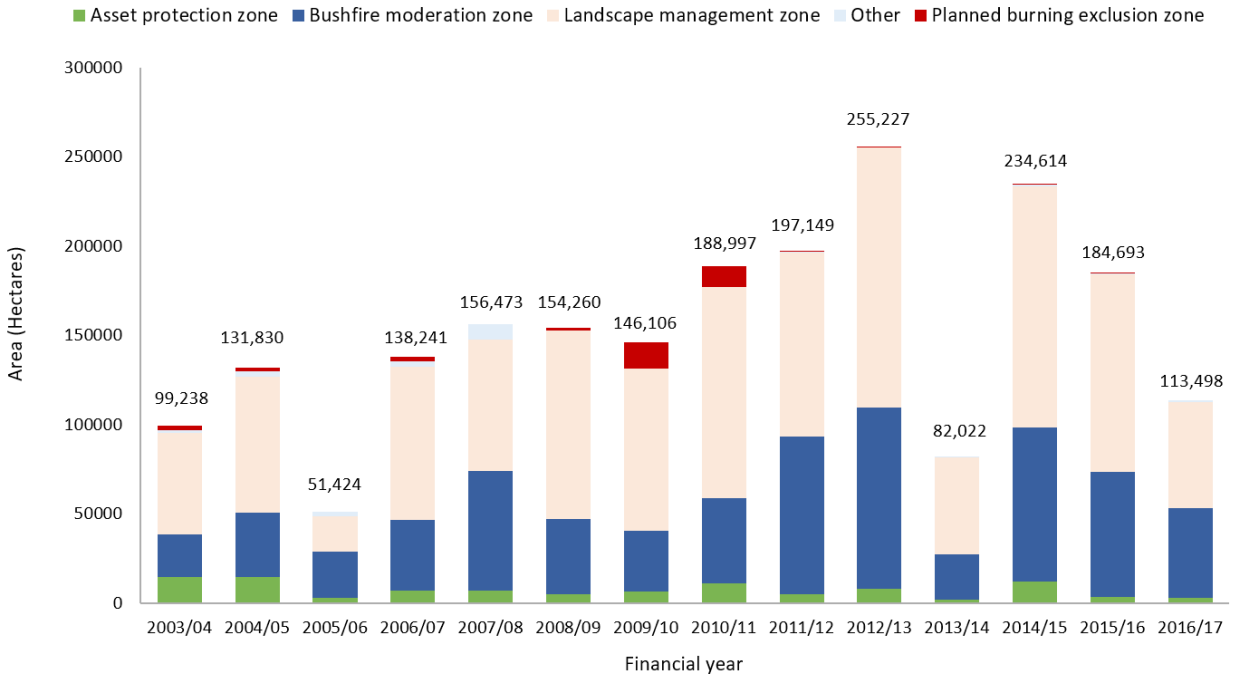


Figure Fo.26 Annual area of planned burns on public land, by fire management zone, 2003–04 to 2016–17

(Data source: DELWP, 2018)

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:09B Area and type of human-induced disturbance – grazing						 DATA QUALITY Poor

Data custodian DELWP

Analysis of grazing activity helps to assess and address issues relating to conservation of native plant biodiversity, water yield and agricultural practices. Pastoral farming is a major contributor to Australia's economy. About two-thirds of Australia's land has been modified for human use, primarily grazing of livestock, including on natural vegetation.[94] Studies indicate that grazing by non-native animals such as cattle and sheep could damage native plant biodiversity and water yield.[95,96]

To balance conservation with agricultural needs, the Victorian Government regulates grazing by issuing licences and permits. These are annual licences with invoices issued each October. Licences can be issued under the *Land Act 1958* and *Forests Act 1958*. They give the licence-holder the right to occupy stipulated Crown land for agricultural purposes, grazing and some cropping (although purposes can vary).

Annual invoices, shown in Table Fo.14, are the sum of payment for rent or other activities on Crown land. Between 2012 and 2013 and 2016 and 2017, licence numbers have been stable. However, the data does not indicate area used for grazing activities. In addition, There is also no/limited information about where grazing is occurring under licence. Grazing in some areas, such as those near catchment areas, may be more harmful to the environment. Therefore, it is difficult to determine whether the current number of grazing licences is environmentally sustainable. An evidence-based approach to determining the sustainable level is urgently needed.[97]

Table Fo.14 Number of licences issued for grazing activities, 2012–13 to 2016–17

Year	No. of licences	Invoiced	Invoices (exc. GST)
2012–13	1,689	253,171	230,156
2013–14	1,681	239,307	217,551
2014–15	1,692	240,661	218,783
2015–16	1,698	240,220	218,382
2016–17	1,710	241,162	219,238

(Data source: DELWP, 2018)

94. Australian Bureau of Statistics 2010, '4613.0-Australia's environment: issues and trends, Jan 2010', Belconnen, Australia, http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/4613.0Chapter95Jan+2010 Accessed 4 December 2018.
95. Bromham L, Cardillo M, Bennett AF, Elgar MA 2009, 'Effects of stock grazing on the ground invertebrate fauna of woodland remnants', Austral Ecology, 24(3), pp. 199-207.
96. Lunt ID 2005, 'Effects of stock grazing on biodiversity value in temperate native grasslands and grassy woodlands in SE Australia: a literature review'. Technical Report 18, Wildlife Research and Monitoring, Lyneham, Australia https://www.environment.act.gov.au/__data/assets/pdf_file/0007/576520/technicalreport18effectsofstockgrazingonbiodiversityvalues.pdf Accessed 4 December 2018.
97. Dorrough J, Yen A, Turner V, Clark SG, Crosthwaite J, Hirth R 2004, 'Livestock grazing management and biodiversity conservation in Australian temperate grassy landscapes', Australian Journal of Agricultural Research, 55(3), pp. 279-295.

Carbon Cycles

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:10 Total forest ecosystem biomass and carbon pool by forest type, age class and succession all stages	○	○	●	○	?	DATA QUALITY: Fair

Data custodian DELWP

Carbon is a fundamental component of terrestrial forest ecosystems, including above- and below-ground biomass, organic soil matter, woody debris and litter. The natural process of photosynthesis by plants enhances terrestrial uptake of atmospheric carbon,[98] making forests ideal for reducing net carbon emissions from anthropogenic activities. Strategies to increase forest-stored carbon would thus assist in meeting state and national carbon emissions commitments.

This indicator provides information on the contribution of Victorian forests to the carbon cycle. Estimates of total forest biomass over time are vital to monitor the changes in regional and localised carbon pool distribution, particularly as carbon stocks are contingent on environmental and land-use conditions.[99]

The total biomass is estimated through field measurements taken between 2011 and 2015 from 786 plots of the VFMP across Victoria, located in parks and reserves and state forests. A standard biomass factor of 0.5[100] is applied in converting total biomass to the amount of carbon (C), to obtain the values found in Figure Fo.28 and Figure Fo.29. The carbon mass is presented by each bioregion, tenure, type and pool. A single time period is presented as provided from the VFMP; however, trend analysis will be possible from 2020, once the five-year panel system is fully implemented.

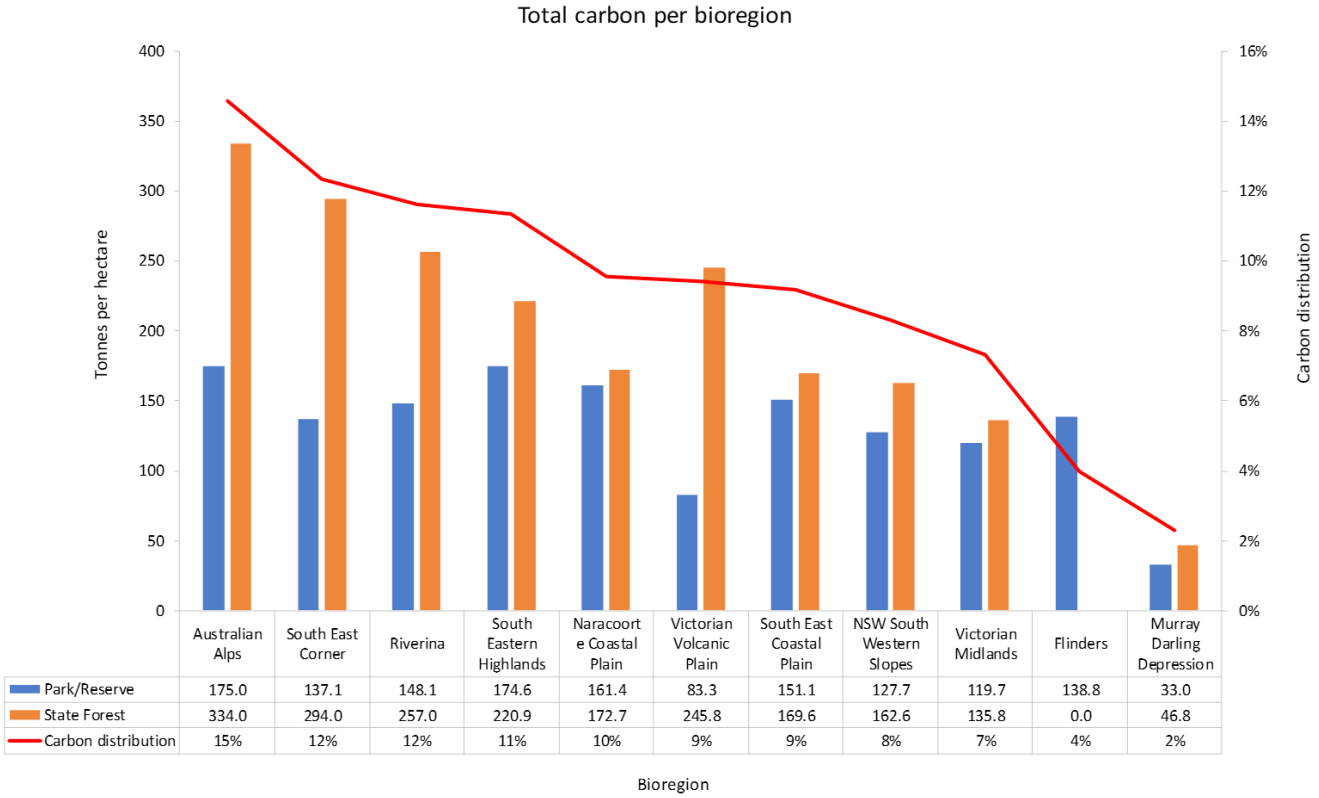
Existing data shows that across all Victorian public forests, the average C and biomass per hectare is 166.2 and 332.3 tonnes per hectare, respectively. The Murray–Darling Depression[101] has the lowest average C and biomass per hectare, with 39.9 and 79.9 tonnes per hectare, respectively.

Across all bioregions, total carbon per hectare is 40% higher on average in state forests than in parks and reserves, with the exception of Flinders. Although parks and reserves are known to occupy a higher proportion of total Crown land,[102] state forests support greater sink capacity through total plant biomass. The higher prevalence of old-growth trees restricted for timber harvest in state forests,[103] relative to younger stands, may contribute to better carbon storage.[104] The following factors also play a role:

- Parks and reserves often have areas of non-forest areas. For example, in the Australian Alps bioregion, the reserve area includes the area above the tree line.
- State forests are managed to achieve high stocking rates while reserves are not managed in the same manner.

98. Zhu K, Zhang J, Niu S, Chu C, Luo Y 2018, 'Limits to growth of forest biomass carbon sink under climate change', Nature Communications, 9(1), pp. 2709.
99. Keith H, Mackey B, Lindenmayer D, Likens G 2009, 'Re-evaluation of forest biomass carbon stocks and lessons from the world's most carbon-dense forests', Proceedings of the National Academy of Sciences of the United States of America, 106(28), pp. 11635-11640.
100. Penman J, Gytarsky M, Hiraishi T, Krug T, Kruger D, Pipatti R, Buendia L, Miwa K, Ngara T, Tanabe K, Wagner F 2003, 'Good practice guidance for Land Use, Land Use Change and Forestry'. Intergovernmental Panel on Climate Change National Greenhouse Gas Inventories Programme, Institute for Global Environmental Studies (IGES), Kanagawa, Japan https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/GPG_LULUCF_FULL.pdf Accessed 4 December 2018.
101. Australian Department of the Environment and Energy 2008, 'Murray-Darling Depression bioregion', Canberra, Australia https://www.environment.gov.au/system/files/resources/a8015c25-4aa2-4833-ad9c-e98d09e2ab52/files/bioregion-murray-darling-depression.pdf Accessed 4 December 2018.
102. Victorian Department of Environment and Primary Industries 2013, 'Victorian Crown Land Area Statement', Melbourne, Victoria https://www.parliament.vic.gov.au/images/stories/committees/enrc/Invasive_Animals_on_Crown_land/210A._2016.09.13_Attachment_1_-_Victorian_Crown_Land_Area_Statement.pdf Accessed 4 December 2018.
103. VAGO 2013, 'Managing Victoria's native forest timber resources', Melbourne, Victoria http://www.vicforests.com.au/static/uploads/files/20131211-timber-resources-wfsdlrklejjj.pdf Accessed 4 December 2018.
104. Keith H, Lindenmayer D, Mackey B, Blair D, Carter L, McBurney L, Okada S, Konishi-Nagano T 2014, 'Managing temperate forests for carbon storage: impacts of logging versus forest protection on carbon stocks', Ecosphere, 5(6), pp. 75.

- Carbon from successive fires, in 2003, 2007 and 2009, from large dead trees in the Australian Alps reserves is high compared with other bioregions. The reserves have at least twice as much carbon from large dead trees than any other bioregion.



	Australian Alps	South East Corner	Riverina	South Eastern Highlands	Naracoorte Coastal Plain	Victorian Volcanic Plain	South East Coastal Plain	NSW South Western Slopes	Victorian Midlands	Flinders	Murray Darling Depression
Park/Reserve	175.0	137.1	148.1	174.6	161.4	83.3	151.1	127.7	119.7	138.8	33.0
State Forest	334.0	294.0	257.0	220.9	172.7	245.8	169.6	162.6	135.8	0.0	46.8
Carbon distribution	15%	12%	12%	11%	10%	9%	9%	8%	7%	4%	2%

Figure Fo.27 Total carbon (tonnes) per hectare in Victoria's public forest (state forests and parks/ reserves) by bioregion estimated based on field measurements between 2011 and 2015

Note: Weighted means by bioregion. Proportional distribution of carbon in Victoria's forest per region is indicated as a red line on the secondary y-axis.

(Data source: DELWP, 2018)

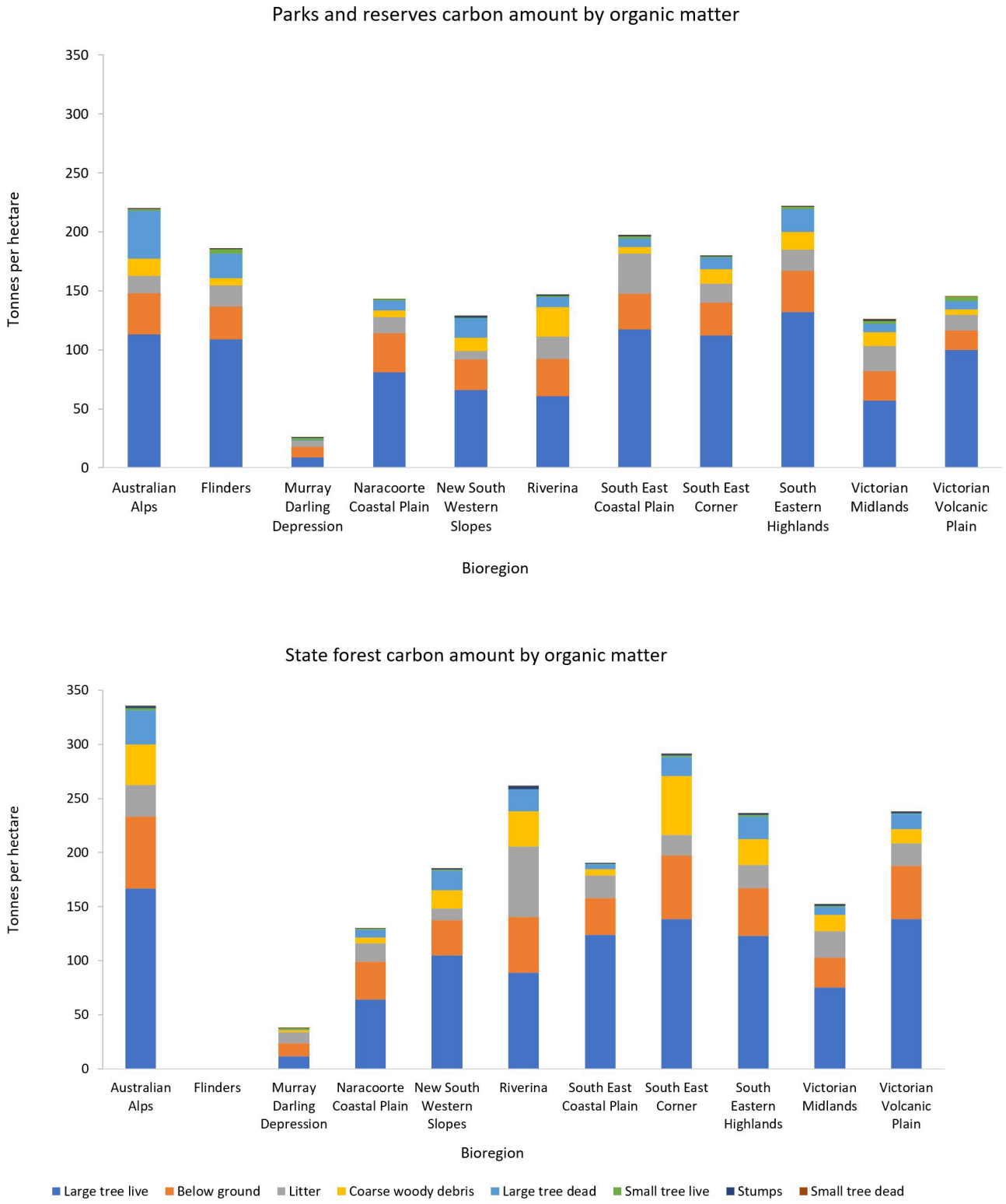


Figure Fo.28 Carbon stores by pool and bioregion in Victoria's public forests (state forests and parks/reserves)

(Data source: DELWP, 2018)

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:11 Contribution of forest ecosystems to the global greenhouse gas balance	○	●	○	○	↗	DATA QUALITY
Data custodian DELWP						Good

Increasing the concentration of greenhouse gases (GHG) intensifies climate change. Monitoring the contribution of Victorian forest ecosystems to the global GHG balance is vital, as forest management can have a positive or negative impact on the balance.[105]

In 2017, the Victorian Government announced that Victoria's *Climate Change Act 2017* would establish a target of net-zero GHG emissions by 2050.[106] For about 20 years, from 1990, Victoria's net GHG emissions gradually increased by 35% to 110,469 gigagrams $CO_{2\text{-}e}$. In 2016, net GHG emissions in Victoria were 91,459 gigagrams CO_2– about a 12% increase from 1990 emissions (Figure Fo.29).

The 20-year increase from 1990 was due principally to emissions from the energy sector, the greatest contributor to net emission outflow. The sector includes production of electricity and direct combustion of fossil fuels in other industries, such as manufacturing.

However, the energy sector's contribution has stabilised since 2004, and the Land Use, Land-Use Change and Forestry (LULUCF) sector has become a net sink of carbon emissions, except for the years when major bushfires occurred, including 2003, 2007 and 2009 (see forest management net outflow in Figure Fo.30). The primary driver of forest-related carbon sequestration (removal) is afforestation/reforestation activities; however, these figures peaked in 2012 and decreased gradually until 2016.

By contrast, since 2011, sequestration from forest management activities has increased, primarily due to 20 vegetation projects funded by the Emissions Reduction Fund over the past 5 years. This trend is observed through an upsurge in the Kyoto Australian Carbon Credit Unit (KACCU, Figure Fo.31), which represents abatement from activities that contribute to the nation's emission targets under the Kyoto protocol.

However, estimated net contribution of the fund to the sequestration in LULUCF is still relatively low. Compared to other sectors, including waste and agriculture, proportional contribution of forest-related activities is minimal. As indicated in Fo:01 (Area of forest by type and tenure), no area of new plantation has been established since 2011. In 2016, about 10% of total carbon emissions were sequestrated by forest-related activities (afforestation, reforestation, forest management and revegetation) (Figure Fo.29 and Figure Fo.30).

105. Keenan R, Nitschke CR 2016, 'Forest management options for adaptation to climate change: a case study of tall, wet eucalypt forests in Victoria's Central Highlands region', Australian Forestry, 79(2), pp. 96–107.
106. DELWP, 'Emissions reduction targets', Melbourne, Victoria, https://www.climatechange.vic.gov.au/reducing-emissions/emissions-targets Accessed 4 December 2018.

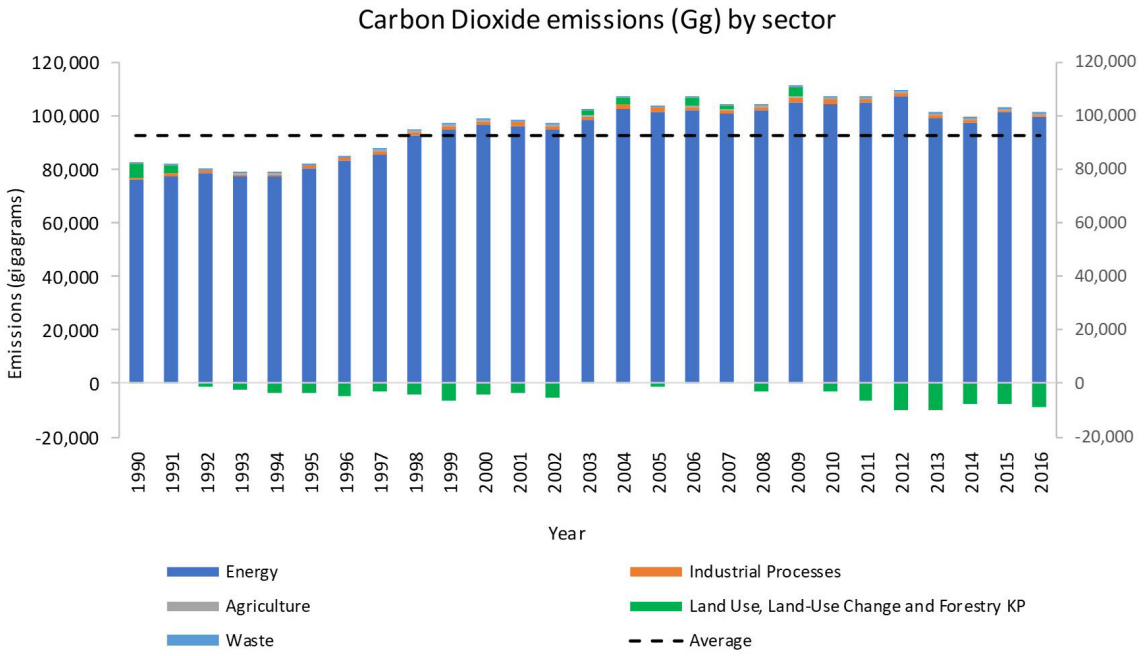


Figure Fo.29 GHG inventory (carbon dioxide) trend by sector in Victoria, 1990–2016

(Data source: Australian Government, Australian Greenhouse Emissions Information System, 2018)

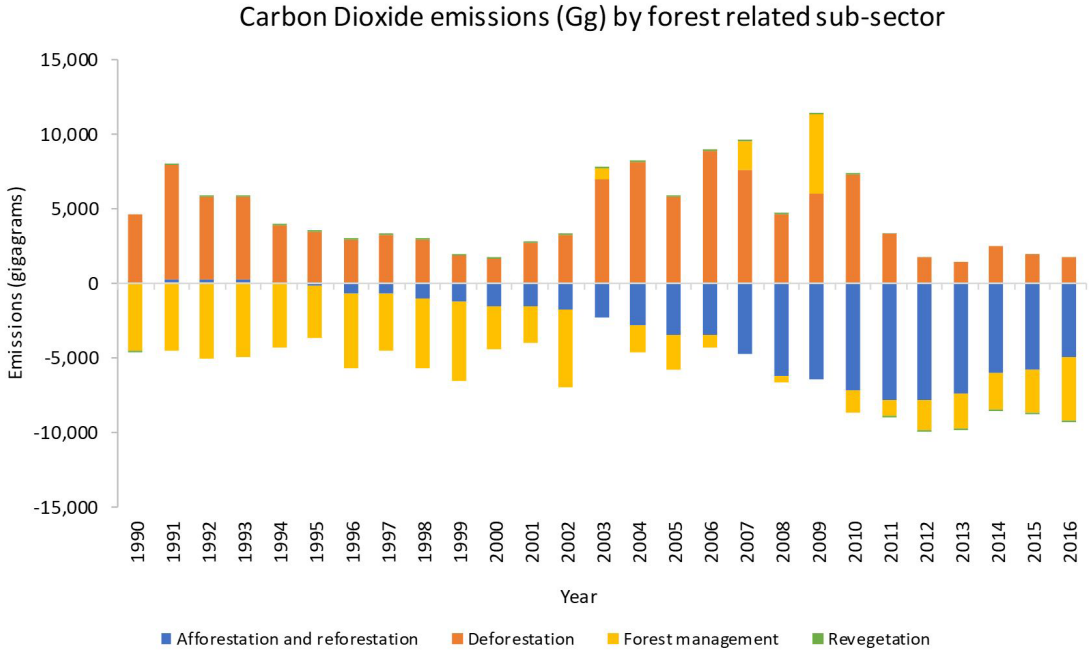


Figure Fo.30 GHG inventory (carbon dioxide) trend by subsector in Victoria, 1990–2016

(Data source: Australian Government, Australian Greenhouse Emissions Information System, 2018)

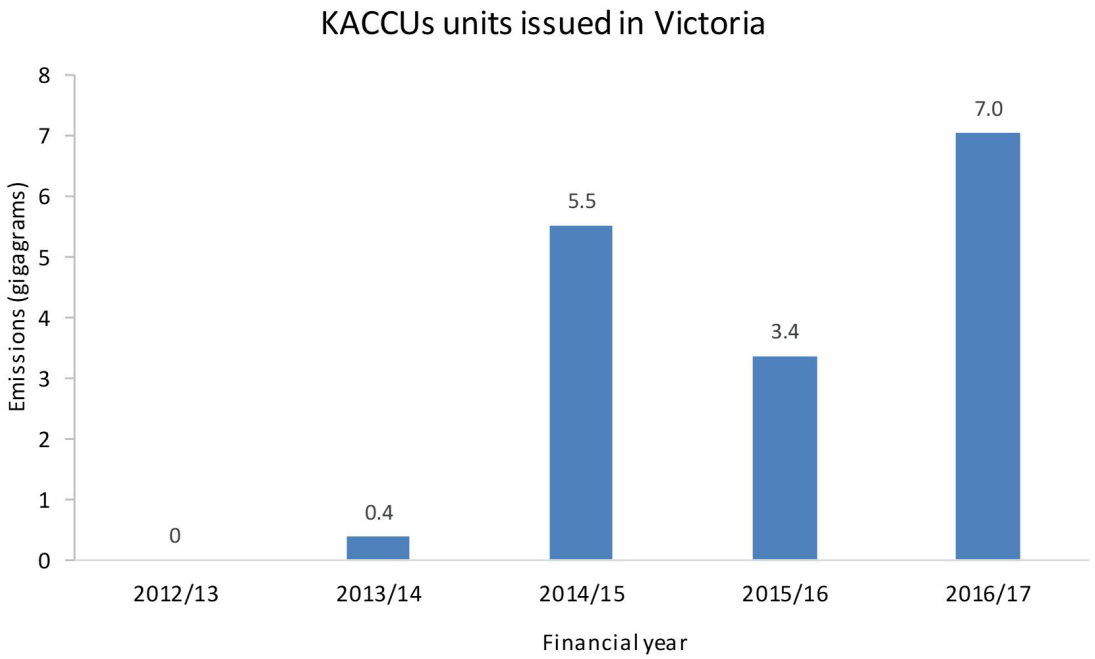


Figure Fo.31 Kyoto Australian Carbon Credit Units (KACCUs) using the 'vegetation method'

Note: Each KACCU unit represents one tonne of carbon dioxide equivalent (tCO_{2-e}) and converted to gigagrams to match Figure Fo.29 and Figure Fo.30.

(Data source: Australian Government, 2018)

Productive Capacity

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:12 Area and percentage of forest and net area of forest available and suitable for wood production	○	●	○	○	↘	DATA QUALITY Good

Data custodians DELWP, VicForests

The area of forest available for timber production, and forest types and age classes, are key planning input for determining long-term sustainable timber production rates. Monitoring trends in available forest area assists the forest sector in managing any change that will affect resource availability. It also provides insight into the changing balance of management objectives across the forested landscape.

Not all public forests are available for commercial native timber harvesting. Commercial trees are those large enough and close enough to a market to allow them to be harvested. In Victoria, most commercially viable native forests are in the east, including the Central Highlands. Data from VicForests (the Victorian government business responsible for the harvest, commercial sale and regrowing of native timber from state forests) shows that approximately 0.04% of native forests are harvested each year.

Table Fo.15 summarises the total available and unavailable area for timber production, in both state forests and parks and conservation reserves. It shows that unavailable area for timber production has increased by more than 200,000 hectares. This is because the area zoned for the protection of threatened species, such as Leadbeater's possum, has increased.

VicForests's Resource Outlook has also reduced the available timber production area in state forests. The Resource Outlook defines the volume of hardwood timber products from native forests to be made available to the market. It separates the species groups of timber supply, as either ash or mixed-species.[107]

Meanwhile, reduced availability of sawlog resource in areas such as the Central Highlands can be attributed to the effects of fire in estimates of sustained yield.[108, 109]

Overall, the trend indicates less timber production in state forests in the future. It is likely that more emphasis will be placed on activities associated with species conservation and carbon sequestration.

107. VicForests 2016, '2016-2017 Resource Outlook', Melbourne, Victoria http://www.vicforests.com.au/static/uploads/files/vicforests-resource-outlook-2016-17-wfasdtpknkdp.pdf Accessed 4 December 2018.

108. Lindenmayer DB 2017, 'Halting natural resource depletion: engaging with economic and political power', The Economic and Labour Relations Review, 28, pp. 41-56.

109. Lindenmayer DB 2018, 'Flawed forest policy: flawed Regional Forest Agreements', Australasian Journal of Environmental Management, 25, pp. 258-266.

Table Fo.15 Area available for harvest in native forest, 2006, 2008, 2012, 2016

Tenure	**Forest management zone**	Year and Area ('000 ha)				
		2006	**2008**	**2012**	**2014**	**2016**
Available						
State forest	General management zone	2,403	2,318	2,110	2026	2,112
	Special management zone	182	172	275	263	159
Parks and conservation reserves	Limited timber production	12	12	18	14	19
Total available		2,597	2,502	2,403	2,302	2,290
Not available						
State forest	Special Protection Zone	828	783	753	747	761
Parks and conservation reserves	No timber production	3,820	3,825	3,982	4,117	4,106
Total not available		4,648	4,608	4,735	4,864	4,862
Grand total		**7,245**	**7,110**	**7,138**	**7,166**	**7,153**

(Data source: DELWP, 2018)

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:13 Area of native forest harvested	○	○	●	○	→	DATA QUALITY: Good

Data custodians DELWP, DEDJTR, VicForests

Monitoring and assessing levels of timber harvest from native forest is an essential part of sustainable forest management. Tracking annual harvest rates in native forests against the available level of harvest rate is important for evaluating whether the current approach is sustainable.

The native-timber industry in Victoria produces a variety of wood products. These include the sawlogs that are used in furniture, construction and flooring, as well as logs of lower quality, used for firewood and pulp or paper production. Sawlogs are mostly sourced from the ash forests of north-eastern Victoria and Gippsland, but can also be derived from mixed-species forests with comparatively lower-quality timber. Mixed-species forests, which have two or more eucalypt species, are widespread among native Victorian forests.

During the harvest process, not all trees or tree elements are deemed sawlog-quality. Some trees are too young or knotty, and tree components such as branches of the upper trunk are considered unsuitable for sawlog production. This 'residual timber' constitutes approximately two-thirds of the harvested volume, and is primarily used for pulp/paper production with a smaller quantity sold as firewood. VicForests suppliestimber harvested from operations in eastern and western Victoria for sawlog processing to roughly 20 mills.[110] Around 90% of this timber is processed by the largest 10 mills.[111]

The mechanism used to determine the sustainable harvest level for native forests in Victoria is the Allocation Order 2013 (AO). The AO was created under Section 13 of the *Sustainable Forests (Timber) Act 2004*. The AO describes the location and extent of timber resources allocated to VicForests for harvest and sale. Timber-harvesting activity beyond the designated locations is not allowed.

The AO[112] has been reviewed three times since its introduction. The first review was of the 'Allocation to VicForests Order 2004' (the predecessor to the AO) to account for the impact of the major bushfires in 2006–07 and 2009.

Following a second review in 2010, the ash forest five-year harvest area limit was increased to allow VicForests to undertake salvage harvesting of the burnt forests following the 2009 bushfires. After another review in 2010, the accounting process used to monitor harvesting compliance with the AO changed from a net area tally to a gross coupe area tally. (Net area is the extent of timber harvesting: the actual area, or 'footprint' of tree felling. Gross coupe area is the area of state forest where timber resources are potentially available to VicForests for harvest and sale. It includes areas that can be harvested and areas that will not be harvested, including those protected under the *Code of Practice for Timber Production 2014*; areas where the timber available is not commercially suitable or commercially viable.)

Since August 2004, the AO has specified the maximum area that may be harvested, setting five-year harvest area limits. The AO currently species a five-year harvest area limit of 14,200 hectares (gross) for ash forest type, and 70,000 hectares (gross) for mixed-species forest type (Table Fo.18). The five-year harvest limit sets a harvest area 'ceiling'. Assuming a commercial forest life of about 100 years, the five-year harvest area limit is a maximum of around 5% of the total area in any five-year period.

110. VAGO 2013 'Managing Victoria's native forest timber resources', Melbourne, Victoria http://www.vicforests.com.au/static/uploads/files/20131211-timber-resources-wfsdlrklejjj.pdf Accessed 4 December 2018.
111. Ibid
112. Victorian Department Economic Development, Jobs, Transport and Resources, 'Timber Allocation Order', Victoria http://agriculture.vic.gov.au/agriculture/forestry/timber-allocation-order Accessed 4 December 2018.

The area of harvesting has not reached the five-year harvest area levels. The area of harvest compared to the AO are:

- In the five years up to June 2009, VicForests harvested some 66% of the ash forest and 57% of the mixed-species forest allocated for that five-year period for non-fire affected forest. In this period VicForests also undertook salvage harvesting of fire-affected forests (Table Fo.16).
- In the period before the current AO from 2009 to 2013 (four years), VicForests harvested some 71% of the ash forest five-year harvest area limit and 24% of the mixed-species forest five-year harvest area limit. VicForests undertook salvage harvesting of fire-affected forests (Table Fo.17 and Table Fo.19) in this period.
- In the period 2013 to 2017 (four years), VicForests harvested 66% of the ash forest five-year harvest area limit and 15% of the mixed-species forest five-year harvest area limit (Table Fo.18).

Table Fo.19 indicates that the area of state forest harvested between 2011–12 and 2016–17 was between 4,400 and 5,600 hectares per year. The average area harvested is less than 1% of the total area available for timber harvesting (see Fo:11 (Area and percentage of forest and net area of forest available and suitable for wood production)). Note that Table Fo.19 presents net area data – not gross area data – and so does not correlate with with Table Fo.17 and Table Fo.18.

The data for this report was finalised before 21 November 2018, when ABC News published an online article and broadcast a story on its *7.30* program speculating about potential timber-harvesting activity by VicForests outside its allocation boundary.[113, 114] However, on 17 November 2018, a joint statement provided to the ABC from the Minister for Energy, Environment and Climate Change, and the Minister for Agriculture, stated that DELWP confirmed that no harvesting occurred in protected areas,[115] and that the apparent discrepancy ABC News identified was due to differences between the legally enforceable map (see appendix 1 of the AO) and a spatial data file provided to the ABC.[116]

The re-elected Andrews Labor Government has committed to providing more detailed spatial data maps for any future AOs.[117] DEDJTR,[118] VicForests[119] and DELWP[120] have also responded to this issue. In addition, the Victorian Government ordered an independent review of timber-harvesting regulations. The recommendations of the independent review will be released publicly.[121] The Office of the Commissioner for Environmental Sustainability will consider this issue in the next reporting cycle, potentially developing a new indicator to address the specific issue of allocation boundaries.

113. ABC NEWS, 'Australia's endangered forests are being 'stolen' and sold in hardware and office stores' https://www.abc.net.au/news/2018-11-21/victorian-forests-appear-to-have-been-logged-illegally/10496424#statements Accessed 4 December 2018.
114. ABC 7.30 Report, 'Government-owned logging company accused of illegally logging state forest' https://www.abc.net.au/7.30/government-owned-logging-company-accused-of/10520270 Accessed 4 December 2018.
115. Joint statement from the Minister for Environment Lily D'Ambrosio and Minister for Agriculture Jaala Pulford, November 17: https://www.documentcloud.org/documents/5194121-Joint-Ministerial-Response.html Accessed 4 December 2018.
116. Response from DELWP spokesperson, November 16 and 18: https://www.documentcloud.org/documents/5194115-DELWP-Response.html Accessed 4 December 2018.
117. Joint statement from the Minister for Environment Lily D'Ambrosio and Minister for Agriculture Jaala Pulford, November 17: https://www.documentcloud.org/documents/5194121-Joint-Ministerial-Response.html Accessed 4 December 2018.
118. Response from the Department of Economic Development, Jobs, Transport and Resources (DEDJTR), November 16: https://www.documentcloud.org/documents/5194120-DEDJTR-Response.html Accessed 4 December 2018.
119. Response from VicForests spokesperson, November 16: https://www.documentcloud.org/documents/5194125-VicForests-Response.html Accessed 4 December 2018.
120. Response from DELWP spokesperson, November 16 and 18: https://www.documentcloud.org/documents/5194115-DELWP-Response.html Accessed 4 December 2018.
121. Joint statement from the Minister for Environment Lily D'Ambrosio and Minister for Agriculture Jaala Pulford, November 17: https://www.documentcloud.org/documents/5194121-Joint-Ministerial-Response.html Accessed 4 December 2018.

Table Fo.16 Harvest area (net hectares) 2004–05 to 2008–09 (five years) compared to the Allocation to VicForests Order 2004.

	2004–05	2005–06	2006–07	2007–08	2008–09	Total	AO max. area for period 1 (5 yrs)	Total area harvested compared to AO (%)
Ash	1,271	1,078	850	1,022	933	5,154	7,810	66
Mixed-species	2,520	2,701	2,325	2,366	2,424	12,336	21,660	57

Note: Additional harvest in this time included 6,110 hectares of fire-affected and salvage harvesting. The AO provided a total allocation of 56,540 hectares of fire-affected and salvage forest stands.

(Data source: DSE1122)

Table Fo.17 Gross coupe area 2009–10 to 2012–13 (four years) compared to AO 2013

	2009–10	2010–11 (gross hectares)	2011–12 (gross hectares)	2012–13 (gross hectares)	Total (4 yrs)	AO five-year harvest area limits (5 yrs)	Total area harvested compared to AO (%)
Ash	3,712	2,776	3,238	2,594	12,629	17,400	71
Mixed-species	5,880	5,032	3,525	2,724	9,332	71,800	24

Note: The Gross Coupe Area listed above includes forest stands impacted by fire. The use of gross area as the Allocation Order harvest area accounting parameter began in May 2010. In this table, the gross area harvest in 2009–10 (before May 2010) is provided.

(Data source: DEDJTR (2017). Internal)

Table Fo.18 Gross coupe area 2013–14 to 2016–17 (four years) compared to AO 2013

	2013–14 (gross hectares)	2014–15 (gross hectares)	2015–16 (gross hectares)	2016–17 (gross hectares)	Total (4 yrs)	AO five-year harvest area limits (5 yrs)	Total area harvested compared to AO (%)
Ash	2,090	2,273	2,583	2,386	9,332	14,200	66
Mixed-species	2,034	2,820	2,847	3,003	10,704	70,000	15

(Data source: VicForests (2018) VicForests annual harvesting and regeneration report 2016–17)

122. State of Victoria 2010, 'Monitoring annual harvesting performance in Victoria's State forests 2008-09', Melbourne, Victoria.

Table Fo.19 Net area (ha) harvested by regime to 2016–17

Year	Net area harvested (ha)					
	Clear fall regime [a]	Thinning regime	Salvage regime	Seed Tree	Selection regime	Total (all regimes)
2011–12	1,400	1,200	100	2,200	700	**5,600**
2012–13	1,500	1,800		1,400	800	**5,500**
2013–14	1,500	1,200		1,400	500	**4,600**
2014–15	1,300	1,000		1,700	400	**4,400**
2015–16	1,100	1,700		1,700	300	**4,800**
2016–17	900	1,500		1,800	600	**4,800**

(a) Clear fall includes Regrowth Retention Harvesting method[123]

(Data source: VicForests, 2018)

123. VicForests, 'Regrowth retention harvesting', Melbourne, Victoria http://www.vicforests.com.au/leadbeaters-possum1/regrowth-retention-harvesting-1 Accessed 4 December 2018.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:14 Annual production of wood products from State forests compared to sustainable harvest levels	○	○	●	○	↘	DATA QUALITY Good

Data custodians DELWP, VicForests

Of 7.9 million hectares of Crown land in Victoria, about 3.7 million hectares are listed as national parks and reserves, and 3.2 million hectares of multi-use state forest. Both tenures have approximately 3 million hectares of forest cover. According to 2016-17 Resource Outlook, approximately 450,000 hectares in eastern Victoria are considered commercially suitable for timber production;[124] however, only a fraction on this area is actually harvested, with approximately 0.04% (gross area) commercially harvested each year since 2010.

Data shown in Table Fo.20 and Figure Fo.32 indicates that total timber annual production from state forests has been gradually decreasing. The production rate for sawlogs has decreased over the past two decades, from 729,000 m^3 in 1996–97 to 299,740 m^3 in 2016–17. Pulpwood production has decreased at a similar rate to sawlogs since 2004–05. However, production of other products, such as 'E grade' (low grade) logs and cull logs, has increased. Since 2012–13, overall production of wood products from state forests has been stable.

The Resource Outlook (RO) is a forecast of available sawlog hardwood timber in native forests to be commercially supplied from state forests in eastern Victoria.[125] VicForests has a statutory obligation to achieve sustainable production of timber products from native forests. Although the available Ash D+ sawlog volume is expected to reduce between 2020–21 and 2029–30, RO forecasts a consistent supply in the range of 100,000 m^3 until 2029–30 for mixed-species D+ sawlog.[126] The reduction in Ash D+ sawlog will be approximately 90,000 m^3 per annum compared to the 2013 RO. VicForests suggests that this is mainly due to:

- increased protection for Leadbeater's possum and other threatened species
- spatial fragmentation of the remaining available forest, as a result of the proximity and density of Leadbeater's possum populations
- increased protection (12,000 m^3/annum) of old-growth forest (all pre-1900 ash stands are in a forest management area)
- the removal of forest from the model that VicForests considers unlikely to be able to be accessed due to community and/or market concerns for ecological values.[127]

Sustainable harvest levels have been more than halved over the past decade. A 2017 VEAC report, showing modelling of predicted climate change impacts, suggests that by the end of the century, standing volume and stand density will be reduced by 15%.[128] This would further reduce resource outlook.

VicForests has a statutory obligation to sustainably produce timber from native forests. It takes into account the risk of bushfires and excludes areas of high community interest, such as those with Leadbeater's possum colonies, in its modelling for commercial sawlog timber supply.[129]

124. VicForests, 'Area Statement', Melbourne, Victoria http://www.vicforests.com.au/planning-1/area-statement Accessed 4 December 2018.
125. VicForests 2016, '2016-2017 Resource Outlook', Melbourne, Victoria http://www.vicforests.com.au/static/uploads/files/vicforests-resource-outlook-2016-17-wfasdtpknkdp.pdf Accessed 4 December 2018.
126. Ibid
127. VicForests 2017, 'Annual Report 2016-17', Melbourne, Victoria http://www.vicforests.com.au/static/uploads/files/vicforests-2016-17-annual-report-wfsjtsyiepto.pdf Accessed 4 December 2018.
128. VEAC 2017, 'Fibre and wood supply: Assessment report', Melbourne, Victoria http://veac.vic.gov.au/investigation/fibre-and-wood-supply-assessment/reports Accessed 4 December 2018.
129. VicForests 2016, '2016-2017 Resource Outlook', Melbourne, Victoria http://www.vicforests.com.au/static/uploads/files/vicforests-resource-outlook-2016-17-wfasdtpknkdp.pdf Accessed 4 December 2018.

There has been some concern about sustainable timber production predictions given strong uncertainty about bushfires and previous production rates.[130, 131, 132] VicForests has therefore increased exclusion areas, where timber harvesting is not allowed, leading to a reduction in wood production.[133]

Moreover, the age structure of the ash forests – mainly mountain ash (*Eucalyptus regnans*) and alpine ash (*Eucalyptus delegatensis*) species – in the Central Highlands in Victoria is heavily imbalanced due to landscape-scale bushfires, including the 1939 'Black Friday' bushfires and 2009 Black Saturday bushfires (Figure Fo.33). In eastern Victoria, where most commercial native-timber harvesting takes place, most forest stands have regenerated from the 1939 bushfires. However, impacts of the 2009 fires intensified the imbalance of age-class distribution of ash species forests in eastern Victoria. As the Victorian sawlog industry currently relies heavily on the 1939 regrowth ash forests, this will cause a significant decrease of available sawlog production from native forests for a few decades.

130. Burgman MA, Church R, Ferguson I, Giijsbers R, Lau A, Lindenmayer DB, Loyn RH, McCarthy M, Vandenberg W 1994, 'Wildlife planning using FORPLAN: a review and examples from Victorian forests', Australian Forestry, 57, pp. 131-140.
131. Blair D, McBurney LM, Blanchard W, Banks SC, Lindenmayer DB 2016, 'Disturbance gradient shows logging affects plant functional groups more than fire', Ecological Applications, 26, pp. 2280-2301.
132. Blair D, McBurney L, Lindenmayer DB, Banks S, Blanchard W 2017, 'The Leadbeater's Possum review', The Australian National University, Canberra, Australia.
133. VicForests 2016, '2016-2017 Resource Outlook', Melbourne, Victoria http://www.vicforests.com.au/static/uploads/files/vicforests-resource-outlook-2016-17-wfasdtpknkdp.pdf Accessed 4 December 2018.

Table Fo.20 Annual production of wood products from state forests, 1996–97 to 2016–17

Year	Volume (cubic metres, m^3)			
	Sawlogs[A]	Pulpwood	Other products[B]	Total
1996–97	729,000	1,033,000	N/A	1,762,000
1997–98	804,000	1,120,000	N/A	1,924,000
1998–99	821,000	1,165,000	N/A	1,986,000
1999–2000	820,000	1,403,000	N/A	2,223,000
2000–01	667,000	1,580,000	N/A	2,247,000
2001–02	682,000	1,365,000	111,000	2,158,000
2002–03	638,000	1,208,000	117,000	1,963,000
2003–04	[C]530,000	1,291,000	112,000	1,933,000
2004–05	[D,E] 583,000	1,335,000	123,000	2,041,000
2005–06	[D,F] 497,000	1,329,000	109,000	1,935,000
2006–07[G]	428,000	1,241,000	124,000	1,793,000
2007–08	433,000	1,478,000	147,000	2,058,000
2008–09	413,000	1,141,000	158,000	1,712,000
2009–10	443,000	1,250,000	172,000	1,865,000
2010–11	329,525	1,210,024	213,600	1,753,149
2011–12	290,546	980,889	182,503	1,453,938
2012–13	332,054	750,633	189,574	1,272,261
2013–14	304,651	756,425	209,742	1,270,818
2014–15	306,672	758,858	241,205	1,306,735
2015–16	344,746	685,612	285,305	1,315,663
2016–17	299,740	703,730	260,901	1,264,371

A: Prior to 2004–05, sawlog volume is expressed as net volume (gross volume minus allowances for defects).

B: Other products include E-grade (low grade) logs and cull logs. Data not available before 2001–02.

C: Includes 118,000 m^3 fire salvage; normal harvest was 412,000 m^3.

D: Gross sawlog volume

E: Includes 50,000 m^3 fire salvage; normal harvest was 533,000 m^3.

F: Includes 27,000 m^3 fire salvage; normal harvest was 470,000 m^3.

G: Over six years (2006–07 to 2011–12), approximately 650,000 m^3 of D+ sawlog was harvested from areas burnt by fire.

(Data source: VicForests[134], 2018)

134. The data is derived from Harvesting History Shapefile from VicForests

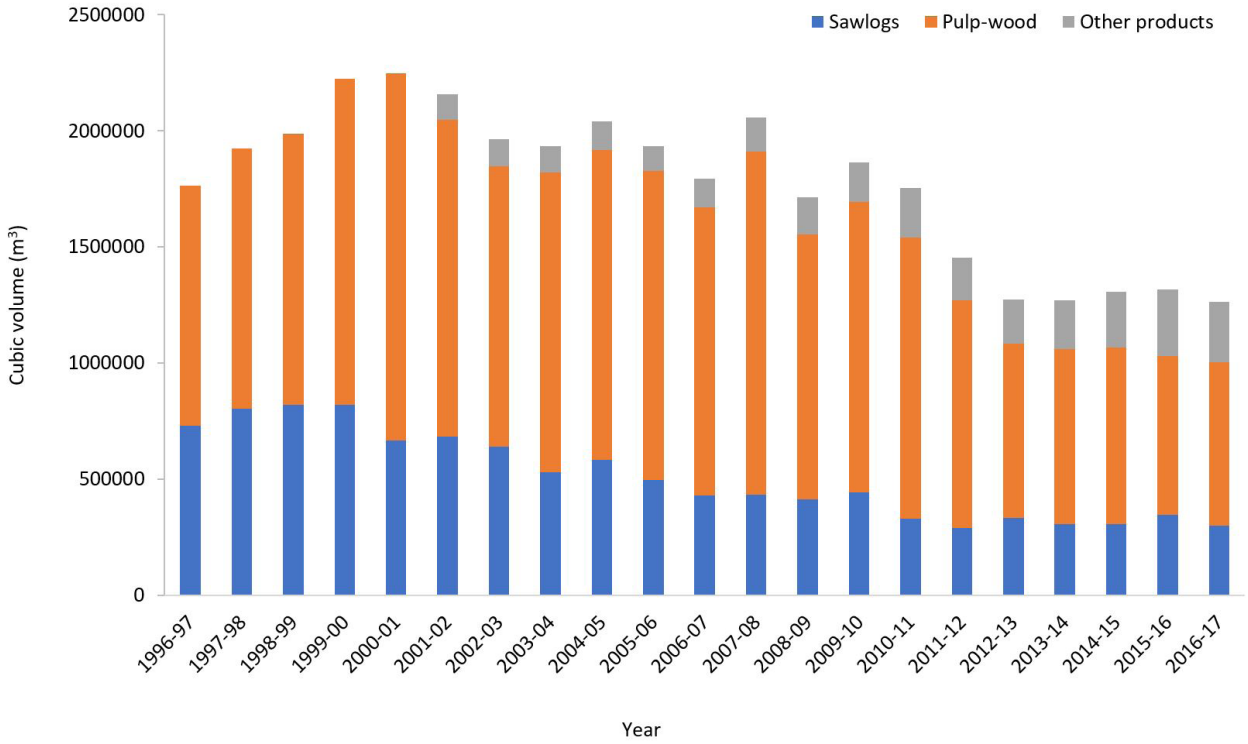


Figure Fo.32 Annual production of wood products from state forests by sawlogs, pulpwood and other products, 1996–97 and 2016–17

(Data source: VicForests, 2018)

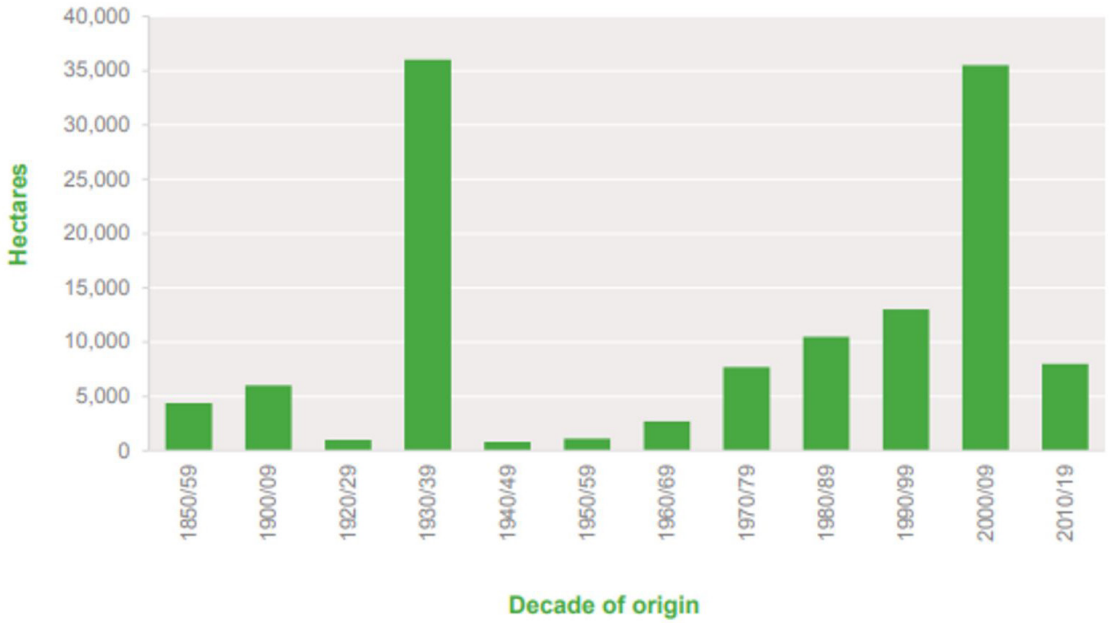


Figure Fo.33 Age class distribution of ash forests

(Data source: VEAC[135], 2018)

135. VEAC 2017, 'Fibre and wood supply: Assessment report', Melbourne, Victoria http://veac.vic.gov.au/investigation/fibre-and-wood-supply-assessment/reports Accessed 4 December 2018.

Firewood

The collection of firewood is allowed in Victoria's state forest and in some forest parks. For many Victorians, firewood is an important energy source for heating and cooking. Most of the firewood used is collected by households for domestic use; the rest is taken by commercial firewood collectors. Firewood collection within the forest estate is restricted to certain areas and times of the year. In September 2011, the licence system for domestic firewood collection was discontinued, but licences are still required for commercial collection. Because of the discontinuation, the amount of domestic firewood collected in state forests after 2011–12 is unknown (Table Fo.21). In terms of commercial firewood, total firewood collected in state forests and some forest parks fluctuated between 2001–02 and 2012–13.

Many invertebrate species depend on the availability of dead wood for survival. It is therefore important to monitor and respond to trends in firewood use as part of sustainable forest management. Although volume of firewood will not be an indicator of threat status to an overall ecosystem, it is difficult to assess the impacts of ongoing firewood collection on forest ecosystems.

Table Fo.21 Volume (m^3) of firewood collected with domestic and commercial licences in state forests, 2001-02 to 2016-17

Year	Domestic	Commercial	Total
2001–02	48,207	12,256	60,463
2002–03	54,826	16,022	70,848
2003–04	54,454	18,736	73,190
2004–05	56,660	26,980	83,640
2005–06	51,330	14,149	65,479
2006–07	35,926	9,061	44,987
2007–08	24,484	12,184	36,668
2008–09	24,365	12,530	36,895
2009–10	33,645	8,348	41,993
2010–11	38,981	6,106	45,087
2011–12*	11,652	6,400	11,747
2012–13	N/A	18,165	18,165
2013–14	N/A	14,979	14,979
2014–15	N/A	26,041	26,041
2015–16	N/A	31,971	31,971
2016–17	N/A	35,720	35,720

* The volume of domestic firewood collected is unknown after 2011–12, as the requirement to licence domestic collection was discontinued.

(Data source: VicForests, 2018)

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:15 Proportion of timber harvest area successfully regenerated by forest type	○	○	●	○	→	DATA QUALITY Good

Data custodian DEDJTR, VicForests

To achieve a sustainable level of timber production, regeneration following timber-harvesting activities (post-harvest regeneration) is a key part of maintaining the productive capacity of forests. Monitoring the success of forest regeneration informs understanding of the future availability of forest resources and any impacts long-term forest productivity. This information supports forest policy and planning activities, and continual improvement in regeneration practices.

The *Code of Practice for Timber Production 2014* (the code) determines that all state forest areas subject to timber-harvesting operations will be regenerated to standards that approximate the original forest composition. Timber harvest managers are required to regenerate all harvested areas.

Successful regeneration is usually achieved at the first attempt 85% to 95% of the time. Failure of regeneration can be due to a range of environmental factors, including death from drought, browsing of seed or seedlings (for example, by wallabies or insects), and frost and snow damage. For areas not regenerated successfully the first time, the harvest manager is required to undertake further regeneration treatments until the minimum standards are met.

The 'Management standards and procedures for timber-harvesting operations in Victoria's state forests 2014', incorporated in the code lists the minimum regeneration standards required. The standards outline three regeneration features:

1. minimum 65% of plots stocked (standard intensity)
2. no discrete unstocked areas greater than one hectare in even aged stands, or greater than two hectares in uneven aged stands
3. at least 10 acceptable seedlings/coppice of those eucalypt species present on the site prior to harvesting must be present on the regenerated site.

The code also lists the survey techniques that must be followed by the harvest manager to confirm regeneration success. The surveys are to be undertaken 15 to 30 months after seedfall and/or sowing in even aged stands, and 15 to 36 months after seedfall in uneven aged stands.

Table Fo.22 indicates the total harvested area of native forest between 2011–12 and 2016–17, and the total harvested area effectively regenerated between 2011–12 and 2016–17. The areas reported as harvested and the areas regenerated for each year relate to different areas given the time period required to report on regeneration success. Between 2011–12 to 2016–17, 2,059 more hectares have been harvested than regenerated. However, DEDJTR states that this does not indicate that sustainable harvest has not been achieved. This data needs to be carefully monitored to ensure that the successful post-harvest timber harvest is fully achieved.

Note that the regeneration data supplied is for eastern Victoria only. Generally, no regeneration is required for harvesting in western Victoria as the harvesting operations are not clearing-style harvesting, but thinning-style harvesting.

The 2013 audit report of the Victorian Auditor-General's Office (VAGO), *Managing Victoria's Native Forest Timber Resource*, found that the harvest manager, VicForests, was meeting the required regeneration standards. However, VAGO recommended improvements in reporting to better align the reporting of harvesting and its corresponding regeneration.

Table Fo.22 Total area of native forest harvested, and effectively regenerated, 2011-12 to 2016-17

Year	Native forest area harvested (ha)	Native Forest Area effectively regenerated (ha)	Net area regenerated
2011–12	4,298	4,055	–243
2012–13	3,327	3,397	70
2013–14	2,981	2,242	–739
2014–15	4,331	3,459	–872
2015–16	2,900	2,426	–474
2016–17[136]	2,800	2,999	199
Total	20,637	18,578	–2,059

(Data source: DEDJTR[137] and VicForests[138], 2018)

136. VicForests and DEDJTR, 'Cengea Site establishment cube'.
137. Department of Economic Development, Jobs, Transport and Resources, 'Harvest History database (LOGSEASON)', Melbourne, Victoria.
138. VicForests, '2015-16 sustainability report', Melbourne, Victoria http://www.vicforests.com.au/about-vicforests/corporate-reporting-1/sustainability-report-2016 Accessed 4 December 2018.

Legal, Institutional and Economic

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:16 Extent to which the legal framework (laws, regulations, guidelines) supports the conservation and sustainable management of forests	○	○	●	○	↗	DATA QUALITY Fair

Data custodian DELWP

A legal framework with laws, regulations and guidelines is necessary to support continuous improvements in sustainable forest management. Such a system assists to establish transparency and public participation in policy and decision-making processes.

There are currently 33 legislations that regulate forest management in Victoria, which creates legislative complexity (Table Fo.23 summarises the legislation, the tenure to which they apply, and lists key amendments made during the reporting period). VEAC seeks to address the problem of legislative complexity in the final report of its *Statewide Assessment of Public Land*, released in May 2017. The report includes several recommendations to reform the public land legislative framework, in particular changes to the:

- *Land Act 1958*
- *Forests Act 1958*
- *National Parks Act 1975*
- *Crown Land (Reserves) Act 1978*.

The rationale for legislative reform is to strengthen, modernise and simplify Crown land legislation to ensure it is responsive to modern challenges and demands. The Victorian Government has accepted, in principle or in part, all recommendations made by VEAC, including committing to rewriting the Crown land legislation over the next four years.

Beekeeping

Between 2013 and 2018, the regulation of beekeeping in Victoria was changed. In March 2016, primary Land Acts were amended to allow for bee-site licences to apply for a longer period of up to 10 years.[139] Administrative processes were altered to enable the revision of licence terms and conditions and the streamlining of licence expiration. These regulatory changes include greater protections between bee sites and other public land boundaries through the requirement of an 800-metre buffer from the centre of a bee site to the boundary of wilderness parks, wilderness zones, reference areas and natural catchment areas.[140]

139. Victorian Government 2016, 'Authorised version No.128, *Land Act 1958*. No 6284 of 1958: Authorised version incorporating amendments as at 19 September 2016', Melbourne, Victoria http://www.legislation.vic.gov.au/domino/Web_Notes/LDMS/LTObject_Store/ltobjst9.nsf/DDE300B846EED9C7CA257616000A3571/305521026ADDC945CA258030001C8255/$FILE/58-6284aa128%20authorised.pdf Accessed 4 December 2018.

140. *Crown Land Legislation Amendment (Canadian Regional Park and Other Matters) Act 2016*. http://www.legislation.vic.gov.au/Domino/Web_Notes/LDMS/PubStatbook.nsf/51dea49770555ea6ca256da4001b90cd/21CF72B25E443BA2CA257F8C0019032A/$FILE/16-012aa%20authorised.pdf Accessed 4 December 2018.

Table Fo.23 Main legislation relevant to sustainable forest management in Victoria

Agency	Legislation	Summary of legislation purpose	Applicable tenure	Key amendments, 2013-17
DELWP	*Conservation, Forests and Lands Act 1987*	To provide a framework for a land management system, to make necessary administrative, financial and enforcement provisions, and to establish a system of land management co-operative agreements	Public/ Private (where applicable)	Streamlining of provisions relating to the making of codes of Practice
DELWP, DEDJTR	*Sustainable Forests (Timber) Act 2004*	To provide a framework for sustainable forest management and sustainable timber harvesting in state forests	State forests	Key amendments during this period are listed below. In 2013: • streamline AO process by vesting timber with VicForests • responsibility for Timber Release Plan approval transferred to VicForests • removal of timber-harvesting operator licences. In 2014: • Establish Timber Harvesting Safety Zones
Victorian Plantations Corporation	*Victorian Plantations Corporation Act 2003*	To establish the Victorian Plantations Corporation to manage state plantations and to require that timber harvesting comply with a code of practice	State forests	No amendments made since 7 June 2012
DELWP	*Forests Act 1958*	To provide for the management and protection of state forests, including timber harvesting and fire management	State forests and all public land for fire matters	Allowance for collection of domestic firewood without a permit, in certain areas, at specified times
DELWP	*Forests (Fire Protection) Regulations 2014*	To provide for the protection of state forests, national parks and protected public land from damage by fire	National parks (including state parks), state forests and protected public land	No amendments
DELWP	*Forests (Recreation) Regulations 2010*	To regulate camping and other activities in certain public land tenures including forests reserves and forest parks	Public land	No amendments

Agency	Legislation	Summary of legislation purpose	Applicable tenure	Key amendments, 2013-17
DELWP	*Flora and Fauna Guarantee Act 1988*	To establish a legal and administrative structure to enable and promote the conservation of Victoria's native flora and fauna, and to provide for a choice of procedures which can be used for the conservation, management or control of flora and fauna and the management of potentially threatening processes	All	No amendments
DELWP	*Catchment and Land Protection Act 1994*	To set up a framework for the integrated management and protection of catchments, to encourage community participation in the management of land and water resources, and to set up a system of controls on noxious weeds and pest animals	All	No amendments
DELWP	*Land Act 1958*	To set out the law relating to the sale and occupation of Crown lands, including provision for a range of licences	Public land	Provision for uniform licensing of bee sites on most Crown land
Parks Victoria	*National Parks Act 1975*	To provide a framework for establishment and management of national parks and other parks	Public national parks and other parks and reserves referred to in the Act	• establishment of new park areas including Lake Tyers Park (8,680 ha) • additional areas added to Great Otway National Park • introduction and removal of power for Minister to grant leases of up to 99 years over certain areas • introduction of total prohibition on cattle grazing in alpine national parks and in the six river redgum national parks.
Parks Victoria	*Parks Victoria Act 2018*	To establish Parks Victoria. There were major changes to the legislative framework, which resulted in having a broad range of direct powers to manage Victoria's parks and waterways	National parks and other conservation reserves	No amendments

Agency	Legislation	Summary of legislation purpose	Applicable tenure	Key amendments, 2013-17
Environment Protection Authority Victoria	*Environment Protection Act 1970*	To establish an Environment Protection Authority and to provide a framework for preventing pollution and environmental damage by setting environmental quality objectives and establishing programs to meet them	All	In 2017, a new Environment Protection Act was passed by the Parliament of Victoria.[141] The Environment Protection Act 2017 also has the function of establishing the Environment Protection Authority. The two Acts are operating together currently, in the transitional period for the reforms.
Environment Protection Authority Victoria	*Environment Effects Act 1974*	To provide a framework for preparation of an Environmental Effects Statement for public works that the Minister considers capable of having a significant effect on the environment	All	No amendments
DELWP	*Heritage Rivers Act 1992*	To make provision for Victorian heritage rivers by providing for the protection of public land, in particular parts of rivers and river catchment areas in Victoria that have significant nature conservation, recreation, scenic or cultural heritage attributes	Public land	No amendments
DELWP	*Crown Land (Reserves) Act 1978*	To provide for the reservation of Crown lands for certain purposes and for the management of such reserved lands	Reserved Crown land	Key amendments are creation of two new regional parks
DELWP	*Reference Areas Act 1978*	Provides for the protection, control and management of certain special areas of Crown land to be preserved in their natural state, as far as is possible, due to their ecological interest and significance	Public	No amendments

141. The Parliament of Victoria 2017, 'Environment Protection Act 2017: No. 51 of 2017', Melbourne, Victoria http://www.legislation.vic.gov.au/Domino/Web_Notes/LDMS/PubStatbook.nsf/51dea49770555ea6ca256da4001b90cd/ABB3C4D755B99F3BCA2581C30009DE28/$FILE/17-051aa%20authorised.pdf Accessed 4 December 2018.

Agency	Legislation	Summary of legislation purpose	Applicable tenure	Key amendments, 2013-17
DELWP, local government	*Planning and Environment Act 1987*	To establish a framework for planning the use, development and protection of land in Victoria in the present and long-term interests of all Victorians. Provides for the protection of natural processes and genetic diversity, and conservation of places of scientific, aesthetic or special conservation value. Requires administration and enforcement of planning schemes that specify appropriate controls on the use, development and protection of land, including timber production on private land	All	No amendments
CFA	*Country Fire Authority Act 1958*	To confer on the authority a responsibility to prevent and suppress fire on all land (urban and rural) outside the Melbourne Metropolitan Fire District, but does not include any forest, national park or protected public land	Private	No amendments
DEDJTR	*Climate Change Act 2017*	To separate ownership of the land from ownership of the trees on the land, and provide legal security to the 'Forest Property Owner'. Recognises carbon sequestration rights and enables ownership of these rights separately from the trees and the land	All forested land	No amendments
DELWP	*Road Management Act 2004*	To establish a coordinated management system for public roads to promote safe and efficient state and local public road networks and the responsible use of roads	Public land	No amendments
DELWP	*Safety on Public Land Act 2004*	Provides for public safety in state forests by providing for the establishment and enforcement of public safety zones	State forests	No amendments

Agency	Legislation	Summary of legislation purpose	Applicable tenure	Key amendments, 2013-17
DELWP	*Forests (Wood Pulp Agreement) Act 1996*	To ratify an agreement between the Minister administering the Forests Act 1958 and AMCOR Limited with respect to the supply of pulpwood for the manufacture of wood pulp and for other purposes	Public	No amendments
DELWP	*Land Conservation (Vehicle Control) Act 1972*	To makes provisions for vehicular traffic on public land, as well as the prevention of soil erosion on, and damage to, public land	Public	Increases in maximum penalties for offences
Department of Premier and Cabinet; DELWP	*Aboriginal Lands Act 1991*	To authorise the granting of the reservations and Crown Grants of certain lands for Aboriginal cultural and burial purposes	Public	No amendments
Department of Premier and Cabinet	*Aboriginal Heritage Act 2006*	To provide for the protection of Aboriginal cultural heritage in Victoria.	All	Major amendments were made to the Act between 2013 and 2018 including changes to: • determine whether a mandatory cultural heritage management plan (CHMP) is required • Change CHMP from a guidance document to an approval document • require involvement of Traditional Owners where there is no Registered Aboriginal Party (RAP) • expand liability for offences and civil penalty provisions • allow for disclosure of Aboriginal heritage surveys.
Department of Justice and Regulation	*Traditional Owner Settlement Act 2010*	To provide for the making of negotiated agreements for land claims between Traditional Owner groups and government	All	No amendments

Agency	Legislation	Summary of legislation purpose	Applicable tenure	Key amendments, 2013-17
DELWP	*Catchment and Land Protection Act 1994*	To set up a framework for the integrated management and protection of catchments and to encourage community participation in the management of land and water resources	All	No amendments
DELWP	*Climate Change Act 2010*	To support climate policy, including the state's adaptation planning framework.	All	No amendments
DELWP	*Marine and Coastal Act 2018*	To provide for coordinated strategic planning and management for the Victorian coast	All	No amendments
DELWP	*Water Act 1989*	To provide for the integrated management of all elements of the terrestrial phase of the water cycle and to promote the orderly, equitable and efficient use of water resources	All	No amendments
DELWP	*Wildlife Act 1975*	To establish procedures, and provide for banning notices and exclusion orders in order to promote the protection and conservation of wildlife, and the prevention of taxa of wildlife from becoming extinct	All	No amendments

(Data source: DELWP, 2018)

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:17 Extent to which the institutional framework supports the conservation and sustainable management of forests	○	○	●	○	↘	DATA QUALITY Fair

Data custodian DELWP

Institutional frameworks aim to encourage certain activities or behaviours within a sector. The processes, resources and activities provided through institutional frameworks create an environment that influences how effectively and efficiently the aims of the framework are delivered. The level of commitment and ability of the framework to produce outcomes can be monitored through the extent to which current conservation and sustainable forest management aims are being supported.

This indicator provides data on the governance framework to support conservation and sustainable forest management of public and private forests. The framework includes laws, plans, policies, public engagement and participation. Table Fo.24 provides an overview of the institutional framework elements in Victoria for conservation and sustainable forest management in both public and private forests. Table Fo.25 outlines key institutions involved in each element of the framework and key activities undertaken during the reporting period.

Table Fo.24 Institutional framework elements in Victoria for conservation and sustainable forest management, 2013-17

Element	Public*	Private*	Responsible organisation	Key activities in period
Administrative arrangements	Yes	Yes	DELWP; local government; Parks Victoria; VicForests; Catchment Management Authorities	Tenure transfer – state forest to Park
Public engagement and participation	Yes	Yes	DELWP; local government	
Periodic forest-related planning	Yes	No	DELWP	
Periodic assessment of forest values	Yes	No	DELWP; VicForests	Victorian Forest Monitoring Program
Periodic review of forest-related policy	Yes	Yes	DELWP	RFA review
Relevant skills development and maintenance	Yes	Yes	Universities; Registered Training Organisations; DELWP	
Infrastructure	Yes	Part	DELWP; Parks Victoria; local government	Access roads Recreation and fire management infrastructure
Law enforcement	Yes	Yes	DELWP; Parks Victoria; local government	Timber-harvesting compliance General forest and park compliance

* 'Yes' or 'no' indicates whether the relevant element has been conducted. 'Part' indicates partial completion

(Data source: DELWP, 2018)

The Victorian Government is responsible for ensuring that commercial timber harvesting activities comply with Victoria's environmental regulatory framework. Harvest coupes are assessed by auditors, and if non-compliance is found, the magnitude of impact is determined based on the following categories: severe, major, moderate, minor, negligible and no impact. More information is available on the DELWP website.[142]

Table Fo.25 demonstrates the overall assessment results of compliant and non-compliant audit elements, by different environmental impact categories, between 2007 and 2017. Audits since 2014 have targeted elements of the regulatory framework that have been assessed as having a 'high risk' of causing environmental harm. While the high-risk elements have been targeted, VicForests has indicated a high level of compliance with

142. DELWP, 'Forest audits', Melbourne, Victoria https://www.forestsandreserves.vic.gov.au/forest-management/forest-audits Accessed 4 December 2018.

prescriptions for timber production harvesting and coupe closure activities throughout the reporting period. Four environmental impacts arising from non-compliances were assessed based on the environmental impact assessment (EIS) tool. The assessment method is provided in the audit report.[143] The majority of non-compliances have been found to have no impact, or to be negligible or to have minor environmental impact.

However, it is important to note that the major environmental impact category has shown an increase. The reason for this must be investigated and identified.

Table Fo.25 Audit results for harvesting and coupe completion operations in Victoria, 2007 to 2016-17

Audit report year	2007	2011	2013	2014	2015–16	2016–17
Harvesting year	2006–07	2008–09	2010–11 & 2011–12	2013–14	2014–15	2015–16
No. coupes assessed	43	27	40	24	83	30
Compliant elements (%)	94	95	96	90	86	91
Severe	0	0	0	0	0	0
Major	16	2	16	6	25	37
Moderate	30	31	21	14	53	35
Minor	43	28	51	70	100	14
Negligible	55	49	34	23	106	9
No impact	25	40	36	19	3	0
Areas with <90% compliance	• Rainforest boundary tracks • Camp maintenance areas • Log landings and dumps	• Major – rainforest • Moderate – waterway, filters	• Major – roading, coupe planning	• Water and soils • Roading	• Planning for crossings • Design and construction of crossings • Removal and rehabilitation of crossings • Water-quality, river-health and soil protection • Planning and design of in-coupe roads • Construction of in-coupe roads • Maintenance, operations, closure and rehabilitation of in coupe roads • Road drainage	• Soils • Water • Roading design • Roading construction • Roading maintenance and closure

(Data source: FAP reports and SoF 2013)

143. Jacobs 2016, 'Forest Audit Program 2015: audit of in-coupe roads: environmental audit of the construction and maintenance of in-coupe roads', Jacobs Group (Australia) Pty Limited, Bendigo, Victoria https://www.forestsandreserves.vic.gov.au/__data/assets/pdf_file/0026/118367/fap2015-in-coupe-roads-final-020320161.pdf Accessed 4 December 2018.

Furthermore, relevant to this indicator is the current focus on the definition of 'old-growth forests'. For example, 'old growth' in mountain ash in the Central Highlands has been defined in two ways. One definition suggests old growth is determined by age structure of the individual tree (between 120 and 150 years old), its senescence and its ability to bear hollows.[144] Another definition uses only age structure (over 250 years, late mature and senescent growth stage) with height and trunk diameter.[145] Old growth in mountain ash can also be determined by the understorey; for example, tree ferns that are greater than 350 years.[146]

These variations in old-growth definitions highlight that each vegetation type has its own ecological characteristics and age structures that need to be considered in determining an ecologically meaningful definition of old growth - rather than applying a one-size-fits-all approach.

In addition, the number of species listed on the IUCN Red List categories in the Central Highlands is expected to increase dramatically within the next 25 years (see indicator Fo:06 (The status of forest-dependent species at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment)). This demonstrates that the current framework needs to improve to better support biodiversity conservation in Victorian public forests.

144. Lindenmayer DB, Blair D, McBurney L, Banks SC 2015, 'Mountain Ash: Fire, Logging and the Future of Victoria's Giant Forests', CSIRO Publishing, Clayton South, Victoria.
145. VicForests 2015, 'Ecologically sustainable forest management plan: working plan Version 1.0', Melbourne, Victoria http://www.vicforests.com.au/static/uploads/files/ecologically-sustainable-forest-management-plan-v1-0-wfctkbfzjkxi.pdf Accessed 4 December 2018.
146. Lindenmayer DB, Blair D, McBurney L, Banks SC 2015, 'Mountain Ash: Fire, Logging and the Future of Victoria's Giant Forests', CSIRO Publishing, Clayton South, Victoria.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:18 Extent to which the economic framework supports the conservation and sustainable management of forests	○	○	●	○	?	DATA QUALITY Fair

Data custodian DELWP

This indicator assesses whether the current economic framework supports sustainable forest management. It lists the economic framework elements considered important for supporting conservation and sustainable management of both public and private forests. The indicator includes assessment of new policies and key developments.

This indicator is assessed using the best available state and national data – but note that state-scale datasets are extremely limited. This makes assessment of this indicator, including comparison of past and present economic frameworks, difficult.

A recent report from Forest and Wood Products Australia indicates that the forest industry contributed about $7.3 billion to the Victorian economy in 2017–18.[147] This consisted of $1.9 billion in direct sales of wood and fibre and $5.4 billion in flow-on effects from other industries involving forest products (socio-economic activities).

Since SoE 2013, several state and federal government investments have contributed to progress for Victorian native forests. As part of Victoria's Regional Tourism Strategy from 2013 to 2016, the 2013–14 state budget committed $13 million to improve tourism in national parks, state forests and on public land.[148] This facilitated upgrades and continual management of Victorian regions containing forests, such as Gippsland, the Macedon Ranges and Daylesford.[149] (A drawback of this is the potential for ecological damage from the removal of prohibitions against private-sector development in national parks. While sustainable environmental outcomes are encouraged in the tourism development guidelines,[150] there are no current assessments for ecological affects due to private-sector development.)

In 2013–14, DEDJTR made grants of $620,000 to a number of wood processing enterprises, as a part of the Regional Growth Fund.[151] However, limited benchmarks and targets meantthe only quantifiable outcomes were in relation to financial returns or employment.[152]

From 2014 to 2017, the Australian Government provided $3 million to enhance the environmental and cultural values of the Dandenong Ranges.[153] The initiative, delivered through the National Landcare Program, funded community groups to undertake activities to strengthen wildlife habitat, regulate weeds and decrease bushfire fuel-loads. As this was a sub-program, outcomes of the fund have not been examined in detail, but will be reviewed as part of the National Landcare Program.[154]

147. Forest & Wood Products Australia 2018, 'Media release: Forest industry adds 7.3 billion to Victorian economy: research', https://www.fwpa.com.au/news/1632-forest-industry-adds-7-3-billion-to-victorian-economy-research.html Accessed 4 December 2018.
148. State Government Victoria 2013, 'Victoria's regional tourism strategy 2013-2016', Melbourne, Victoria https://corp.rdp.tourismnortheast.com.au/wp-content/uploads/sites/54/6588_victoria_-regional_tourism_strategy_2013-16_WEB-1.pdf Accessed 4 December 2018.
149. Ibid
150. DELWP 2015, 'Tourism lease in National Parks: guidance note', Melbourne, Victoria https://www.ecotourism.org.au/assets/Resources-Hub-Protected-Area-Management/tourism-leases-in-national-parks.pdf Accessed 4 December 2018.
151. Department of State Development Business and Innovation 2014, 'Annual report 2013-14', Melbourne, Victoria https://web.archive.org/web/20150301094836/http://dsdbi.vic.gov.au/__data/assets/pdf_file/0018/1006353/DSDBI-ANNUAL-REPORT-2013-14-FINAL_web.pdf Accessed 4 December 2018.
152. VAGO 2015, 'Regional growth fund: outcomes and learnings', Melbourne, Victoria https://www.audit.vic.gov.au/report/regional-growth-fund-outcomes-and-learnings Accessed 4 December 2018.
153. Australian Government, 'Dandenong Ranges', Canberra, Australia http://www.nrm.gov.au/national/local/dandenong-ranges Accessed 4 December 2018.
154. Australian Department of the Environment and Energy and Australian Department of Agriculture and Water Resources 2017, 'Report on the review of the national landcare program', Canberra, Australia http://www.nrm.gov.au/system/files/resources/fb8af1b3-f8fc-4b07-9334-4ae013da9188/files/nlp-review-final-report.pdf Accessed 4 December 2018.

Information to evaluate this indicator is scant. However, a regional set of environmental–economic accounts for the Central Highlands[155, 156] has been developed to assess ecosystem assets and their benefits for human wellbeing, including a framework to measure conservation and sustainable forest management. This assessment of native forest management uses the United Nations System of Environmental and Economic Accounting (SEEA) framework, which has been adopted in more than 45 countries.[157] In the Central Highlands, the results show that the economic value of water, tourism and plantation industries on private land is greater than the economic value of the native timber harvesting industry. (This excludes 2009–10, due to the 2009 Black Saturday bushfires.) The value of plantation forestry was found to be greater than that for native forestry, even though the size of the area managed for plantations is only 14% of the area of native forest available for harvest.[158]

Results from the trade-off analysis show that cesasing native forest timber harvesting could increase the economic value of ecosystem assets such as carbon. This trade-off analysis provides an opportunity to systematically and regularly assess the costs and benefits of changing ecosystem assets and services. However, the analysis in this study focuses only on the Central Highlands and does not include a state-scale assessment. A rigorous and scientific state-scale approach to assess the economic framework for sustainable forest management, following the international SEEA standard, is critical for policy development and implementation. This environmental–economic accounts approach has been discussed in Fo:23 (Value ($) of forest derived ecosystem services).

With the exception of 2006-07, 2008-09 and 2011-12, VicForests has made a net profit since its inception in 2004 and up until 2015–16. Its profitability was significantly undermined by the 2006-07 'Great Divide' bushfires and 2009 Black Saturday bushfires.[159] VAGO has indicated that VicForests had a loan facility of $26.8 million in 2013 from the Treasury Corporation of Victoria to cover cashflow problems resulting from the impacts of catastrophic bushfires and some delays in payments from mills.[160] This needs to be repaid.

There are different opinions relating to the economic sustainability and profitability of native forest harvesting in Victoria. Those who believe the harvesting is unprofitable cite evidence of the declining number of people directly employed in state forest industries, down 28.4% in total employment in the forest industry between 2006 and 2016.[161, 162] Others cite profit-loss and Victorian Government loans to VicForests as further evidence of the lack of profitability.[163, 164]

155. Keith H, Vardon M, Stein JA, Stein JL, Lindenmayer DB 2017, 'Ecosystem accounts define explicit and spatial trade-offs for managing natural resources'. Nature Ecology and Evolution, 1, pp. 1683-1692.
156. Keith H, Vardon M, Stein JA, Stein JL, Lindenmayer DB 2017, 'Experimental ecosystem accounts for the Central Highlands of Victoria. Summary Report'. The Australian National University and the Threatened Species Recovery Hub, Canberra, Australia.
157. United Nations 2012, 'System of Environmental-Economic Accounting Central Framework', New York, USA https://seea.un.org/content/seea-central-framework Accessed 4 December 2018.
158. Keith H, Vardon M, Stein JA, Stein JL, Lindenmayer DB 2017, 'Ecosystem accounts define explicit and spatial trade-offs for managing natural resources', Nature Ecology and Evolution, 1, pp. 1683-1692.
159. VAGO 2013, 'Managing Victoria's native forest timber resources', Melbourne, Victoria http://www.vicforests.com.au/static/uploads/files/20131211-timber-resources-wfsdlrklejjj.pdf Accessed 4 December 2018.
160. Ibid
161. Schirmer J, Mylek M, Magnusson A, Yabsley B, Morison J 2018, 'Socio-economic impacts of the forest industry Victoria (exc. The Green Triangle)'. Forest & Wood Products Australia, Melbourne, Victoria https://www.fwpa.com.au/resources/reports/other/1631-socio-economic-impacts-of-the-forest-industry-victoria-exc-the-green-triangle.html Accessed 4 December 2018.
162. Australian Department of Agriculture, Fisheries and Forestry, 'Australia's Green Triangle: a growing region with significant opportunities for forest sector investment', Canberra, Australia http://www.agriculture.gov.au/SiteCollectionDocuments/forestry/green_triangle_investment_ver8.pdf Accessed 4 December 2018.
163. VicForests 2013, 'Corporate and business plans, 2013-2014 to 2015-2016', Melbourne, Victoria.
164. Lindenmayer D 2017, 'Halting natural resource depletion: engaging with economic and political power', The Economic and Labour Relations Review, 28(1), pp. 41-56.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:19 Capacity to conduct and apply research and development aimed at improving forest management, including development of scientific understanding of forest ecosystem	○	○	○	●	→	DATA QUALITY Good

Data custodian DELWP

Forest ecosystems in Victoria are highly diverse and complex in terms of ecosystem diversity and health, carbon sequestration, and genetic diversity. This indicator assesses Victoria's capacity to conduct and apply research and development to improve sustainable forest management.

The number of forest researchers employed by the Victorian Government has declined slightly from 21.9 to 17.9 full-time-equivalent (FTE) workers between 2011–12 and 2015–16. All research personnel have focused on native forest, with a significant proportion working on fire ecology (6.8 FTE), fauna ecology (5.8 FTE) and sustainable forest management (1.5 FTE) in 2015–16.

The data on FTE forest researchers in government agencies, shown in Table Fo.26 and Table Fo.27, include employees of DELWP, VicForests and Arthur Rylah Institute.

In addition, there were 26.3 FTE academics working in forest research and development in Victoria. This figure includes those funded by DELWP through the Integrated Forest and Ecosystem Research (IFER) program at the University of Melbourne, and by the BNHCRC (Bushfire and Natural Hazards Co-operative Research Centre (BNHCRC).

These personnel all focused on native forests, and for 2015–16 included 5.2 FTE working on forest hydrology, 12.9 FTE on fire behaviour, 4.5 FTE on fire ecology, 0.9 FTE on sustainable forest management and 2.8 FTE on forest health.

Table Fo.26 Numbers of FTE government staff engaged in forest-related research and development, by state, 2010–11 and 2015–16

	FTE staff					
	Plantations		Native forest		Total	
State	2010–11	2015–16	2010–11	2015–16	2010–11	2015–16
ACT	0.0	0.0	7.0	7.0	7.0	7.0
NSW	12.5	8.0	12.5	8.0	25.0	16.0
NT	3.2	0.9	0.0	0.2	3.2	1.1
Qld	31.6	20.5	0.9	1.2	32.5	21.7
SA	15.8	0.0	0.8	0.0	16.6	0.0
TAS	52.5	2.1	62.8	5.3	115.3	7.3
VIC	0.0	0.0	21.9	17.8	21.9	17.8
WA	0.0	0.0	22.0	15.6	22.0	15.6
Total	**115.6**	**31.5**	**127.9**	**55**	**243.5**	**86.5**

(Data source: Australia's State of the Forests 2018)

Note: This table shows the numbers of research personnel reported by each state and territory for 2011–12 and 2015–16. NSW total staff numbers have been split equally between plantations and native forest.

Table Fo.27 demonstrates trends in research focuses in Victoria, in government agencies and academia, between 2011–12 and 2016–17. The data on FTEs in government agencies includes DELWP employees (policy leads for IFER and BNHCRC projects), VicForests employees, and ARI employees. Academic FTEs include those funded by DELWP through the IFER program and BNHCRC, who represent a subset of the total number of researchers in Victoria. The overall number of FTE employees is unchanged. FTE employees in academia increased by about 4 FTE in total in fire behaviour and forest hydrology, and decreased by about 4 FTE in government agencies (in fire and flora ecology). For both years, topics related to fire, ecology and hydrology accounted for 80% of overall FTE employees.

Table Fo.27 Numbers of FTE employees engaged in forest-related research and development, by research focus, 2011–12 and 2016–17

Research and development activity	Government agencies		Academia	
	Native forest			
	2011–12	2016–17	2011–12	2016–17
Silvicultural research	0.50	0.50		
Tree breeding (not horticultural)				
Forest hydrology	0.23	0.28	4.00	5.20
Timber use				
Fire behaviour	0.20	0.85	9.78	12.91
Forest pathology				
Agroforestry				
Fauna ecology	5.68	5.79		
Fire ecology	10.12	6.84	5.25	4.50
Forest entomology				
Flora ecology	0.63	0.00		
Non-timber forest products				
Climate change				
Statistical analysis				
Other (aquatic biota)	2.00	1.00		
Other (forest biotechnology)				
Other (forest industries)				
Other (sustainable forest management)	1.51	1.51	0.90	0.90
Other (plantations & health)	1.02	1.02	2.80	2.80
Total number of research FTEs	**21.89**	**17.79**	**22.73**	**26.31**

Note: Only includes the time fraction of researchers, technicians and other staff directly involved with research and development activity. Does not include the time fraction of overhead staff (for example, administrative and general service employees, personnel officers and janitors).

Note: The data on FTEs in government agencies includes DELWP employees (policy leads for IFER and BNHCRC projects), VicForests employees, and ARI employees. Academic FTEs include those funded by DELWP through the IFER program and BNHCRC, thus representing a subset of the total number of researchers in Victoria.

Note: Nobody engaged in research in plantations and private companies; therefore, these were excluded in the table

Note: While FTE data was mostly available, it was derived for BNHCRC by dividing the annual cost of a researcher (approximately $180,000). ARI and academic FTE was data taken from DELWP internal spreadsheets.

(Data source: DELWP, 2018)

The two main research head agreements (with the University of Melbourne and BNHCRC) are the major providers involved in forestry research and development in Victoria.

1. University of Melbourne – IFER

IFER[165] is a research agreement between the School of Ecosystem and Forest Sciences at the University of Melbourne, and DELWP. It aims to enhance the evidence base for managing the impacts of fire, climate and management regimes on multiple forest values in Victoria's forest ecosystems. The IFER program investigates forest ecosystems in Victoria under six main landscape-level themes: biodiversity, carbon, integration, social and economic values, vulnerability and water.

2. BNHCRC (successor of the Bushfire CRC)

As a consequence of Victoria's Black Saturday bushfires in February 2009, the Commonwealth Government granted the Bushfire CRC an extension of funding to examine national issues arising from the tragedy. This led to a new three-year research program for the Bushfire CRC from 2010 to 2013. The research built on outputs from the CRC's first seven years of research to give communities and fire managers a solid basis to better prepare for, manage and respond to severe bushfires. The research focused on understanding the risks associated with bushfires, how to better communicate these risks to the public, and how to better manage direct threats of bushfire.

BNHCRC,[166] established in 2013, builds on the work of the Bushfire CRC and is conducting coordinated and interdisciplinary research. This includes working with communities to improve disaster resilience and reduce the human, social, economic and environmental costs of bushfires and other natural hazards. Research undertaken by BNHCRC supports the development of cohesive, evidence-based policies, strategies, programs and tools to build a more disaster-resilient Australia. The BNHCRC provides long-term research that directly supports emergency services and other government and non-government agencies as they work to prevent, prepare for, respond to and recover from natural disasters.

The BNHCRC, like the Bushfire CRC before it, is 'end-user driven'. This means its partners, including various emergency service agencies, departments and non-government organisations around the country, have a significant say in the development and use of the research program.

DELWP's current budget allocation for research and development is based on identification and prioritisation of research directions. For trends in financial investment in research and development, see indicators 6.2b and 6.2c of the SoF 2018 report.

165. University of Melbourne, 'Integrated forest ecosystem research (iFER)', Parkville, Victoria https://ecosystemforest.unimelb.edu.au/research/research-programs/integrated-forest-ecosystem-research-ifer Accessed 4 December 2018.

166. Bushfire & Natural Hazards CRC, https://www.bnhcrc.com.au/ Accessed 4 December 2018.

Socio-economic Benefits

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:20 Investment and expenditure in forest management	○	○	●	○	→	DATA QUALITY: Good

Data custodian DELWP

Effective sustainable forest management relies on adequate investment and expenditure. This ensures that infrastructure, facilities, forest health and conservation values are maintained.

This indicator measures trends in forest management expenditure, reported as Victorian Government expenditure on forest-management-related activities. This includes expenditure on state forests, and parks and reserves, as well as VicForests's expenditure on forest management.

There are two main investment components: forest and fire management, and conservation and recreation.

The agency responsible for managing natural resources, including state forests, in Victoria has changed several times during the reporting period. In April 2013, the Department of Sustainability and Environment merged with the Department of Primary Industries to form the Department of Environment and Primary Industries (DEPI). In January 2015, DELWP, which has broad responsibility for Victoria's natural environments (including forest management, and fire and emergency management), was created following a government restructure. Together with Parks Victoria and VicForests, DELWP is responsible for managing Victoria's parks and reserves, and state forests. VicForests is a separate government-owned business responsible for the harvest, commercial sale and regrowing of wood from Victoria's state forests.

Table Fo.28 shows expenditure on managing Victoria's forests, parks and public land between 2012–13 and 2016–17. Expenditure has steadily increased over the five-year period. Forest and fire expenditure has remained comparatively steady, with a slight decrease in 2016–17 mainly attributed to a less-severe fire season. Expenditure on conservation and recreation increased significantly in 2013–14 and continued to increase during the period. The changes over five years may indicate that the Victorian Government has increased focus on and investment in conservation and recreational values in state forests, parks and reserves.

Table Fo.29 shows the forest management expenditure on general maintenance, capital roading and capital bridge works between 2012–13 and 2016–17. Total expenditure decreased across the period, particularly on maintenance work. This was mainly due to decreasing timber production and available production areas, which reduced the maintenance works required for state forests, and parks and reserves.

Table Fo.28 Victorian Government expenditure on forest management, 2012–13 to 2016–17

	Expenditure ($ millions)				
Expenditure category	**2012–13**	**2013–14**	**2014–15**	**2015–16**	**2016–17**
Forest and fire management	383.5	382.3	347.8	396.5	372.3
Conservation and recreation	199.0	199.3	298.9	328.2	369.8
Total	582.5	581.6	646.7	724.7	742.1

(Data source: DELWP, 2018)

Table Fo.29 Victorian Government forest management expenditure on maintenance, capital roading and capital bridges, 2012–13 to 2016–17

	Expenditure ($ millions)				
Expenditure category	**2012–13**	**2013–14**	**2014–15**	**2015–16**	**2016–17**
Maintenance	16.0	16.8	12.6	9.0	7.9
Capital roading	0.2	0.7	0.4	0.3	0.2
Capital bridges	2.2	2.4	2.6	3.2	1.4
Total	18.3	19.9	15.5	12.5	9.5

(Data source: DELWP, 2018)

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:21 Value ($) of forest derived ecosystem services	○	○	●	○	?	DATA QUALITY: Fair

Data custodian DELWP

Environmental/economic accounting provides a framework for valuing the economic benefit of ecosystem services to the economy and society. The contribution forests make to the economy is partly captured in the System of National Accounts (SNA), which accounts for goods and services from forests, such as timber and tourism, when they are produced and consumed in the economy. The System of Environmental Economic Accountng (SEEA) extends the SNA by including forests environmental assets, and the natural inputs and ecosystem services forests produce.

Forest ecosystems provide a suite of ecosystem services, including climate regulation, carbon sequestration, water supply and filtration, and habitat. The management and condition of forests determines the level and extent of these services and, in turn, the benefits to the economy and community. A qualitative example of forest ecosystem accounting – from asset to benefits – is set out in Table Fo.30.

Table Fo.30 Qualitative example of ecosystem accounting for Victorian forests

Asset extent	Asset condition	Ecosystem services	Benefits
Forests can be classified into different assets using EVCs or production forest classes	Condition assessment must be linked to the impact on asset's ability to provide ecosystem services Size of habitat	Examples include: • habitat • water supply and filtration • climate regulation (carbon sequestration • temperature regulation • nourishment for bees • opportunities for recreation and tourism • opportunities for cultural connection • landscape	Examples include: • water consumption by humans and animals • timber • avoided impacts from climate change • urban cooling • apiculture (pollination or crops and honey) • recreation and tourism • avoided health impacts • cultural connection • visual amenity

(Data source: DELWP, 2018)

Ecosystem accounting has increasingly been applied to forest areas in Australia and around the world. In 2015, Parks Victoria and DELWP accounted for forest ecosystem assets in parks as part of an assessment of benefits from ecosystem services provided by Victorian parks.[167] The analysis estimates that Victorian parks contribute about $1 billion in gross value and 14,000 jobs. The park-based apiary sector was estimated to contribute between $3.4 million and $4.6 million per annum (between $0.6 million and $1 million per annum, respectively).

At the regional scale, the Australian National University has published ecosystem accounts for the Central Highlands across state forests and parks, focusing on water provisioning, timber provisioning, tourism and carbon sequestration.[168] The key findings show that the value of ecosystem services for agriculture production has the greatest value ($121 million) – because of pollination services as an ecosystem service – followed by the water provisioning service ($101 million). By contrast, the native timber provisioning service was valued at just $19 million. The tourism sector in the Central Highlands is estimated to produce benefits of $71.1 million as direct and indirect gross value added, with corresponding increases in employment of 470 direct jobs and 280 indirect jobs after 10 years of investment in the tourism industry.[169]

Forests provide a key natural input that is priced in the economy: timber. Once harvested, timber is accounted for in the SNA. Environmental/economic accounts can record the stock of native forest and plantation forest assets over time, which can increase due to natural growth or decrease due to timber harvesting or other events such as bushfires. The Australian Bureau of Statistics produces accounts on native and plantation timber resources for the whole of Australia, and reported a net value of $11.6 billion in 2016–17, or $471.6 per person. Of this, $9.9 billion is plantation timber and $1.7 billion is native timber.

Currently there is no state-scale approach to quantifying the dollar-value of forest-derived ecosystem services in Victoria. Environmental/economic accounting provides a consistent framework for assessing the range of natural inputs and ecosystem services provided by forests, and the benefits each of these deliver to the economy and community. This type of information, presented in a consistent and comparable format, can help to improve understanding of the different benefits forests provide, and can be used to inform land use and forest management trade-offs and decision-making.

167. Varcoe T, Betts O'Shea H, Contreras Z 2015, 'Valuing Victoria's parks: Accounting for ecosystems and valuing their benefits', DELWP and PV, Melbourne, Victoria https://parkweb.vic.gov.au/__data/assets/pdf_file/0010/695764/Valuing-Victorias-Parks-Report-Accounting-for-ecosystems-and-valuing-their-benefits.pdf Accessed 4 December 2018.
168. Keith H, Vardon M, Stein JA, Stein J, Lindenmayer DB 2017, 'Experimental Ecosystem Accounts for the Central Highlands of Victoria', The Australian National University and the Threatened Species Recovery Hub, Canberra, Australia.
169. Nous Group 2017, 'Great forests national park: economic contribution of park establishment, park management, and visitor expenditure: The Wilderness Society', Melbourne, Victoria http://www.greatforestnationalpark.com.au/uploads/1/5/5/7/15574924/nous_gfnp_economic_contribution_study_3_february_2017.pdf Accessed 4 December 2018.

Future Focus

Understand the impacts of forest fragmentation on biodiversity and improve assessment of protected areas

A systematic approach to understanding the status and future trends of Victorian public forests is critical. DELWP developed the Victorian Forest Monitoring Program (VFMP) in 2011. The VFMP completed its first full cycle of field measurements in 2015 and is expected to complete its second cycle by 2020. It is critical that minimal changes to the VFMP data-collection methods occur following the completion of the second full cycle of data retrieval. Consistency in methodology, with only essential amendments, would allow the identification of underlying trends and improve the utility of the evidence base. Any changes to data collection and analysis methods to achieve more accurate data must not disrupt comparative analysis with existing datasets or future trend analyses.

Furthermore, although the VFMP maps forest fragmentation at the state scale (including private forests), it does not provide a complete assessment of forest fragmentation and its impacts on biodiversity in native forests. Long-term monitoring and detailed spatial research have been conducted to explore impacts of fragmentation on native forests and forest-dependent species at the regional scale (such as mountain ash forests in the Central Highlands) and this research has demonstrated that forest fragmentation is becoming intensified, and its impact on threatened species has been increasing.[170, 171, 172, 173, 174] The study of biodiversity impacts from forest fragmentation is also impeded by the lack of an authoritative list of Victorian forest-dependent species.

Further research is critical as a complement to VFMP mapping and to understand the impact of forest fragmentation on biodiversity at the state scale. This research program would also assist in the establishment and management of protected areas. The International Union for Conservation of Nature (IUCN) protected areas in Victoria increased by 140,000 hectares between 2004 and 2016. However, there is little evidence of the level of long-term species protection provided by the classification of these areas. A viability analysis, for example, would provide risk assessment and management options to better protect target species in protected areas. Such analysis would also provide an indication of species conservation benefits if an increase in protected areas was to occur.

Recommendation 8: That DELWP maintain their commitment to resourcing and maintaining the VFMP and enhance it to (i) improve statewide understanding of the impacts of forest fragmentation on forest-dependent species (including the development of an authoritative list of Victorian forest-dependent species) and (ii) improve assessment of protected areas by conducting detailed research to identify the benefits of various types of IUCN-protected areas for target species. Any amendments to the VFMP must not disrupt future trend analyses.

170. Lindenmayer DB, Blair D, McBurney L, Banks S 2015, 'Mountain Ash: Fire, logging and the future of Victoria's giant forests', CSIRO Publishing, Melbourne.
171. Blair D, McBurney L, Lindenmayer DB, Banks S, Blanchard W 2017, 'The Leadbeater's Possum review', The Australian National University, Canberra.
172. Blair D, McBurney L, Lindenmayer DB 2018, 'Failing to conserve Leadbeater's Possum and its Mountain Ash forest habitat', Australian Zoologist, 39(3), 442-448. Doi:https://doi.org/10.7882/AZ.2018.008.
173. Lindenmayer DB, Blanchard W, Blair D, McBurney L 2018, 'The road to oblivion – quantifying pathways in the decline of large old trees', Forest Ecology and Management, In re-review.
174. Meney B, Cunningham S, Weston MA, Whisson DA 2018, 'Woodland birds and rural towns: artificial clutch survival in fragmented Box-Ironbark forests', The Royal Society of Victoria, 130, 7-17.

Accounting for the Environment

Environmental/economic accounting provides a framework for linking forests (a type of land account) to the natural inputs and ecosystem services they produce that benefit the economy and society. The contribution forests make to the economy is partly captured in the SNA, which accounts for goods and services from forests, such as timber and tourism, when they are produced and consumed in the economy. The SEEA extends the SNA by including forests environmental assets and the natural inputs and ecosystem services they produce.

See indicator Fo.23 (Value ($) of forest-derived ecosystem services) for further analysis.

Case Study: A pilot approach to estimating the potential for forests to provide habitat services

A key service provided by forest ecosystems is habitat for species. Fauna and flora species have different habitat requirements. They need a place to live and reproduce. They also need to tolerate changes in the weather as well as flood and fire disturbances. Because of these different needs, species are found in different locations across the landscape. Some species have highly specific habitat requirements (such as hollow-dependent arboreal marsupials that are present only in limited parts of mountain ash and alpine ash forests that support hollow-bearing trees), while other species can thrive in many different habitat types.

Habitat distribution models (HDMs) have been developed for all rare or threatened Victorian species where sufficient data is available. For this assessment, 1,750 HDMs were used. HDMs collect and compare information on where a species has been recorded and relate that data to environmental variables, such as soil, prevailing climate and topography. Sophisticated statistical and mathematical processes are then used to estimate the distribution of a species's habitat. The HDMs do not predict whether or not a species currently occupies the habitat at a particular location. Many factors can influence whether a species is present in the habitat at any given time, including: biogeography; size of the habitat patch and distance from other suitable habitat; the condition of the habitat; natural disturbance cycles; historical catastrophes; the impact of predators or disease; and seasonal factors.[175]

A pilot approach to estimating the potential for forests to provide habitat services is to examine the links between the distribution of important Victorian species to the extent of forest cover in Victoria. This approach describes the relative importance of forests in providing potential habitat for species. However, as HDMs do not predict whether or not a species occupies the habitat at a particular location, this approach does not reveal whether forest assets are actually providing habitat services. Forest-cover extent is used as a proxy for potential habitat, and this approach does not incorporate the condition of forest ecosystem assets, which is a key factor in providing habitat. In 2015, this approach was used to account for the habitat services provided by Victorian parks.[176] Approaches to measuring the flow of habitat services provided by ecosystem assets is a complex area that can be refined in the lead-up to a systematic approach to accounting for the environment (see Recommendation 19).

Figure Fo.34 and Table Fo.31 show the extent of forest cover within the intersection of bioregions[177] and natural resource management[178] (NRM) regions across Victoria. Figure Fo.36 is an intersection between bioregion/NRM region and the 1,750 HDMs. It represents the number of HDMs that intersect with each bioregion/NRM class, which indicates the potential for these areas to provide habitat services.

175. DELWP 2017 'Biodiversity information explanatory document: measuring value when removing or offsetting native vegetation', Melbourne, Victoria https://www.environment.vic.gov.au/__data/assets/pdf_file/0025/91267/Biodiversity-information-explanatory-document-Measuring-value-when-removing-or-.pdf Accessed 4 December 2018.
176. Varcoe T, Betts O'Shea H, Contreras Z 2015, 'Valuing Victoria's parks: Accounting for ecosystems and valuing their benefits', DELWP and PV, Melbourne, Victoria https://www.forestsandreserves.vic.gov.au/__data/assets/pdf_file/0027/57177/Valuing-Victorias-Parks-Report-Accounting-for-ecosystems-and-valuing-their-benefits.pdf Accessed 4 December 2018.
177. Australian Department of the Environment and Energy, 'Interim Biogeographic Regionalisation for Australia (IBRA7) codes', Canberra, Australia http://www.environment.gov.au/land/nrs/science/ibra/ibra7-codes Accessed 4 December 2018.
178. CSIRO 'Impacts and adaptation information for Australia's NRM regions', Climate Change in Australia: projections for Australia's NRM regions, Canberra, Australia https://www.climatechangeinaustralia.gov.au/en/impacts-and-adaptation/nrm-regions/ Accessed 4 December 2018.

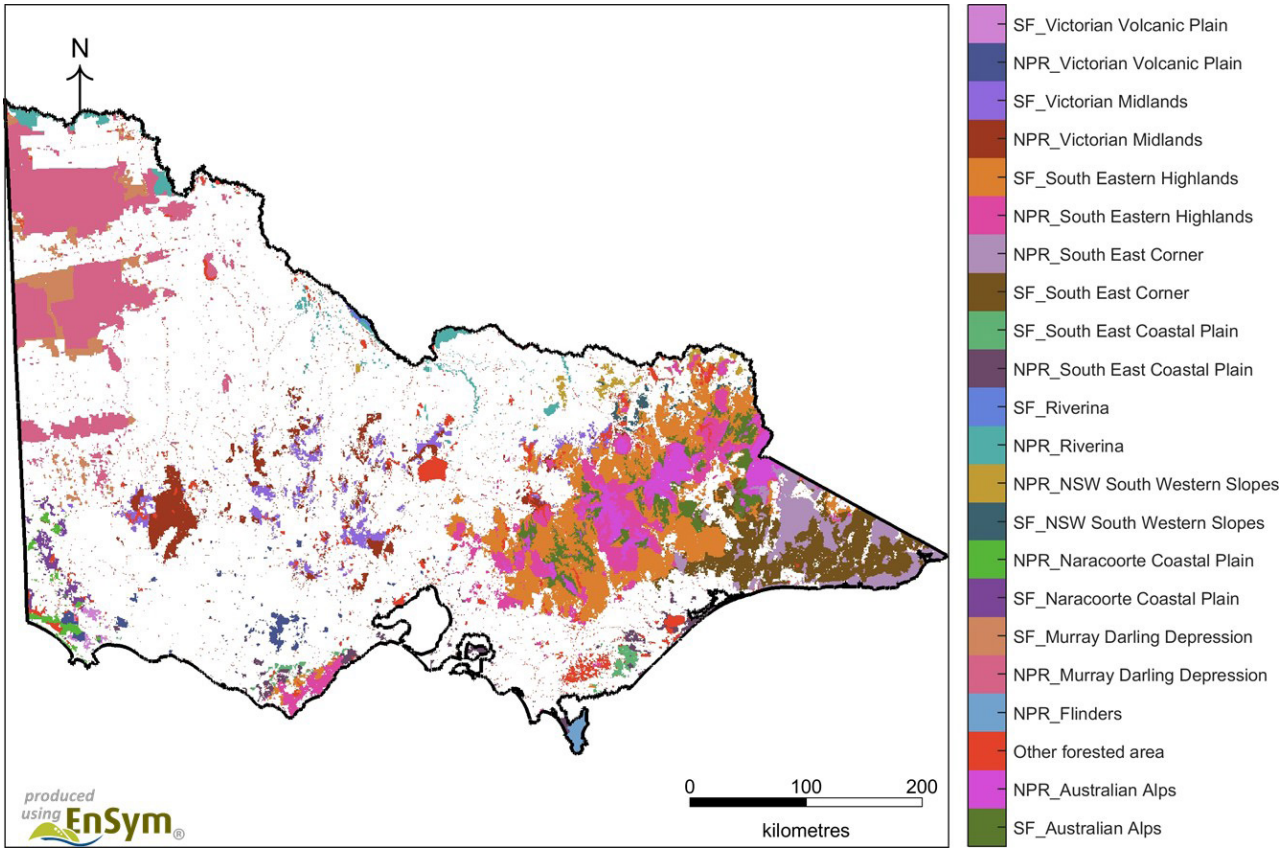


Figure Fo.34 Forest cover by bioregion/NRM class in Victoria

(Data source: DELWP, 2018)

Table Fo.31 Forested area in each bioregion/NRM class (per cent)

Bioregion	NRM Region	Area (ha)	Forest (%)
Australian Alps	Murray Basin	370,412	5
Flinders	Murray Basin	40,141	1
Murray–Darling Depression	Murray Basin	1,476,822	19
Naracoorte Coastal Plain	Murray Basin	67,847	1
NSW South Western Slopes	Murray Basin	68,926	1
Riverina	Murray Basin	211,861	3
South East Coastal Plain	Murray Basin	156,420	2
South East Corner	Murray Basin	429,514	5
South Eastern Highlands	Murray Basin	684,825	9
Victorian Midlands	Murray Basin	420,261	5
Victorian Volcanic Plain	Murray Basin	96,739	1
Australian Alps	Southern Slopes	336,865	4
Murray–Darling Depression	Southern Slopes	302,859	4
Naracoorte Coastal Plain	Southern Slopes	71,981	1
NSW South Western Slopes	Southern Slopes	43,108	1
Riverina	Southern Slopes	11,688	0
South East Coastal Plain	Southern Slopes	51,924	1
South East Corner	Southern Slopes	696,317	9
South Eastern Highlands	Southern Slopes	1,373,900	17
Victorian Midlands	Southern Slopes	284,708	4
Victorian Volcanic Plain	Southern Slopes	23,838	0
Other forested area	Southern Slopes	641,911	8
Total		**7,862,867**	**100**

(Data source: DELWP, 2018)

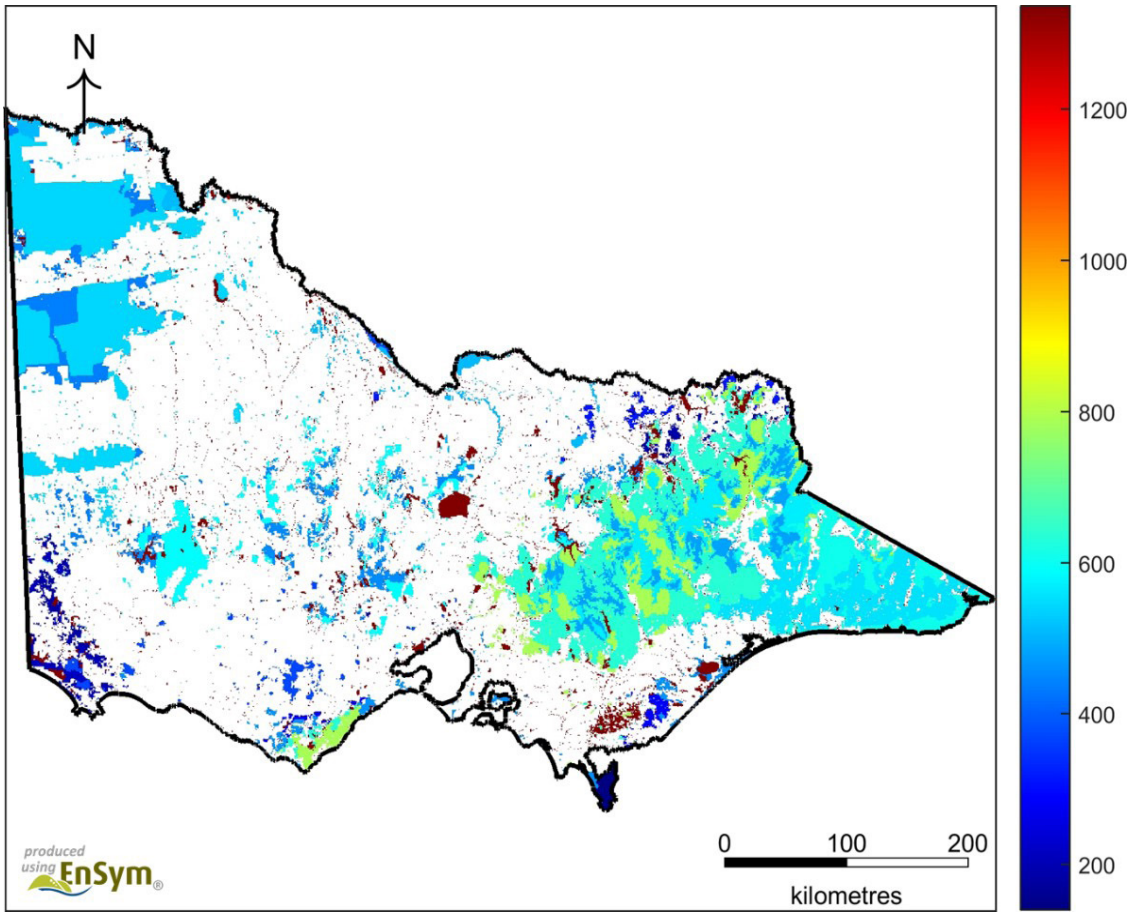


Figure Fo.35 Number of HDMs in each bioregion/NRM class in Victoria

(Data source: DELWP, 2018)

Figure Fo.36 is the same as Figure Fo.35, but with data classified for easier viewing. Note that there are large areas that intersect with more than 500 HDMs, suggesting that these forest areas may potentially provide valuable habitat services.

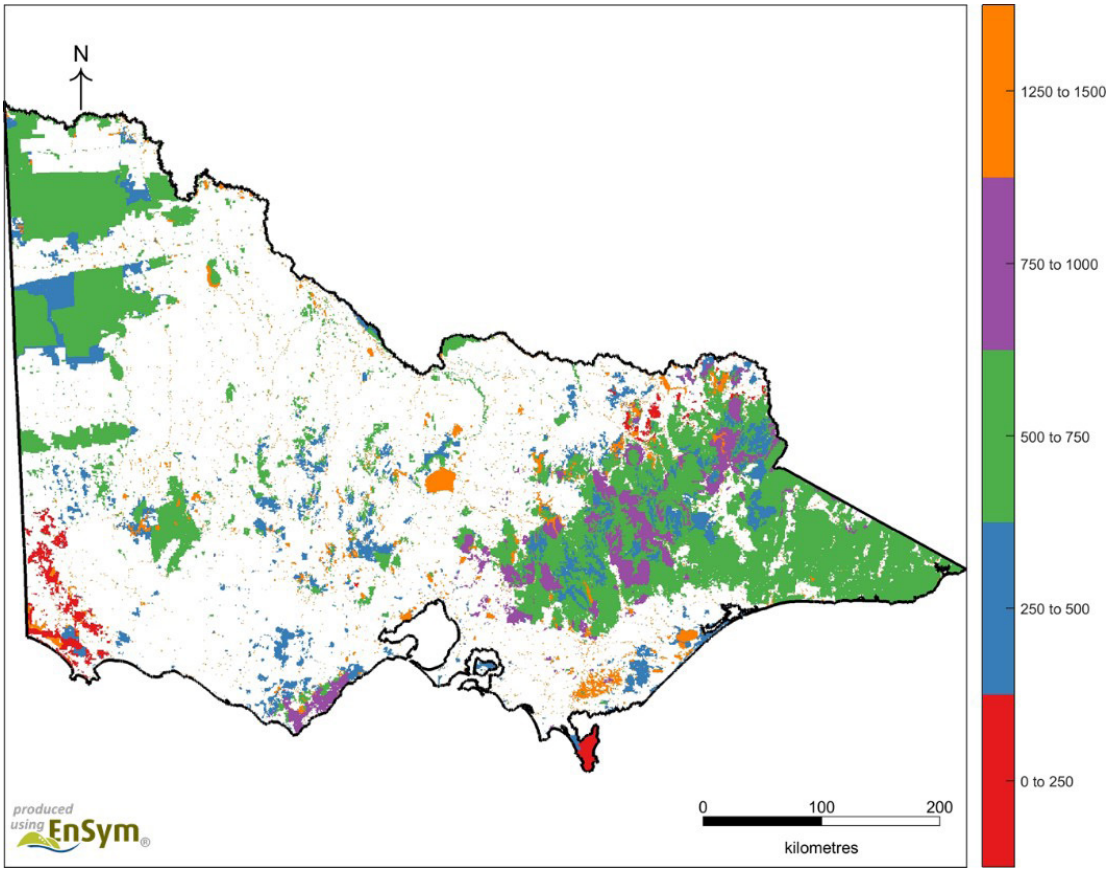


Figure Fo.36 Number of HDMs in each bioregion/NRM class in Victoria – grouped by count

(Data source: DELWP, 2018)

Table Fo.32 shows the potential species habitat presence for each bioregion/NRM class, out of the 1,750 species for which habitat distribution has been modelled. 9 out of 22 classes have potential habitat for species presence of greater than 500 species based on the HDMs. These nine bioregion/NRM classes represent 80% of the bioregion area. Note that the larger areas are expected to have an intersection with more species HDMs. Further work would be required to disaggregate the larger areas into specific management areas (for example, into regions and coupes) to gain a more accurate representation of the links to HDMs.

Table Fo.32 Number of HDMs for species within bioregion/NRM classes in Victoria

Bioregion	NRM region	Number of species HDM				
		Low		Medium		High
		0–250	250–500	500–750	750–1,000	1,250–1,500
Australian Alps	Murray Basin			✓		
Flinders	Murray Basin	✓				
Murray–Darling Depression	Murray Basin			✓		
Naracoorte Coastal Plain	Murray Basin	✓				
NSW South Western Slopes	Murray Basin		✓			
Riverina	Murray Basin			✓		
South East Coastal Plain	Murray Basin		✓			
South East Corner	Murray Basin			✓		
South Eastern Highlands	Murray Basin				✓	
Victorian Midlands	Murray Basin			✓		
Victorian Volcanic Plain	Murray Basin		✓			
Australian Alps	Southern Slopes		✓			
Murray–Darling Depression	Southern Slopes		✓			
Naracoorte Coastal Plain	Southern Slopes	✓				
NSW South Western Slopes	Southern Slopes	✓				
Riverina	Southern Slopes		✓			
South East Coastal Plain	Southern Slopes		✓			
South East Corner	Southern Slopes			✓		
South Eastern Highlands	Southern Slopes			✓		
Victorian Midlands	Southern Slopes		✓			
Victorian Volcanic Plain	Southern Slopes	✓				
Other forested area	Southern Slopes					✓
Total		**5**	**8**	**7**	**1**	**1**

(Data source: DELWP, 2018)

Table Fo.33 and Table Fo.34 show potential species habitat presence for each bioregion/NRM class, specifically for endangered and vulnerable species.

Table Fo.33 shows the potential endangered species habitat presence for each bioregion/NRM class. 6 classes have potential endangered species habitat presence of greater than 100 species, based on the HDMs. 10 bioregions have potential endangered species habitat presence of 50 to 100; 6 bioregions have potential endangered species habitat presence of less than 50.

Table Fo.33 Number HDMs for endangered species within bioregions/NRM classes in Victoria

Bioregion	NRM region	Number of endangered species HDM			
		0–50	50–100	100–150	250–300
Australian Alps	Murray Basin		P		
Flinders	Murray Basin	✓			
Murray–Darling Depression	Murray Basin			✓	
Naracoorte Coastal Plain	Murray Basin	✓			
NSW South Western Slopes	Murray Basin		✓		
Riverina	Murray Basin			P	
South East Coastal Plain	Murray Basin		✓		
South East Corner	Murray Basin		✓		
South Eastern Highlands	Murray Basin			✓	
Victorian Midlands	Murray Basin			✓	
Victorian Volcanic Plain	Murray Basin		✓		
Australian Alps	Southern Slopes	✓			
Murray–Darling Depression	Southern Slopes		✓		
Naracoorte Coastal Plain	Southern Slopes	✓			
NSW South Western Slopes	Southern Slopes	P			
Riverina	Southern Slopes		P		
South East Coastal Plain	Southern Slopes	P			
South East Corner	Southern Slopes		P		
South Eastern Highlands	Southern Slopes		P		
Victorian Midlands	Southern Slopes			P	
Victorian Volcanic Plain	Southern Slopes		P		
Other forested area	Southern Slopes				P
Total		**6**	**10**	**5**	**1**

(Data source: DELWP, 2018)

Table Fo.34 shows the potential vulnerable species habitat presence for each forest class. 10 forest classes have potential vulnerable species habitat presence of greater than 150 species, based on the HDMs. 6 forest classes have potential vulnerable species habitat presence of 100 to 150; 6 forest classes have potential vulnerable species habitat presence of less than 50.

Table Fo.34 Number of HDMs for vulnerable species within bioregions/NRM classes in Victoria

Bioregion	NRM region	Number of species HDM				
		50–100	100–150	150–200	200–250	400–450
Australian Alps	Murray Basin			✓		
Flinders	Murray Basin	✓				
Murray–Darling Depression	Murray Basin			✓		
Naracoorte Coastal Plain	Murray Basin	✓				
NSW South Western Slopes	Murray Basin		✓			
Riverina	Murray Basin			✓		
South East Coastal Plain	Murray Basin		✓			
South East Corner	Murray Basin			✓		
South Eastern Highlands	Murray Basin				✓	
Victorian Midlands	Murray Basin			✓		
Victorian Volcanic Plain	Murray Basin		✓			
Australian Alps	Southern Slopes		✓			
Murray–Darling Depression	Southern Slopes			✓		
Naracoorte Coastal Plain	Southern Slopes	✓				
NSW South Western Slopes	Southern Slopes	✓				
Riverina	Southern Slopes		✓			
South East Coastal Plain	Southern Slopes	✓				
South East Corner	Southern Slopes			✓		
South Eastern Highlands	Southern Slopes			✓		
Victorian Midlands	Southern Slopes		✓			
Victorian Volcanic Plain	Southern Slopes	✓				
Other forested area	Southern Slopes					✓
Total		**6**	**6**	**8**	**1**	**1**

(Data source: DELWP, 2018)

Case Study: accounting for water supply from forests

This case study shows how an environmental/economic accounting framework can be applied – both conceptually and quantitatively – to forest ecosystems to demonstrate the link between biophysical information and socio-economic benefits.

Asset extent and condition

As shown in Table Fo.35, and illustrated in Figure Fo.36, there are 3,499,602 hectares of forest across the prescribed water supply catchment (PWSC) areas that contain ash forest in Victoria. Of this, 459,393 hectares (or 13%) are eucalypt ash forest of mountain ash (*Eucalyptus regnans*) and alpine ash (*Eucalyptus delegatensis*). The largest extent of forest assets are in the catchment areas of Lake Hume, Mitchell River, Ovens River, Upper Goulburn and Tambo River. The largest extent of ash forest assets are in the catchment areas of Mitchell River, Lake Hume, Upper Goulburn and Upper Yarra.

Table Fo.35 Extent of forest assets by catchment area

PWSC with ash forest	Ash forest (ha)	Other forest (ha)	Other land cover (ha)	Total area (ha)
Armstrong Creek	2,039	2,074	73	4,186
Barham River	3,566	1,591	1,198	6,355
Bemm River	2,009	88,592	2,647	93,248
Britannia Creek	1,580	239	-	1,819
Brodribb River (Orbost)	455	91,903	1,247	93,605
Buchan River (Buchan)	10,930	67,629	3,072	81,631
Buckland River	6,414	25,520	446	32,380
Buffalo River (Lake Buffalo)	9,697	101,633	4,283	115,613
Bunyip River	3,084	859	32	3,975
Cann River	241	59,039	3,075	62,355
Cement Creek	808	0	0	808
Deep Creek & Loch River (Noojee)	6,686	4,691	517	11,894
Drouin	309	1,081	36	1,426
Gellibrand River	3,086	36,122	10,121	49,329
Gellibrand River (South Otway)	1,971	11,526	3,131	16,628
Glenmaggie	18,753	155,843	15,546	190,142
Kilmore	1,186	1,952	141	3,279
King River (Lake William Hovell)	8,469	24,303	258	33,030
Kinglake	5,006	5,913	89	11,008
Lake Hume	44,058	211,065	65,756	320,879
Lake Hume Northern Section	55,617	434,098	197,642	687,357
Lorne	1,001	1,651	28	2,680
Maroondah	13,605	4,135	197	17,937
McCraes Creek	192	353	0	545
McMahons Creek	3,689	728	8	4,425
Merrimans Creek (Seaspray)	27	31,748	21,896	53,671
Micks Creek	29	325	129	483
Mitchell River	58,553	315,098	17,349	391,000
Nicholson River	724	45,386	1,587	47,697
Ovens River (Bright)	7,503	25,088	2,070	34,661
Ovens River (Wangaratta)	5,153	148,930	143,344	297,427
Starvation Creek	3,532	88	25	3,645
Tambo River	18,476	202,815	49,227	270,518
Tanjil River	13,168	29,297	8,221	50,686
Tarago River	7,818	905	2,342	11,065

PWSC with ash forest	Ash forest (ha)	Other forest (ha)	Other land cover (ha)	Total area (ha)
Tarra River	391	2,201	237	2,829
Thomson River (stage 3)	5,540	8,886	738	15,164
Thomson River (stages 1,1a,2)	15,693	17,310	182	33,185
Tomahawk Creek (Gembrook)	287	30	0	317
Tyers River	7,039	22,085	2,834	31,958
Upper Barwon	1,475	12,608	1,210	15,293
Upper Goulburn	49,679	178,606	50,711	278,996
Upper Goulburn (Upper Delatite)	4,876	12,270	6,741	23,887
Upper Kiewa	15,435	17,717	7,549	40,701
Upper Kiewa (East Kiewa U2)	1,627	75	0	1,702
Upper Yarra	37,915	9,395	871	48,181
Total	**459,391**	**2,413,403**	**626,806**	**3,499,600**

(Data source: DELWP, 2018)

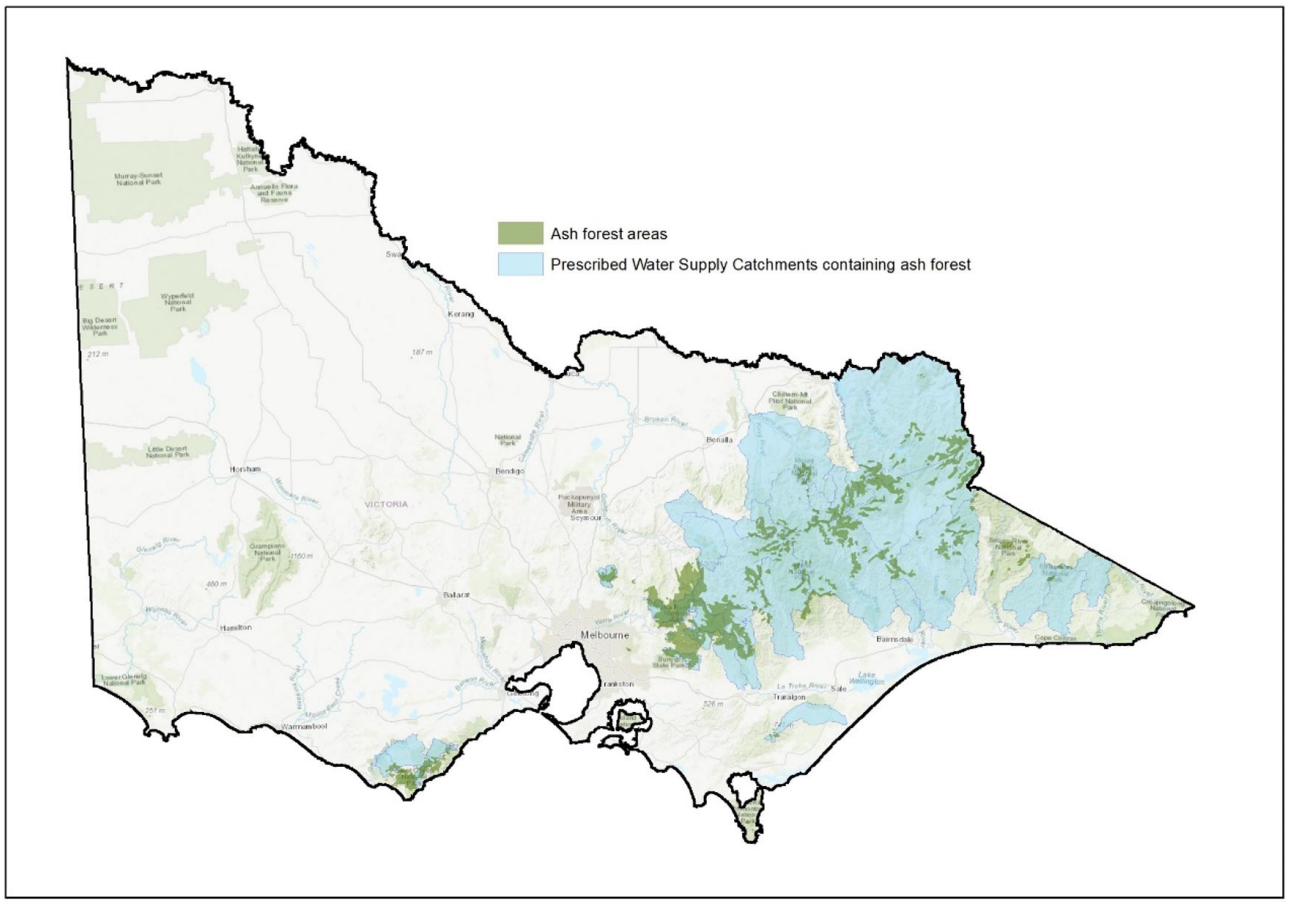


Figure Fo.37 Prescribed water supply catchments and ash forest extent in Victoria

(Data source: DELWP, 2018)

Ecosystem services and benefits

Forest assets provide a range of ecosystem services, as outlined in Figure Fo.39. This case study focuses on quantifying the water supply services provided by forest assets in the Kilmore, Mitchell River and Nicholson River catchment areas. Due to stream flow data limitations, absolute yearly flows could not be determined for other catchment areas listed in Figure Fo.39, including the Melbourne water catchments.

Asset extent

422,899 hectares of forest across Kilmore, Mitchell and Nicholson catchments:

- 60,463 hectares of ash forest
- 362,436 hectares of other forest

Condition

63 per cent of ash forest across Kilmore, Mitchell and Nicholson catchments has been disurbed since 1989, comprising:

- 62 per cent of ash forest disturbed by fire
- 1 percent of ash forest disturbed by logging

Services

Habitat

Water supply and filtration

Climate regulation (carbon sequestration)

Temperature regulation

Nourishment for bees

Opportunities for recreation and tourism

Opportunities for cultural connection

Landscape

Benefits

Water

Climate change mitigation

Timber resources

Pollination services

Recreation and tourism

Figure Fo.38 Forests in an environmental / economic accounting framework

(Data source: DELWP, 2018)

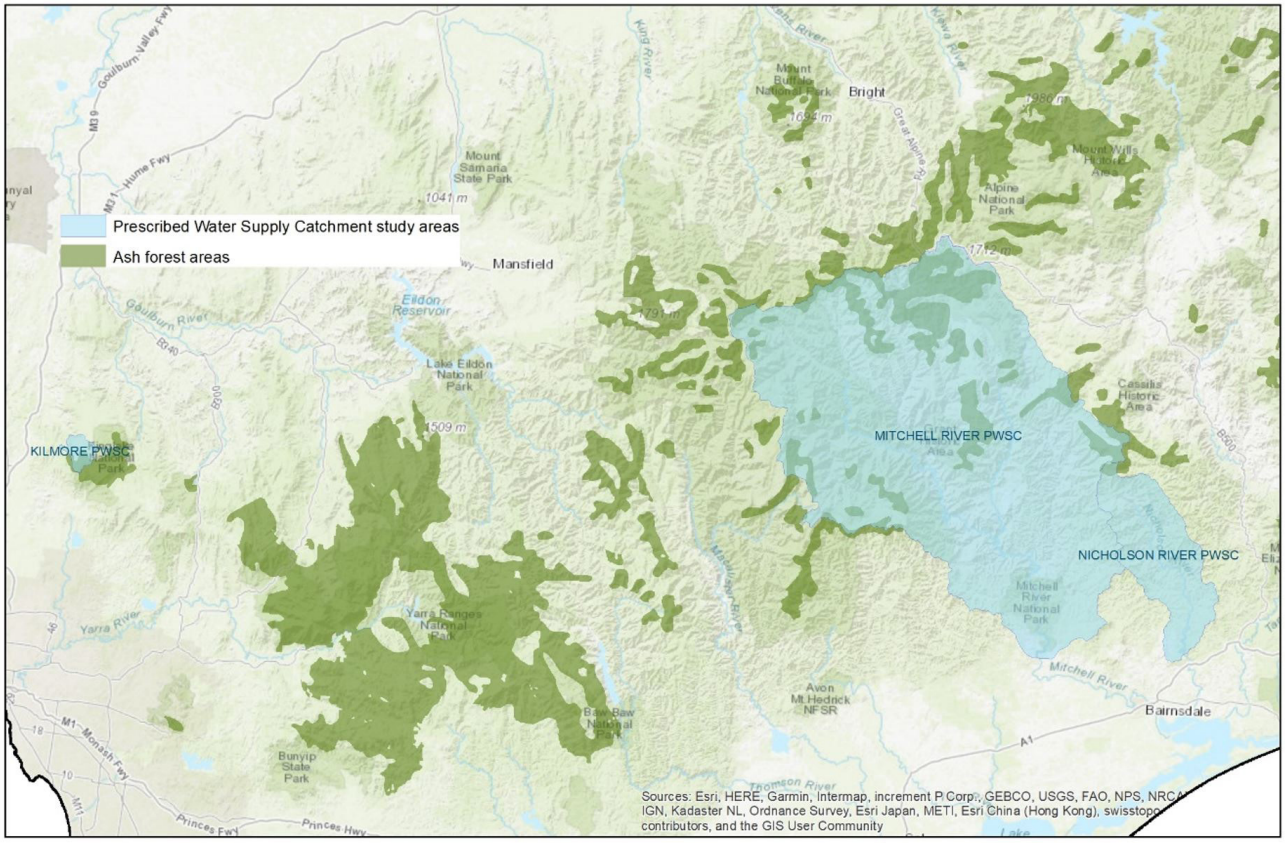


Figure Fo.39 Case study catchment areas

(Data source: DELWP, 2018)

The extent of forest ecosystem assets and yearly flow of water supply services for the three catchment areas is presented in Table Fo.37 and Table Fo.37. In 2017, the Kilmore PWSC area supplied 1,646 ML of water, the Mitchell River PWSC area supplied 504,098 ML of water, and the Nicholson River PWSC area supplied 4,979 ML of water.[179]

Table Fo.36 Forest ecosystem asset extent across three catchments

Forest type	Kilmore (ha)	Mitchell (ha)	Nicholson (ha)	Total (ha)
Ash forests	1,186	58,553	724	60,463
Other forests	1,952	315,098	45,386	362,436
Other land cover	141	17,349	1,587	19,077
Total	**3,279**	**391,000**	**47,697**	**441,976**

(Data source: DELWP, 2018)

Table Fo.37 Ecosystem-service flow – water supply – for three catchments, 2013-17

Catchment	Recorded annual flow (ML) – actual				
	2013	2014	2015	2016	2017
Kilmore	3,767	2,891	1,570	2,245	1,646
Mitchell River	841,139	519,979	486,647	1,125,627	504,098
Nicholson River	37,303	38,891	51,950	62,492	4,979
Total	**882,209**	**561,761**	**540,167**	**1,190,364**	**505,744**

(Data source: DELWP, 2018)

Table Fo.37 shows the annual flow of water-supply ecosystem services. However, to understand and value the benefit for the economy and society, the relevant agencies must develop an understanding of water-use.

An example in the context of the Mitchell River is useful. The largest remaining river system in Victoria that is not dammed, it provides valuable irrigation water to Lindenow Valley farmers in East Gippsland, as well as supplying urban water users. The Mitchell River supplies water to Bairnsdale and Paynesville, and to towns in adjacent river basins including Bruthen, Nicholson, Nowa Nowa, Johnsonville, Swan Reach, Metung and Lakes Entrance. It also supplies environmental flows to the Gippsland Lakes.

The Mitchell River underpins a substantial economic base in the region, including irrigated agricultural production, tourism, a growing number of small businesses and manufacturers, and an increasing population. The Gippsland Lakes are important environmental assets and are partially dependent on water from the environmental water reserve in the Mitchell Basin. The lakes are listed as internationally significant wetlands under the Ramsar Convention and rely on freshwater inputs from the Mitchell Basin to function ecologically. Other environmental assets that rely on the environmental water reserve include heritage river reaches, fish populations (Australian grayling, black bream), waterbirds (great egret) and botanical values (yellowwood).

179. Stream gauge data sourced from the Victorian Water Measurement Information System (WMIS) http://data.water.vic.gov.au/monitoring.htm Accessed 4 December 2018.

Diversions take out a relatively small proportion of total inflows, varying from approximately 1.5% during wetter years to 4.5% during drier years.[180] Applying these proportions to the amount of water supplied annually from forest assets gives the volumes outlined in Table Fo.38. In 2017, water supply that can be attributed to diversion for use was estimated at 7,561 ML to 22,684 ML.

Table Fo.38 Water supply to Mitchell River – diversions (ML), 2013-17

	2013	2014	2015	2016	2017
Lower bound (1.5%)	12,617	7,800	7,300	16,884	7,561
Upper bound (4.5%)	37,851	23,399	21,899	50,653	22,684
Total	**50,468**	**31,199**	**29,199**	**67,537**	**7,561**

(Data source: DELWP, 2018)

For the forest assets supplying regional and rural Victoria, water supply can be valued for agricultural users and regional townships using current entitlement prices.[181] This valuation approach is conservative, because the value of water to households is likely to be higher than for irrigated agriculture in many situations.

The value of water yields flowing to regulated rivers can be calculated using average high-reliability entitlement prices ($1,350/ML) across Victorian-regulated trading zones. This approach reflects the fact that the water is callable from water storages, and high-reliability entitlements are, therefore, the appropriate valuation basis.

The value of water yields flowing to unregulated rivers can be calculated using low-reliability entitlement prices ($190/ML) across Victorian unregulated trading zones. For unregulated flows outside trading zones (such as flows to Bass Strait), a zero value can be assumed, as these are likely non-consumptive uses. This approach yields conservative valuation estimates.

As the Mitchell River is an unregulated (undammed) river, applying the second value to the proportion of annual water supply from forest assets that is expected to be diverted gives an estimated value of the benefit from ecosystem services of between $1.4 million and $4.3 million in 2017. There are also additional benefits from environmental flows which have not been estimated.

180. Southern Rural Water 2014, 'Local Management Plan: Mitchell River Basin', Maffra, Victoria http://www.srw.com.au/files/Local_management_rules/Mitchell_River_Basin_LMP_January_2014.pdf Accessed 4 December 2018.

181. This valuation approach was used in Varcoe T, Betts O'Shea H, Contreras Z 2015, 'Valuing Victoria's parks: Accounting for ecosystems and valuing their benefits', DELWP and PV, Melbourne, Victoria https://parkweb.vic.gov.au/__data/assets/pdf_file/0010/695764/Valuing-Victorias-Parks-Report-Accounting-for-ecosystems-and-valuing-their-benefits.pdf Accessed 4 December 2018.

Impact of ash forest disturbance on water-supply services

Major disturbance to ash forests, and subsequent seed-bed regeneration, causes major reductions in water yield for up to 100 years, peaking at approximately 33 years post-disturbance with approximately 50% reductions in flow.[182] Post-1989 disturbance in the Kilmore, Mitchell River and Nicholson River catchment area is illustrated in Table Fo.39.[183] Theoretical maximum water yield from these catchments has been modelled and is reported in Table Fo.40. Theoretical maximum water yield has been calculated using the 3PG+ model within the EnSym[184] framework, assuming no forest disturbance since the 1939 'Black Friday' bushfires. This will create a conservative maximum yield estimate, as the water-yield impact of the 1939 Black Friday bushfires are still being experienced and will not return to normal until the middle of this century.

The difference between actual recorded flows and theoretical maximum flows is reported in Table Fo.40. For instance, if there was no ash forest disturbance post-1939 in the Mitchell River catchment area, there would have been an additional 18,503 ML of water supply in 2017. This type of analysis can help to assess the potential impacts of fire, fire management and forest harvesting on forest assets and the ecosystem services they provide.

Table Fo.39 Forest ecosystem asset condition across three catchments, since 1989

	Kilmore (ha)	**Mitchell** (ha)	**Nicholson** (ha)	**Total** (ha)
Ash disturbed by fire since 1989 (%)	87	61	54	62
Ash disturbed by logging since 1989 (%)	5	1	4	1
Total ash disturbed since 1989 (%)	92	62	58	63

(Data source: DELWP, 2018)

182. Kuczera G 1987, 'Prediction of water yield reductions following a bushfire in ash-mixed species eucalypt forest', Journal of Hydrology, 94(3-4), pp. 215-236.
183. CRCSI, '4.104 LandFor: Landsat for forests – a monitoring and forecasting framework for the sustainable management of SE Australian forests at the large area scale', Docklands, Victoria http://www.crcsi.com.au/research/4-1-agriculture-natural-resources-and-climate-change/4-104-landfor-landsat-for-forests/ Accessed 4 December 2018.
184. DELWP, 'EnSym native vegetation regulations tool', Melbourne, Victoria https://ensym.biodiversity.vic.gov.au/cms/ Accessed 4 December 2018.

Table Fo.40 Ecosystem-service flow – theoretical maximum water supply from forest assets in three catchments, 2013-17

Catchment	Theoretical maximum annual flow with no post-1939 ash forest disturbance (ML)				
	2013	2014	2015	2016	2017
Kilmore	6,511	4,776	2,732	3,567	2,853
Mitchell River	857,006	535,634	506,186	1,144,856	522,601
Nicholson River	38,234	39,823	52,749	63,525	5,301
Total	**895,240**	**575,457**	**558,935**	**1,208,381**	**522,601**

(Data source: DELWP, 2018)

Table Fo.41 Ecosystem-service flow – theoretical loss of water supply due to disturbance in three catchments, 2013-17

Catchment	Theoretical additional recorded annual flow (ML) under a no post-1939 ash forest disturbance, compared to actual recorded flow				
	2013	2014	2015	2016	2017
Kilmore	2,744	1,885	1,161	1,322	1,207
Mitchell River	15,867	15,655	19,539	19,228	18,503
Nicholson River	931	932	799	1,033	322
Total	**16,798**	**16,587**	**20,338**	**20,261**	**18,825**

(Data source: DELWP, 2018)



FIRE (Fi)
SCIENTIFIC ASSESSMENTS Part III

Commissioner *for* Environmental Sustainability Victoria

Fire

The Fire chapter has four indicators that discuss the impacts of bushfire and planned burns on humans, property and biodiversity. This chapter does not provide comprehensive discussions about fire ignition control, which includes aerial attack capability and the overall likely impact of climate change on the Victorian community. Instead, this chapter focuses on the link between climate change and fire. In addition, this chapter does not provide detailed information and interpretation of each threatened fauna species in relation to fire, but demonstrates a need for a dual-scale (state and regional) approach for successful biodiversity monitoring in response to fire in Victoria.

Background

Fire regimes play a vital, yet complex role in Victorian ecosystems, which provide habitat for a diverse range of fire-adapted native flora and fauna species, with some plant species only germinating after stimulation by heat or smoke. The beneficial effects of fire on ecosystem processes are well researched. Locally, fire catalyses plant nutrient cycles by decomposing organic materials into available nutrients that provide fertile soil conditions. At the landscape level, fire assists key processes such as tree decay, tree collapse and stand tree germination.[1, 2, 3, 4] However, unanticipated or inappropriate fire regimes will impact dangerously on the survival of threatened flora and fauna species. These ecological complexities highlight another important aspect of optimising fire management in Victoria.

Compounded by population growth and residential incursion into previously uninhabited forest areas, the risk of fire to people and property has increased. It is estimated that about $8.5 billion (or 1.15%) of Australia's gross domestic product accounts for the total annual cost of fires in Australia.[5] In Victoria, the economic cost of the 2009 Black Saturday fires was evaluated as $4.4 billion.[6]

Fire managers and communities must plan for more frequent and extreme bushfire events.[7, 8] It is predicted that Victoria will encounter more dangerous conditions than other states.[9] Climate change predictions show the likely impact on biodiversity, with some effects being noticed already – such as changes in plant growth rates, fuel loads and moisture content, as a result of longer periods of weather associated with high fire risk.[10] Although many native Australian flora and fauna species are tolerant of individual fires, an increase in fire intensity and frequency may impose a variety of negative impacts on biodiversity. Some habitats and species are more likely to be adversely influenced than others.[11] In addition, the *Flora and Fauna Guarantee Act 1988* listed inappropriate fire regimes and high-frequency fires as potentially threatening processes to the survival of flora and fauna in Victoria.

1. Lindenmayer DB, Blanchard W, Blair D, McBurney L 2018, 'The road to oblivion – quantifying pathways in the decline of large old trees', Forest Ecology and Management, 430, pp. 259-264.
2. Lindenmayer DB, Blanchard W, Blair D, McBurney L, Banks SC 2018, 'Empirical relationships between tree fall and landscape-level amounts of logging and fire', PLOS One, 13(2), e0193132.
3. Lindenmayer DB, Blanchard W, McBurney L, Blair D, Banks S, Likens GE, Franklin JF, Stein J, Gibbons P 2012, 'Interacting factors driving a major loss of large trees with cavities in an iconic forest ecosystem', PLOS One, 7, e41864.
4. Smith AL, Blair D, McBurney L, Banks SC, Barton PS, Blanchard W, Driscoll DA, Gill AM, Lindenmayer DB 2014, 'Dominant drivers of seedling establishment in a fire-dependent obligate seeder: climate or fire regimes?' Ecosystems, 17, pp. 258-270.
5. Ashe B, Mc Aneney KJ, Pitman AJ 2009, 'Total cost of fire in Australia' Journal of Risk Research, 12, pp. 121-136.
6. Teague B, McLeod R, Pascoe S 2010, '2009 Victorian Bushfires Royal Commission Final Report', 2009 Victorian Bushfires Royal Commission, Parliament of Victoria, Melbourne, Victoria http://royalcommission.vic.gov.au/finaldocuments/summary/PF/VBRC_Summary_PF.pdf Accessed 4 December 2018.
7. Hughes L 2003, 'Climate changes and Australia: trends, projections and impacts', *Austral Ecology*, 28, pp. 423-443.
8. Downie C 2006, 'Heating up: bushfires and climate change'. The Australia Institute, Manuka, ACT. http://www.tai.org.au/sites/defualt/files/WP92_8.pdf Accessed 4 December 2018.
9. Dowdy JA 2018 'Climatological variability of fire weather in Australia', Journal of Applied Meteorology and Climatology, 57, pp. 221-234.
10. Enright NJ, Fontaine JB, Bowman DMJS, Bradstock R, Williams RJ 2015, 'Interval squeeze: altered fire regimes and demographic responses interact to threaten woody species persistence as climate changes', Frontiers in Ecology and the Environment, 13, pp. 265-272.
11. Williams D, Bowman D, Little J 2014, 'Climate Change, Fire and Terrestrial Biodiversity: information sheet six', James Cook University, Townsville, Queensland http://nccarf.jcu.edu.au/terrestrialbiodiversity/documents/information_sheet_6_fire_final.pdf Accessed 4 December 2018.

Smoke from fires (planned burns and bushfires) has health implications for surrounding communities. In some cases, the area of effect can expand to 50 km from the source of the fire.[12] Particulate matter and noxious gases associated with smoke can reduce air quality in rural and urban areas and may affect people's health.[13] In addition, smoke can also have economic impacts – tainting grapes, for example,[14] or forcing road closures that prevent or delay transportation of goods and services,[15] and hinder emergency transport. The critical challenges facing Victoria's bushfire management now and in the future include:

- minimising the impact of major bushfires on human life, communities, essential and community infrastructure, industries, the economy and the environment
- monitoring responses of biodiversity (flora and fauna) to both planned burns and bushfires on regional and state scales
- maintaining or improving the resilience of natural ecosystems and their ability to deliver services such as biodiversity, water, carbon storage and forest products[16]
- maintaining the persistence of key fire-response species to increasing fire frequency and intensity
- increasing community awareness and establishing effective emergency management systems, especially in peri-urban areas
- developing a structured framework for analysing the impacts of bushfires on human life and property
- protecting human health from more frequent smoke exposure.

12. Goodrick SL, Achtemeier GL, Larkin NK, Liu Y, Strand TM 2013, 'Modelling smoke transport from wildland fires: a review', International Journal of Wildland Fire, 22, pp. 83-94.
13. Health Victoria, 'Bushfire smoke and planned burns', Melbourne, Victoria. https://www2.health.vic.gov.au/public-health/environmental-health/climate-weather-and-public-health/bushfires-and-public-health/bushfire-smoke-and-planned-burns Accessed 4 December 2018.
14. Whiting J, Krstic M 2007, 'Understanding the sensitivity to timing and management options to mitigate the negative impacts of bush fire smoke on grape and wine quality-scoping study', Project report (MIS No. 06958 and CMI No. 101284), Victorian Department of Primary Industries, Knoxfield, Victoria https://www.wineaustralia.com/getmedia/7e0159f4-037c-42e5-a642-05585f07be9e/200707_Understanding-impacts-of-bush-fire-smoke.pdf Accessed 4 December 2018.
15. Stephenson C 2010, 'A literature review on the economic, social and environmental impacts of severe bushfires in south-eastern Australia', Fire and adaptive management Report no.87, Bushfire CRC, East Melbourne, Victoria https://www.ffm.vic.gov.au/__data/assets/pdf_file/0009/21114/Report-87-A-Lit.Rvw-On-The-Economic,-Social-and-Envtal-Impacts-of-Severe-Bushfires-In-SE-Aust..pdf Accessed 4 December 2018.
16. DSE 2012, 'Code of practice for bushfire management on public land', Melbourne, Victoria https://www.ffm.vic.gov.au/__data/assets/pdf_file/0006/21300/Code-of-Practice-for-Bushfire-Management-on-Public-Land.pdf Accessed 4 December 2018.

Current Victorian Government Settings: Legislation, Policy, Programs

The Victorian Government published *Safer Together: A New Approach to Reducing the Risk of Bushfire in Victoria* in 2015 based on recommendations from the Inspector-General for Emergency Management (IGEM). *Safer Together* adopts a risk reduction target, replacing the previous hectare target approach to bushfire fuel management on public land. This approach enables the government to act more strategically, by planning and implementing risk-reduction activities in areas that will derive the greatest benefit. The government has committed to maintaining residual bushfire risk at or below 70%. In addition, the Department of Environment, Land, Water and Planning (DELWP), along with the Country Fire Authority (CFA) and Forest Fire Victoria, now involves local communities in prioritising fuel management activities and identifying opportunities to reduce risk across all land tenures.

Since the new approach was initiated, IGEM has published two monitoring reports that review DELWP's progress in response to the recommendations.[17] These recommendations are to reform bushfire risk management since the 2015 review and investigation. All of four recommendations are being implemented as part of *Safer Together*. The recommendations will be continually monitored as part of ongoing assurance activities, including breaches of planned burn control lines.

Underpinning the government's efforts to reduce risk of bushfires is the Code of Practice for Bushfire Management on Public Land. The code was adapted from its 2006 iteration, following the 2009 Victorian Bushfires Royal Commission. Risk-based planning, where human life is afforded the highest priority, is a fundamental part of the code; however, it also recognises the impacts of fire on the natural environment and thereby considers risk to human life, infrastructure and ecological assets within its approach.

17. Inspector-General for Emergency Management Victoria 2017, 'Annual report: implementation of recommendations on bushfire fuel management', Melbourne, Victoria https://www.igem.vic.gov.au/sites/default/files/embridge_cache/emshare/original/public/2018/01/6d/d7d449083/Annual_Report_Implementation_of_bushfire_fuel_management_recommendations_2017.pdf Accessed 4 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.

Poor
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

Poor
Evidence and consensus too low to make an assessment

Fair
Limited evidence or limited consensus

Good
Adequate high-quality evidence and high level of consensus

FIRE

	Summary	Status	Trend
Indicator **Fi:01** Area of native vegetation burnt in planned fires and bushfires **Region** Victoria **Measures** Annual planned burn area and annual total area affected by bushfires **Data custodian** DELWP	The area of annual planned burns have been decreasing since 2012-13 due to weather-related constraints. Since 2016-17 the area-based target (5% annual burn of public land) has concluded and a risk-based approach has commenced. Bushfire affected area has been decreasing since 2003. The change in planned burn strategy from area to risk based approach was used as a threshold to determine status.	UNKNOWN POOR FAIR GOOD DATA QUALITY Good	

	Summary	Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **Fi:02** Impacts of bushfires **Region** Victoria **Measures** Impacts of bushfires on human settlements, businesses and natural resources **Data custodian** None	The Bushfire Co-operative Research Centre was the leading agency collating evidence on bushfire impact. Since 2013, there has been a lack of clarity regarding responsibility for data collation and dissemination to utilise for evidence-based future decision making. Fragmented information has been identified from EMV and DHHS.	 DATA QUALITY Poor	
Indicator **Fi:03** Actual fire regimes compared to optimal fire regimes **Region** Victoria **Measures** Tolerable Fire Interval (TFI) and Growth Stage Structure (GSS) distribution on public forests between 2007 and 2017 **Data custodian** DELWP	Victorian Government uses tolerable fire internal as a metric to determine the current resilience condition of key fire response species. An increase in area where lower than minimum TFI and ongoing reduction in long unburnt habitats between 2007-17 is a threat to biodiversity. Future large fires may determine if current TFI regimes are appropriate.	 DATA QUALITY Good	
Indicator **Fi:04** Bushfire risk **Region** Victoria **Measures** Residual risk Impact of climate change on fire weather Data on biodiversity in response to fire **Data custodian** DELWP and BOM	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. DELWP has a system to monitor bushfire risks to human and property.	 DATA QUALITY Poor Data quality for biodiversity is poor while that for life and property is assessed as good	

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fi:01 Area of native vegetation burnt in planned fires and bushfires	○	●	○	○	↘	DATA QUALITY
Data custodian DELWP						Good

Until 2015–16, the Victorian Government had an annual planned-burning target. Prior to 2010–11, the annual target was 130,000 hectares. This increased to 200,000 hectares in 2010–11, 225,000 hectares in 2011–12 and 250,000 hectares in 2012–13. These increases were responses to recommendations from inquiries into large fires since 2002, including the 2009 Victorian Bushfires Royal Commission, which recommended an annual planned-burning target of 390,000 hectares (from 1.3% to 5% of public land).[18] The annual planned-burning targets aimed to reduce risks to life and property.

Planned burns are always dependent on weather and fuel conditions. Burning is not possible when conditions are too hot and dry, nor when conditions are too wet. Weather conditions therefore dictate the amount of burning carried out in a given year to meet planned-burning targets, and account for much of the annual fluctuations.

In order to meet the targets each year, the Victorian Government progressively increased the annual planned-burning area until 2012–13. The following year (2013–14) provided very few days that permitted planned burns. Regular showers and unstable weather conditions, especially in the Far South West, Otways and Midlands districts, limited burning opportunities. As a result, DELWP was only able to treat 82,022 hectares through planned burns. The subsequent years also had few days when planned burns could be conducted, resulting in burning of less than the annual target of 390,000 hectares until 2015–16.

In 2016–17, the annual burn area target was abolished, based on the recommendations from IGEM, and replaced by a risk-reduction target. In response to the recommendations, DELWP initiated the Safer Together program,[19] which is in development and will be fully functional for forest fuel management by 2020.

Between 2003–04 and 2016–17, just over 2 million hectares of native vegetation was burnt in planned fires in Victoria (Figure Fi.1). Much of the ecological and fuel-reduction burns were concentrated on the eastern part of Victoria (Figure Fi.2). The majority of planned burns (86%) were carried out for fire suppression purposes by reducing fuel levels. While the area of the fuel-reduction burn has been decreasing from a maximum of 94% in 2006–07 to 76% in 2016–17 (Figure Fi.1), ecological-burn activities have proportionally increased from 3% to 22% over the same period. The increase in planned-burning area since 2009–10 was a response to recommendations by royal commissions[18] that opportunities for planned burns should be maximised where possible to reduce fuel loads in Victorian forests. However, such recommendations do not adequately address aspects of forest ecosystem health, such as the risk of extinction in a range of native species. Biodiversity in the Mallee shrublands and in the woodlands of north-western Victoria is particularly at risk.[20]

18. State of Victoria 2012, 'Bushfire Royal Commission Implementation Monitor: Final report 2012', State of Victoria, Melbourne, Victoria https://www.igem.vic.gov.au/sites/default/files/embridge_cache/emshare/original/public/2017/07/01/d8b8a164d/Publication%20-%20brcim_final_report_July%202012.PDF Accessed 4 December 2018.

19. DELWP 2015, 'Safer Together: A new approach to reducing the risk of bushfire in Victoria', Melbourne, Victoria http://www.delwp.vic.gov.au/__data/assets/pdf_file/0004/319531/DELWP_SaferTogether_FINAL_17Nov15.pdf Accessed 4 December 2018.

20. Giljohann KM, McCarthy MA, Regan TJ 2015, 'Choice of biodiversity index drives optimal fire management decisions', Ecological Applications, 25(1), pp. 264-277.

Since 2015–16, the hectare-based target has shifted from a hectare-based approach to a risk-based approach for fire management. The new risk-based approach focuses on strategic areas near housing and infrastructure where there is a high chance of fire impacting on people and property. This shift is also in-line with research that demonstrates that fuel treatments close to property will more effectively mitigate impacts from bushfires in peri-urban communities than standard (hectare-based approaches).[21] But significant risk of human loss from bushfires still remains, depending on the rate of fuel treatment.[22] More information can be found in the indicator Fi:04 Bushfire risk.

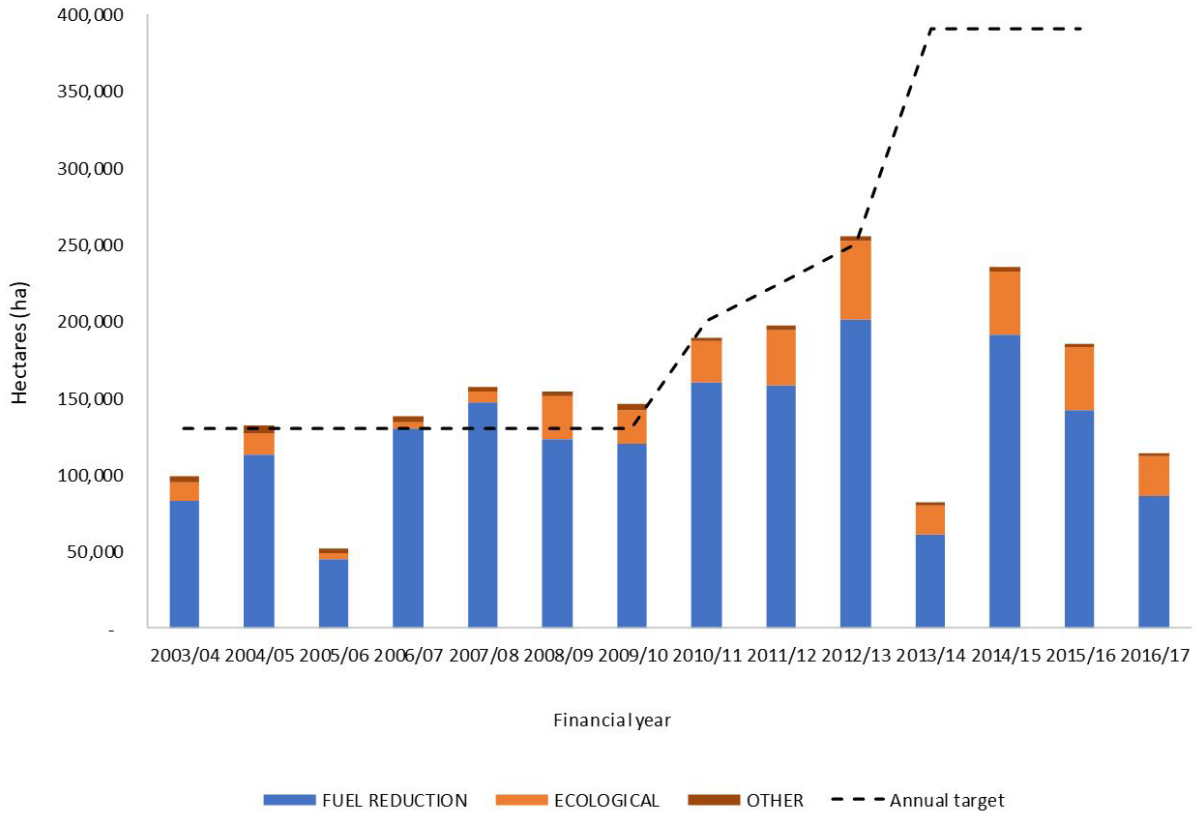


Figure Fi.1 Area of planned burns by type, 2003–04 to 2016–17

(Data source: DELWP, 2018)

21. Gippsons P, van Bommel L, Gill AM, Cary GJ, Driscoll DA, Ross A, Bradstock RA, Knight E, Moritz MA, Stephens SL, Lindenmayer DB 2012, 'Land management practices associated with house loss in wildfires'. PLOS One, 7, e29212.
22. Bradstock RA, Cary GJ, Lindenmayer, Price OF, Williams RJ 2012, 'Wildfires, fuel treatment and risk mitigation in Australian eucalypt forests: insights from landscape-scale simulation', Journal of Environmental Management, 105, pp. 66-75.

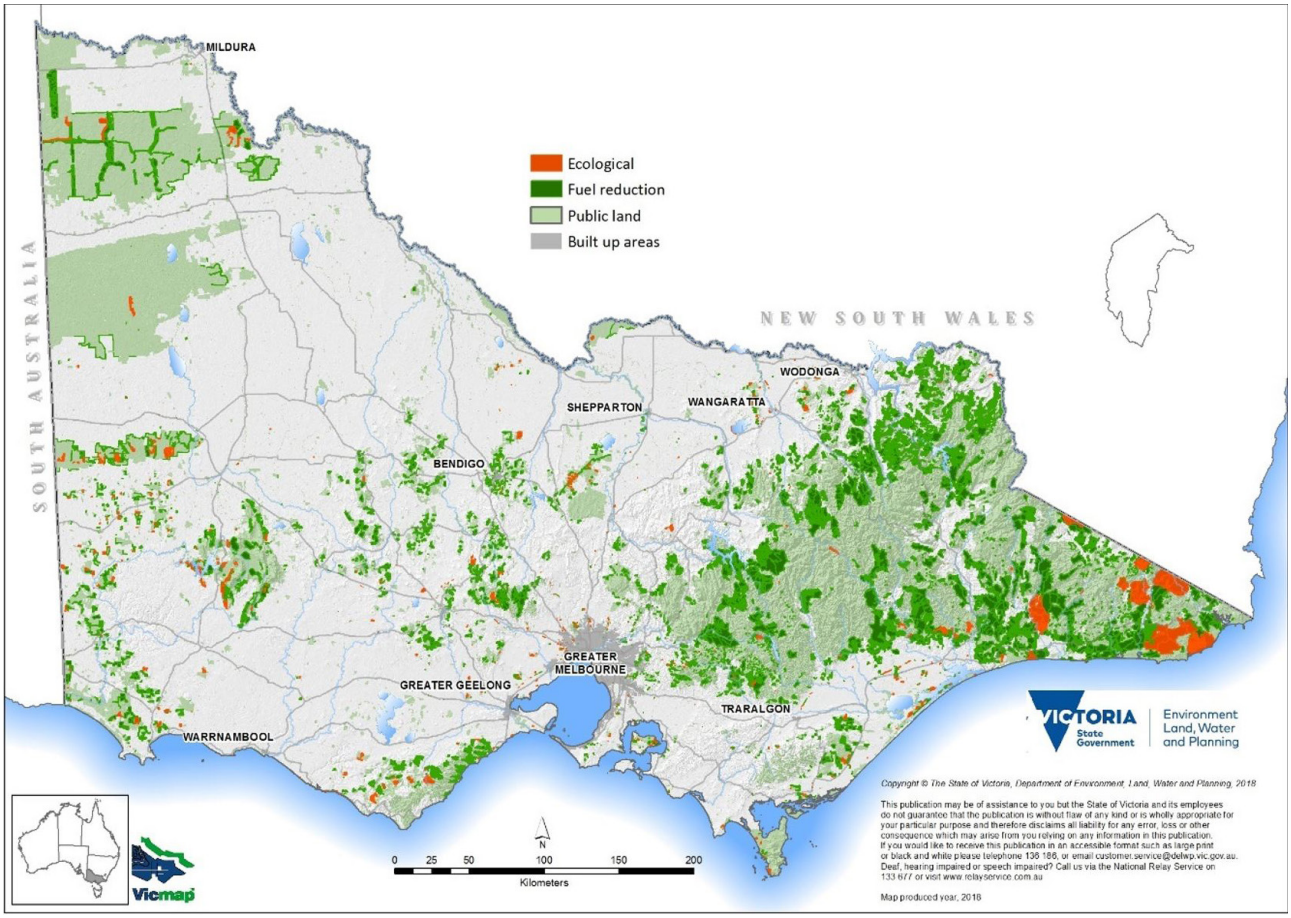


Figure Fi.2 Map of planned-burn areas in Victoria, 2000–2017

(Data source: DELWP, 2018)

Area of Planned Burns by Region and Fire District

DELWP applies fire management plans throughout six Victorian regions: Hume, Gippsland, Port Phillip, Grampians, Loddon Mallee and Barwon South West. Each region is comprised of several districts. The Gippsland region accounted for the largest area of planned burns between 2003–04 and 2016–17, with 829,000 hectares or 39% of the total planned-burning area. The Hume region was the second-largest area, with 621,000 hectares or 29% of the total planned-burning area. The high proportion of the state's planned burns in Gippsland and Hume (Figure Fi.3) is explained by the extent of public land close to assets in these regions, which has remained relatively consistent over time. The Snowy district in the Gippsland region was subject to extensive planned burns over the period, accounting for 19% (403,000 hectares). Upper Murray, in the Hume region, and Tambo, also in the Gippsland region, had 14% (293,000 hectares) and 12% (250,000 hectares) of the total area burnt over the period respectively (Figure Fi.4).

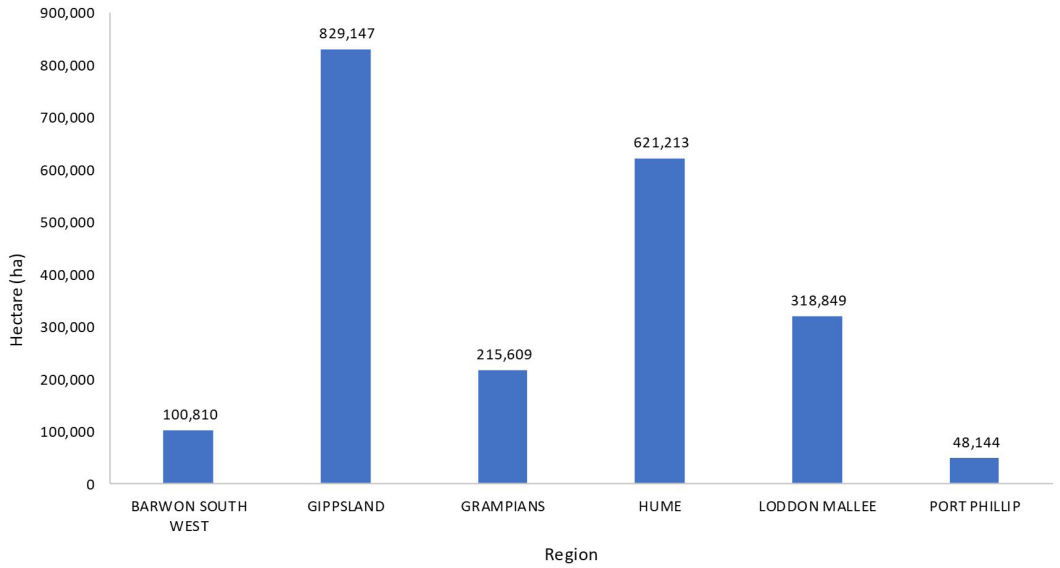


Figure Fi.3 Cumulated planned-burning area in Victoria by region, 2003–04 to 2016–17

(Data source: DELWP, 2018)

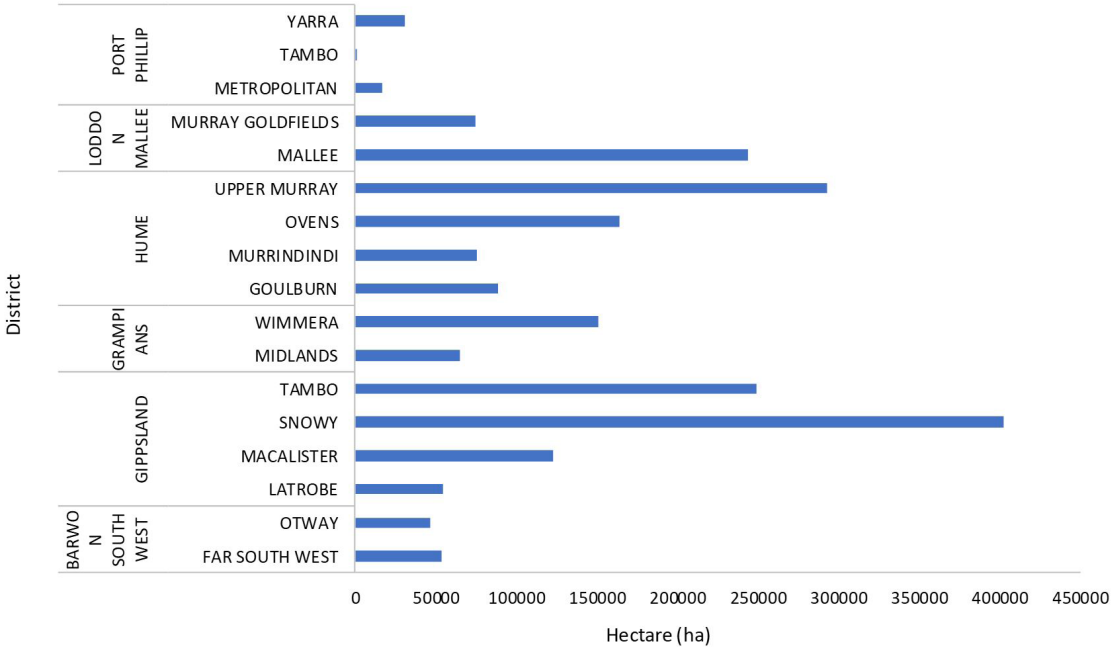


Figure Fi.4 Cumulated planned-burning area in Victoria by fire district, 2003–4 to 2016–17

(Data source: DELWP, 2018)

Area Burnt by Bushfire

More than 85% of the area burnt by bushfire in Victoria between 2003–04 and 2016–17 was burnt in four extensive bushfires between 2003 and 2017: 2003 (1.6 million hectares), 2007 (1.2 million hectares), 2009 (446,000 hectares) and 2014 (415,000 hectares). The 2003, 2007 and 2009 bushfires occurred during the millennium drought of 1996 to 2010, which increased the frequency and severity of large bushfires (Figure Fi.5 and Figure Fi.6).

In 2013–14, Victoria experienced its most significant fire season since 2008–09, challenging both emergency services and Victorian communities. Across the season, Victoria had 19 days of 'extreme' and 'severe' fire danger rating, and 16 days of 'total fire ban'. More than 463,000 hectares of public and private land was burnt, and 80 residences were destroyed.[23] The respective land management and fire agencies (including the CFA and DELWP, and their Networked Emergency Management partners – Parks Victoria, VicForests and Melbourne Water (DEPI/NEO) – and the Metropolitan Fire Brigade) responded to more than 4,600 bushfires and grassfires over a five-month period.

The Hazelwood mine fire also occurred in 2014, releasing significant amounts of smoke and ash that settled on the adjacent township of Morwell.[24] Following the fire, IGEM identified issues around the initial availability of air-quality monitoring, health-monitoring data, decision-making protocols and community information. These issues were addressed through two inquiries into the fire and the EPA inquiry, and their recommendations are now being implemented are now being implemented, as discussed in indicator A:09 (Health impacts of air pollution).[25]

Subsequent years up to 2017 have seen relatively low fire activity.

23. Emergency Management Victoria 2014, 'Post season operations review: Fire danger period 2013/14', Melbourne, Victoria https://www.emv.vic.gov.au/publications/post-season-operations-review-2013-14 Accessed 4 December 2018.
24. Environmental Protection Australia Victoria 2015, 'Summarising the air monitoring and conditions during the Hazelwood mine fire, 9 February to 31 March 2014', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1598.pdf Accessed 4 December 2018.
25. Hazelwood Mine Fire Inquiry 2014, 'Hazelwood Mine Fire Inquiry Report', Melbourne, Victoria http://report.hazelwoodinquiry.vic.gov.au/wp-content/uploads/2014/08/Hazelwood_Mine_Inquiry_Report_Intro_PF.pdf Accessed 4 December 2018

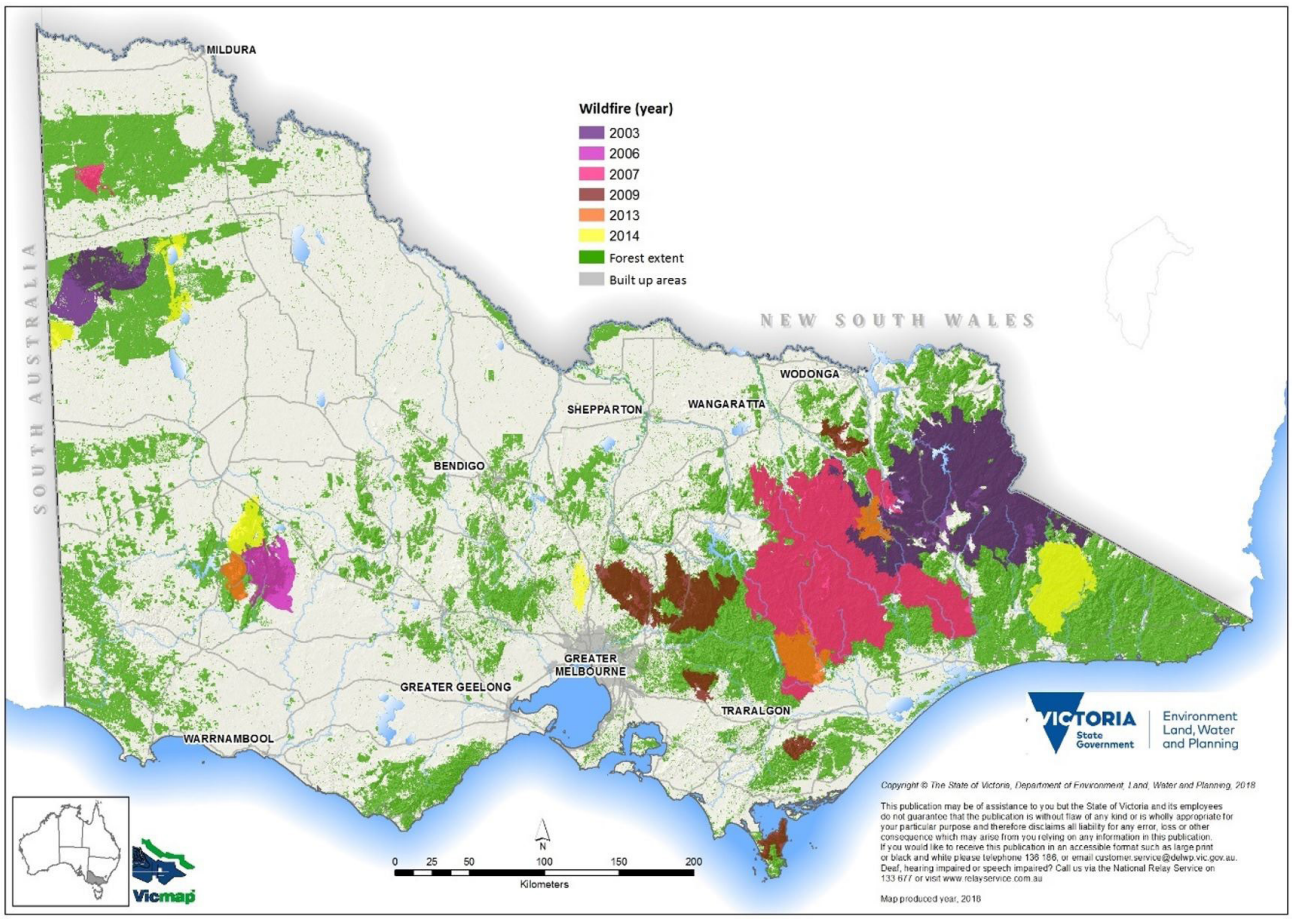


Figure Fi.5 Major bushfires in Victoria, 2000–2017

(Data source: DELWP, 2018)

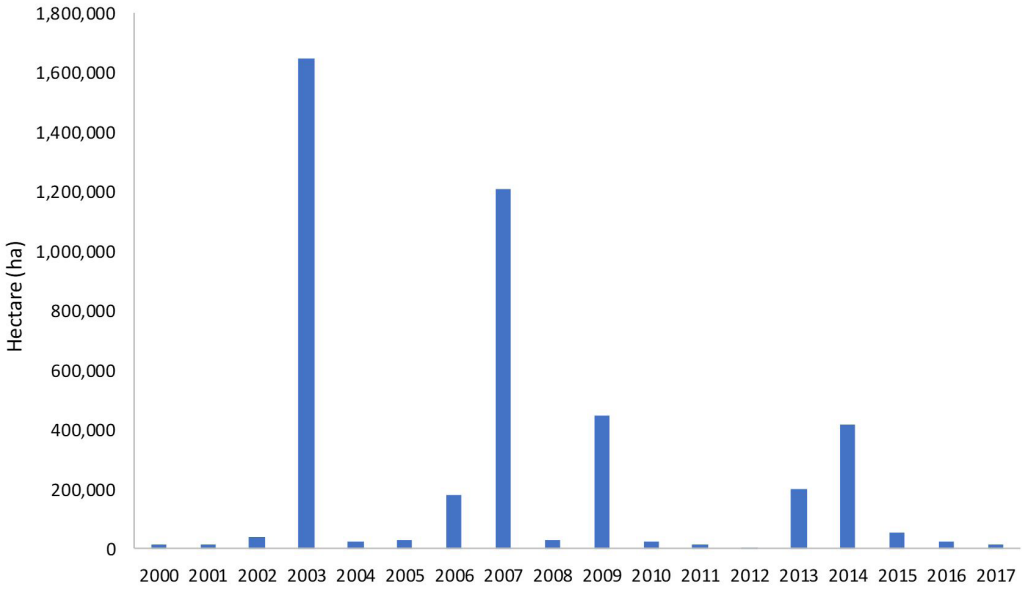


Figure Fi.6 Total area in Victoria affected by bushfires, 2000–2017

(Data source: DELWP, 2018)

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fi:02 Impacts of bushfires	○	●	○	○	?	DATA QUALITY: Poor

Data Custodian None

The Victorian Government's highest priority is to protect people, property and infrastructure. It is therefore extremely important to monitor and evaluate the cumulative impacts on society of bushfires.

Given the cost of fire responses, the drain on water resources, and the devastating impact of bushfires on biodiversity and communities, it is critical to identify data custodians responsible for collating information on the impacts of fire on essential community infrastructure (i.e. hospitals, power supplies), businesses, water resources, biodiversity and the cost of fire responses.

Previously, the Bushfire Cooperative Research Centre was the leading agency collating evidence on the economic, social and environmental impacts of bushfires in Victoria, with funding provided by the Victorian Government.[26, 27] Since 2013, the only information that was identified to be held by emergency management agencies was property loss from bushfires over the past three years (Table Fi.1).

During major emergencies, the Department of Health and Human Services (DHHS) is responsible for:

- overseeing and coordinating the health system's response, including understanding the impacts on the community, the health sector, and the department's clients and services, and working with EPA Victoria where there may be significant impacts on, or risks to, public health
- coordinating regional relief and recovery, the social recovery environment and the following services:
    - emergency shelter, housing and accommodation
    - emergency financial assistance
    - health, medical assistance and first aid
    - psychosocial support.

No specific bushfire-related information was available from DHHS for this report. DHHS referred to its annual reports,[28] which aggregate data from all emergency events, such as flooding, storms and thunderstorm asthma events.

Impact of bushfire on biodiversity is discussed in the next indicator (Fi:03 Actual fire regimes compared to optimal fire regimes).

Table Fi.1 Available property-loss data from bushfires, 2015–16 to 2017–18

Year	Property loss
2015–16	148 (116, from Wye River bushfire)
2016–17	1
2017–18	27 (26, South West Complex; 1, Carrum Downs fire)

(Data source: Emergency Management Victoria, 2018)

26. Stephenson C 2010, 'A literature review on the economic, social and environmental impacts of severe bushfires in south-eastern Australia', Fire and adaptive management Report no.87, Bushfire CRC, East Melbourne, Victoria https://www.ffm.vic.gov.au/__data/assets/pdf_file/0009/21114/Report-87-A-Lit.Rvw-On-The-Economic,-Social-and-Envtal-Impacts-of-Severe-Bushfires-In-SE-Aust..pdf Accessed 4 December 2018.
27. Stephenson C 2010, 'The impacts, losses and benefits sustained from five severe bushfires in south-eastern Australia'. Fire and adaptive management Report no. 88, Bushfire CRC, Melbourne, Victoria https://www.ffm.vic.gov.au/__data/assets/pdf_file/0010/21115/Report-88-The-Impacts-Losses-and-Benefits-Sustained-from-Five-Severe-Bushfires-in-SE-Aust..pdf Accessed 4 December 2018
28. DHHS 2017, 'Annual report 2016-17', Melbourne, Victoria https://dhhs.vic.gov.au/dhhs-annual-report-2016-17-pdf Accessed 4 December 2018.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fi:03 Actual fire regimes compared to optimal fire regimes	○	○	●	○	↘	DATA QUALITY: Good

Data custodian DELWP

A fire regime is a combination of factors including frequency, intensity, size, pattern, season, interval and severity. Inappropriate fire regimes can cause disruption to sustainable ecosystems and result in a loss of biodiversity by changing the structure of plant communities and the composition of fauna communities.

Fires impact on the habitat extent of some fauna species. For example, sugar glider (*Petaurus breviceps*) and Leadbeater's possum (*Gymnobelideus leadbeateri*) are subject to high-severity bushfire.[29] Landscape-level fire severity was found to have strong effects on bird species richness and the detection frequency of the majority of bird species after the 'Black Saturday' bushfire event in 2009.[30] For any given plant community, the suitable fire interval to maintain species composition is dictated by the life-history attributes of the plant species in that community, particularly the time required for species to mature and set seed, as well as their time to mortality in the absence of fire. The tolerable fire interval for a vegetation community is defined by the minimum and maximum intervals between fires of the species in that community that are most sensitive to fire. These are denoted as 'key fire response species (KFRS)'.[31] If fire frequency is above or below minimum fire tolerance intervals, KFRS may not be able to reproduce and repopulate and thus the vegetation community may change. Information on the vital attributes of plants that define their KFRS status is collated and subject to regular updating by DELWP, but is not published publicly and if requested, the status of KFRS is available. This information is regularly updated from ongoing field-monitoring activities. The KFRS is created based on the life-history characteristics or 'vital attributes' of flora species. The vital attributes of plants will dictate the response of a plant population to a particular disturbance.[32] At a minimum, three vital attributes of plants are required to determine their response to fire and tolerable fire intervals:

1. Method of persistence
2. Conditions for establishment
3. Relative longevity of each life stage.

Once the vital attributes of a species are identified, the sensitivity of a species to repeated fire can be determined. The purpose of defining the vital attributes of individual species is to ensure the viability of all species at a given location. However, it is impractical to manage all individual species at all locations across the landscape. Mapping of vegetation using floristic information is conducted at the community level. Thus, the viability of the community can be defined to a large extent by the viability of the individual species in the community. By identifying the plant species within each plant community which will be either significantly reduced in abundance by too frequent fire or by fire exclusion for long periods. These species are the key fire response species for the community. Once these KFRS have been identified, these species can be monitored regularly to see if they are developed to survive from next fire.

29. Lindenmayer DB, Blanchard W, McBurney L, Blair D, Banks SC, Driscoll D, Smith AL, Gill AM 2013, 'Fire severity and landscape context effects on arboreal marsupials', Biological Conservation, 167, pp. 137-148.
30. Lindenmayer DB, Blanchard W, McBurney L, Blair D, Banks SC, Driscoll DA, Smith A, Gill AM 2014, 'Complex responses of birds to landscape-level fire extent, fire severity and environmental drivers', Diversity and Distributions, 20, pp. 467-477.
31. Cheal D 2010, 'Growth stages and tolerable fire intervals for Victoria's native vegetation data sets', Fire and adaptive management Report no.84, Bushfire CRC, Melbourne, Victoria https://www.ffm.vic.gov.au/__data/assets/pdf_file/0009/21114/Report-87-A-Lit.Rvw-On-The-Economic,-Social-and-Envtal-Impacts-of-Severe-Bushfires-In-SE-Aust..pdf Accessed 4 December 2018.
32. Noble IR, Slatyer RO 1981, 'Concepts and models of succession in vascular plant communities subject to recurrent fire', In '*Fire and the Australian biota*', Eds Gill Am, Groves RH, Noble IR, pp. 311-335, Australian Academy of Science, Canberra, ACT.

At a landscape level, the Victorian Government uses Tolerable Fire Interval (TFI) as a metric to determine the current resilience condition of ecosystems. TFI thresholds provide minimum and maximum fire intervals to ensure ecosystem resilience. Currently, TFIs are determined based on expert elicitation, which uses a combination of published knowledge of plant vital attributes and information derived from experts on the responses of plants and plant communities to fire[33]. To complete the database of vital attributes for Victorian flora species, extensive and labour-intensive field measurements are needed. This requires field-surveys and long-term monitoring of plant communities. This could be a fundamental caveat of the system as the database is incomplete currently. However DELWP regularly updates the vital attributes dataset to establish TFIs on the basis of field-collected data.

Vegetation types in Victoria are classified by ecological vegetation classes (EVC).[34] EVCs are described through a combination of ecological characteristics, lifeforms and floristics. In order to use the EVC system in fire management for general monitoring, evaluation and reporting (MER) process, an Ecological Vegetation Division system was developed so that EVC data is grouped into larger ecological vegetation divisions (EVD) map units, based on EVC groups that have similar ecological characteristics. In addition, EVC data is attributed using an Ecological Fire Group (EFG) attribute field that provides specific fire-response information for particular (subsets of) EVCs. The interval since the last fire for each EFG has been estimated based on the mapped history of bushfires and planned burning in Victoria over recent decades. TFI analysis provides an opportunity for detecting the potential of vegetation to undergo fundamental ecological changes related to the extinction of KFRS in the event of a recurrence or absence of fire.

The proportion of public land below minimum TFI is representative of the total area that is younger than that recommended for the recurrence of fire. For example, if a recommended minimum TFI is 15 years for a given vegetation, and it was last burnt 10 years ago, the land is now below the minimum TFI and will continue to be for another five years. By contrast, the proportion of public land above maximum TFI is the percentage that remained unburnt longer than the recommended interval. The proportion of public land with no fire history is the percentage for which no identifiable record was found – or the percentage of land with vegetation that does not have a recommended TFI.

Figure Fi.7 (a) demonstrates that in 2017, 54% (4,119,000 hectares) of native vegetation was found to be below minimum TFI, with only 2% (163,000 hectares) above the maximum TFI. This means that more than half of Victoria's native vegetation is in a state where another fire would threaten the persistence of that vegetation type on that site, because, for example, many key plant species will not have set seed to replace themselves. Only 20% of native vegetation assessed was found to be within the required TFI to successfully maintain vegetation communities in 2017. The trend over the past decades to maintain their condition has been slightly deteriorating for Victorian vegetation. Figure Fi.7 (b) demonstrates that areas below minimum TFI increased by 5% (443,815 hectares) between 2007 and 2017, while areas within the TFI threshold decreased by 2% (107,914 hectare). The area below minimum TFI reflects a large number of extensive fires over that period.

33. Cheal D 2010, 'Growth stages and tolerable fire intervals for Victoria's native vegetation data sets', Fire and adaptive management Report no.84, Bushfire CRC, Melbourne, Victoria https://www.ffm.vic.gov.au/__data/assets/pdf_file/0009/21114/Report-87-A-Lit.Rvw-On-The-Economic,-Social-and-Envtal-Impacts-of-Severe-Bushfires-In-SE-Aust.pdf Accessed 4 December 2018.
34. Ibid

This index is a warning sign that future subsequent fires before minimum TFI is reached may have a large ecological impact, with the potential to drive localised extinction of some plant species. When a subsequent fire occurs in young forest at an immature stage, and where there is an absence of mature vegetation, the area dominated by young forest has potential to preclude the development of new cohorts of old-growth forest,[35] with corresponding negative impacts on the persistence of biodiversity.[36] Many bushfire-affected vegetation types have relatively long minimum TFIs (between 15 and 80 years), so the reported increases in areas below minimum TFI can remain for a considerable time.

Between 2007 and 2017, areas with no fire history reduced by 11% (834,000 hectares). This is partly a consequence of areas with no recorded history of fire being impacted by bushfires. Some of these areas are long-unburnt habitats, which could potentially impact on biodiversity. An extensive report on suitable growth stages for different habitat types observed that early growth stages 'can be created far more easily than can late (mature) stages'.[37] Recently burnt vegetation can be created in a single season. Some important habitat features occur only in mature to senescent vegetation and thus take decades, or even centuries, to develop. The decrease of long-unburnt area is a great concern as these habitats are very hard to re-establish once lost.

Long-unburnt areas provide an essential habitat: hollow-bearing trees. There is scant monitoring of bushfire impact on critical habitat structures, especially tree hollows, hollow logs and coarse woody debris on the ground, which are critically important to threatened species in Victoria.

'Hollow tree' is defined as 'a cavity in tree >20 mm diameter that appears to extend beyond the surface of bark/wood (i.e. has some 'depth', such that it could shelter a bird or mammal), or fissure extending beyond outer surface into interior of tree'.[38] Several peer-reviewed studies have indicated the importance of maintaining or improving the presence of a large range of tree hollows in the landscape.[39, 40, 41] Frequent fires can damage these important structural components of forests and woodlands.

A study by DELWP also demonstrates that planned burns in Gippsland significantly increase the risk of collapse of hollow-bearing trees, which is likely to result in loss of habitat for fauna species that rely on hollows for survival, such as Great gliders (*Petauroides volans*).[42] Thus, planned burns, which typically utilise low-intensity prescription burns, may cause some destruction of hollow-bearing trees.[43]

35. Lindenmayer DB, Hobbs RJ, Likens GE, Krebs C, Banks S 2011, 'Newly discovered landscape traps produce regime shifts in wet forests', Proceedings of the National Academy of Sciences, 108, pp. 15887-15891.
36. Todd CR, Lindenmayer DB, Stamation K, Acevedo-Catteneo S, Smith S, Lumsden LF 2016, 'Assessing reserve effectiveness: application to a threatened species in a dynamic fire prone forest landscape', Ecological Modelling, 338, pp. 90-100.
37. Cheal D 2010, 'Growth stages and tolerable fire intervals for Victoria's native vegetation data sets', Fire and adaptive management report no.84, Bushfire CRC, Melbourne, Victoria https://www.ffm.vic.gov.au/__data/assets/pdf_file/0009/21114/Report-87-A-Lit.Rvw-On-The-Economic,-Social-and-Envtal-Impacts-of-Severe-Bushfires-In-SE-Aust..pdf Accessed 4 December 2018.
38. Clarke M, personal communication dated 25/08/2018 (Leonard S, Haslem A, Bennett A, Clarke M 2018, 'Guidelines for ecosystem resilience monitoring, evaluation and reporting within the Victorian Bushfire Monitoring Program: scientifically-based monitoring project – final report', Latrobe University, Melbourne, Victoria).
39. Stares MG, Collins L, Law B, French K 2018, 'Long-term effect of prescribed burning regimes and logging on coarse woody debris in South-Eastern Australia', Forests, 9(5), pp. 242.
40. Lindenmayer DB 2009, 'Forest pattern and ecological process: a synthesis of 25 years of research'. CSIRO Publishing, Collingwood, Victoria.
41. Lindenmayer DB, Cunningham RB, Tanton MT, Smith AP 1990, 'The conservation of arboreal marsupials in the montane ash forests of the Central Highlands of Victoria, southeast Australia: II. The loss of trees with hollows and its implications for the conservation of Leadbeater's possum *Gymnobelideus leadbeateri* McCoy (Marsupialia: Petauridae)'. *Biological Conservation*, 54, pp. 133-145.
42. Bluff L 2016, 'Reducing the effect of planned burns on hollow-bearing trees'. Fire and adaptive management report no. 95, DELWP, Melbourne, Victoria https://www.ffm.vic.gov.au/__data/assets/pdf_file/0006/21120/Report-95-Reducing-the-effect-of-planned-burns-on-hollow-bearing-trees-2016.pdf Accessed 4 December 2018.
43. Parnaby H, Lunney D, Ian S, Fleming M 2010, 'Collapse rates of hollow-bearing trees following low intensity prescription burns in the Pilliga forests, New South Wales', Pacific Conservation Biology, 16(3), pp. 209-220.

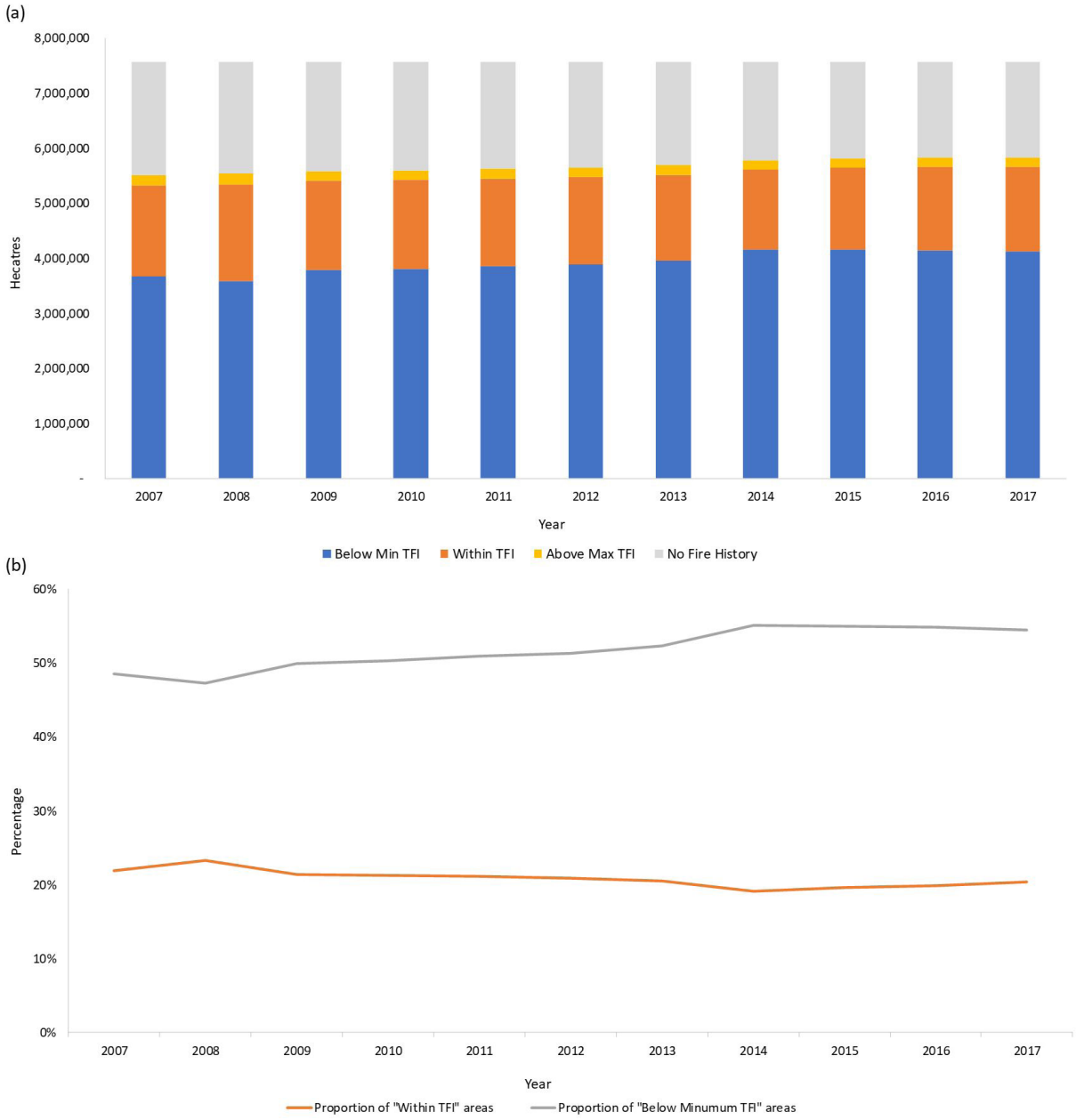


Figure Fi.7 Tolerable fire interval status on Victoria's public land

Graph (a) Area of native vegetation on Victoria's public land by TFI status, 2007–2017

Graph (b) Proportion of areas 'Within TFI' and 'Below minimum TFI', 2007-2017

(Data source: DELWP, 2018)

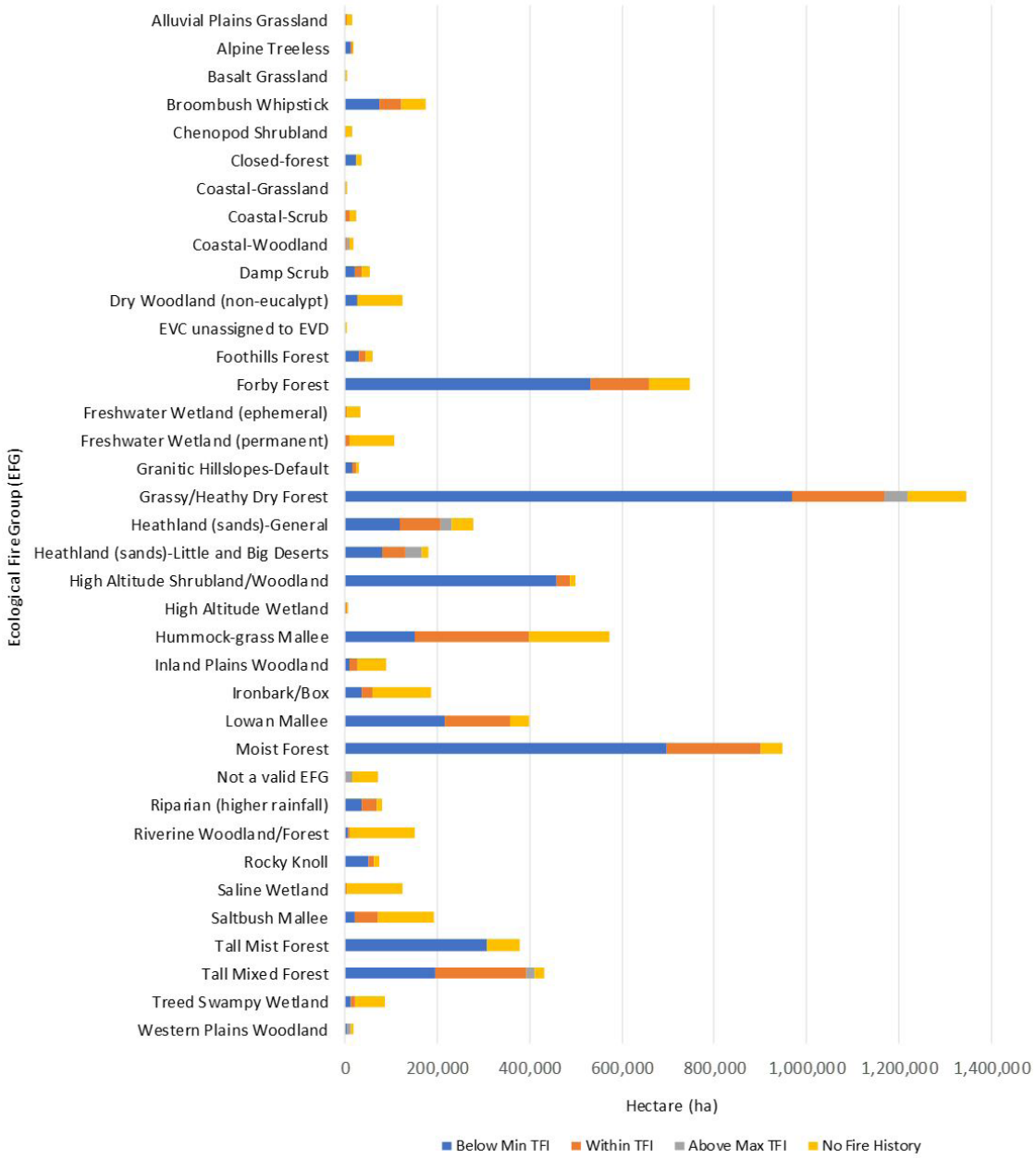


Figure Fi.8 Area of below minimum TFI, within TFI, above maximum TFI with no fire history in each EFG, 2016–17

(Data source: DELWP, 2018)

When Victorian public land is categorised by Ecological Fire Group (EFG), only 12 of 37 ecological groups have more than 25% of land that meets the required TFI standard. More than half (19) have more than 25% of land below the minimum TFI standard.

Hummock-grass Mallee and Tall Mixed Forest have the highest area within TFI, with 43% and 46% respectively. Three EFGs have more than 75% of the area below minimum TFI: Alpine Treeless, High Altitude Shrubland/Woodland, and Tall Mist Forest. Data for these fire groups is a warning that subsequent fires may impose more local or regional extinction risk on key threatened species. Detailed assessment of impacts on threatened vegetation community and/or species is an important process to ensure successful management of the Victorian environment.

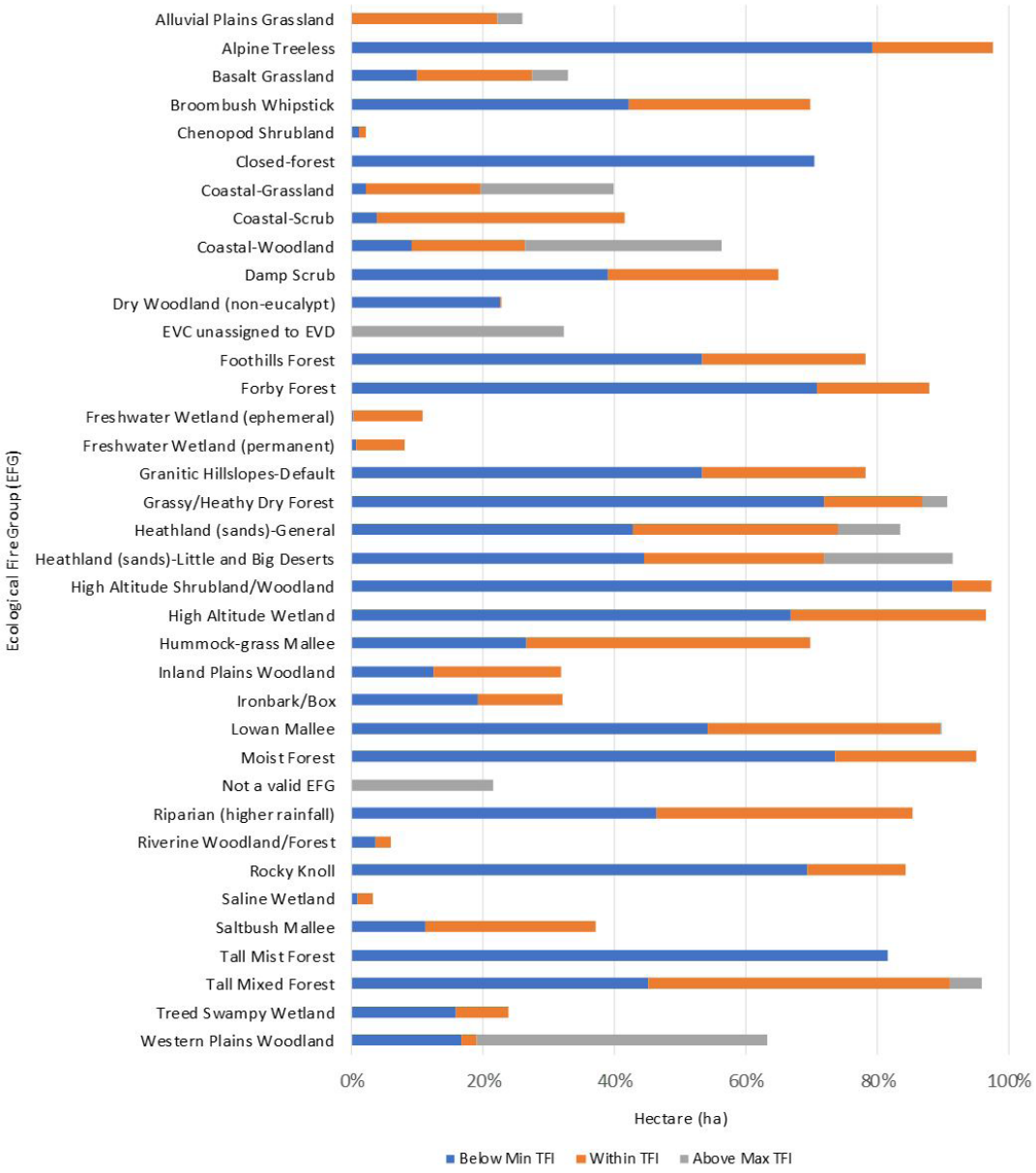


Figure Fi.9 Proportional distribution of below minimum TFI, within TFI and above maximum TFI in EFGs, 2016–17

(Data source: DELWP, 2018)

Vegetation growth stage structure (GSS) is used to indicate ecosystem resilience at a landscape level, as well as TFI. GSS is a mix of different age stages: juvenile, adolescent, mature and old. A vegetation's GSS depends on when it was last burnt or otherwise disturbed.

Figure Fi.10 shows changes in GSS for Victorian public land between 2007 and 2017 and demonstrates that overall, vegetation on public land has aged. There has been a 9% decrease in vegetation (724,400 hectares) in the juvenile growth stage, but a 10% increase in the adolescent growth stage (779,500 hectares) and a 4% increase in the mature growth stage (20,000 hectares). Areas that have no fire history were decreased by approximately 325,000 hectares within the same period, similar to Figure Fi.7 (a). This potentially means that some areas experienced an ongoing reduction in long-unburnt habitats as they succumbed to recent bushfires.

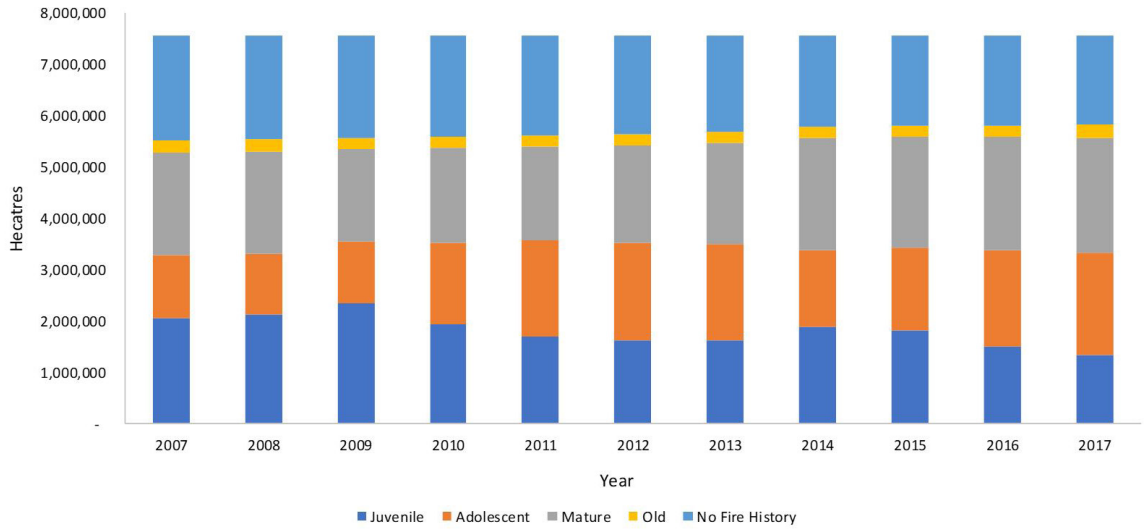


Figure Fi.10 Area of vegetation growth stage on Victoria's public land, 2007–2017

(Data source: DELWP, 2018)

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fi:04 Bushfire risk	○	○	●	○	↘	DATA QUALITY
Data custodian DELWP, BoM						Poor

Bushfire risk is composed of two variables: the likelihood of a fire starting, and its impact on communities and the environment. Planned burns are the main tool used to reduce bushfire risk globally.

Planned burns aim to reduce fuel loads at target locations to hinder fire intensity and spread rate. They are also used to provide benefits to key native fauna and flora species by providing heterogeneous landscape in nature. However, planned burns could harm biodiversity, including homogenised landscapes, if their impact is not properly assessed.[44]

As explained above, the Victorian Government set an annual burn-area target until 2015–16, which increased from 130,000 hectares to 390,000 hectares between 2003–04 and 2015–16 (Figure Fi.1). The government then shifted from a hectare-based approach to a risk-based approach for fire management. The new risk-based approach focuses on strategic areas near housing and infrastructure where there is a high chance of fire impacting on people and property.

To achieve this, the Victorian Government has adopted a fire-behaviour simulation program, PHOENIX RapidFire. The program provides a method to estimate bushfire risk by comparing the predicted difference in house loss in a maximum-risk scenario with maximum fuel load, with a scenario with fuel loads after a planned burn on public land.[45] The difference between the two scenarios is known as 'residual risk'. Residual risk can be expressed as a ratio of the average property impact from a modified risk scenario following planned burning, to the average impact of the maximum risk scenario, reported as a percentage.

The government's goal is to keep residual risk below 70%. DELWP estimated that residual risk in Victoria in 2018 was 63%[46] (Figure Fi.11). The figure below also indicates how dramatically residual risk fell after major bushfire events, such as the 'Ash Wednesday' fires in 1983, and the Black Saturday fires in 2009, and the comparatively higher-impact bushfires have had on residual risk than planned burns as those 1983 and 2009 bushfires dropped residual risk sharply.

44. Holland GJ, Clarke MF, Bennett AF 2017, 'Prescribed burning consumes key forest structural components: implications for landscape heterogeneity'. Ecological Applications, 27(3), pp. 845-858.

45. DELWP 2015, 'Measuring bushfire risk in Victoria', Melbourne, Victoria http://www.delwp.vic.gov.au/__data/assets/pdf_file/0009/318879/DELWP0017_BushfireRiskProfiles_rebrand_v5.pdf Accessed 4 December 2018.

46. DELWP 2015, 'Safer Together: a new approach to reducing the risk of bushfire in Victoria', Melbourne Victoria http://www.delwp.vic.gov.au/__data/assets/pdf_file/0004/319531/DELWP_SaferTogether_FINAL_17Nov15.pdf Accessed 4 December 2018.

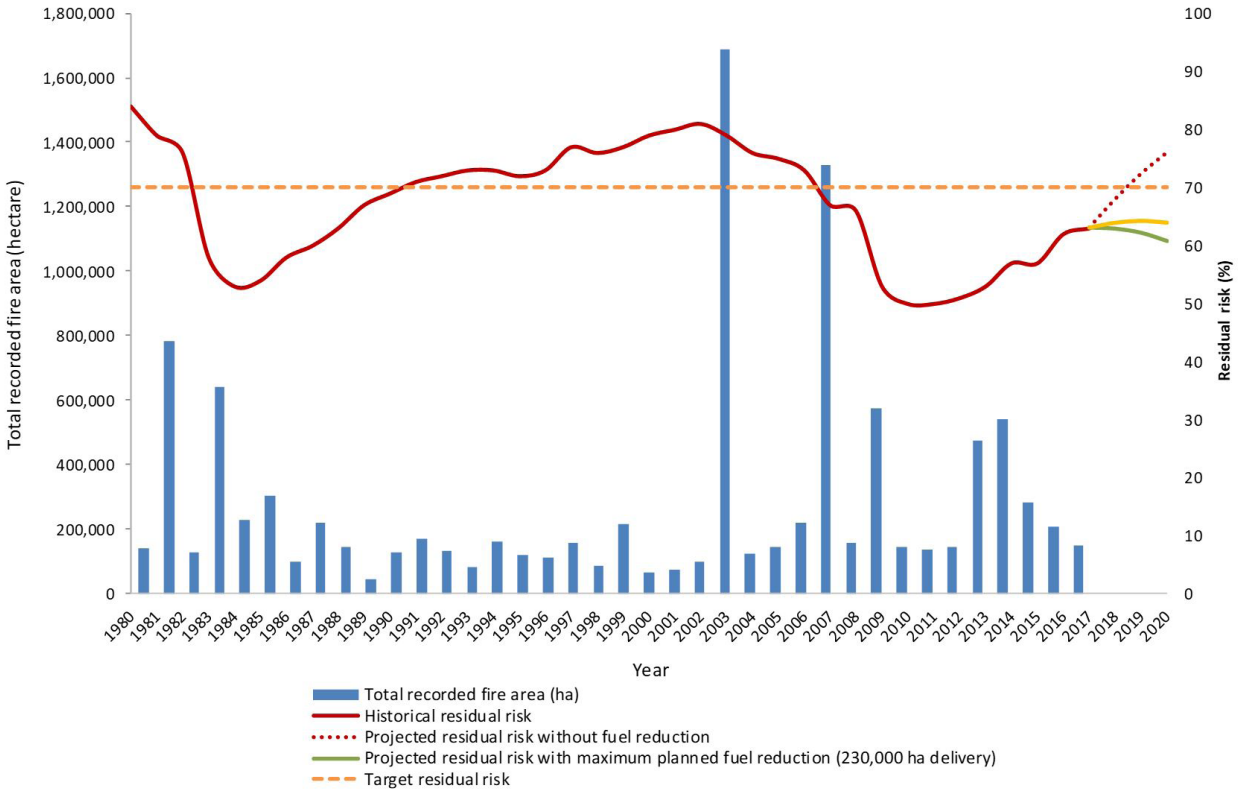


Figure Fi.11 Residual risk profile in Victoria, 1980–2020

(Data source: DELWP[47])

One criticism levelled at forest fire management agencies was that the previous hectare-based approach to planned burns did not adequately address potential harm to Victorian ecosystems.[48, 49] A similar concern may be raised regarding the current approach under the Safer Together program. However, Safer Together provides a framework for assessing the new burning approach in relation to ecological resilience and biodiversity. Although it has been in an establishment phase over the past two years, it has yet to incorporate the risk to biodiversity in the residual risk calculations. Therefore, data quality for biodiversity is assessed as 'poor' while that for life and property is assessed as 'good'.

It is important to note that after disturbances such as logging or fire, forests are prone to subsequent high-severity fires (typically crown-scorching fires). A 2018 study found that in tall, wet forests dominated by ash-type eucalypts, post-disturbance stands of trees could be more than eight times as likely to burn than mature stands.[50] In some areas, especially the alps areas, areas below minimum TFI may be more prone to subsequent high-severity fires, resulting in forest degradation and loss of the original formation of forests.

While the use of planned burns may still be necessary for the management of some native species, variability of subsequent high-severity fires must be considered in risk assessment.

47. Ibid.
48. Ingamells P 2012, 'Statewide fuel reduction target threatens biodiversity', Park Watch, 249, pp. 16-17.
49. Kelly L, Giljohann K, McCarthy M 2015, 'Burning issues: state-wide percentage targets for planned burning are blunt tools that don't work', Decision Point, 88, pp. 4-5.
50. Zylstra PJ 2018, 'Flammability dynamics in the Australian Alps', Austral Ecology, 43, pp. 578-591.

Climate Change

The impact of climate change on weather conducive to fire is well understood by researchers and land managers.[51, 52] There is a trend towards more dangerous weather conditions for bushfires in south-east Australia, including significant increases in the frequency and magnitude of extreme conditions in some regions.

The figures provided are for the Forest Fire Danger Index (FFDI), which is configured from temperature, rainfall, humidity and wind speed, and used throughout Victoria by fire agencies. Fire weather is monitored with FFDI in Australia. FFDI patterns have changed in recent decades, with the strongest increases to the index generally in summer and spring. This upward trend in FFDI is due to increasing temperatures and drying conditions.[53] Changes to the springtime pattern indicate a shift towards an earlier start to the fire season (Figure Fi.12). These recent changes are attributable, at least in part, to anthropogenic (human-related) climate change, including increasing temperatures.

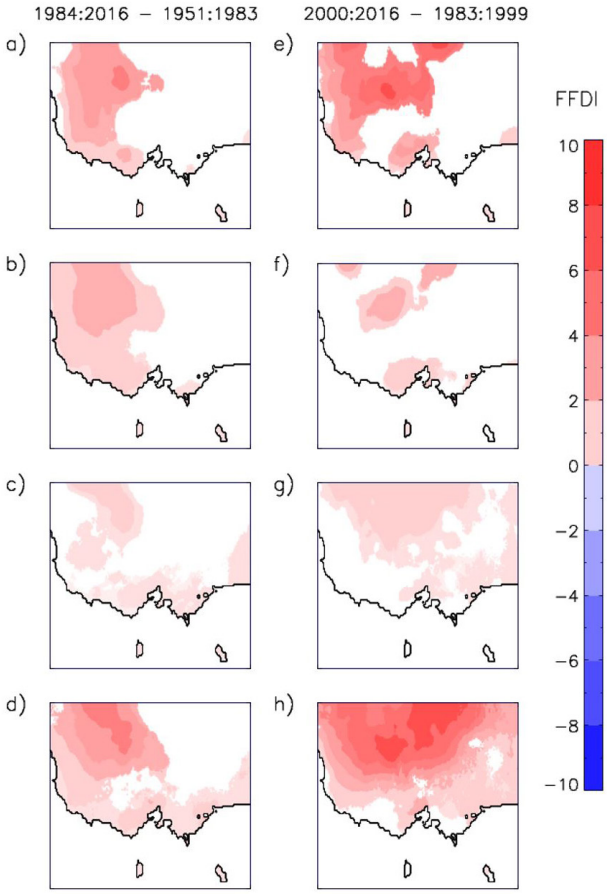


Figure Fi.12 Long-term changes in seasonal mean FFDI values

Note: This is shown for the change from the first half (1951–83) to the second half (1984–2016) of the study period during (a) December–February, (b) March–May, (c) June–August and (d) September–November. This is also shown for the change from 1983–1999 period to 2000–2016 period during the same four seasons mentioned above for (e), (f), (g) and (h) respectively. The coloured regions represent locations where the magnitude of the change is significant at the 95% confidence level.[54] (Figure (a) – (h) are modified by the author).

(Data source: Dowdy[55])

51. Hennessy, K, Lucas C, Nicholls N, Bathols J, Suppiah R, Ricketts J 2005, 'Climate change impacts on fire-weather in south-east Australia'. CSIRO, Aspendale, Victoria http://www.cmar.csiro.au/e-print/open/hennessykj_2005b.pdf Accessed 4 December 2018.
52. Clarke H, Evans JP 2018, 'Exploring the future change space for fire weather in southeast Australia', Theoretical and Applied Climatology, pp. 1-15.
53. CSIRO and Bureau of Meteorology 2016, 'State of the Climate 2016'. http://www.bom.gov.au/state-of-the-climate/State-of-the-Climate-2016.pdf Accessed 4 December 2018.
54. Dowdy AJ 2018, 'Climatological variability of fire weather in Australia', American Meteorological Society, 57, pp. 221-234.
55. Ibid.

Fire authorities use the Southern Australia Seasonal Bushfire Outlook for making strategic decisions on resource planning and prescribed fire management. Each year, the outlook is developed at an annual workshop attended by relevant expert practitioners, and convened by the Bushfire & Natural Hazards CRC and Australian Fire and Emergency Services Authorities Council Limited (AFAC). Throughout the workshop, stakeholders discuss fire weather, landscape conditions and potential areas where above-normal or below-normal fire season may occur in Australia in the upcoming fire season.

The most recent outlook through to the end of 2018 in Victoria demonstrates that much of East Gippsland will have above normal fire potential due to two consecutive years of record low rainfall during autumn and winter, leading to forests in East Gippsland being more flammable than normal (Figure Fi.13).[56] The outlook also stated that there is extensive and historically unprecedented dryness across the majority of southern Australia, due to the combination of increasing temperatures and drying conditions.

Given the intensifying impacts of climate change, addressing the risks and impacts of climate change that are facing the emergency management sector, including fire, is an urgent and significant challenge for fire management agencies. The agencies have been working collaboratively to identify key risks and priorities for action.[57] In response to this, the Emergency Management Climate Change Program was initiated in 2017, led by Emergency Management Victoria. The program will work with the emergency management sector to tackle potential risks to the Victorian environment, community and economy.

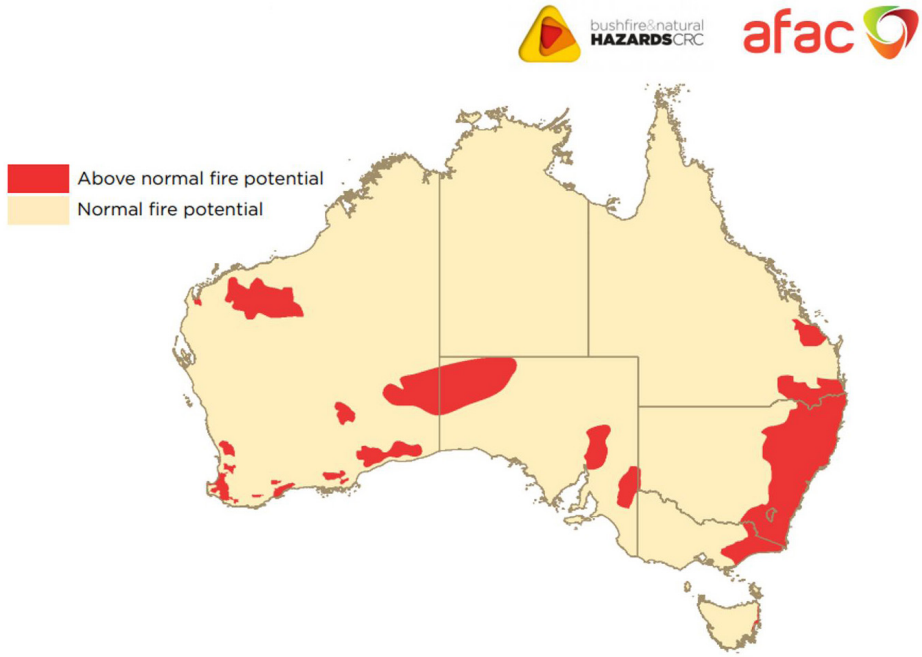


Figure Fi.13 Areas where higher and normal fire potential exist in Australia through to the end of 2018

(Data source: Bushfire & National Hazards CRC, 2018)

56. Bushfire & Natural Hazards CRC and Australian Fire and Emergency Services Authorities Council Limited 2018, 'Southern Australia seasonal bushfire outlook 2018', Hazard Note Issue 51, Bushfire & Natural Hazards CRC, Melbourne, Victoria https://www.bnhcrc.com.au/hazardnotes/51 Accessed 4 December 2018.
57. Australian Fire and Emergency Services Authorities Council Limited 2018, 'Climate change and the emergency management sector: discussion paper version 1.0', Australian Fire and Emergency Services Authorities Council Limited, East Melbourne, Victoria https://files-em.em.vic.gov.au/public/EMV-web/AFAC-Climate-Change-Discussion-3July2018FINAL.pdf Accessed 4 December 2018.

Future Focus

Understand fire impacts on the environment statewide using a structured, integrated framework

Ecological values are not currently included in the DELWP residual risk prediction program (PHOENIX RapidFire) used to inform the risk-based approach to forest fire management, Safer Together.[58] To address this and assess the impact of current fire management strategies on Victoria's native species and ecosystems, as recommended by the 2009 Victorian Bushfires Royal Commission,[59] DELWP, in partnership with La Trobe University, developed an ecosystem resilience monitoring program in 2017–18 to collect, analyse and interpret comprehensive data on how bushfire and fire management activities affect plants, animals and their habitats in the landscape.

This program is described in the *Guidelines for Ecosystem Resilience Monitoring, Evaluation and Reporting within the Victorian Bushfire Monitoring Program: Scientifically-based Monitoring Project – Final Report.* The ecosystem-resilience monitoring program has been piloted and includes recommendations for deployment. It is structured around a dual-scale approach to monitoring: regional and statewide. Regional monitoring activities focus on the immediate and short-term effects of fuel-management actions (primarily planned burns) on species of local interest and/or significance (such as the impact of planned burns on the greater glider by causing the loss of hollow-bearing trees in Alpine-North East). The statewide program would examine the effects at a broader scale and the long-term relationships between plants and animals, and fire, at sites across the landscape with a varied fire history.

The full implementation of this program would help establish a science-based, state-scale approach to the monitoring, evaluation and reporting framework for ecosystem resilience on public land in Victoria. An approach that includes both flora and fauna species at the state scale has never been implemented before.

Conserving flora and fauna species in fire-prone landscapes in Victoria requires an evidence-based approach to identify how fires affect ecosystems that can be modified by cumulative threats. There are two contemporary fire management paradigms: fire mosaic paradigm and functional types paradigm.[60] Current fire management has adopted the functional types paradigm, which focuses on plant responses to recurrent fires. This paradigm is guided by life-history traits of plants such as the Tolerable Fire Interval (TFI), and aims for temporal variation within acceptable fire intervals. By contrast, the fire mosaic paradigm focuses on animal responses to fire events, aiming to create spatially diverse fire mosaics for promoting biodiversity and assisting the persistence of isolated, localised species.

Research indicates[61] that both paradigms need to be integrated in evidence-based monitoring for fire management for biodiversity conservation, as animals and plants are interdependent and influenced by the spatial and temporal dimensions of fire regimes. The new ecosystem-resilience program will provide an opportunity to integrate these two paradigms to better evaluate and report on the effectiveness of bushfire for maintaining resilient and biodiverse ecosystems.

Recommendation 9: That the Victorian Government establish a structured framework based on the findings of the dual-scale ecosystem-resilience monitoring program, piloted by DELWP in 2017–18, and undertake a detailed analysis of the persistence of key fire-response species to increased fire frequency in Victoria, particularly in areas where below-minimum TFI exists.

58. DELWP 2015, 'Measuring bushfire risk in Victoria', Melbourne, Victoria http://www.delwp.vic.gov.au/__data/assets/pdf_file/0009/318879/DELWP0017_BushfireRiskProfiles_rebrand_v5.pdf Accessed at 5 December 2018.
59. Teague B, McLeod R, Pascoe S 2010, 2009 'Victorian Bushfires Royal Commission Final Report', Parliament of Victoria, Melbourne, Victoria.
60. Kelly LT, Brotons L, Giljohann KM, McCarthy MA, Pausas JG, Smith AL. 2018, 'Bridging the divide: integrating animal and plant paradigms to secure the future of biodiversity in fire-prone ecosystems', Fire, 29, 1-8.
61. Ibid

Accounting for the Environment

Forest and grass fires impact on both built and natural assets, affecting the production of goods and services, that benefits the economy and society.

The impact of fire on the economy is partly captured in the System of National Accounts (SNA) through changes to stock of built assets and the flow of goods and services. However, the SNA does not capture the impact of fire on the environment, and the ecosystem services that flow from the environment to the economy. The System of Environmental-Economic Accounting (SEEA) provides a framework for measuring the impact of fire on the environment (ecosystem assets including wetlands, rivers and ecological vegetation) and the connection between this and the economy and society.

When fire burns an area of land, it can affect both the extent and condition of different types of vegetation (different ecosystem assets). Most Victorian plant communities are fire tolerant and exhibit some form of recovery after fire. However, under certain circumstances fire can change the mix of environmental assets in an area by killing one type of vegetation, which is then replaced by another. Depending on the ecological vegetation type and the severity and frequency of fire, fire can increase or reduce the extent and condition of ecosystem assets.

Fire can impact on the ecosystem services produced by ecosystem assets. For example, fire can increase the habitat services provided by ecosystems, as some flora species depend on fire or smoke for seed germination. However, fire can reduce the timber resources available from native or plantation forests, as well as reduce carbon storage, water filtration and soil stabilisation services. For example, when fire burns plants that stabilise soil, water runoff can carry increased amounts of soils and nutrients into rivers and water storages. This reduces the quality of water for human and animal consumption. The risk of landslides can increase, potentially impacting on other ecosystem assets or built assets such as roads or buildings. For example, in 2003, the Australian Capital Territory was significantly affected by fire. In the aftermath, storm events resulted in sediment entering Canberra's water storages, and the closure of these storages for water supply.[62] This illustrates the connection between fire and water supply and quality accounts (discussed further in the Water Resources, Water Quality, and Forests chapters).

62. Daniell T, White I 2005, 'Bushfires and their implications for management of future water supplies in the Australian Capital Territory', Climatic and Anthropogenic Impacts on the Variability of Water Resources, HydroSciences Montpellier, pp. 1-15 http://www.bom.gov.au/water/about/waterResearch/document/Daniell_and_White_Montpellier_2005.pdf Accessed 4 December 2018.

Case Study: Accounting for the Impact of Fire on Ash Eucalypt Vegetation

This case study draws on the numerous studies on the ash-reseeding.[63, 64, 65, 66, 67, 68]

In the past 15 years, bushfires have burnt large areas of forest in the alpine area of Victoria, with major fires in 2003 (Alpine fires), 2006–07 (Great Divide fires), 2009 (Black Saturday fires) and 2013 (Harrietville, Tomahawk and Aberfeldy fires). Although most Victorian plant communities are well adapted to fire, the eucalypt ash forests of mountain ash (*Eucalyptus regnans*) and alpine ash (*Eucalyptus delegatensis*) are particularly vulnerable to increased fire frequency and intensity.[69] Ash eucalypt species are vulnerable to demographic collapse if their life cycles become de-synchronised with the fire regimes to which they are adapted.[70]

Data is available on the area of public and private land burnt by bushfire, including the area of ash eucalypt species burnt, and the proportion of this that is burnt immature ash regrowth. That is, ash that had already been burnt prior to reaching sexual maturity. Mature ash eucalypt forests can recover from a single high-intensity fire through mass seed regeneration. But if the regenerated forest is subject to another high-intensity fire prior to setting seed, management intervention (revegetation) is needed for the ecosystem asset to be maintained. After major fires in the Victorian alpine areas, DELWP, VicForests and Parks Victoria intervened to maintain ash ecosystem assets, through aerial sowing (via helicopter) and planting seedlings.

Available data has been used to construct account tables for each of the major fires (see from Table Fi.2 to Table Fi.5).[71] Each account shows an opening stock of assets burnt, the loss of ash forest due to fire (where immature ash forest was burnt), and additions to ash forest. Additions are either from human activity (aerial sowing or planting seedlings) or additions to other forest type as the composition of ecosystem assets changes where areas of burnt immature ash have not been revegetated (termed 'reclassifications' under SEEA).

Overlap of areas burnt in each fire event has resulted in increasing losses of ash eucalypt species relative to the size of the fires. For example, Table Fi.5 shows that the total area of the 2013 fires (126,002 hectares) was much smaller than the area burnt in previous years; however, 5,537 hectares of immature ash was still killed in 2013. The areas of immature ash killed in 2013 included some areas of triple-burnt ash stands – that is, areas that were burnt three times between 2003 and 2013.

63. Fagg P, Lutze M, Slijkerman C, Ryan M, Bassett O 2013, 'Silvicultural recovery in ash forests following three large bushfires in Victoria'. Australian Forestry, 76(3-4), pp. 140-155.
64. Jewell C, Lutze M, Fagg P, Ryan M 2008 'Bushfire recovery - forest values (silviculture). 2007 regeneration report', Department of Sustainability and Environment, Melbourne, Victoria.
65. Slijkerman C, Lutze M, Fagg P 2010, '2006/07 great divide fire recovery (forest values) 2008 regeneration report', Department of Sustainability and Environment, Melbourne, Victoria (internal report).
66. Slijkerman C, Fagg P, Lutze M, Notman W, Patrick R, Cleaver J, Harper E, Doherty K 2011, 'Bushfire recovery silviculture report-2009 Black Saturday fires', Department of Sustainability and Environment, Melbourne, Victoria (internal report).
67. Stabb T 2013, 'Alpine fires - north east Victoria & Gippsland bushfire recovery plan', Department of Environment and Primary Industries (internal report), Melbourne, Victoria. Spreadsheet 'Sowing summary_ area_kg_fire-In20-20130705.xls' as supplied by Carolyn Slijkerman
68. Slijkerman et al (2010) 2006/2007 Great Divide Fire recovery (Forest Values) 2008 Silviculture Report. Department of Sustainability and Environment, Victoria (internal report)
69. Williams RJ, Bradstock RA, Cary GJ, Enright NJ, Gill AM, Liedloff AC, Lucas C, Whelan RJ, Andersen AN, Bowman DJMS, Clarke PJ, Cook GD, Hennessy KJ, York A 2009, 'Interactions between climate change, fire regimes and biodiversity in Australia: A preliminary assessment', Australian Department of Climate Change and Department of the Environment, Water, Heritage and the Arts, Canberra, ACT.
70. Keeley JE 1986, 'Resilience of Mediterranean shrub communities to fires. In: Resilience in Mediterranean-type ecosystems', pp 95-112, Springer, Netherlands.

71. Re-seeding data sourced from numerous DELWP internal fire recovery documents and associated reports, each listed at the end of this chapter.

Table Fi.2 Change in stock of assets burnt in 2003 Alpine fires (hectares)

	State forest and other public land		Private land	Total
	Ash eucalypt species	Other species (a)		
	ha	ha	ha	ha
Opening stock of assets	81,000	923,000	96,000	1,100,000
Reductions in stock				
Losses due to natural events	3,550			
Total reductions in stock	*3,550*	-	-	-
Additions to stock				
Improvements due to human activity – aerial seeding	2,000			
Reclassifications		1,550		
Total additions to stock	*2,000*	*1,550*	-	-
Closing stock of assets	**79,450**	**924,550**	**96,000**	**1,100,000**

(a) Other species are fire tolerant, so while they were burnt, this does not necessarily change the ecosystem type

(Data source: DELWP, 2018)

Table Fi.3 Change in stock of assets burnt in 2006–07 Great Divide fires (hectares)

	State forest and other public land		Private land	Total
	Ash eucalypt species	Other species		
	ha	ha	ha	ha
Opening stock of assets	65,000	1,020,000	105,000	1,190,000
Reductions in stock				
Losses due to natural events	15,000			
Total reductions in stock	*15,000*	-	-	-
Additions to stock				
Improvements due to human activity – aerial seeding	5,880			
Improvements due to human activity – seedling planting	376			
Reclassifications		8,744		
Total additions to stock	*6,256*	*8,744*	-	-
Closing stock of assets	**56,256**	**1,028,744**	**105,000**	**1,190,000**

(Data source: DELWP, 2018)

Table Fi.4 Change in stock of assets burnt in 2009 Black Saturday fires (hectares)

	State forest and other public land		Private land	Total
	Ash eucalypt species	Other species		
	ha	ha	ha	ha
Opening stock of assets	43,000	244,000	119,000	406,000
Reductions in stock				
Losses due to natural events	4,500			
Total reductions in stock	*4,500*	-	-	-
Additions to stock				
Improvements due to human activity – aerial seeding	3,965			
Improvements due to human activity – seedling planting	102			
Reclassifications		433		
Total additions to stock	*4,067*	*433*	-	-
Closing stock of assets	**42,567**	**244,433**	**119,000**	**406,000**

(Data source: DELWP, 2018)

Table Fi.5 Change in stock of assets burnt in 2013 Harrietville, Tomahawk and Aberfeldy fires (hectares)

	State forest and other public land		Private land	Total
	Ash eucalypt species	Other species		
	ha	ha	ha	ha
Opening stock of assets	7,800	105,332	12,870	126,002
Reductions in stock				
Losses due to natural events	5,537			
Total reductions in stock	*5,537*	-	-	-
Additions to stock				
Improvements due to human activity – aerial seeding	2,425			
Improvements due to human activity – seedling planting	-			
Reclassifications		3,112		
Total additions to stock	*2,425*	*3,112*	-	-
Closing stock of assets	**4,688**	**108,444**	**12,870**	**126,002**

(Data source: DELWP, 2018)

Cost data associated with management intervention – revegetation of ash forest – is available (see Table Fi.6). If information on the ecosystem services provided under different scenarios (for example, revegetation or no revegetation) was available, this could be assessed against management intervention to help determine where management interventions are likely to deliver greatest benefits for the community.

Table Fi.6 Cost of additions to stock from human activity (revegetation of ash forest)

	Aerial sowing	Seedling planting	Total
	$	$	$
2003 Alpine fires	899,600	-	899,600
2006–07 Great Divide fires	1,813,578	793,020	2,606,598
2009 Black Saturday fires	1,615,060	249,000	1,864,060
2013 Harrietville, Tomahawk and Aberfeldy fires	787,445	-	787,445

(Data source: DELWP, 2018)

MARINE AND COASTAL ENVIRONMENTS (MC)

SCIENTIFIC ASSESSMENTS Part III

Commissioner *for* Environmental Sustainability Victoria



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:

1. 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 km^2 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).

1. Government of South Australia 2013, 'State of the Environment Report 2013', Adelaide, South Australia http://www.epa.sa.gov.au/soe_2013/main/coast-1-why-is-it-important.html Accessed 4 December 2018.
2. 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 two-thirds 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]

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

4. ABS 2016, 'Quick Stats 2016', www.abs.gov.au/websitedbs/censushome.nsf/home/quickstats?opendocument&navpos=220/ Accessed 4 December 2018.
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.
6. Victorian Coastal Council 2017, 'Population and growth', http://vcc.vic.gov.au/page/victorian-coastal-strategy/population-and-growth 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 Island[7] – 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]

7. 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.
8. 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://www.business.vic.gov.au/tourism-industry-resources/research/regional-visitation Accessed 4 December 2018.
9. Victorian Coastal Council 2014, 'Victorian coastal strategy', Victorian Coastal Council, Melbourne, Victoria, p.24.
10. 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.
13. Boon P, Cook P, Woodland R 2015, 'The Gippsland Lakes: management challenges posed by long-term environmental change', *Marine and Freshwater Research* 67 (6), pp.721-737 http://dx.doi.org/10.1071/MF14222 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.[15] 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.[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]

14. 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.

15. EPA 2018, 'Yarra and Bay', www.yarraandbay.vic.gov.au/issues/stormwater Accessed 4 December 2018.
16. Ibid
17. 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.
18. 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 survey[24] 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]

19. CES 2016, 'State of the Bays 2016', Melbourne, Victoria.
20. EPA 2018, 'Litter', Melbourne, Victoria https://yarraandbay.vic.gov.au/issues/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.
22. EPA 1993, 'Backyard to bay: tagged litter report', Melbourne, Victoria.
23. Headifen R 2017, 'A new survey method to determine plastic rubbish in Port Phillip Bay', BeachPatrol Australia.
24. Port Phillip EcoCentre 2017, 'Turn off the tap – catchment to bay litter prevention and monitoring. Final report', Port Phillip EcoCentre, St Kilda, Victoria.
25. 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.
26. 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.
27. Zoos Victoria 2013, 'Seal the Loop 2012-2013 report', Zoos Victoria, Melbourne, Victoria.
28. Roman L, Schuyler QA, Hardesty BD, Townsend KA 2016, 'Anthropogenic debris ingestion by avifauna in eastern Australia', *PLoS One*, 11(8) pp. 1-14 https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0158343 Accessed 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 short-tailed 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 assessment[31] 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]

29. 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.
30. Victorian Coastal Council 2018, 'Victoria's coast and marine environments under projected climate change: impacts, research gaps and priorities', Melbourne, Victoria.
31. 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] 721,000[37] and 830,000[38] (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 https://vfa.vic.gov.au/commercial-fishing/commercial-fish-production Accessed 4 December 2018.
34. 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.
35. 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.
36. Henry G, Lyle J 2003, 'The national recreational and indigenous fishing survey', Project No. 1999/158. A report for the Australian Government Department of Agriculture, Fisheries and Forestr. Canberra, Australian Capital Territory.
37. VFA 2010, 'Economic study of recreational fishing in Victoria – headline results VRFish', Melbourne, Victoria https://vfa.vic.gov.au/about/publications-and-resources/fisheries-reports/your-licence-fees-at-work-reports/2009-2010/economic-study-of-recreational-fishing-in-victoria-headline-results-vrfish Accessed 4 December 2018.
38. Ernst and Young 2015, 'Economic study of recreational fishing in Victoria', a report for VFA Melbourne, Victoria.
39. VFA 2018, 'Target one million budget 2015–2019', Melbourne, Victoria www.vfa.vic.gov.au/recreational-fishing/target-one-million/budget 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]

40. Infrastructure Victoria 2017, 'Advice on securing Victoria's port capacity', Melbourne, Victoria.
41. 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.
43. Smith B 2015, 'World-class fossil site in Beaumaris threatened by marina expansion plans', *The Age* 20 February 2015.

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)*.

44. 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 research[49] 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. Ibid
47. PV 2018, '*Centrostepohanus rodgersii* (black-spined sea urchin) impact management plan', Melbourne, Victoria.
48. PV 2018, 'United against the urchin front in East Gippsland', media release, Melbourne, Victoria.
49. 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 Government[51] 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 Ninety-mile 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]

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

51. The Hon Pallas T, MP 2018, 'Offshore gas exploration to build future supply', media release, Melbourne, Victoria.
52. CES 2013, 'State of the environment report', Melbourne, Victoria.
53. 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.

54. 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.gov.au/__data/assets/pdf_file/0004/265585/Seagrass_Resilience_in_Port_Phillip_Bay.pdf Accessed 4 December 2018.
55. 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.
56. 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 ecosystem-based 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 to:

- 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 2017–2020[58] 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.
58. 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.

Poor
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

Poor
Evidence and consensus too low to make an assessment

Fair
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)

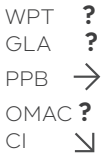
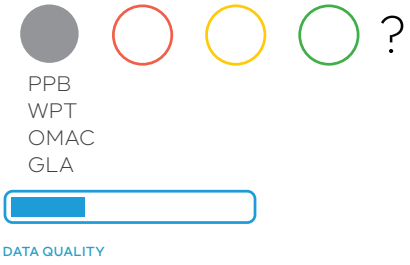
St Kilda (STK)

West Gippsland Catchment Management Authority (WGCMA)

Western Port (WPT)

	Summary	Status	Trend
Indicator **MC:01** Mangrove extent **Region** Western Port (WPT), Corner Inlet (CI), Nooramunga Marine & Coastal Park (NMCP), Other Marine & Coastal Areas (OMAC) **Measures** Spatial extent **Data custodian** DELWP Biodiversity	**Western Port** has retained 90-95% of its pre-1750s mangrove habitat that was estimated at 1320 hectares. Losses have been caused by harvesting, land claim for industrial and port development and the drainage of adjacent land. **Corner Inlet and Nooramunga Mangroves** are at their southern-most limit in Corner Inlet and Nooramunga, where 80% of the pre-1750s cover remains. **Other marine and coastal areas** On a statewide basis, 90% of the pre-1750 extent of mangroves remains. Spatial extent may be expanding in response to climate change. There is insufficient data to determine condition of mangroves.	UNKNOWN POOR FAIR GOOD CI NMCP WPT OMAC DATA QUALITY Good	?

Indicator **MC:02** Saltmarsh extent **Region** Port Phillip Bay (PPB), Western Port (WPT), All Gippsland Lakes (GLA), Other Marine & Coastal Areas (OMAC) **Measures** Spatial extent **Data custodian** DELWP Biodiversity	**Port Phillip Bay** About 50% of Port Phillip Bay's pre-1750s saltmarsh cover of 3710 hectares remains today. **Western Port** In Western Port, 90–95% of saltmarsh that once covered 1460 hectares remains today. **Gippsland Lakes** Historical mapping of the various lakes indicates that between 80-100% of pre-1750s saltmarsh has been retained. **Other marine and coastal areas** 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 is insufficient data to determine condition of mangroves.	OMAC PPB GLA WPT DATA QUALITY Fair - PPB & WPT DATA QUALITY Poor - GLA & OMAC	OMAC ? PPB → GLA ? WPT ↘

	Summary	Status	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** DELWP Biodiversity	**Port Phillip Bay** 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 km^2 per year between 1965 and 2013, with algal blooms and turbidity both impacting on light penetration. There is limited data on density and epiphytes.		
Indicator **MC:04** Seagrass-dependent fish **Region** Port Phillip Bay (PPB), Western Port (WPT), Other Marine & Coastal Areas (OMAC) All Gippsland Lakes (GLA) **Measures** Change in relative abundance, diversity and biomass of seagrass-dependent fish **Data custodian** DELWP Biodiversity; PV	**Port Phillip Bay** There is insufficient data for an assessment of status and trends. **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. **Other marine and coastal areas** There is insufficient data for an assessment of status and trends.		

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

	Summary	Status	Trend
Indicator **MC:07** Sessile invertebrates on intertidal reefs **Region** Marine National Parks & Sanctuaries (MNPS), Other Marine & Coastal Areas (OMAC) **Measures** Change in percentage cover of sessile invertebrates Total diversity of sessile invertebrates 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	**Marine National Parks and Marine Sanctuaries** Good condition in nine parks, and fair condition in three parks. **Other marine and coastal areas** Data are limited for sites outside Victoria's marine protected areas.	UNKNOWN POOR FAIR GOOD OMAC MNPS DATA QUALITY Good - MNPS DATA QUALITY Poor - OMAC	OMAC ? MNPS →

	Summary	Status	Trend
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 size–class 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** 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.	UNKNOWN POOR FAIR GOOD OMAC NPPB MNPS SPPB DATA QUALITY Good - MNPS, NPPB & SPPB DATA QUALITY Poor - OMAC	OMAC ? MNPS ? NPPB ↘ SPPB →
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 SPPB DATA QUALITY Good - SPPB & MNPS DATA QUALITY Fair - NPPB DATA QUALITY Poor - OMAC	OMAC ? NPPB ? MNPS ? SPPB ↗

	Summary	Status	Trend
Indicator **MC:10** Macroalgae-dominated 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** 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.	UNKNOWN: OMAC POOR: FAIR: NPPB GOOD: SPPB MNPS DATA QUALITY Good - SPPB & MNPS DATA QUALITY Poor - NPPB & OMAC	OMAC ? NPPB ? MNPS ? SPPB ↘
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.	UNKNOWN: OMAC POOR: FAIR: GOOD: PPB MNPS DATA QUALITY Good - PPB & MNPS DATA QUALITY Poor - OMAC	OMAC ? PPB → MNPS →

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

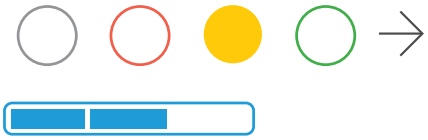
	Summary	Status	Trend
Indicator **MC:14** Piscivorous (fish-eating) birds **Region** Corner Inlet (CI), Western Port (WPT), Other Marine & Coastal Areas (OMAC) **Measures** Total counts of terns, cormorants and Australian pelican in summer (February) and winter (June–July) **Data custodian** ARI, Birdlife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

	Summary	Status	Trend
Indicator **MC:16** Over-abundant 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).	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.	UNKNOWN / POOR / FAIR / GOOD OMAC NPPB BRMS SPPB NMCP DATA QUALITY Fair -SPPB, BRMS, NMCP & NPPB DATA QUALITY POOR - OMAC	OMAC ? NPPB ↘ BRMS ? SPPB → NMCP →
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.	OMAC PPB DATA QUALITY Fair - PPB DATA QUALITY Poor - OMAC	OMAC ? PPB ↘

	Summary	Status	Trend
Indicator **MC:18** Catchment inputs into coastal waters/reefs **Region** Port Phillip Bay (PPB), 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) pH Metals **Data custodian** DELWP Catchments, Waterways, Cities and Towns; EPA Victoria	**Port Phillip Bay** EPA water-quality report cards from 2012–13 to 2016–17 for the bay's catchments showed a higher percentage of catchments with fair to very good ratings than those with very poor to poor ratings. Water quality was better in the middle and upper reaches of the catchments. **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).	UNKNOWN: ○ POOR: ● WPT, GCMA FAIR: ● PPB, CCMA, WGCMA GOOD: ● EGCMA DATA QUALITY Good - PPB & WPT & CMAs	WPT ? GCMA ? PPB ↗ CCMA ? WGCMA ? EGCMA ?
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	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.	UNKNOWN: OMAC FAIR: PPB, GLA DATA QUALITY: Good - PPB & GLA 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 *Enterococci* 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.	UNKNOWN: OMAC GOOD: PPB DATA QUALITY: Good - PPB DATA QUALITY: Poor - OMAC	OMAC ? PPB →

	Summary	Status	Trend
Indicator **MC:22** Impacts of fisheries production **Region** Victoria **Measures** Status of key fish stocks from most recent published assessments Independent peer-reviewed scientific research of impacts Changes in targeted fish species and stocks Changes in trophic structures Trends in the species composition, number and/or weight taken as bycatch Impacts on marine and coastal habitats Interactions with threatened species **Data custodian** VFA	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.	UNKNOWN POOR FAIR GOOD  DATA QUALITY Poor	?

	Summary	Status	Trend
Indicator **MC:23** Conservation of coastal ecosystems in protected areas **Region** Victoria **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	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.	UNKNOWN POOR FAIR GOOD  DATA QUALITY Fair	

	Summary	Status	Trend
Indicator **MC:24** Conservation of marine ecosystems in protected areas **Region** All Gippsland Lakes (GLA) and East Gippsland Inlets 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	Although marine protected areas cover approximately 11% of Victoria's marine waters, their spatial extent is skewed to Corner Inlet/Nooramunga and Wilsons Promontory, indicating that the network is failing to meet the National Representative System of Marine Protected Areas principles of comprehensiveness, adequacy and representativeness across all five marine bioregions.	UNKNOWN POOR FAIR GOOD GLA and East Gippsland Inlets Five marine bioregions DATA QUALITY Good	

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 inventory[60] 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.

59. DELWP 2016, 'Climate change vulnerability and adaptive capacity of coastal wetlands. Decision Support Framework – Volume Two', Melbourne, Victoria.
60. Boon PI, 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. 454–479.
61. National Land and Water Resources 2002, 'Australian catchment river and estuary assessment', Canberra, Australian Capital Territory.
62. 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.

	Status				Trend	Data quality
	UNKNOWN	POOR	FAIR	GOOD		
MC:01 Mangrove extent	○	○	● CI NMCP	● WPT OMAC	?	DATA QUALITY Good

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]

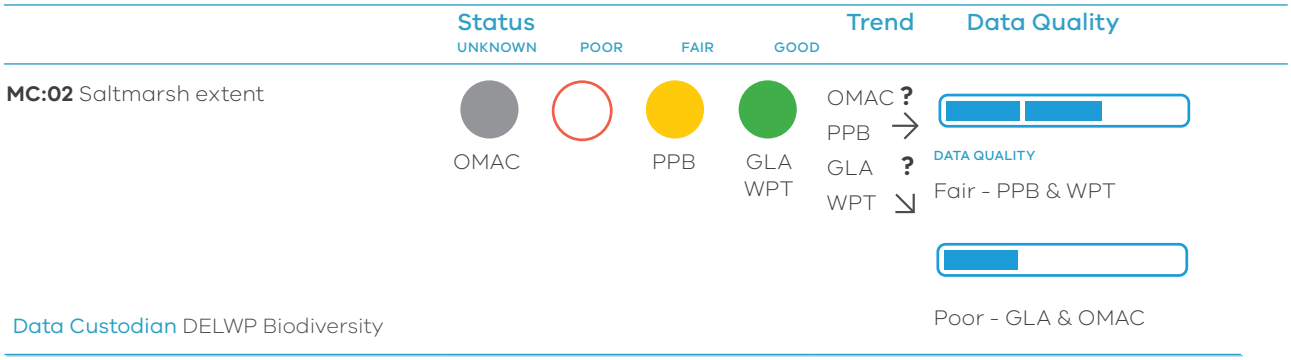
Corner Inlet and Nooramunga

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]

63. 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.
64. Melbourne Water Corporation 2011, 'Understanding the Western Port environment', Melbourne, Victoria.
65. Ibid
66. 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.
67. 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 hectares[70] remains today. In addition to the impact of mangrove encroachment and subsequent saltmarsh displacement along tidal creeks, significant portions of saltmarsh were removed for agriculture. Saltmarsh has returned in some areas, particularly around the northern and western shores of Western Port, for example near Tooradin airport; however, concerns over declining saltmarsh extent remain, with erosion a problem on the eastern shoreline.[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, sea-level rise will increase the time that water covers saltmarsh, facilitating mangrove encroachment. This has been occurring at several sites including Rhyll, Koo Wee Rup, French Island and Quail Island.[73]

68. Ibid
69. CES 2016, 'State of the Bays 2016', Melbourne, Victoria.
70. 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.
71. CES 2016, 'State of the Bays 2016', Melbourne, Victoria.
72. Ibid
73. Ibid

Gippsland Lakes

Historical mapping[74] 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 non-halophytic 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. Ibid
76. Boon PI, Cook P, Woodland R 2016, 'The challenges posed by chronic environmental change in the Gippsland Lakes Ramsar site', *Marine and Freshwater Research*, 67(6), pp. 721-737.
77. 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,* https://doi.org/10.1071/MF18145 Accessed 4 December 2018.
79. 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.
80. 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	l	.	.	w	.	.	.	.	l	.	l	.	.	l	l	w	.	l	w	l
Fawthrop-Belfast	w	l	.	w	.	.	.	.	l	.	l	.	.	l	l	w	.	l	w	l
Western estuaries	l	.	.	?	.	.	l	l	w	.	l	.	l	l	l	w	.	.	w	l
Aire-Gellibrand	w	.	.	.	.	.	.	l	w	.	w	.	.	.	.	.	.	.	w	w
Surf-coast estuaries	l	.	.	w	.	.	l	.	l	.	l	.	l	l	.	w	.	l	w	w
Breamlea	l	l	w	l	.	.	w	l	w	.	l	.	.	l	.	w	.	w	w	w
Connewarre	l	l	w	l	l	.	.	l	l	l	l	l	l	l	l	w	l	w	w	w
Bellarine Lakes	l	.	Na	l	.	.	.	l	l	.	?	.	.	l	.	w	.	l	l	l
Salt Lagoon	.	.	Na	?	.	.	.	l	.	.	?	.	.	?	.	w	.	l	w	w
Swan Bay	l	l	l	l	l	.	.	l	l	.	l	.	.	.	l	w	l	l	w	l
Mud Island	.	.	.	.	.	.	.	.	.	.	.	.	.	.	l	.	.	.	.	l
Port Phillip	l	.	l	l	?	l	w	l	?	.	?	.	l	l	l	l	.	w	w	l
The Inlets	l	l	.	w	.	.	.	l	l	.	l	l	.	.	.	.	.	w	w	.
Western Port	l	l	.	l	.	.	.	l	l	.	l	.	.	l	l	w	.	l	w	l
French Island	.	.	.	.	.	l	.	l	l	w	l	.	.	.	l	.	.	.	l	l
Rhyll Inlet	l	l	.	w	.	.	.	l	l	.	l	.	.	l	.	w	.	l	w	.
Lang Lang coast	.	.	.	.	.	.	.	l	l	.	l	.	.	.	.	.	.	.	w	.
Bass River	l	.	.	.	.	.	.	l	l	.	l	l	.	.	.	.	.	w	w	.
Powlett-Kilcunda	w	.	.	.	.	.	.	l	w	.	l	.	.	l	.	w	.	l	w	.
Anderson Inlet	w	l	.	l	.	.	.	l	l	.	l	w	l	l	l	w	.	w	w	.
Shallow Inlet	w	.	.	l	.	.	.	.	.	.	l	.	.	.	l	.	.	w	w	.
Wilsons Promontory	.	.	.	.	.	.	.	.	.	l	?	.	.	.	l	.	.	.	.	.
Corner Inlet	w	l	l	l	.	.	.	l	l	l	l	l	.	?	L	l	.	w	w	w
Nooramunga Coast	w	l	l	?	.	.	.	l	l	l	?	l	.	l	l	l	.	.	l	.
Nooramunga Is.	.	.	l	.	.	.	.	l	l	l	?	?	.	.	?	.	.	.	.	.
Jack Smith Lake	.		Na	?.	.	.	.	l	l	l	?	.	.	.	.	.	.	w	w	l?
Lake Reeve	l	l	l	.	.	.	.	l	l	l	l	.	.	.	.	l	.	l	w	.
Lakes Victoria & King	l	.	.	.	.	.	.	l	l	l	l	.	.	l	l	.	.	l	w	l?
Lake Wellington	l	.	l	.	.	.	.	l	l	l	l	.	.	.	l	.	.	w	w	l
East Gippsland Inlets	w	.	l	?	.	.	.	l	w	l	?	.	.	?	?	.	.	l	l	w

Figure MC.1 An assessment of saltmarsh degradation according to degrading processes throughout Victoria, assessed sector-by-sector[81]

Note: The intensity of impact is colour-coded where red is high, orange is medium and yellow is low. The letter 'l' 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 sea-level rise impacts.

81. 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.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
MC:03 Seagrass condition	WPT OMAC		GLA CI	PPB	WPT ? GLA ? PPB → OMAC ? CI ↘	DATA QUALITY Fair

Data Custodian DELWP Biodiversity

Rationale

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 study[87] for Melbourne Water estimated that 32% of the sediment was sourced from the erosion of a nine-kilometre stretch of shoreline in the bay's north-eastern corner between the mouth of the Yallock Creek and the Lang Lang caravan park.

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]

82. 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.
83. 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.gov.au/__data/assets/pdf_file/0004/265585/Seagrass_Resilience_in_Port_Phillip_Bay.pdf Accessed 4 December 2018.
84. Ibid
85. Ibid
86. Ibid
87. 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.
88. 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.[90] Conversely, over the same period seagrass density had increased from 50% to 63%. The report rated seagrass extent as 'fair' and its condition as 'good'.[91]

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 km^2 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.

89. 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. Ibid
92. 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.
93. 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.
94. 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. Ibid
96. Ibid

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

Rationale

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 sub-tidal 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.

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

98. 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.

99. 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

Rationale

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.

101. National Land and Water Resources 2002, 'Australian Catchment River and Estuary Assessment', Canberra, Australian Capital Territory.
102. 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.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
MC:06 Mobile invertebrates on intertidal reefs	WPT OMAC PPB			MNPS	WPT ? OMAC ? PPB ? MNPS →	DATA QUALITY Good MNPS
Data Custodian PV Intertidal Reef Monitoring Program, Sea Search/Museum of Victoria ad-hoc surveys						DATA QUALITY Poor OMAC, PPB & WPT

Rationale

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:

1. 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]

Other Marine and Coastal Areas

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

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

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

Rationale

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				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
MC:08 Mobile megafaunal invertebrates on subtidal reefs	OMAC	NPPB		MNPS SPPB	OMAC ? MNPS ? NPPB ↘ SPPB →	DATA QUALITY Good MNPS, NPPB, SPPB DATA QUALITY Poor OMAC
Data Custodian Parks Victoria; Reef life survey						

Rationale

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 sanctuaries[105] 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-management/environment/research-and-scientific-management/technical-series2 Accessed 4 December 2018.
105. Survey reports for the subtidal reef biota in the three sanctuaries can be found at https://parkweb.vic.gov.au/park-management/environment/research-and-scientific-management/technical-series2 Accessed 4 December 2018.
106. 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.
108. Ibid
109. 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.[110] 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.[111]

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]

110. 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.
111. 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.
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.
113. 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.
114. 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.
115. 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.
116. 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.
117. Department of Primary Industries 2012, 'Abalone Recovery Review Workshop', Fisheries Victoria Management Report Series No. 83, Melbourne, Victoria.

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

Rationale

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.

118. 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.

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

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

121. 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.

122. 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.
123. 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.
126. 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.
128. 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				Trend	Data quality
	UNKNOWN	POOR	FAIR	GOOD		
MC:10 Macroalgae-dominated subtidal reefs	OMAC		NPPB	SPPB MNPS	OMAC ? NPPB ? MNPS ? SPPB ↘	DATA QUALITY Good - SPPB & MNPS DATA QUALITY Poor - NPPB & OMAC

Data Custodian PV Reef Life Survey

Rationale

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*) 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.

Most reefs in the north are low-wave energy and have been permanently changed by purple sea urchins (*H. erythrogramma*) and the highly-invasiveJapanese 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]

129. CES 2016, 'State of the Bays 2016', Melbourne, Victoria.
130. 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.
131. CES 2016, 'State of the Bays 2016', Melbourne, Victoria.
132. The survey reports can be found at https://parkweb.vic.gov.au/park-management/environment/research-and-scientific-management/technical-series2 Accessed 4 December 2018.
133. 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.
134. 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 Promontory[135] and Bunurong[136] 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 Reefs[139] and Merri[140] 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.

135. 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.
136. 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.
138. 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.
139. 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.
140. 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.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
MC:11 Macroalgae on intertidal reefs	OMAC			PPB MNPS	OMAC ? PPB → MNPS →	DATA QUALITY Good - PPB & MNPS
Data Custodian PV Intertidal Reef Monitoring Program; Sea Search/Museum of Victoria ad-hoc surveys						DATA QUALITY Poor - OMAC

Rationale

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

Rationale

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 sharp-tailed sandpipers (*Calidris acuminate*) have been counted during high tide twice a year at eight coastal sites in Port Phillip Bay. Their numbers are declining in-line with populations throughout the world over the past 20 years, largely due to the development and reclamation of intertidal flats in Asia, especially the Yellow Sea. However, periods of drought and high rainfall can cause variations in wetland coverage and affect shorebird distribution in Australia (for example, there were fewer sharp-tailed sandpipers (*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 data[144] on numbers of the red-necked 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.
143. 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.
144. Birdlife Australia, https://birdata.birdlife.org.au Accessed 4 December 2018.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
MC:13 Little penguins	OMAC			STK PI	OMAC ? STK → PI →	DATA QUALITY Good STK & PI DATA QUALITY Poor OMAC

Data Custodian Phillip Island Nature Park/ Earthcare St Kilda

Rationale

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, 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).[148] 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.

145. 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.

146. Earthcare St Kilda 2018, 'Penguin report 2016-17', St Kilda, Victoria.
147. Ibid
148. Birdlife International 2018, 'Data Zone', http://datazone.birdlife.org/site/factsheet/gabo-and-tullaberga-islands-iba-australia/text Accessed 4 December 2018.
149. 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

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
MC:14 Piscivorous (fish-eating) birds	OMAC			CI WPT	OMAC ? CI ↗ WPT ↘	DATA QUALITY Good CI & WPT
Data Custodian ARI, Birdlife Australia; Deakin University						DATA QUALITY Poor OMAC

Rationale

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.[150] 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.[151] 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				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
MC:15 Marine and coastal Waterbirds	OMAC PPB		WPT GLA		OMAC ? WPT ↘ PPB ? GLA (Trend depends on species)	DATA QUALITY Good WPT & GLA
Data Custodian Birdlife Australia (Western Port Waterbird Survey)/DELWP						DATA QUALITY Poor OMAC & PPB

Rationale

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 survey[152] 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.

152. 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.

154. Ibid

155. 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.

Indicator	Status				Trend	Data quality
	UNKNOWN	POOR	FAIR	GOOD		
MC:16 Over-abundant sea urchins on subtidal reefs	OMAC	NPPB	BRMS	SPPB NMCP	OMAC ? NPPB ↘ BRMS ? SPPB → NMCP →	DATA QUALITY Fair - SPPB, BRMS & NMCP NPPB DATA QUALITY Poor OMAC

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

Rationale

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.[158] A native animal impact management plan has been prepared by Parks Victoria and further urchin management and monitoring is planned.

156. Deakin University 2018, 'Sea urchin cull in Port Phillip Bay to help restore kelp forests', Media release, 15 March 2018, Deakin University, Geelong, Victoria.
157. Parks Victoria 2017, 'Seagrass meadows saved from sea urchin attack', Media release 28 July 2017, Melbourne, Victoria.
158. 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 / PPB	OMAC ? PPB ↘	DATA QUALITY Fair PPB DATA QUALITY Poor OMAC

Data CustodianDELWP Biodiversity; DEDJTR Biosecurity and Agriculture Services; PV

Rationale

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 Welshpool[162]
- *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]

159. Ross J, Longmore A, Keough M 2013, 'Spatially variable effects of a marine pest on ecosystem function', *Oecologia*, 172(2), pp. 525-538.
160. 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.
161. 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.
162. Parks Victoria 2018, 'Marine pests', Melbourne, Victoria http://parkweb.vic.gov.au/park-management/environment/weeds-and-pests/marine-pests Accessed 4 December 2018.
163. 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				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
MC:18 Catchment inputs into coastal watersl reefs		WPT GCMA	PPB CCMA WGCMA	EGCMA	WPT ? GCMA ? PPB ↗ CCMA ? WGCMA ? EGCMA ?	DATA QUALITY Good - PPB & WPT & CMAs

Data Custodian DELWP Catchments, Waterways, Cities and Towns; EPA Victoria

Rationale

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 cards', https://yarraandbay.vic.gov.au/report-card Accessed 4 December 2018.

165. EPA 2018, 'Port Phillip Bay report card for July 2016-June 2017,' https://yarraandbay.vic.gov.au/report-card/report-card-2017/port-phillip/port-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 2016–17[166]

Water quality index rating	2012–13 Port Phillip Bay %	2013–14 Port Phillip Bay %	2014–2015 Port Phillip Bay %	2015–16 Port Phillip Bay %	2016–17 Port Phillip Bay %	2016–17 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.[169] 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.[170]

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.[171,172,173] 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 Council[175]

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

167. 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
171. 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.
173. 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.
174. 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.
175. Victorian Catchment Management Council 2017, 'Catchment condition and management report', Melbourne, Victoria.

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

Data Custodian EPA Victoria

Rationale

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.cleanocean.org/national-outfall-database.html Accessed 4 December 2018.

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

178. Ibid

Indicator	Status	Trend	Data Quality
MC:20 Harmful algae blooms reefs	UNKNOWN: OMAC; POOR; FAIR: PPB GLA; GOOD	OMAC ? PPB → GLA ?	DATA QUALITY Good PPB & GLA DATA QUALITY Poor OMAC

Data Custodian EPA Victoria

Rationale

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.
180. Australian Associated Press 2002, 'Shellfish warning for Port Phillip Bay', *The Age* 24 December 2002.
181. East Gippsland Catchment Management Authority, 'State of the Gippsland Lakes: Technical Report', (*Publication pending*).
182. 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				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
MC:21 Enterococci bacteria	OMAC			PPB	OMAC ? PPB →	DATA QUALITY Good PPB DATA QUALITY Poor OMAC

Data Custodian EPA Victoria

Rationale

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-report/2016-17-summer-highlights-report Accessed 4 December 2018.

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

Data Custodian VFA

Rationale

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.

185. Victorian Catchment Management Council 2017, 'Catchment condition and management report', Melbourne, Victoria.
186. Ibid
187. 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	○	○	●	○	→	DATA QUALITY: Fair

Data Custodian DELWP Biodiversity

Rationale

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).[188] 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.

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.

Table MC.4 Changes in the conservation status of some Victorian coastal EVCs[189]

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
MC:24 Conservation of marine ecosystems in protected areas	UNKNOWN: GLA and East Gippsland Inlets; POOR: Five marine bioregions; FAIR; GOOD	→	DATA QUALITY: Good
Data Custodian DELWP Biodiversity			

Rationale

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 high-level 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.
192. Ibid
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 bioregion[194]

Ecological Vegetation Class	Pre-1750s (ha)	Current (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	145
9 Coastal Saltmarsh	15,813	12,471
10 Estuarine Wetland	10,276	8,484
11 Coastal Lagoon Wetland	863	852
12 Wet Swale Herbland	4,768	4,768
140 Mangrove Shrubland	5,387	4,243
144 Coast Banksia Woodland/Warm Temperate Rainforest Mosaic	244	148
154 Bird Colony Shrubland	413	411
160 Coastal Dune Scrub	5,320	4,119
161 Coastal Headland Scrub	8,218	5,677
162 Coastal Headland Scrub/Coastal Tussock Grassland Mosaic	2,151	1,331
163 Coastal Tussock Grassland	2,484	2,087
181 Coast Gully Thicket	346	219
302 Coastal Saltmarsh/Mangrove Shrubland Mosaic	5,928	4,508
309 Calcareous Swale Grassland	559	559
311 Berm Grassy Shrubland	191	125
656 Brackish Wetland	1,314	662
665 Coastal Mallee Scrub	597	337
858 Coastal Alkaline Scrub	29,910	17,122
876 Spray-zone Coastal Shrubland	155	141
900 Coastal Saltmarsh/Coastal Dune Grassland/Coastal Dune Scrub/Coastal Headland Scrub Mosaic	153	63
904 Coast Banksia Woodland/Swamp Scrub Mosaic	327	65
906 Brackish Grassland/Swamp Scrub Mosiac	153	15
909 Coastal Dune Scrub/Bird Colony Succulent Herbland Mosaic	148	131
914 Estuarine Flats Grassland	560	157
919 Coastal Headland Scrub/Coast Banksia Woodland Mosaic	357	66
921 Coast Banksia Woodland/Coastal Dune Scrub Mosaic	1,288	876
922 Coastal Alkaline Scrub/Bird Colony Succulent Herbland Mosaic	120	53
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 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 Dunes Beach Saltmarsh Mangrove Seagrass Reef Macroalgae Sandy sediments Muddy sediments	There is no universal condition metric for coastal and marine ecosystem assets. Potential metrics include: • habitat hectares (for EVCs in coastal areas) • denitrification efficiency (muddy sediments) Condition measure should relate to ecosystem services produced by the asset.	Plants, algae and animals for food Nutrients for aquaculture Climate regulation Water quality regulation Water flow regulation Opportunities for recreation and tourism Opportunities for cultural connection Landscape	Food for human and animal consumption Avoided impacts of climate change Coastal asset protection Recreation and tourism Avoided health impacts Information and knowledge Cultural connection 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.

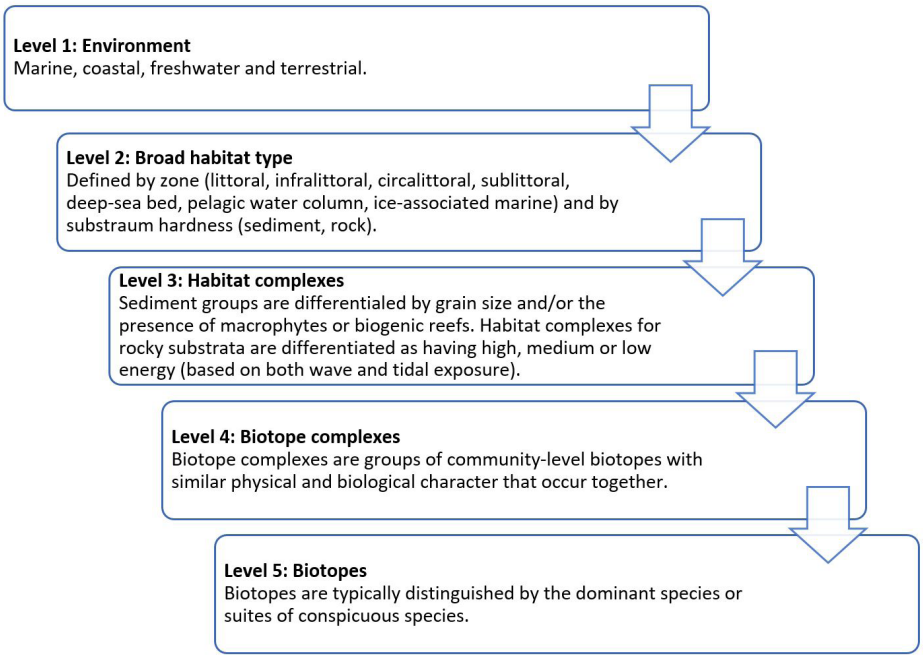


Figure MC.2 Combined Biotope Classification Scheme (CBiCS) hierarchy[198]

196. 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.
197. 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).

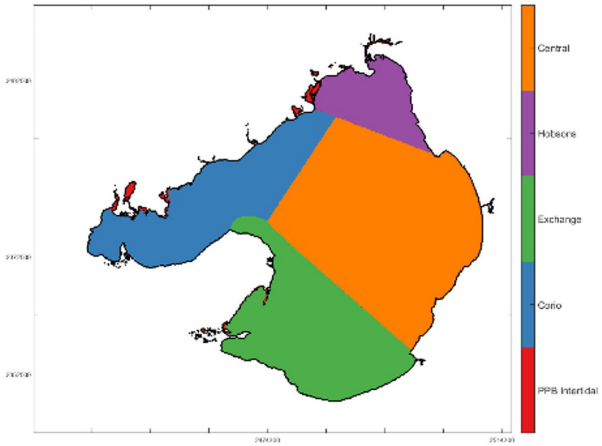


Figure MC.3 Geographic aggregations for Port Phillip Bay accounts[200]

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.

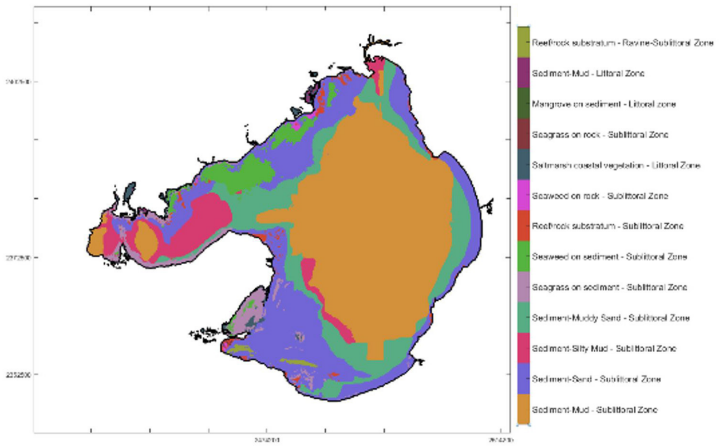


Figure MC.4 Port Phillip Bay habitats[201]

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.

199. Commissioner for Environmental Sustainability 2016, 'State of the Bays 2016', Commissioner for Environmental Sustainability, Melbourne, p.205.
200. Combined Biotope Classification Scheme 2018, www.cbics.org Accessed 4 December 2018.
201. 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 assets[202]

Broad habitat	Habitat complex	Central (ha)	Corio (ha)	Exchange (ha)	Hobsons (ha)	Intertidal (ha)	Total (ha)
Littoral sediment	Mangrove					4	4
	Mud					274	275
	Saltmarsh		87	475	5	1,868	2,435
Total littoral sediment			*87*	*475*	*5*	*2,147*	*2,714*
Sublittoral rock	Ravine			798		11	809
	Rock (unclassed)	299	471	760	902	48	2,481
	Seagrass			209			209
	Seaweed		298	64	3	5	369
Total sublittoral rock		*299*	*769*	*1,832*	*904*	*63*	*3,868*
Sublittoral sediment	Mud	69,923	3,391	7,393	3,922	234	84,863
	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 sublittoral 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 environmental-economic 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.

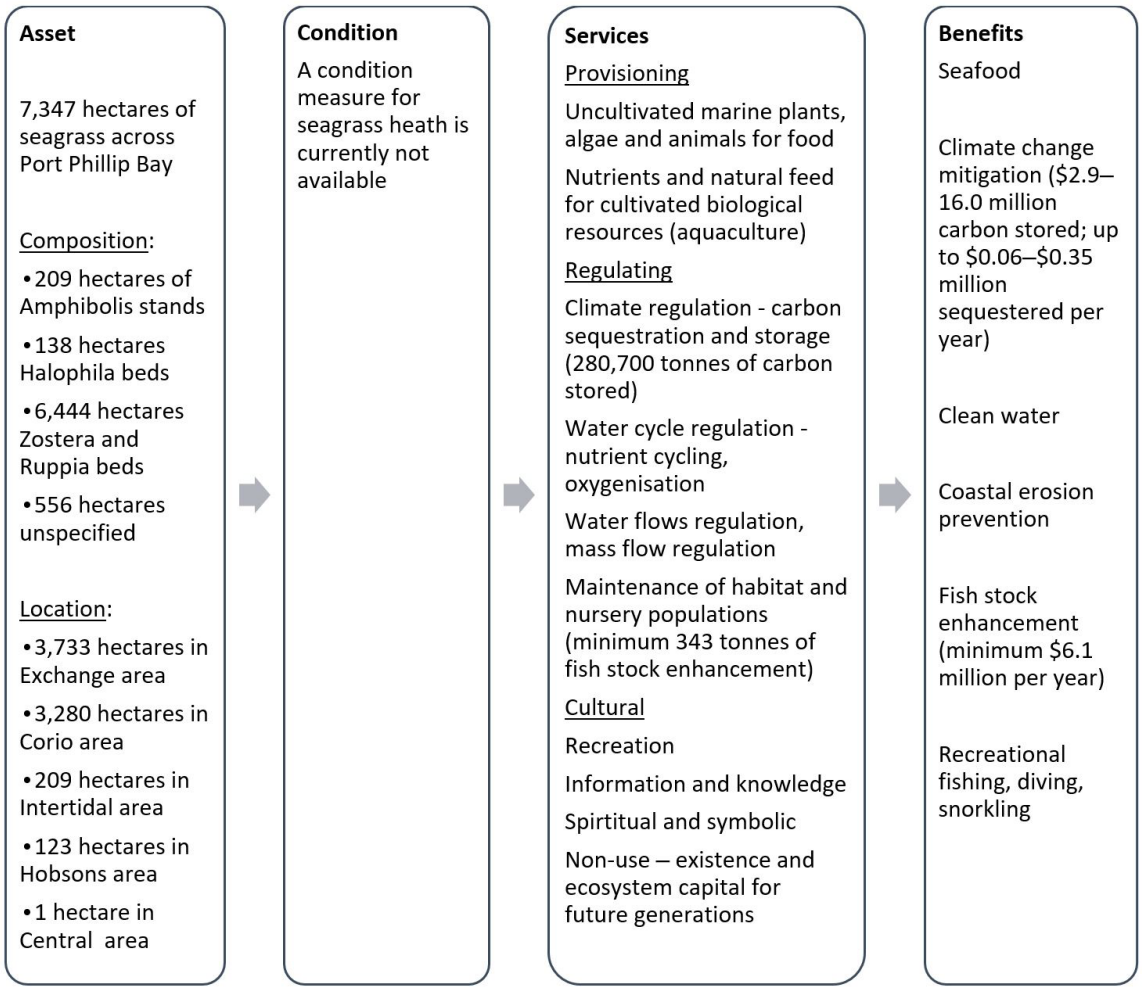


Figure MC.5 Seagrass in an environmental-economic accounting framework, Port Phillip Bay[203]

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

WATER RESOURCES (WR)

SCIENTIFIC ASSESSMENTS Part III

Commissioner *for* Environmental Sustainability 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]

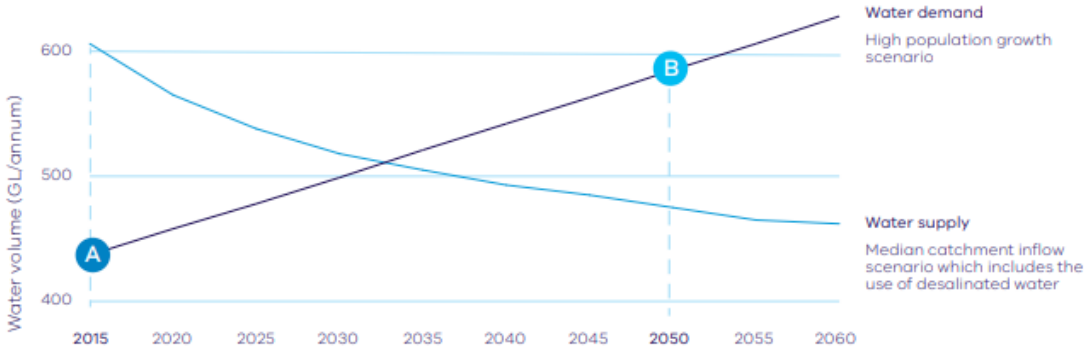


Figure WR.1 Projected water supply and demand for Melbourne.[4]

1. 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.
2. Ibid
3. 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.pdf Accessed 3 December 2018.
4. 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.

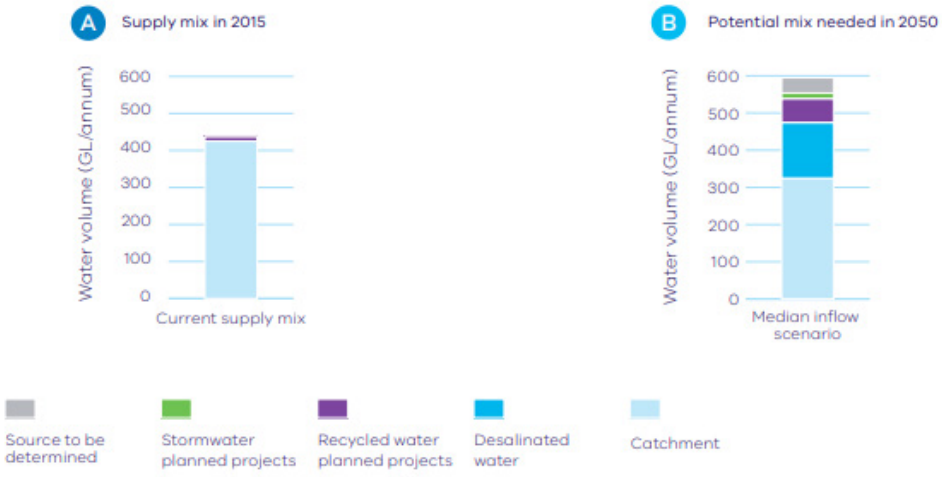


Figure WR.2 Current (2015) and potential (2050) water supply mix for Melbourne.[5]

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 land-use 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
6. DEDJTR, 'Food and fibre', Melbourne, Victoria https://economicdevelopment.vic.gov.au/priority-industries-sectors/food-and-fibre# Accessed 3 December 2018.
7. Australian Bureau of Statistics 2018, '4610.0.55.008 - Gross Value of Irrigated Agricultural Production, 2016-17', Canberra, ACT. http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/4610.0.55.008Main+Features12016-17?OpenDocument Accessed 3 December 2018.
8. 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. Ibid
10. 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.
11. 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 CO_2-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 CO_2 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.

12. 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.
13. DELWP 2014, 'Dams in Victoria', East Melbourne, Victoria https://www.water.vic.gov.au/__data/assets/pdf_file/0018/54126/Dam-Safety-Factsheet-FINALv4b.pdf Accessed 3 December 2018.
14. 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.
15. Ibid
16. 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.pdf Accessed 3 December 2018.

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*.[20] 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.

17. DELWP, 'Victoria's water grid', East Melbourne, Victoria https://www.water.vic.gov.au/water-grid-and-markets/the-grid Accessed 3 December 2018.
18. Ibid
19. Ibid
20. DELWP 2017, 'Integrated Water Management Framework for Victoria', East Melbourne, Victoria https://www.water.vic.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.pdf 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 CO_2-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.vic.gov.au/water-industry-and-customers/your-water-suppliers-performance/climate-change Accessed 3 December 2018.
24. Ibid
25. DELWP 2018, 'Delivering Water for Victoria Progress Report', East Melbourne, Victoria https://www.water.vic.gov.au/__data/assets/pdf_file/0033/391497/Delivering-Water-for-Victoria-Progress-Report-web-20180919.pdf Accessed 3 December 2018.
26. 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/__data/assets/pdf_file/0014/52331/Guidelines-for-Assessing-the-Impact-of-Climate-Change-on-Water-Availability-in-Victoria.pdf Accessed 3 December 2018.
27. DELWP, 'The Victorian Water and Climate Initiative', East Melbourne, Victoria https://www.water.vic.gov.au/climate-change/climate-and-water-resources-research/the-victorian-water-and-climate-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.

Poor
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

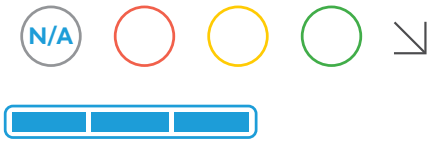
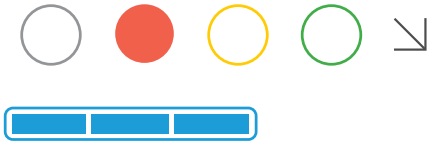
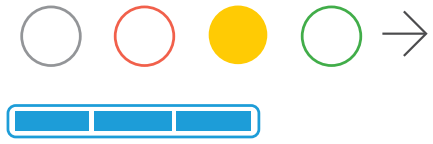
Poor
Evidence and consensus too low to make an assessment

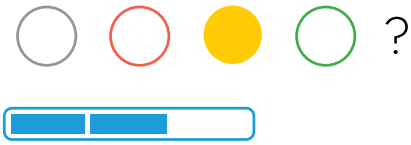
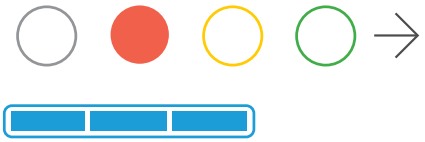
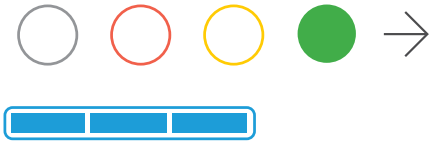
Fair
Limited evidence or limited consensus

Good
Adequate high-quality evidence and high level of consensus

WATER RESOURCES

	Summary	Status	Trend
Indicator **WR:01** Water resources and storage trends **Region** Victoria **Measures** Water storage levels in Victoria as a percentage of capacity **Data custodian** DELWP	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 years.	UNKNOWN POOR FAIR GOOD DATA QUALITY Good	

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

	Summary	Status UNKNOWN POOR FAIR GOOD	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.	 DATA 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 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)	
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.	  DATA QUALITY Poor (no data available to provide a status or trend assessment)	

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

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Indicator **WR:01** Water resources and storage trends Data Custodian DELWP	○	○	●	○	→	DATA QUALITY Good

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.

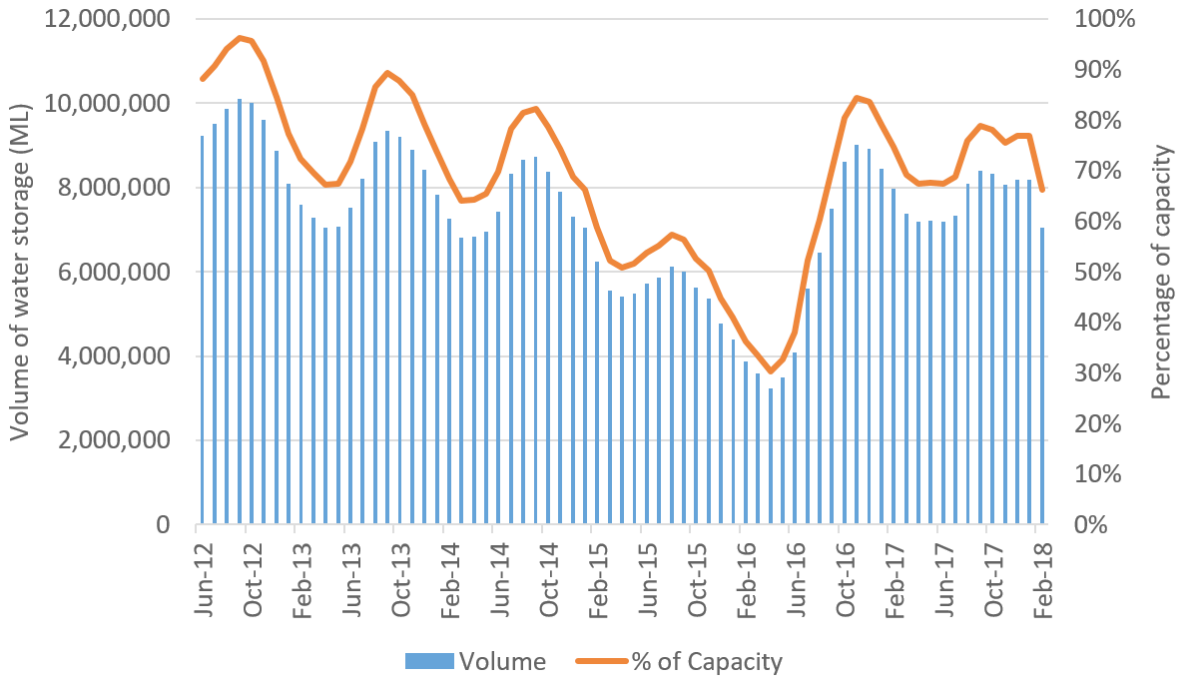


Figure WR.3 Water storage levels in regional Victoria, June 2012 to February 2018

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)

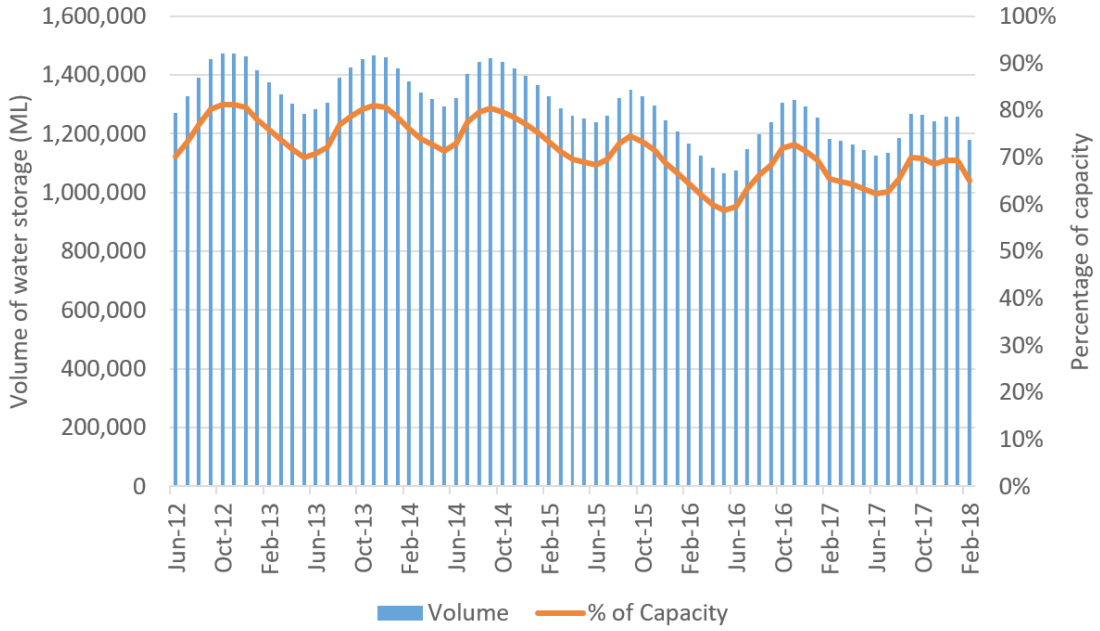


Figure WR.4 Water storage levels in Melbourne, June 2012 to February 2018

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.

28. 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.

29. 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.pdf Accessed 3 December 2018.
30. 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	Trend	Data Quality
WR:02 Projected runoff to dams and catchments	UNKNOWN: N/A; POOR; FAIR; GOOD	↘	DATA QUALITY: Good

Data Custodian BoM, CSIRO

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.)

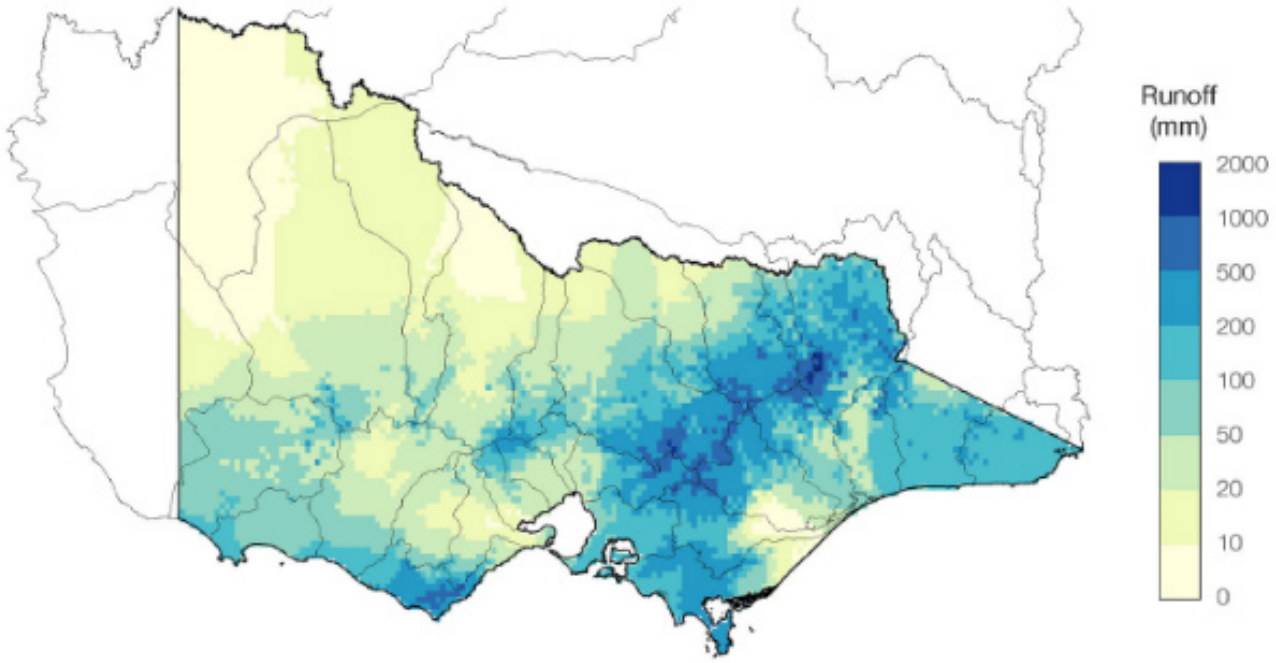


Figure WR.5 Runoff across Victoria, 1975–2014.[32]
(Data source: Victorian Climate Initiative, 2018)

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

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.

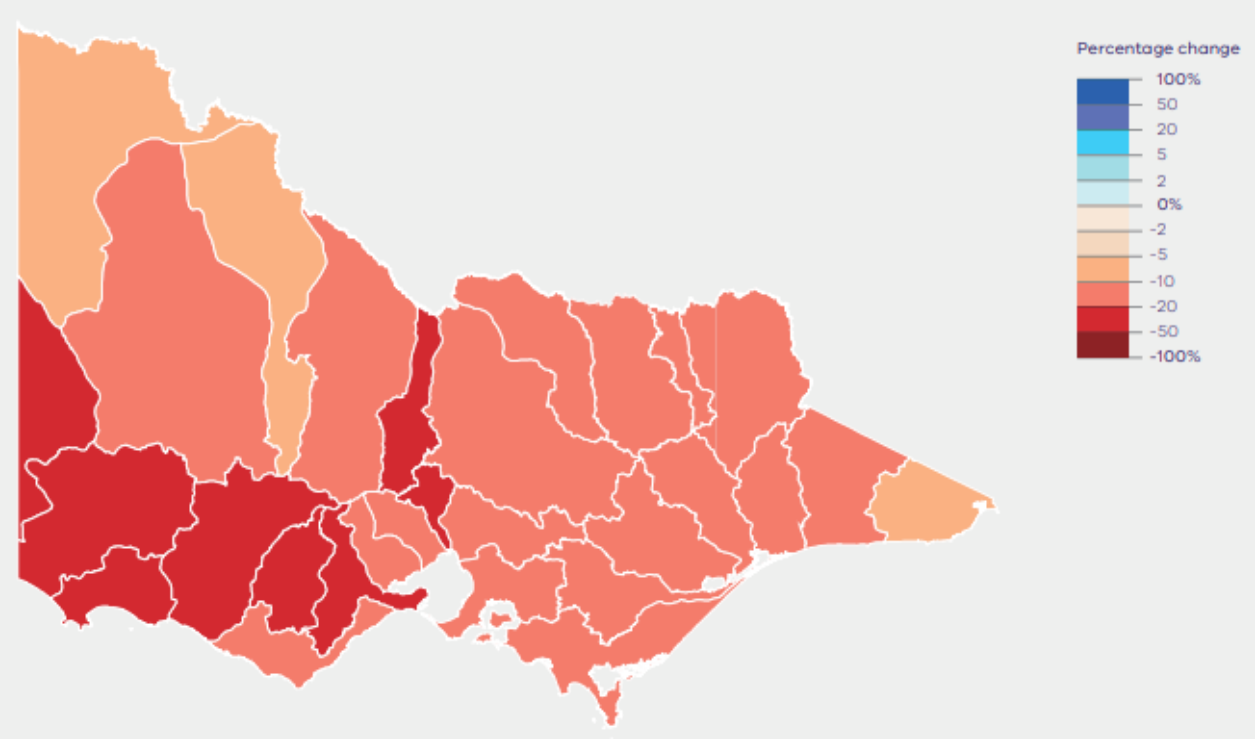


Figure WR.6 Projected changes in runoff for 2065 (intermediate emissions scenario).

(Data Source: DELWP, 2018)[35]

35. 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.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
WR:03 Condition of flow regimes	○	●	○	○	↘	DATA QUALITY
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.

36. 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.

- **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.

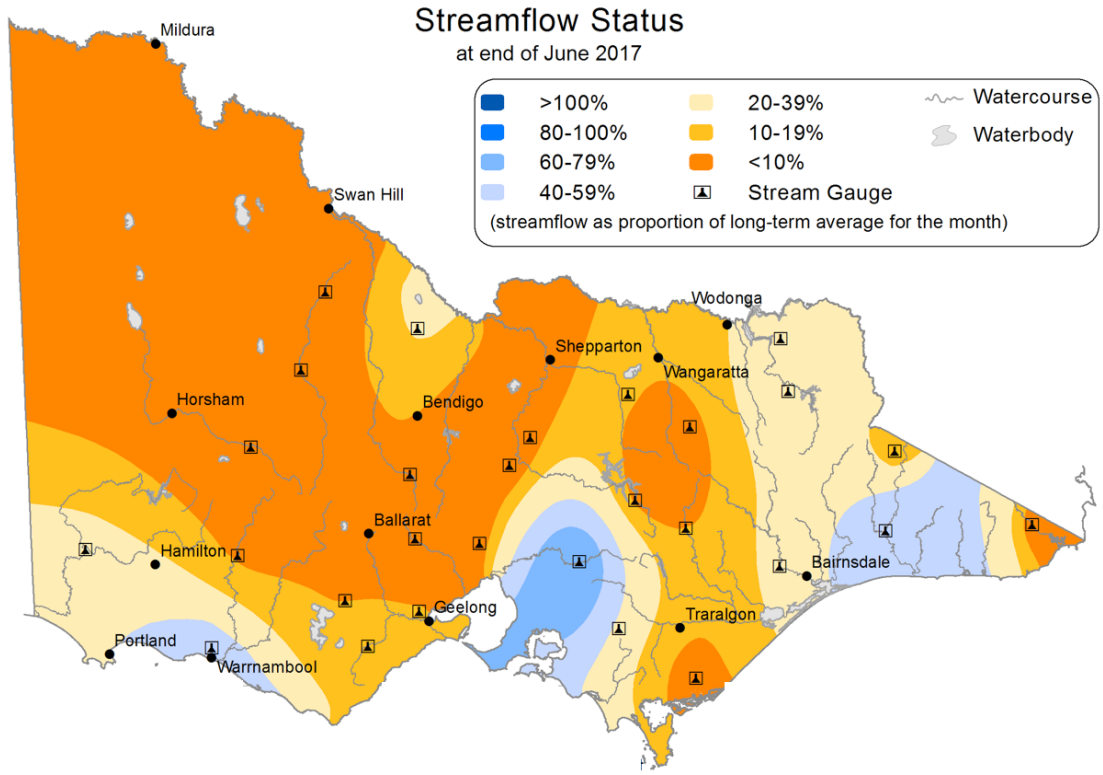


Figure WR.7 Streamflow status as at June 2017
(Data source: DELWP, 2018)

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.

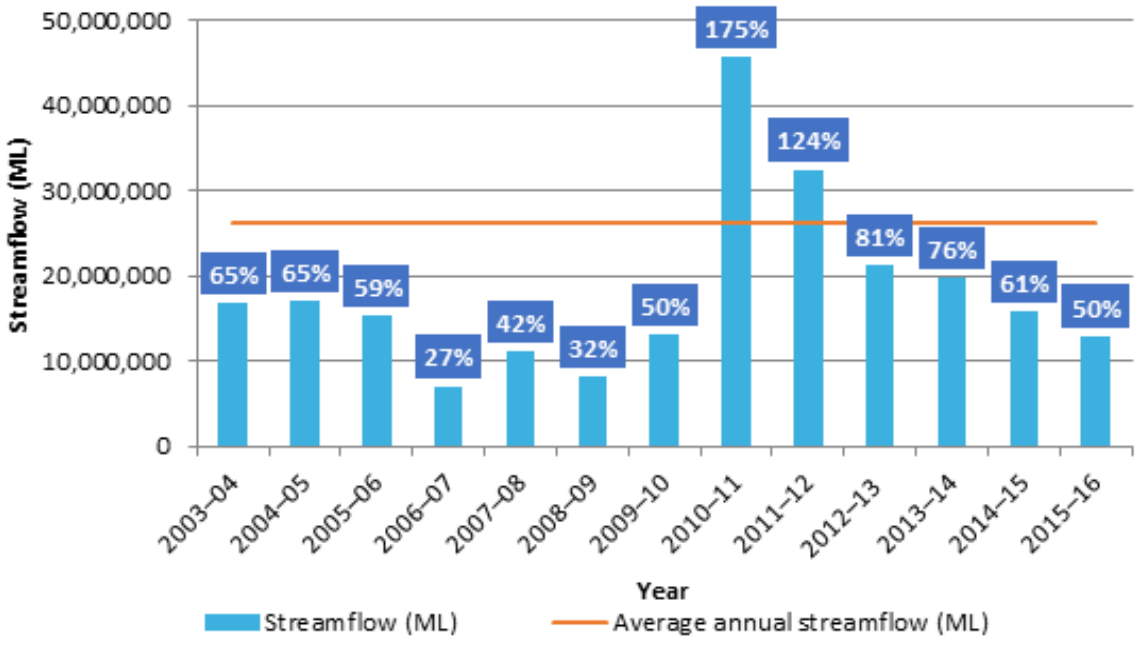


Figure WR.8 Victorian streamflow compared to long-term average

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)

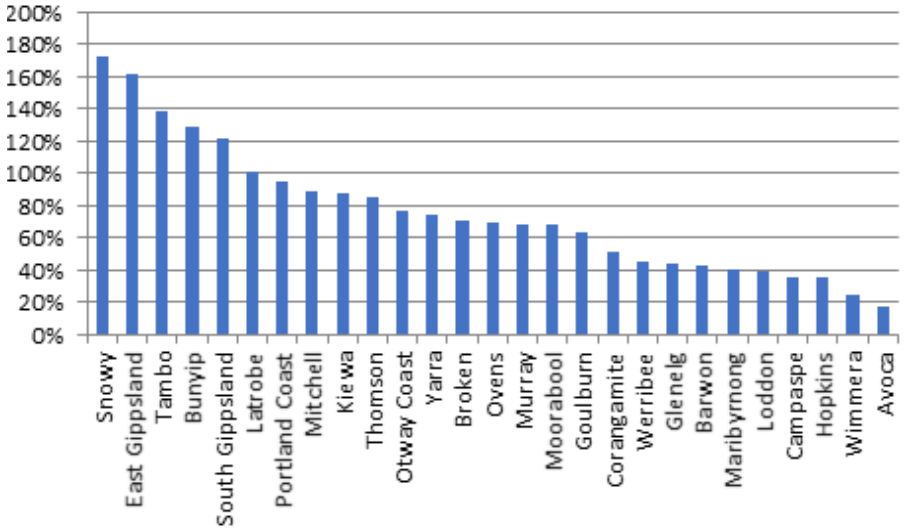


Figure WR.9 Average Victorian streamflow at river basins for 2011–12 to 2015–16 compared to the long-term averages at each river basin

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.

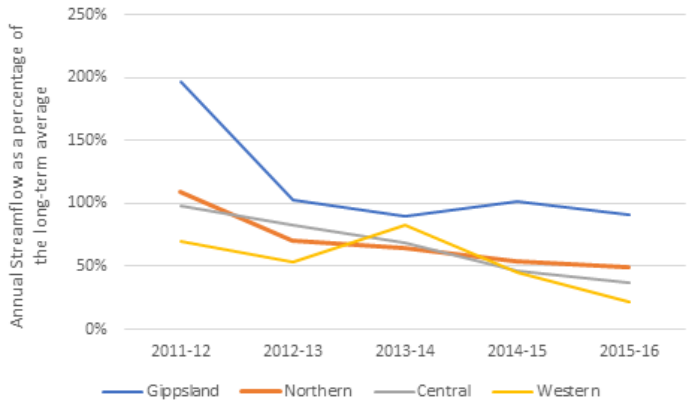


Figure WR.10 Victorian annual streamflows, by region for 2011–12 to 2015–16 compared to long-term averages

(Data source: DELWP, 2018)

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
WR:04 Delivering water for the environment			 DATA QUALITY
Data Custodian VEWH			Good

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:** a 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]

37. Victorian Environmental Water Holder, 'Victoria's rivers and wetlands get a helping hand from watering plan', East Melbourne, Victoria http://www.vewh.vic.gov.au/news-and-publications/news/victorias-rivers-and-wetlands-get-a-helping-hand-from-watering-plan Accessed 3 December 2018.
38. Ibid
39. Ibid
40. Ibid

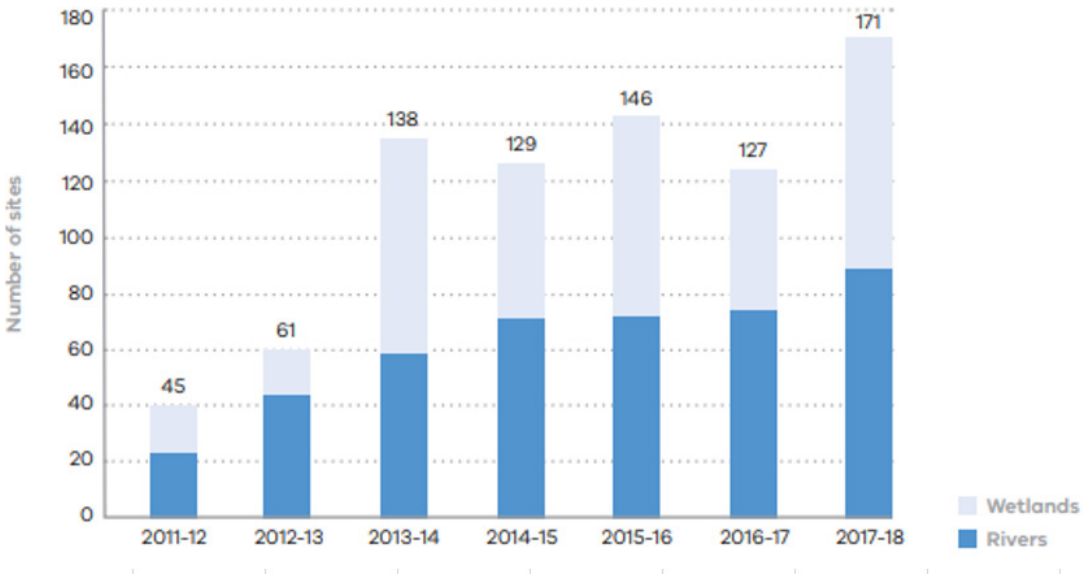


Figure WR.11 Number of river reaches and wetlands watered since 2011–12.[41]

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 in-stream 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]

41. 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.

42. 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.

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 2017–18[43]

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 reported separately	Not reported separately	48,124	52,219	48,081	53,648	73,186
Central Region			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 2017–18[44]

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 reported separately	Not reported separately	27,351	28,872	28,797	20,637	45,180
Central Region			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. Ibid

Table WR.3 Total volume delivered as a percentage of environmental entitlements by region, 2011–12 to 2017–18[45]

Area	2011–12 %	2012–13 %	2013–14 %	2014–15 %	2015–16 %	2016–17 %	2017–18 %
Southern Victoria (Gippsland + Central)	44	48	44	58	46	44	62
Gippsland Region	Not reported separately	Not reported separately	57	55	60	38	62
Central Region			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.

45. Ibid
46. 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.vic.gov.au/__data/assets/pdf_file/0021/70194/VEFMAP-Fact-sheet-Stage-6.pdf Accessed 3 December 2018.

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

Data Custodian DELWP

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).

48. DELWP 2014, 'Dams in Victoria', East Melbourne, Victoria https://www.water.vic.gov.au/__data/assets/pdf_file/0018/54126/Dam-Safety-Factsheet-FINALv4b.pdf Accessed 3 December 2018.
49. DELWP 2015, 'DELWP Output data standards', East Melbourne, Victoria https://www.water.vic.gov.au/__data/assets/pdf_file/0016/120463/DELWP-OutputDataStandard-web-V4.0.pdf Accessed 3 December 2018.
50. DELWP, 'Fishways and fish movement', East Melbourne,Victoria https://www.ari.vic.gov.au/research/rivers-and-estuaries/fishways-and-fish-movement Accessed 3 December 2018.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
WR:06 Surface water harvested for consumptive use	○	●	○	○	→	DATA QUALITY Good

Data Custodian DELWP

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 aquifers. 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 surface-water bulk entitlements and volumes taken in 2015–16.

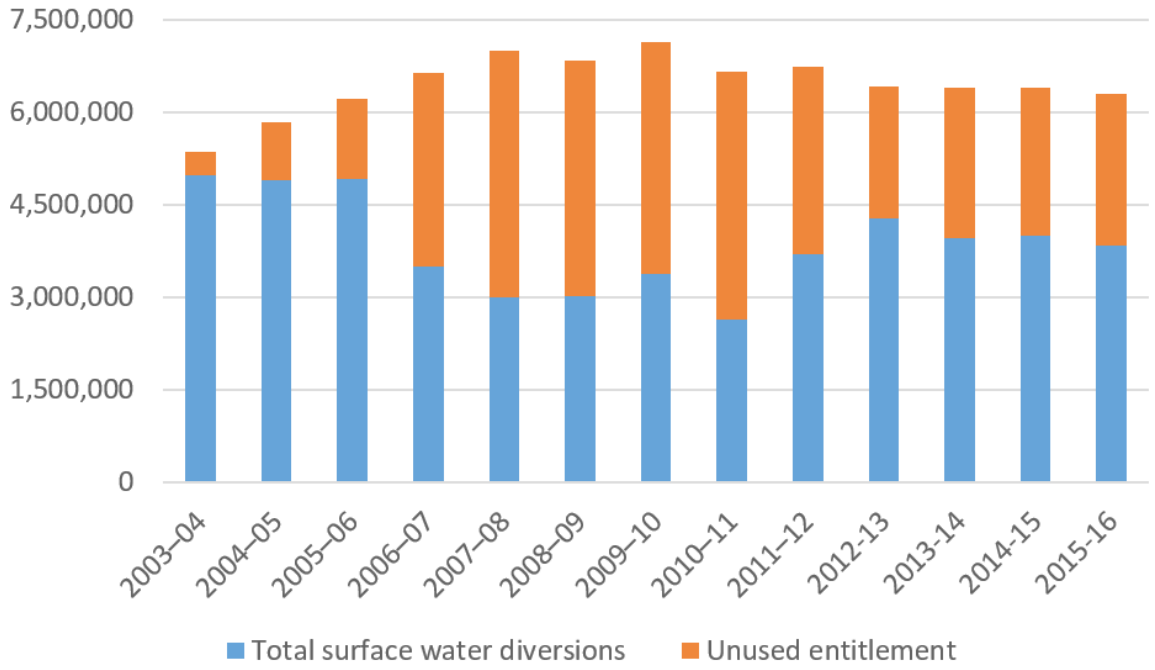


Figure WR.12 Total surface-water diversions and unused entitlements (ML) from 2003–04 to 2015–16

(Data source: DELWP, 2018)

Indicator	Status	Trend	Data Quality
WR:07 Percentage of waterways and groundwater areas, subject to extraction, with a limit on extraction Data custodian DELWP	UNKNOWN / POOR / FAIR / GOOD	→	DATA QUALITY: Good

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 non-agricultural 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).

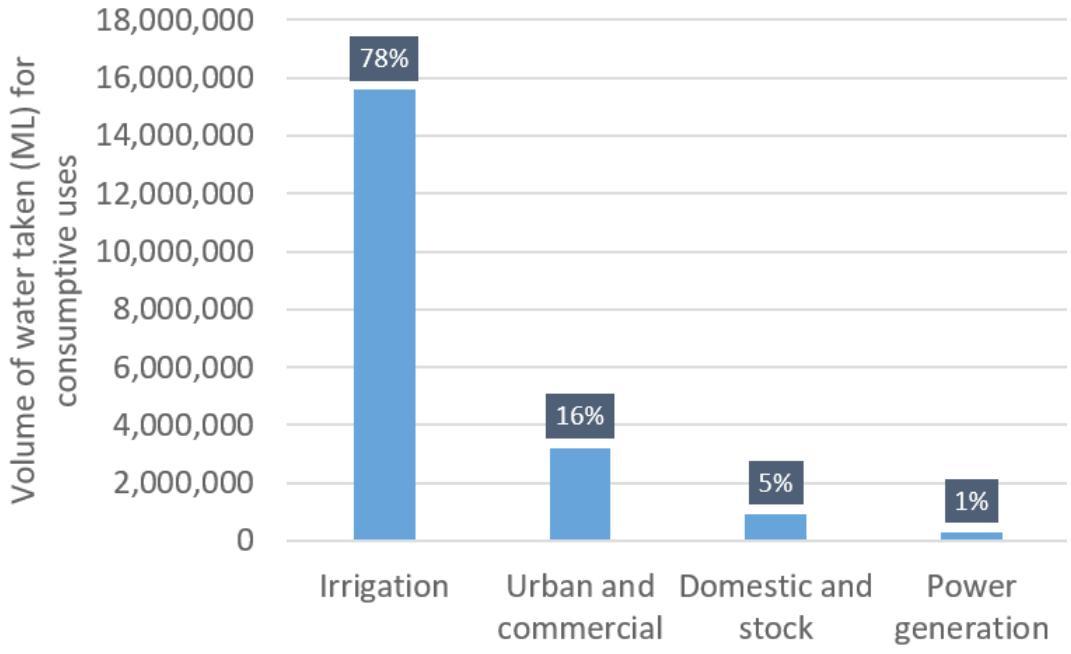


Figure WR.13 Volume of water (ML) taken for different consumptive uses under surface-water entitlements, Victoria, 2011–12 to 2015–16

(Data source: DELWP, 2018)

51. 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.

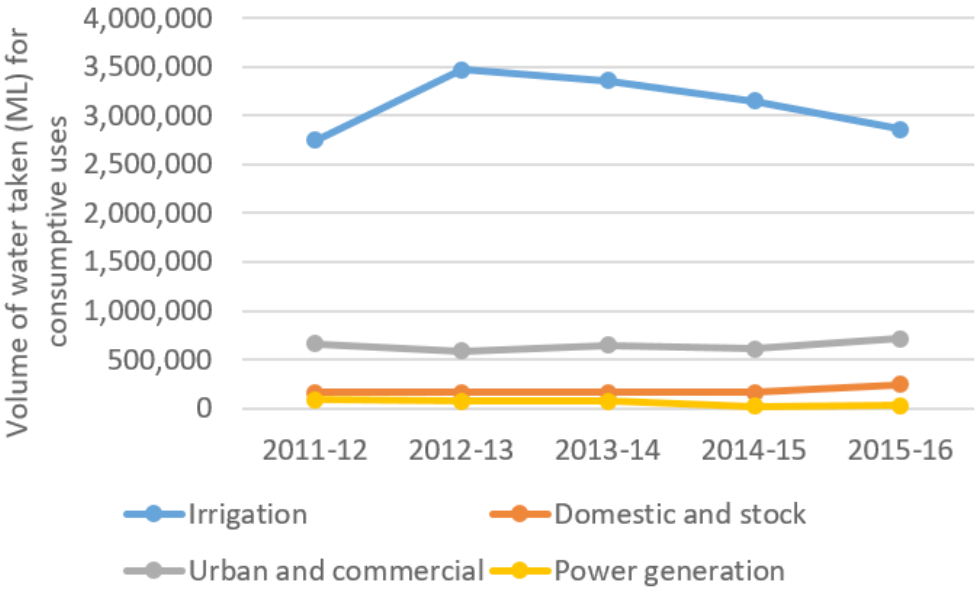


Figure WR.14 Volume (ML) of water taken for different consumptive uses under surface-water entitlements, Victoria, 2011–12 to 2015–16

(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 aquifer 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.

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

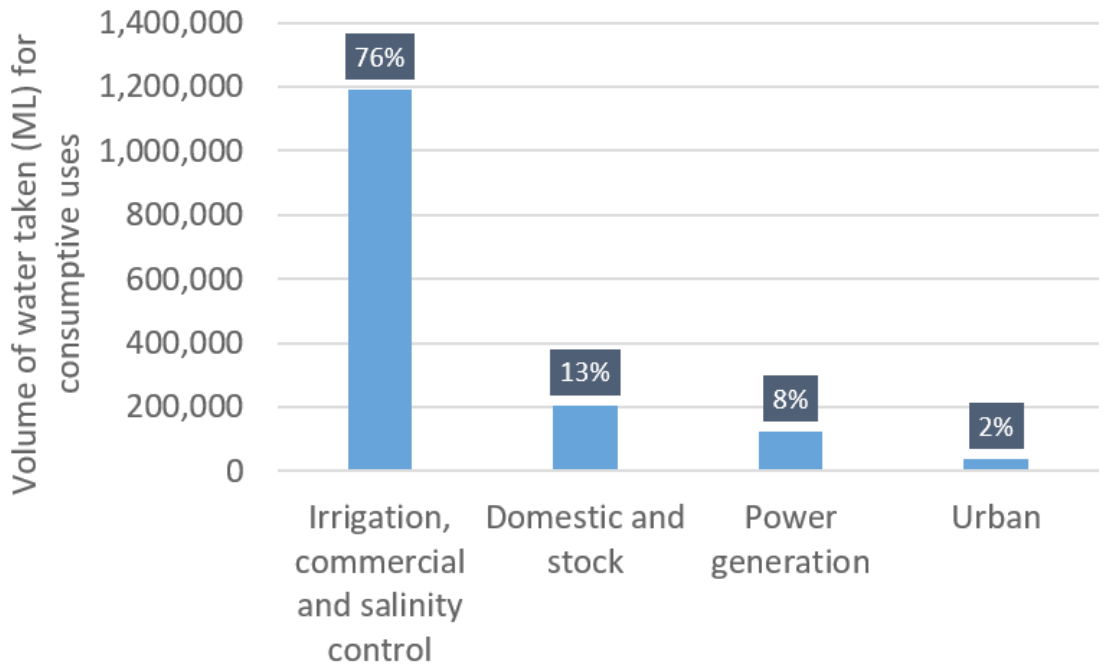


Figure WR.15 Volume of water (ML) taken for different consumptive uses by groundwater extraction, Victoria, 2012–13 to 2015–16

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

(Data source: DELWP, 2018)

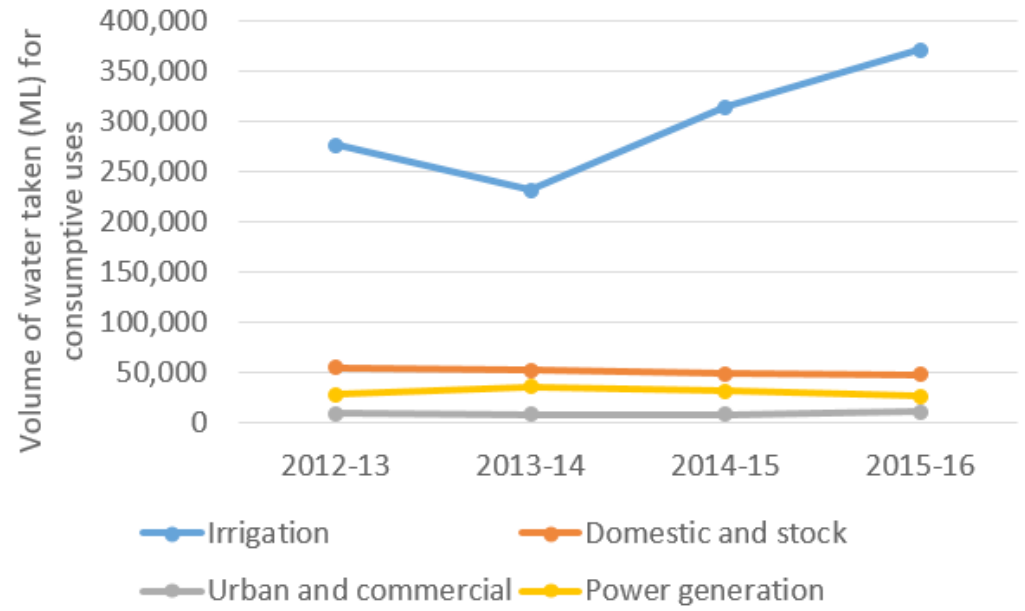


Figure WR.16 Volume (ML) of water taken for different consumptive uses by groundwater extraction, Victoria, 2012-13 to 2015–16

(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	POOR	FAIR	GOOD		
WR:08 Water recycling	○	○	●	○	↗	DATA QUALITY
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. Ibid

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).

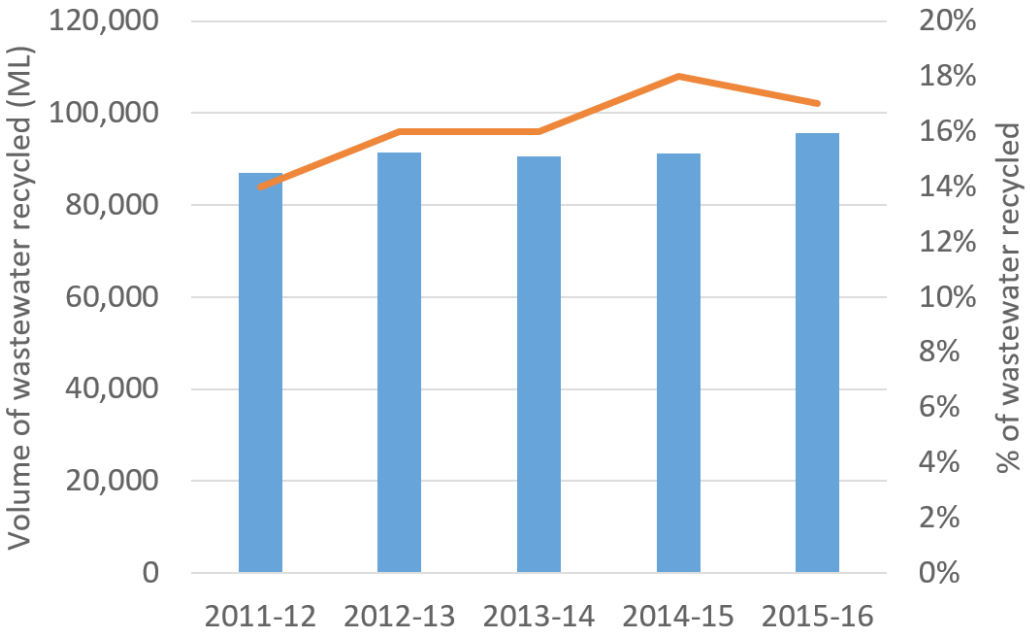


Figure WR.17 Wastewater recycling in Victoria, 2011–12 to 2015–16
(Data source: DELWP, 2018)

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).[57] 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.

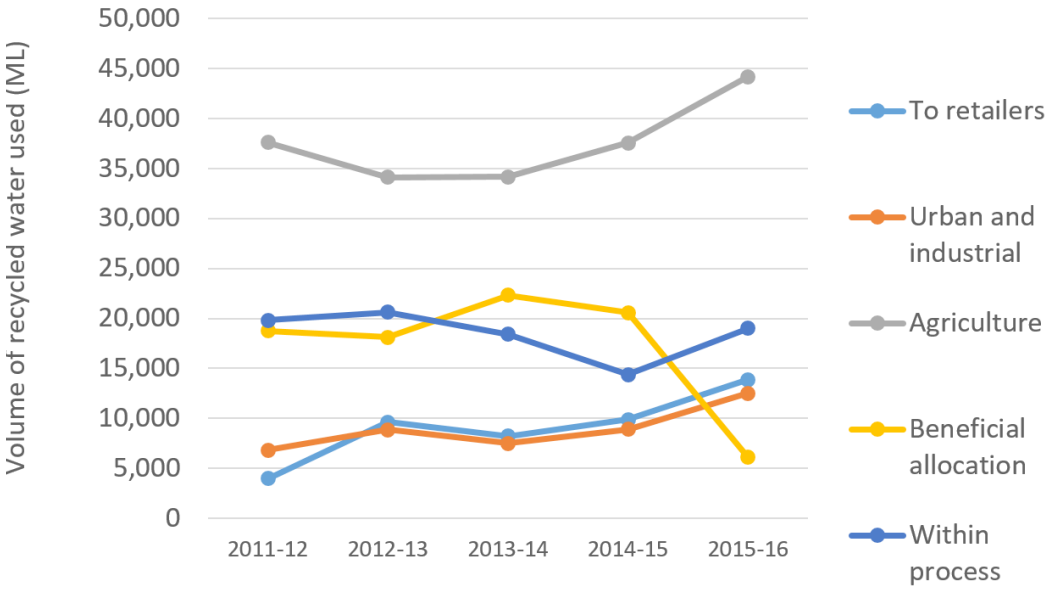


Figure WR.18 End-use of recycled water, 2011–12 to 2015–16
(Data source: DELWP, 2018)

57. Essential Services Commission 2018, 'Water Performance Indicator Definitions', Melbourne, Victoria https://www.esc.vic.gov.au/sites/default/files/documents/water-performance-reports-2017-18-water-performance-indicator-definitions.pdf Accessed 3 December 2018.

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

Data Custodian CMAs

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.

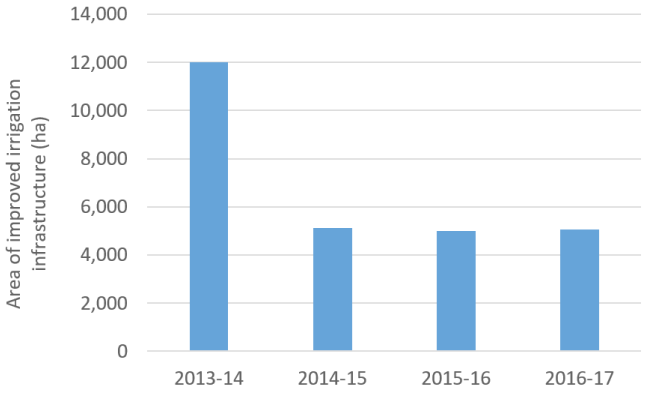


Figure WR.19 Area (ha) of Victorian land with improved irrigation infrastructure

(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.

58. Australian Bureau of Statistics 2018, '4610.0.55.008 - Gross Value of Irrigated Agricultural Production, 2016-17', Canberra, Australia http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/4610.0.55.008Main+Features12016-17?OpenDocument Accessed 3 December 2018.

59. 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, Bairnsdale, Hamilton, Shepparton, Irymple, Huntly, Wodonga, Frankston, Traralgon, Horsham, Victoria.

60. 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.

61. 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.

62. 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.

63. DELWP 2015, 'DELWP Output data standards', East Melbourne, Victoria https://www.water.vic.gov.au/__data/assets/pdf_file/0016/120463/DELWP-OutputDataStandard-web-V4.0.pdf 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 (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
WR:10 Groundwater ecosystems		?	 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.

64. 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. Ibid

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
WR:11 Groundwater quality	Good in eastern Victoria, Poor in north western Victoria and Fair elsewhere	→	DATA QUALITY: Fair (no trends can be determined from private bores)
Data Custodian DELWP			

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.

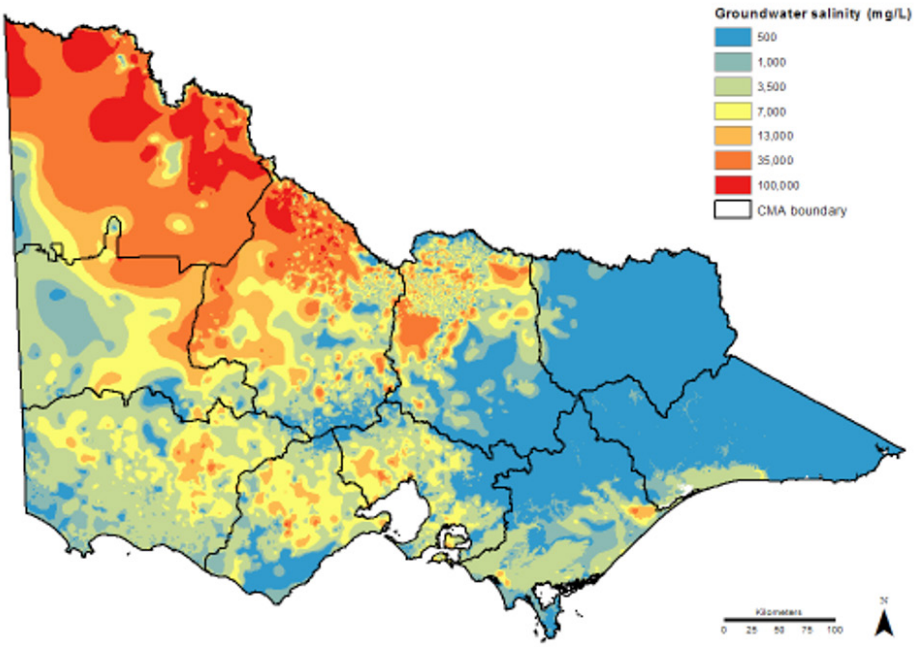


Figure WR.20 Baseline watertable salinity in Victoria
(Data source: DELWP, 2018)

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]

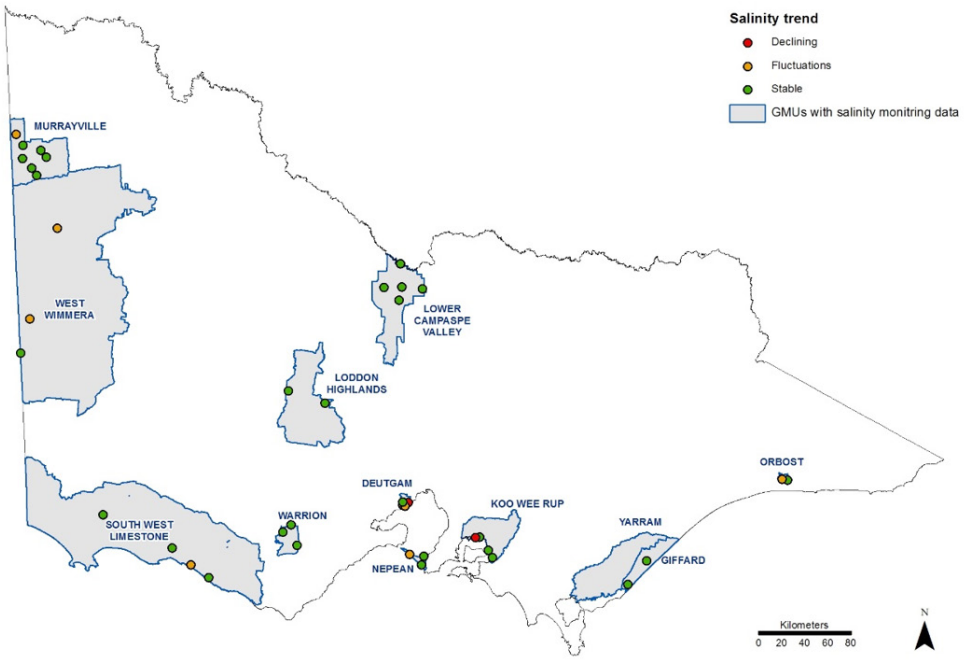


Figure WR.21 Groundwater salinity trend in GMUs
(Data source: DELWP, 2018)

66. 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/gqruz-map Accessed 3 December 2018.

Indicator	Status	Trend	Data Quality
WR:12 Groundwater levels		Stable: most shallow aquifers. Deteriorating (lower aquifers in the Gippsland Basin and northern region, and confined aquifers around Western Port and the Otway Ranges)	DATA QUALITY Fair (data not available across the state)
Data Custodian DELWP			

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)

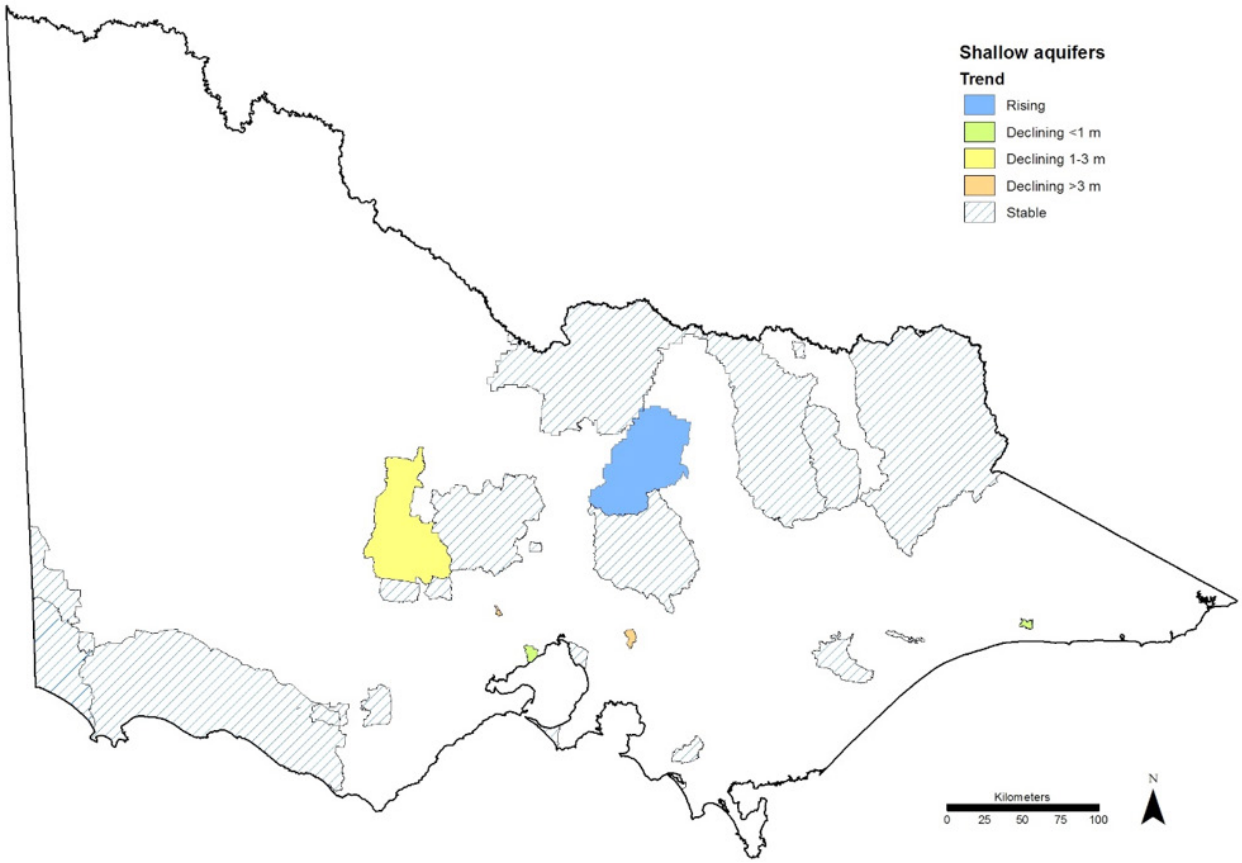


Figure WR.22 Groundwater-level trends in shallow-aquifer GMUs
(Data source: DELWP, 2018)

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.

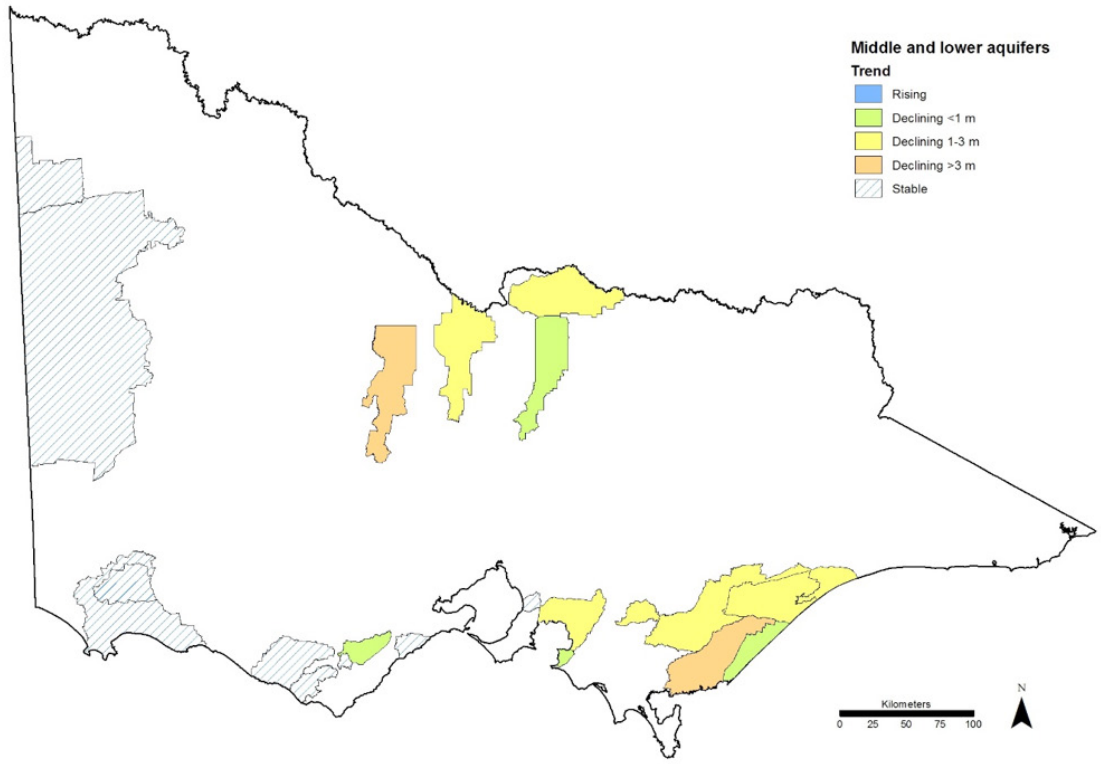


Figure WR.23 Groundwater-level trends in middle and lower aquifer GMUs

(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.

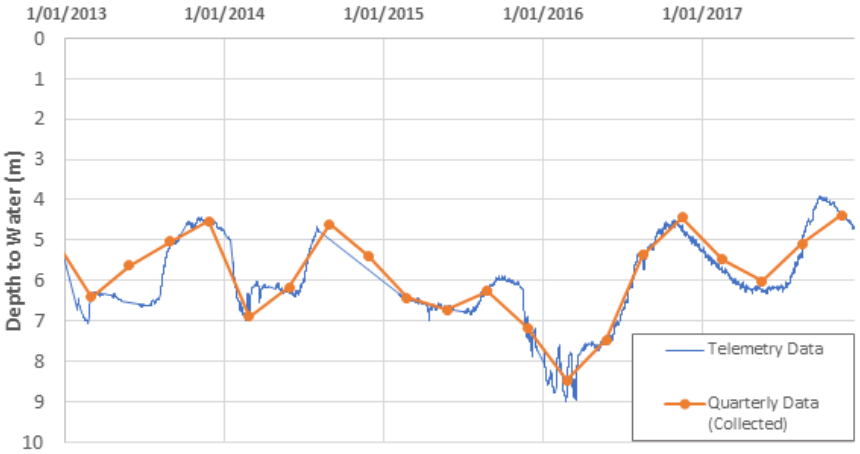


Figure WR.24 Example of telemetered hourly groundwater-level data and quarterly (manual) data for a bore (bore ID 62085)

(Data source: DELWP, 2018)

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
WR:13 Groundwater harvested for consumptive use	○	○	●	○	→	DATA QUALITY Good

Data Custodian DELWP

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 released in 2019.

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

1. 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 15-year period between LTWRAs, as more frequent assessments may be required to maintain ecosystem health and function.

67. Office of the Chief Parliamentary Counsel Victoria 1989, 'Water Act 1989', Melbourne, Victoria, http://www.legislation.vic.gov.au/Domino/Web_Notes/LDMS/LTObject_Store/LTObjSt5.nsf/DDE300B846EED9C7CA257616000A3571/F8DBB7E6417A03EDCA2577CB00024075/$FILE/89-80a099B.pdf.
68. DELWP 2016, 'Water for Victoria Water Plan', Melbourne, Victoria https://www.water.vic.gov.au/__data/assets/pdf_file/0030/58827/Water-Plan-strategy2.pdf.
69. DELWP, 'Assessment process: Long-Term Water Resource Assessment', Melbourne, Victoria https://www.water.vic.gov.au/planning-and-entitlements/long-term-water-resource-assessment/ltwra-assessment.
70. DELWP, 'Long-Term Water Resource Assessment', Melbourne, Victoria https://www.water.vic.gov.au/planning-and-entitlements/long-term-water-resource-assessment.
71. DELWP, 'Long-Term Water Resource Assessment', Melbourne, Victoria https://www.water.vic.gov.au/__data/assets/word_doc/0025/328174/LTWRA-General-Fact-Sheet.docx.
72. Office of the Chief Parliamentary Counsel Victoria 1989, 'Water Act 1989', Melbourne, Victoria, http://www.legislation.vic.gov.au/Domino/Web_Notes/LDMS/LTObject_Store/LTObjSt5.nsf/DDE300B846EED9C7CA257616000A3571/F8DBB7E6417A03EDCA2577CB00024075/$FILE/89-80a099B.pdf.
73. DELWP, 'Long-Term Water Resource Assessment', Melbourne, Victoria https://www.water.vic.gov.au/__data/assets/word_doc/0025/328174/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 (WQ)

SCIENTIFIC ASSESSMENTS Part III

Commissioner *for* Environmental Sustainability Victoria

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 water-quality 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]

1. VAGO 2016, 'Monitoring Victoria's Water Resources', Melbourne, Victoria https://www.audit.vic.gov.au/sites/default/files/20160525-Water-Resources.pdf Accessed 3 December 2018.
2. DELWP 2018, 'Water for Victoria', East Melbourne, Victoria https://www.water.vic.gov.au/__data/assets/pdf_file/0030/58827/Water-Plan-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 water-quality 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.

3. Murray-Darling Basin Ministerial Council 2015, 'Basin Salinity Management 2030 (BSM2030)', Canberra, Australia https://www.mdba.gov.au/sites/default/files/pubs/D16-34851-basin_salinity_management_st rategy_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 citizen-science 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 long-term 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.[6] 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.[7] 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,[8] to create the new SEPP (Waters).

4. DELWP 2018, 'Water for Victoria', East Melbourne, Victoria https://www.water.vic.gov.au/__data/assets/pdf_file/0030/58827/Water-Plan-strategy2.pdf Accessed 3 December 2018.
5. Melbourne Water Corporation 2018, 'Healthy Waterways Strategy 2018', Melbourne, Victoria https://www.melbournewater.com.au/media/6361/download Accessed 3 December 2018.
6. DELWP, 'Melbourne Urban Stormwater Institutional Arrangements Review', East Melbourne, Victoria https://www.water.vic.gov.au/managing-floodplains/stormwater-review Accessed 3 December 2018.
7. EPA, 'State Environment Protection Policy (Waters) review', Melbourne, Victoria https://www.epa.vic.gov.au/our-work/setting-standards/environmental-standards-reform/water Accessed 3 December 2018.
8. 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.

Poor
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

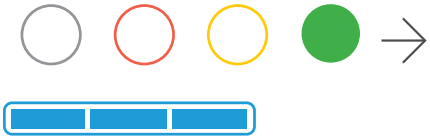
Poor
Evidence and consensus too low to make an assessment

Fair
Limited evidence or limited consensus

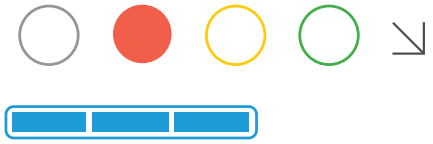
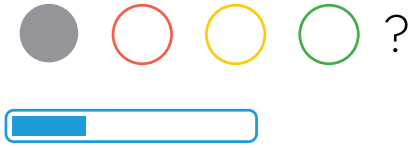
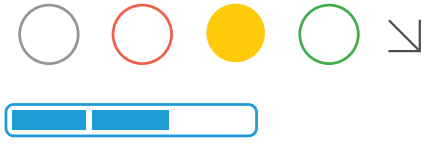
Good
Adequate high-quality evidence and high level of consensus

WATER QUALITY

	Summary	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend
Indicator **WQ:01** Occurrence of algal blooms **Region** Victoria **Measures** Number of algal blooms (trigger level for reporting is when cyanobacteria in any water body exceed 0.2 mm^3/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.	DATA QUALITY Fair (due to the absence of suitable trend data)	?

	Summary	Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **WQ:02** Dissolved oxygen concentration in rivers **Region** Victoria **Measures** % of sites that attained SEPP (WoV) water quality objectives **Data custodian** DELWP, Melbourne Water	Dissolved oxygen in Victorian rivers and streams for 2010–17 was rated as excellent in the east and central regions of the state, and good in the western Catchment Management Authority regions.	 DATA QUALITY Good	
Indicator **WQ:03** Salinity concentrations in rivers **Region** Victoria **Measures** % of sites that attained SEPP (WoV) water quality objectives **Data custodian** DELWP, Melbourne Water	Salinity in Victorian rivers and streams for 2010–17 was rated as good or excellent in seven catchments, fair in a further two and poor in Glenelg Hopkins.	 Poor in the Glenelg Hopkins catchment, Fair in the Wimmera and Port Phillip and Westernport catchments, Good in the other catchments DATA QUALITY Good	
Indicator **WQ:04** Total nitrogen concentration in rivers **Region** Victoria **Measures** % of sites that attained SEPP (WoV) water quality objectives **Data custodian** DELWP, Melbourne Water	There was a gradient for total nitrogen (2010–17) from excellent water quality in the east deteriorating to poor and very poor water quality in Victoria's west and the urbanised catchment of the Port Phillip and Western Port.	 Good in the North East and East Gippsland catchments, Fair in the Goulburn Broken and West Gippsland catchments, and Poor in other catchments. Unknown in the Mallee catchment. DATA QUALITY Good	

	Summary	Status	Trend
Indicator **WQ:05** Total phosphorus concentrations in rivers **Region** Victoria **Measures** % of sites that attained SEPP (WoV) water quality objectives **Data custodian** DELWP, Melbourne Water	There was a gradient for total phosphorus (2010-17) from excellent water quality in the far east of Victoria to very poor water quality in the west of the state	 UNKNOWN POOR FAIR GOOD Good in the East Gippsland catchment, Fair in the North East and West Gippsland catchments, and Poor in other catchments. Unknown in the Mallee catchment.  DATA QUALITY Good	
Indicator **WQ:06** Turbidity levels in rivers **Region** Victoria **Measures** % of sites that attained SEPP (WoV) water quality objectives **Data custodian** DELWP, Melbourne Water	Turbidity in Victorian rivers and streams from 2010-17 was rated as moderate to very poor. The Mallee and Wimmera catchments were both ranked as very poor. Turbidity has increased in recent times compared to historical data.	 Fair in the East Gippsland, North East and Glenelg Hopkins catchments, and Poor in other catchments.  DATA QUALITY Good	
Indicator **WQ:07** pH **Region** Victoria **Measures** % of sites that attained SEPP (WoV) water quality objectives **Data custodian** DELWP, Melbourne Water	Water quality with respect to pH in Victorian rivers and streams for 2010-17 was rated as excellent across all catchment regions and river basins.	  DATA QUALITY Good	

	Summary	Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **WQ:08** Proportion of bodies of water with good ambient water quality **Region** 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	The current assessment suggests that water quality is generally better in the east of the state than in the central and western regions. 26% of all sites rated as having good or better water quality for 2010-17, a reduction from 37% of sites for 2004-09.	 DATA QUALITY Good	
Indicator **WQ:09** Volume of sewage discharge to surface waters **Region** Victoria **Measures** Volumes of discharged pollutants **Data custodian** EPA Victoria	Data on water pollutants that are discharged from EPA Victoria's licensed sites was unavailable at a statewide level. Therefore, the status and trend assessments for this indicator have been provided as unknown and unclear respectively.	 DATA QUALITY Poor (No data available to make 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 (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
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.[10] Even high levels of non-toxic algae can affect water quality and treatment through filter-clogging.[11]

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 mm^3/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.

9. 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
10. DELWP 2015, 'Blue-Green Algae Circular 2016-17', East Melbourne, Victoria https://www.water.vic.gov.au/__data/assets/word_doc/0033/65589/BGA-Circular-2016-17final_-.docx Accessed 3 December 2018.
11. Ibid.
12. 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*.
13. 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 water-quality 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://data.water.vic.gov.au/monitoring.htm Accessed 3 December 2018.
15. Melbourne Water Corporation, 'Waterway water quality data', Melbourne, Victoria https://www.melbournewater.com.au/water/health-and-monitoring/river-health-and-monitoring/waterway-water-quality-data Accessed 3 December 2018.
16. 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 years.
17. 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.au/seppwaters 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]

18. State Government of Victoria, 'Report Card 2016–2017', Melbourne, Victoria https://yarraandbay.vic.gov.au/report-card/report-card-2017 Accessed 3 December 2018.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
WQ:02 Dissolved oxygen concentration in rivers	○	○	○	●	→	DATA QUALITY: Good

Data Custodian DELWP, Melbourne Water

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.

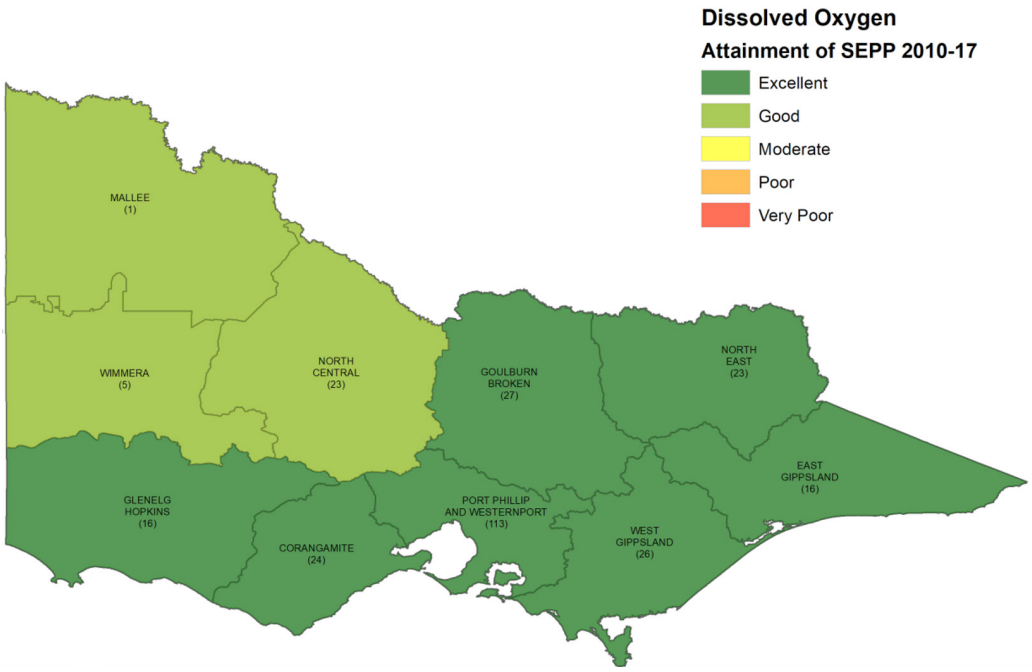


Figure WQ.2 SEPP (WoV) attainment of the dissolved oxygen threshold of ≥ 3.5 mg/L by CMA regions

Note: Numbers represent the average number of monitoring locations in each region used in the assessment.
(Data source: DELWP, Melbourne Water, 2018)

19. 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.

20. King AJ, Tonkin Z, Lieshcke J 2012, 'Short-term effects of a prolonged blackwater event on aquatic fauna in the Murray River, Australia: considerations for future events', *Marine and Freshwater Research*, 63(7), pp. 576–586.
21. 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).
22. EPA, 'Blackwater event at One Mile Creek, Wangaratta', Carlton, Victoria https://www.epa.vic.gov.au/about-us/news-centre/news-and-updates/news/2018/january/31/wangaratta-blackwater-event Accessed 3 December 2018.

Indicator	Status	Trend	Data Quality
WQ:03 Salinity concentrations in rivers	UNKNOWN POOR FAIR GOOD 		 DATA QUALITY Good
Data Custodian DELWP, Melbourne Water	Poor in the Glenelg Hopkins catchment, Fair in the Wimmera and Port Phillip and Westernport catchments, Good in the other catchments		

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 to:

- 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.

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).

23. Kefford BJ, Schäfer RB, Liess M, Goonan P, Metzeling L, Nugegoda D 2010, 'A similarity-index based method to estimate chemical concentration limits protective for ecological communities', *Environmental Toxicology and Chemistry*, 29(9), pp. 2123–31.
24. 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.
25. 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.
26. Ventia 2018, 'Victorian Water Quality Trends 1991-2016'.
27. Ibid.
28. Ibid.

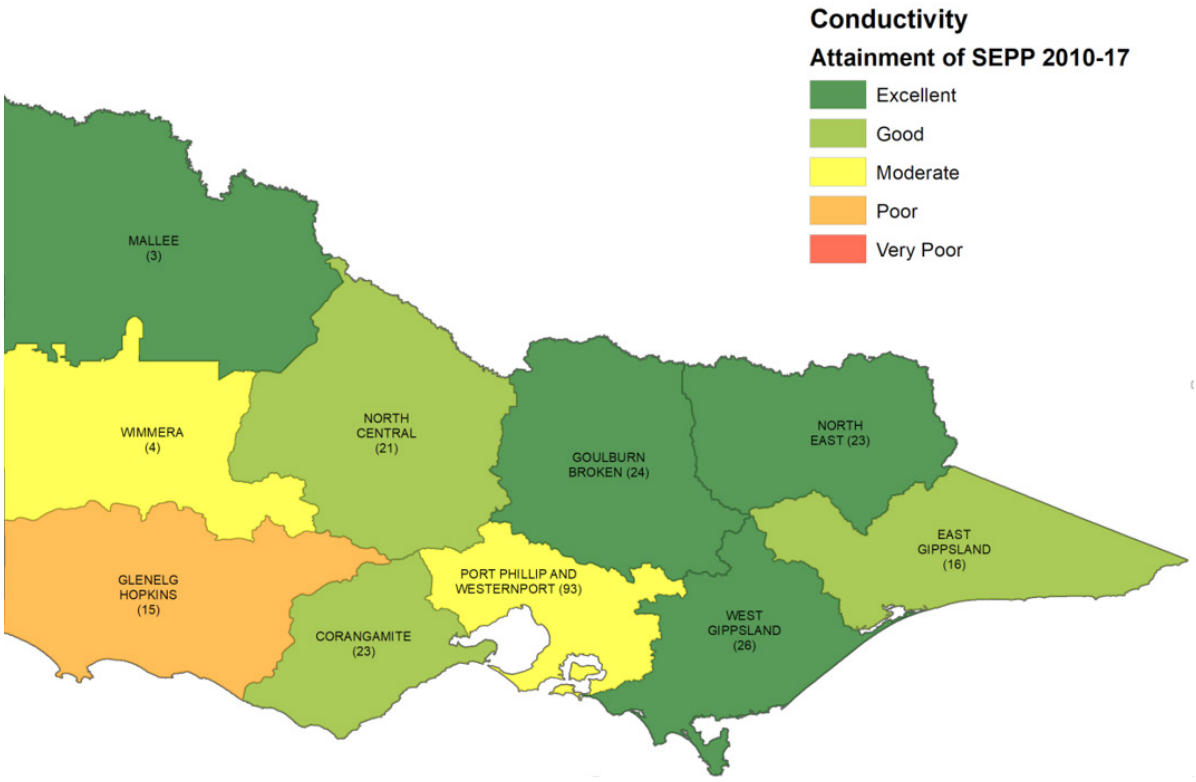


Figure WQ.3 SEPP (WoV) attainment of water-quality objectives for electrical conductivity (as an indicator of salinity) by CMA regions

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	0	40	50	0	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	 Good in the North East and East Gippsland catchments, Fair in the Goulburn Broken and West Gippsland catchments, and Poor in other catchments. Unknown in the Mallee catchment.		 DATA QUALITY Good

Data Custodian
DELWP, Melbourne Water

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 micro-organisms. 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). Longer-term 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.

29. Harris GP 2001, 'Biogeochemistry of nitrogen and phosphorus in Australian catchments, rivers and estuaries: effects of land use and flow regulation and comparisons with global patterns', *Marine and Freshwater Research*, 52(1), pp. 139–149.

30. Ventia 2018, 'Victorian Water Quality Trends 1991-2016'.
31. Ibid.
32. Ibid.

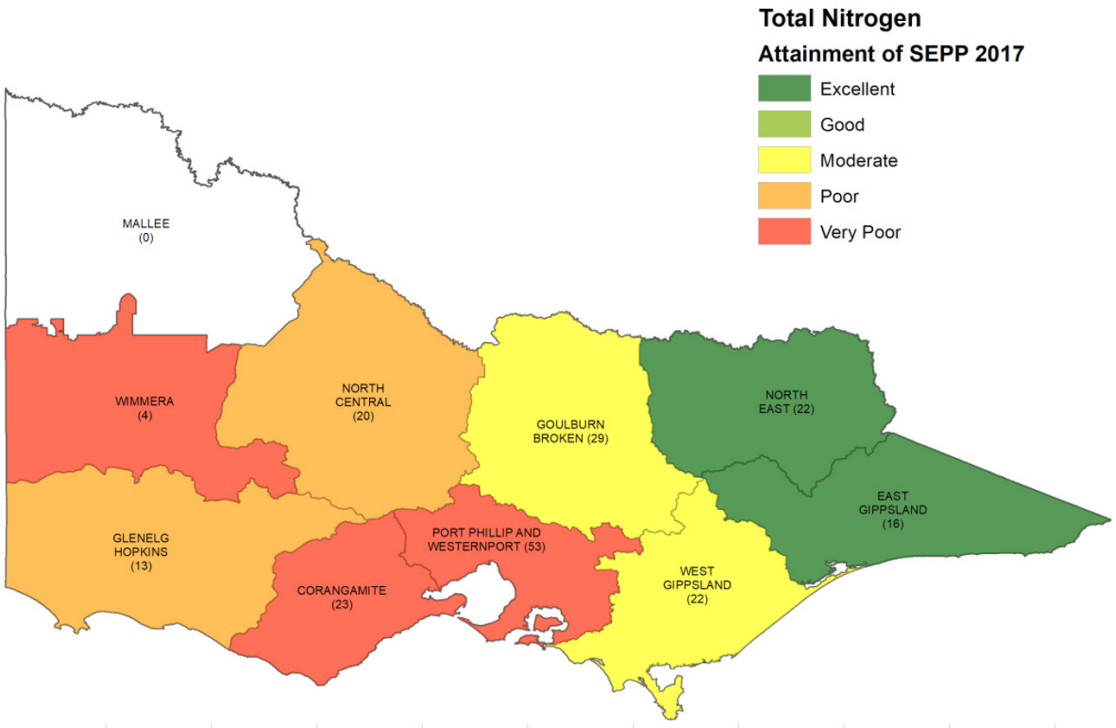


Figure WQ.4 SEPP (WoV) attainment of water-quality objectives for total nitrogen by CMA regions

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

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	8	23	15	15	38	23	23	20
North Central (22)	5	0	0	14	19	24	0	25	11
Port Phillip & Western Port (115)	4	5	5	8	9	9	2	4	6
Corangamite (23)	4	4	4	0	5	0	0	4	3
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	Trend	Data Quality
WQ:05 Total phosphorus concentrations in rivers	 Good in the East Gippsland catchment, Fair in the North East and West Gippsland catchments, and Poor in other catchments. Unknown in the Mallee catchment.		 DATA QUALITY Good
Data Custodian DELWP, Melbourne Water			

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). Longer-term 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

33. Ibid.

34. Ibid.
35. Ibid.

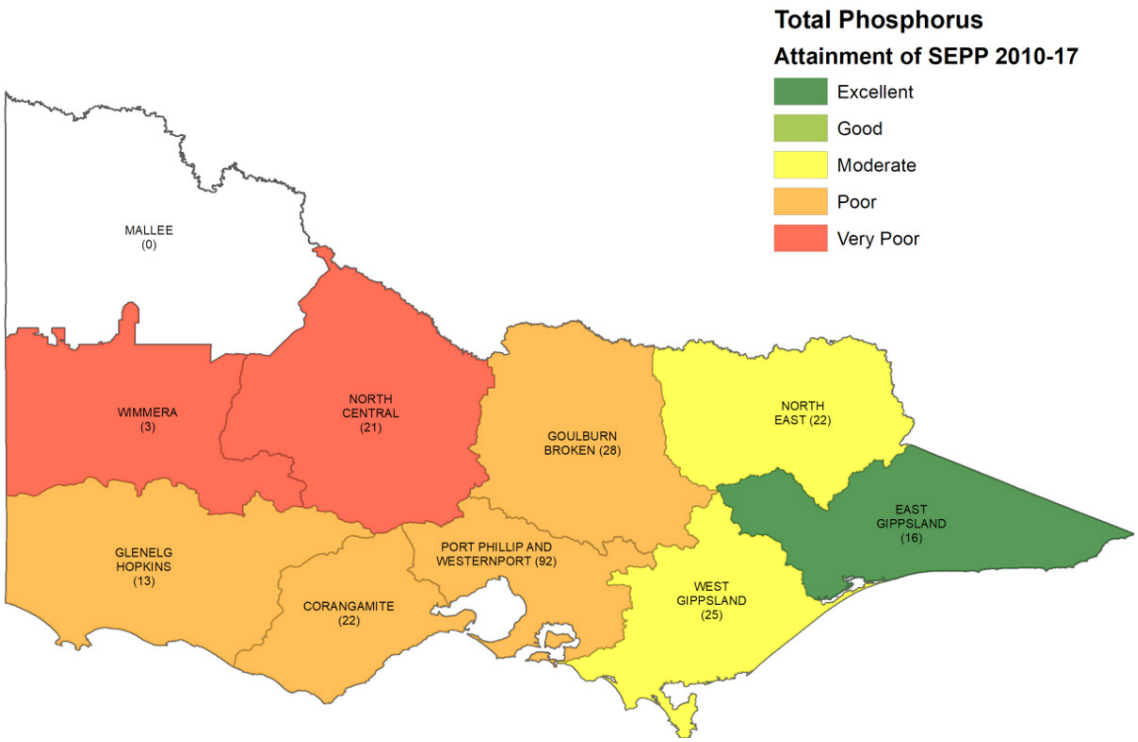


Figure WQ.5 SEPP (WoV) attainment of water-quality objectives for total phosphorus by CMA regions

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	8	23	23	46	46	8	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	0	4	10	10	14	11	14	8
Wimmera (4)	0	0	0	0	0	0	0	0	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)

Indicator	Status	Trend	Data Quality
WQ:06 Turbidity levels in rivers	UNKNOWN POOR FAIR GOOD		
Data Custodian DELWP, Melbourne Water	Fair in the East Gippsland, North East and Glenelg Hopkins catchments, and Poor in other catchments.		DATA QUALITY Good

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.

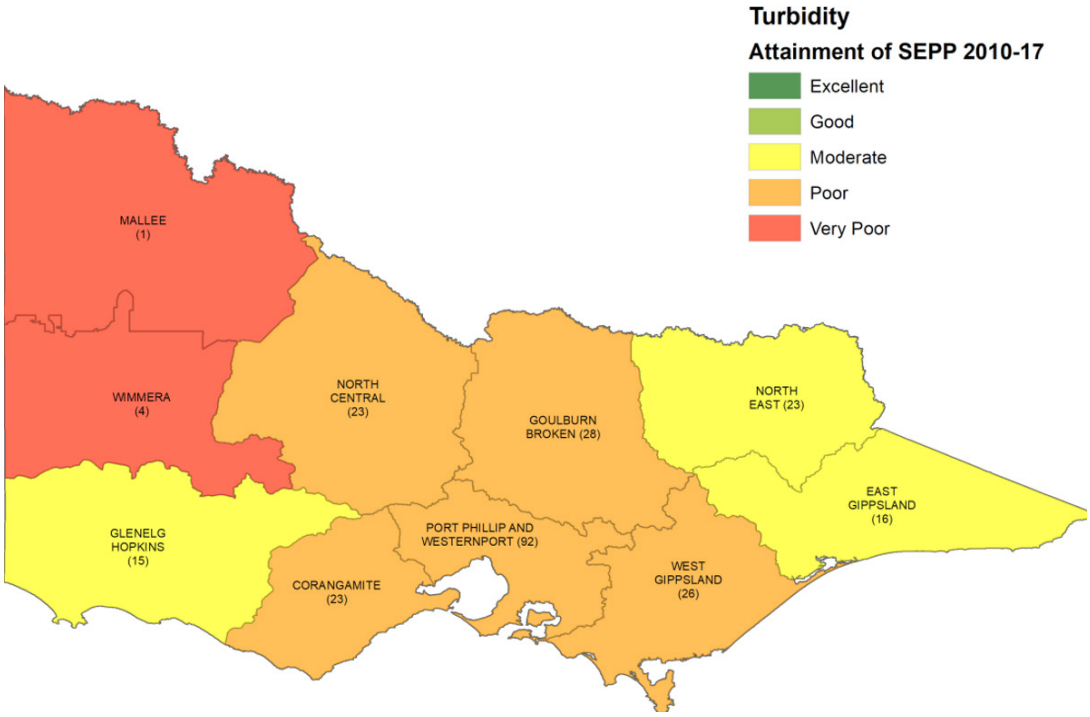


Figure WQ.6 SEPP (WoV) attainment of water-quality objectives for turbidity (as an indicator of water clarity) by CMA regions

Note: Numbers represent the average number of monitoring locations in each region used in the assessment.

(Data source: DELWP, Melbourne Water, 2018)

36. 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 long-term 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 land-clearing, 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)	8	23	42	25	35	30	16	46	29
Corangamite (23)	17	0	17	23	23	54	23	33	24
West Gippsland (26)	22	19	15	19	30	28	20	36	23
Goulburn Broken (28)	3	3	10	15	24	41	8	34	17
Port Phillip & Western Port (92)	18	6	5	14	31	24	6	19	14
Wimmera (4)	0	0	25	0	0	0	0	0	3
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)

37. Ventia 2018, 'Victorian Water Quality Trends 1991-2016'.
38. Ibid.
39. 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.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
WQ:07 pH	○	○	○	●	→	DATA QUALITY: Good

Data Custodian DELWP, Melbourne Water

pH is a measure of the acidity or alkalinity of water. It is measured on a logarithmic scale from 0 (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]

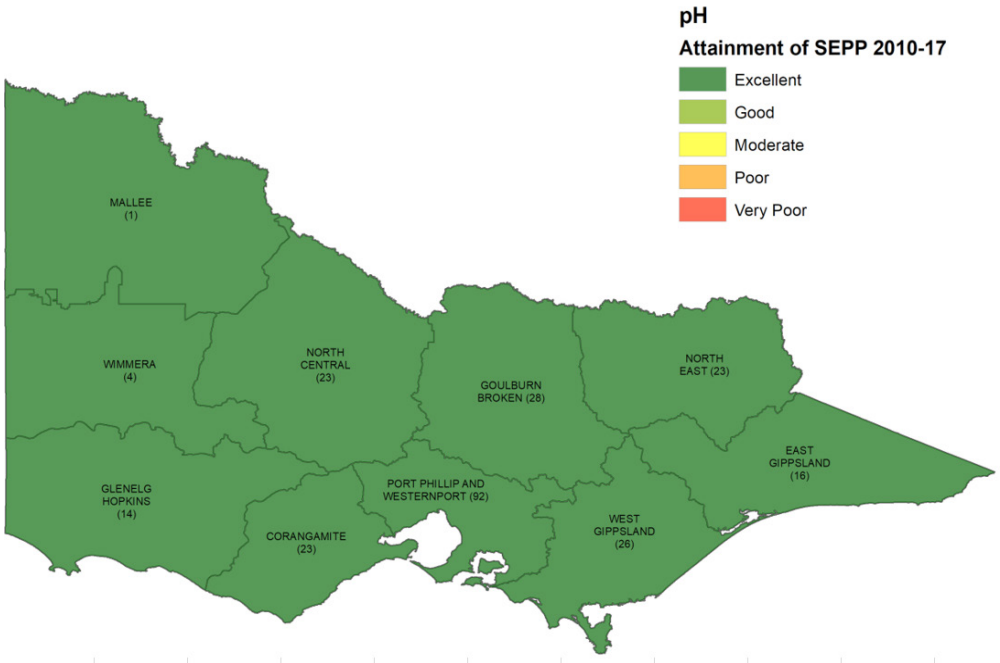


Figure WQ.7 SEPP (WoV) attainment of water-quality objectives for pH by CMA regions

Note: Numbers represent the average number of monitoring locations in each region used in the assessment. (Data source: DELWP, Melbourne Water, 2018)

40. Apte, S. and Batley, G. 2011, 'Water: Science and solutions for Australia', CSIRO Publishing, Collingwood. Victoria.

41. 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.

42. 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 (average number of sites)	2010	2011	2012	2013	2014	2015	2016	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				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
WQ:08 Proportion of bodies of water with good ambient water quality	○	●	○	○	↘	DATA QUALITY: Good

Data Custodian DELWP, Melbourne Water

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 catchment.

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.

44. United Nations, 'Indicator 6.3.2 – Water quality', New York City, New York http://www.sdg6monitoring.org/indicators/target-63/indicators632/ Accessed 3 December 2018.
45. DELWP, 'Third Index of Stream Condition report', East Melbourne, Victoria https://www.water.vic.gov.au/water-reporting/third-index-of-stream-condition-report Accessed 3 December 2018.

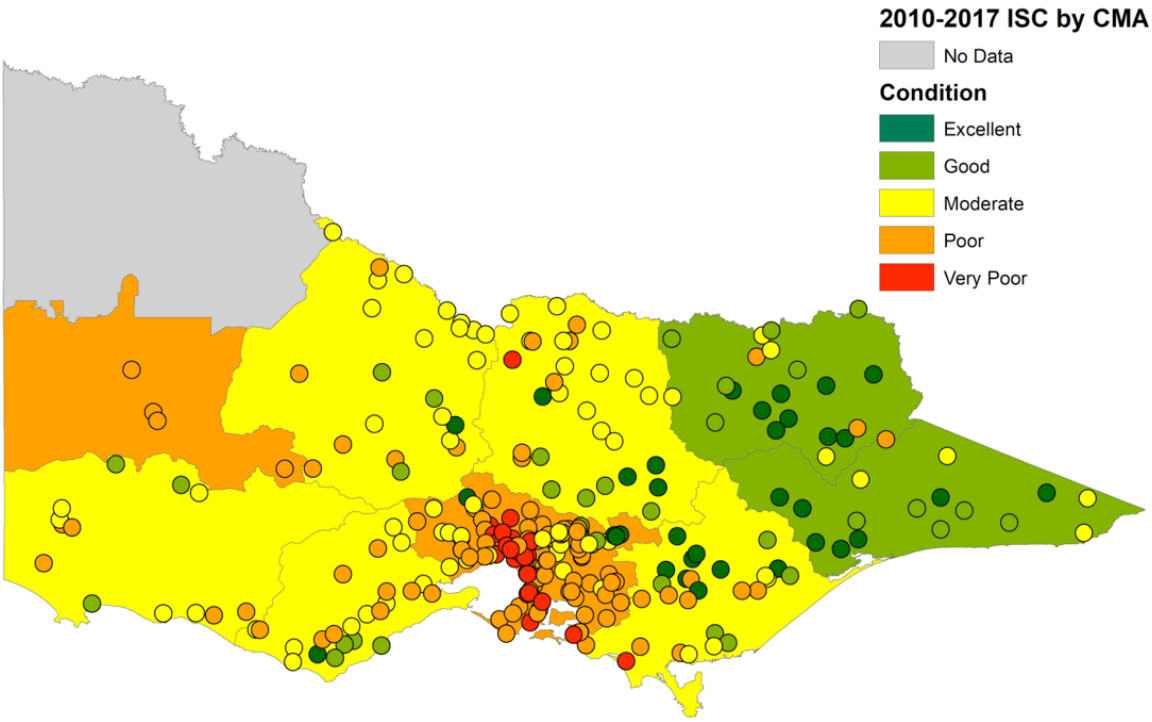


Figure WQ.8 Water-quality scores and rankings for Victoria (2010–17), based on the methodology developed to calculate the ISC

(Data source: DELWP, Melbourne Water, 2018)

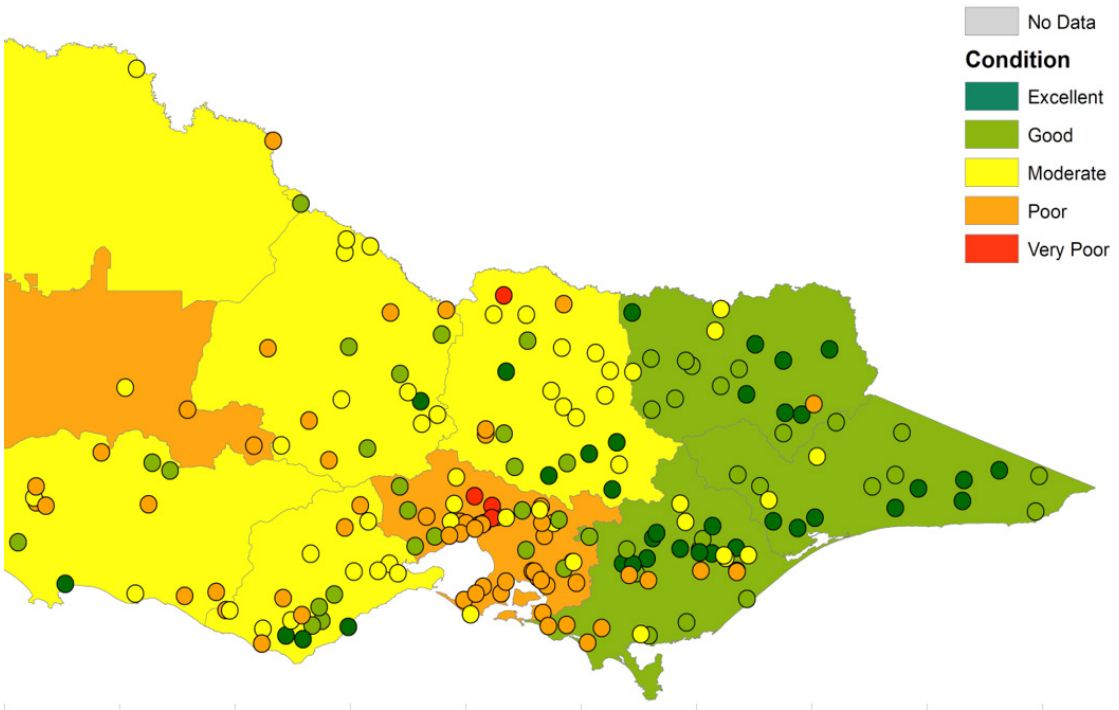


Figure WQ.9 ISC integrated water-quality scores for CMA regions, 2004–09, showing scores for individual sites

(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.

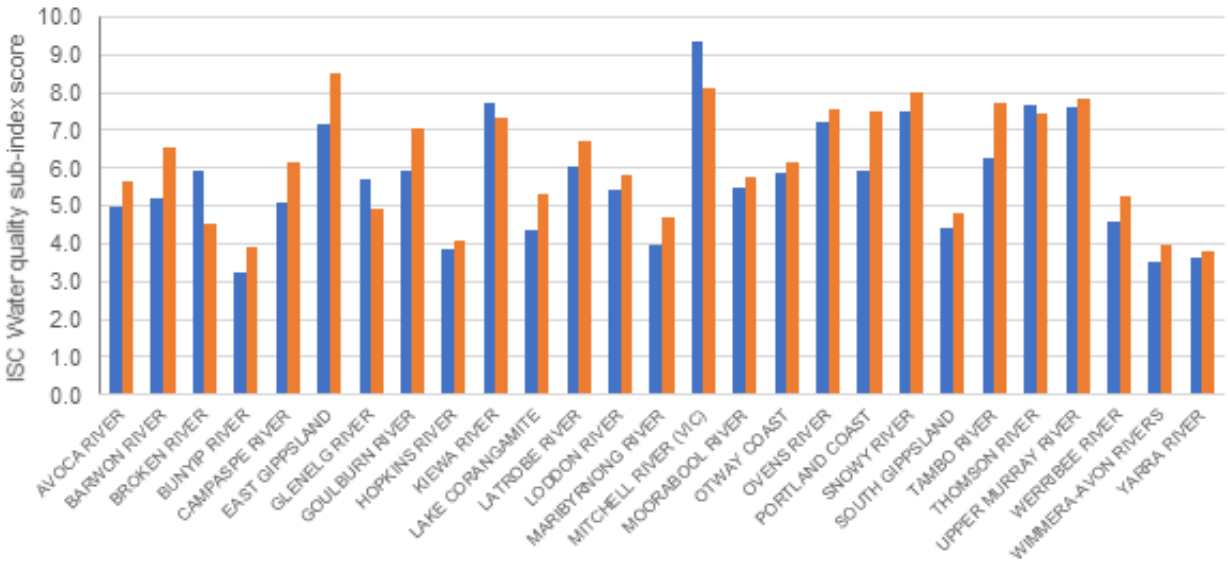


Figure WQ.10 ISC water-quality sub-index scores from the 2010 assessment (data from 2004–09) and the current assessment (data from 2010–17) for river basins

Note: ISC rankings are: excellent ≥ 9; good 8–9; moderate 6–7; poor 4–5; very poor ≤ 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.

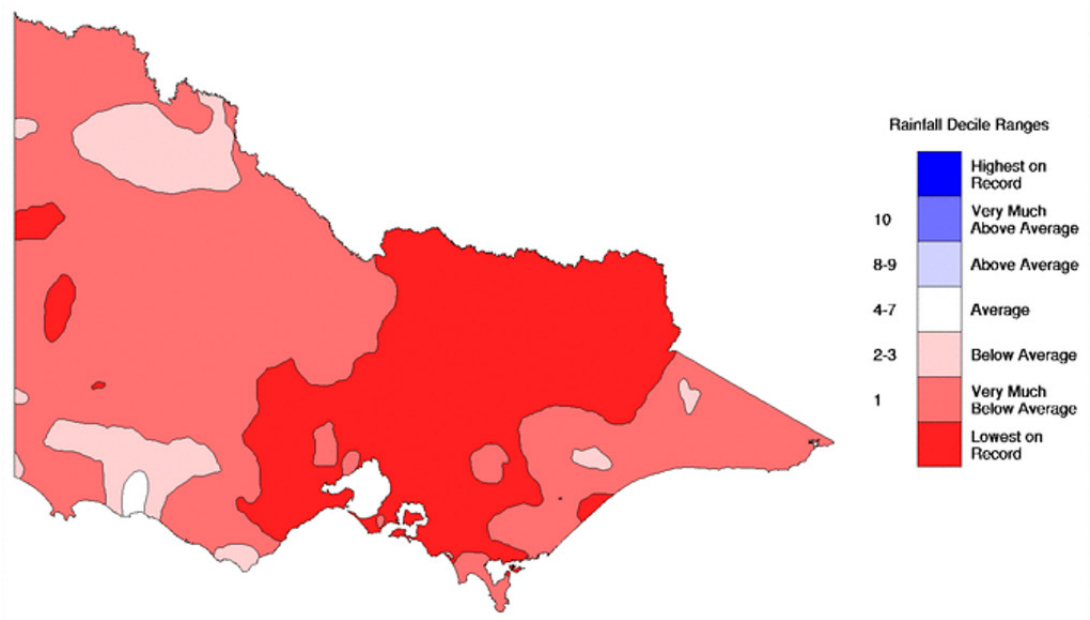


Figure WQ.11 Rainfall, 2006–09 (as an indicator of conditions during the current ISC assessment) compared to long-term averages

(Data source: BoM, 2018)

46. Bond NR, Lake PS, Arthington AH 2008, 'The impacts of drought on freshwater ecosystems: an Australian perspective', ***Hydrobiologia***, 600(1), pp. 3–16.
47. 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.
49. 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.

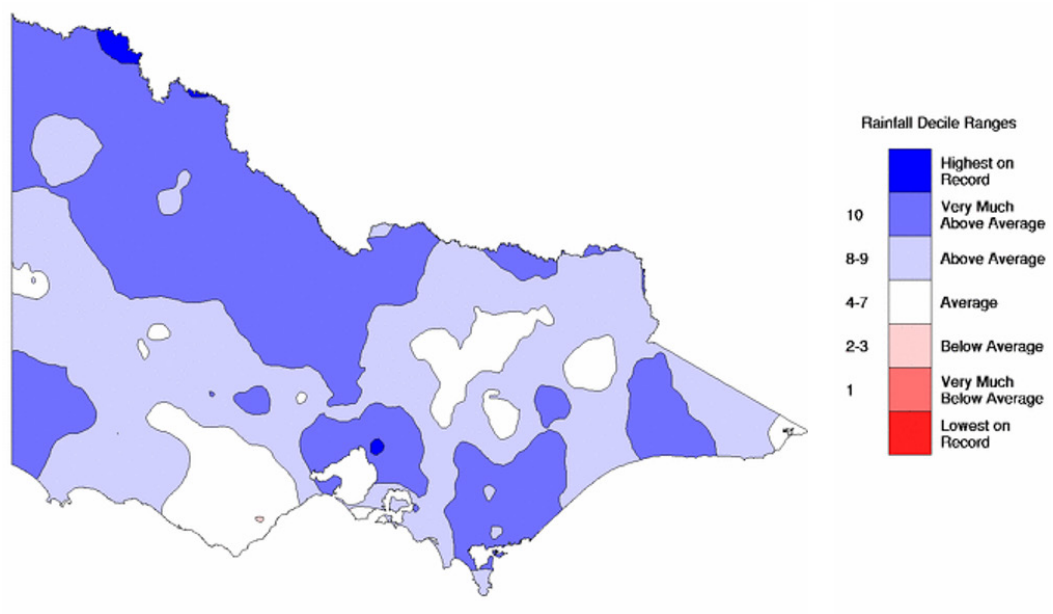


Figure WQ.12 Rainfall in 2011 (as an indicator of conditions during the current ISC assessment) compared to long-term averages

(Data source: BoM, 2018)

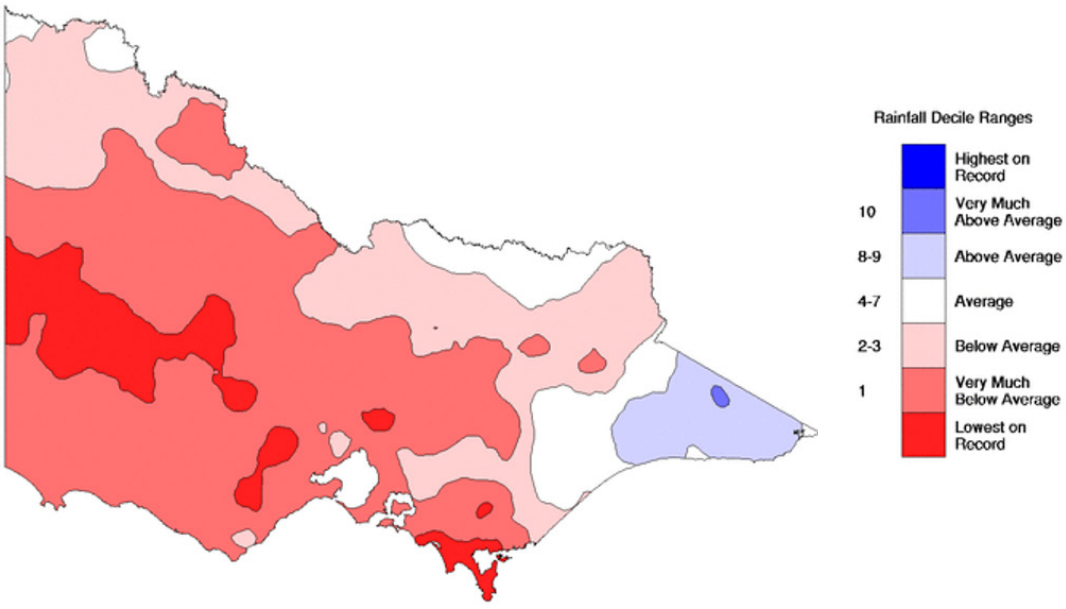


Figure WQ.13 Rainfall, 2014–15 (as an indicator of conditions during the current ISC assessment) compared to long-term averages

(Data source: BoM, 2018)

Discharges

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
WQ:09 Volume of sewage discharge to surface waters	●	○	○	○	?	DATA QUALITY: Poor (no data available to make an assessment)

Data Custodian EPA Victoria

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 in-stream fauna, animals drinking the water and people (through direct contact or piped water-supply 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.

50. 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.
51. Tolkou A and Zouboulis A, 2016, 'Effect of Climate Change in WWTPs with a focus on MBR infrastructure', *Desalination and Water Treatment*, 57(5): pp. 2344-2354.
52. Hobday AJ, Lough JM 2011, 'Projected climate change in Australian marine and freshwater environments', *Marine and Freshwater Research*, 62, pp. 1000-1014.
53. 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 (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
WQ:10 Reported inland water pollution incidents		↘	DATA QUALITY: Fair (data provided not linked to water bodies)

Data Custodian EPA Victoria

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.

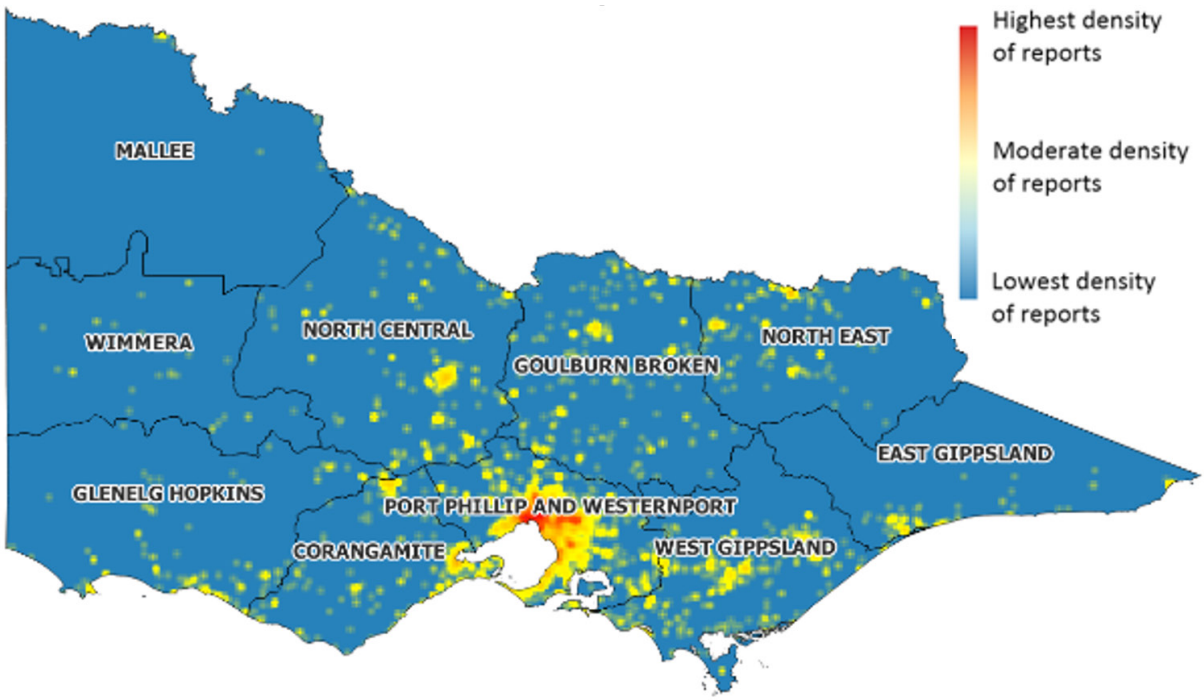


Figure WQ.14 Heat map of water pollution reports received by EPA Victoria, 2013–17

(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 fish-death 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.

54. Agriculture Victoria, 'Rainfall', http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/rainfall Accessed 3 December 2018.

55. 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.

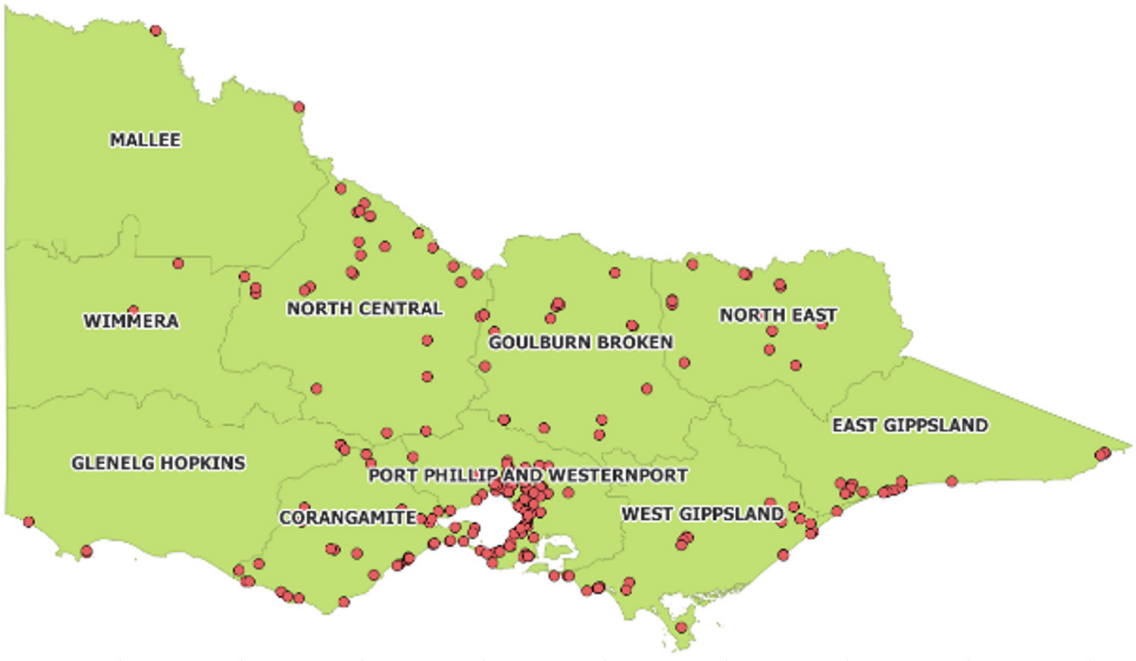


Figure WQ.15 The locations of fish death pollution reports in Victoria, 2013–17

(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 pollution-reporting database would assist the determination of potential hotspot areas for monitoring.

Recommendation 12: That DELWP, working with its portfolio agencies, implement an agile water-quality monitoring framework that (i) clarifies the roles and responsibilities of all agencies and the community, (ii) improves monitoring of pollution hotspots, and (iii) builds on EPA Victoria's implementation of EPA Inquiry recommendations 6.3 and 7.2.

56. Ministerial Advisory Committee 2016, 'Independent inquiry into the Environment Protection Authority', http://www.epa-inquiry.vic.gov.au/__data/assets/file/0008/336698/Inquiry-report-EPA_June.pdf.

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 water-resources 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). Water-emissions 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 water-pollutant 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

Commissioner *for* Environmental Sustainability Victoria



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 products[1]
- 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 to landfill.

1. Sustainability Victoria 2018, 'Lifecycle Kerbside Recycling Calculator', http://www.sustainability.vic.gov.au/Government/Victorian-Waste-data-portal/Lifecycle-assessment-of-kerbside-recyclables-in-Victoria/LCA-kerbside-recycling-calculator Accessed 3 December 2018.
2. Sustainability Victoria 2018, 'Victorian Recycling Industry Annual Report 2016-17', Melbourne, Victoria.
3. 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/system/files/resources/291b8289-29d8-4fc1-90ce-1f44e09913f7/files/hazardous-waste-australia-2017.pdf Accessed 3 December 2018.
4. Sustainability Victoria 2018, 'Statewide Waste and Resource Recovery Infrastructure Plan', Melbourne, Victoria.

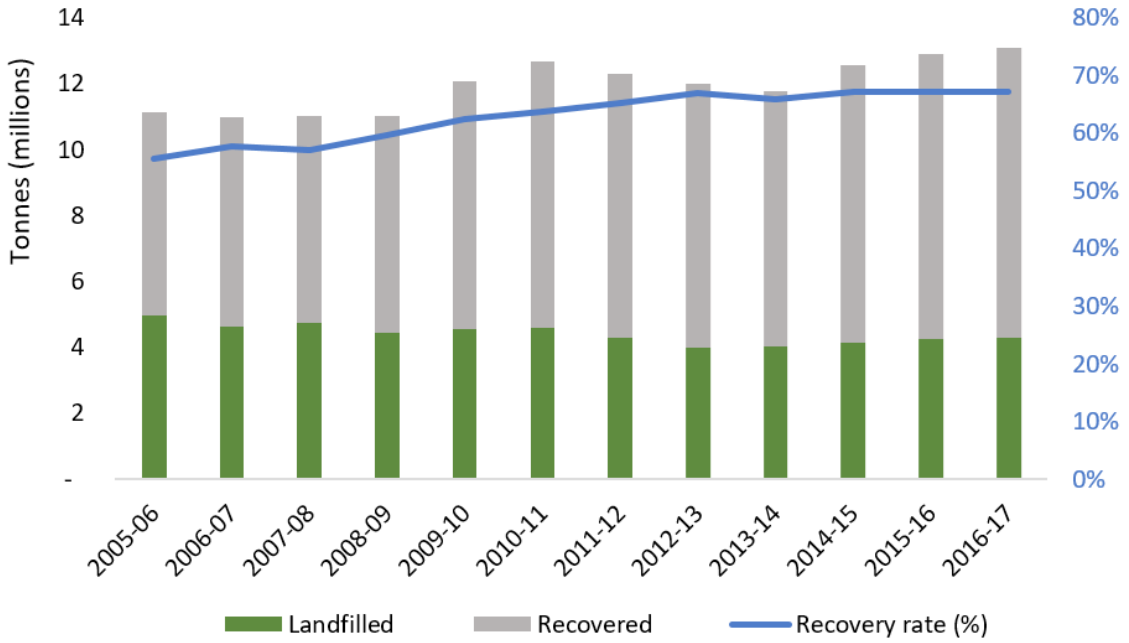


Figure W.1 Total waste generated, landfilled and recovered 2005–06 to 2016–17 [2]

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-of-system 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).

5. 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 re-manufacturing, 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 Index[6], 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 annually[7] and at least 20% of all food produced, contributing to undue pressure on finite natural resources, the environment and climate change.[8]

6. Keep Australia Beautiful 2017, 'National Litter Index', Newtown, New South Wales http://kab.org.au/litter-research/national-litter-index/ Accessed 3 December 2018.
7. Sustainability Victoria 2018, 'Statewide Waste and Resource Recovery Infrastructure Plan', Melbourne, Victoria.
8. Institution of Mechanical Engineers 2013, 'Global Food: Waste Not, Want Not', Westminster, London https://www.imeche.org/docs/default-source/default-document-library/global-food---waste-not-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 Fund[9] 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.

9. DELWP 2018, 'Sustainability fund', Melbourne, Victoria https://www.environment.vic.gov.au/sustainability/sustainability-fund Accessed 3 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 long-term, 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 phase-out 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

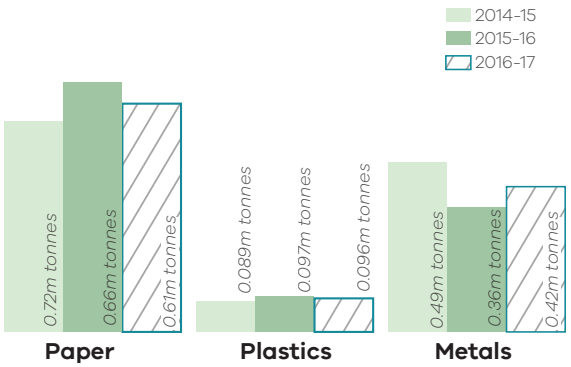
Metals (1.7m tonnes)
recycled into new product

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.

Poor
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

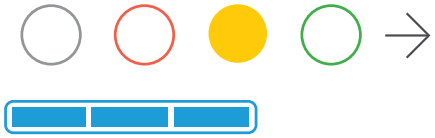
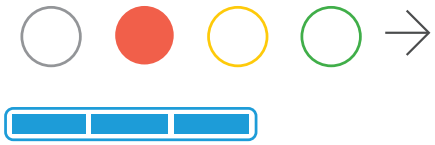
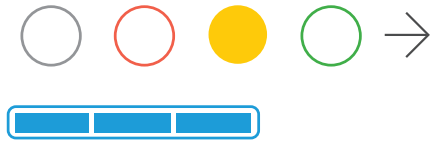
Poor
Evidence and consensus too low to make an assessment

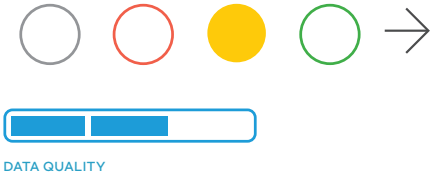
Fair
Limited evidence or limited consensus

Good
Adequate high-quality evidence and high level of consensus

WASTE AND RESOURCE RECOVERY

	Summary	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend
Indicator **W:01** Total Waste Generation **Region** Victoria **Measures** Tonne/yr **Data custodian** Landfill data (EPA) and Victorian Recycling Industry Annual (SV)	Reported waste to landfill plus reported material recovered (recyclables and organics), not including hazardous waste.	DATA QUALITY Good	

	Summary	Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **W:02** Generation of municipal waste per capita **Region** Victoria **Measures** Kg/capita **Data custodian** Victorian Local Government Annual Survey (SV) and ABS population figure	Kerbside waste and recycling collections by weight divided by population.	 DATA QUALITY Good	
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	

	Summary	Status UNKNOWN POOR FAIR GOOD	Trend
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	

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
W:01 Total Waste Generation	○	○	●	○	→	DATA QUALITY Good

Data Custodian EPA and Victorian Recycling Industry Annual (SV)

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.

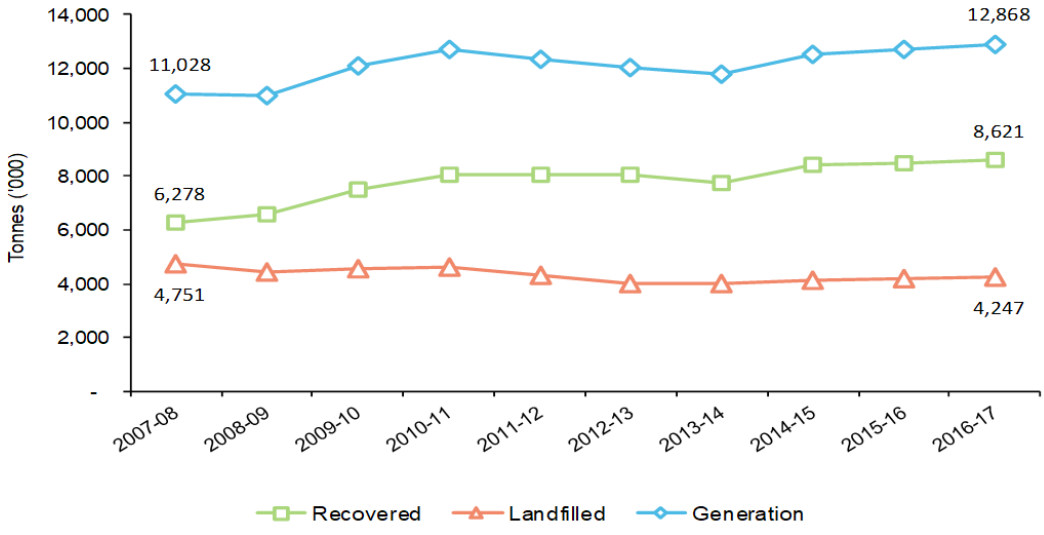


Figure W.2 Waste managed, Victoria, 2007–08 to 2016–17 (tonnes)[13]

10. Sustainability Victoria 2018, 'Statewide Waste and Resource Recovery Infrastructure Plan', Melbourne, Victoria, p170.
11. Sustainability Victoria 2018, 'Victorian Recycling Annual Survey Report 2016–17', Melbourne, Victoria.
12. ABS 2018, 'Australian Demographic Statistics, Estimated Resident Population, Persons, 3101.0 – Victoria.'
13. Sustainability Victoria 2018, 'Victorian Recycling Annual Survey Report 2016–17', Melbourne, Victoria.

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.

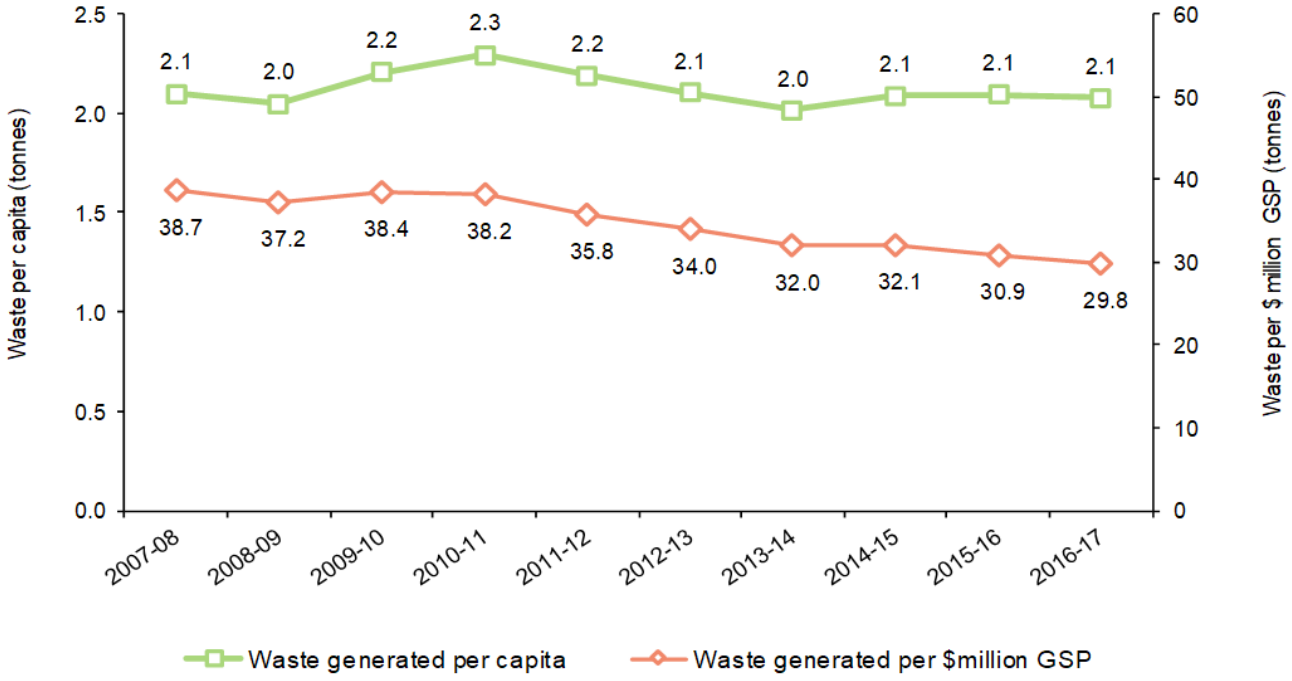


Figure W.3 Total waste managed relative to economic and population trends, Victoria, 2007–08 to 2016–17 (tonnes)[15]

14. Sustainability Victoria 2018, 'Victorian Recycling Annual Survey Report 2016–17', Melbourne, Victoria.
15. Ibid

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.

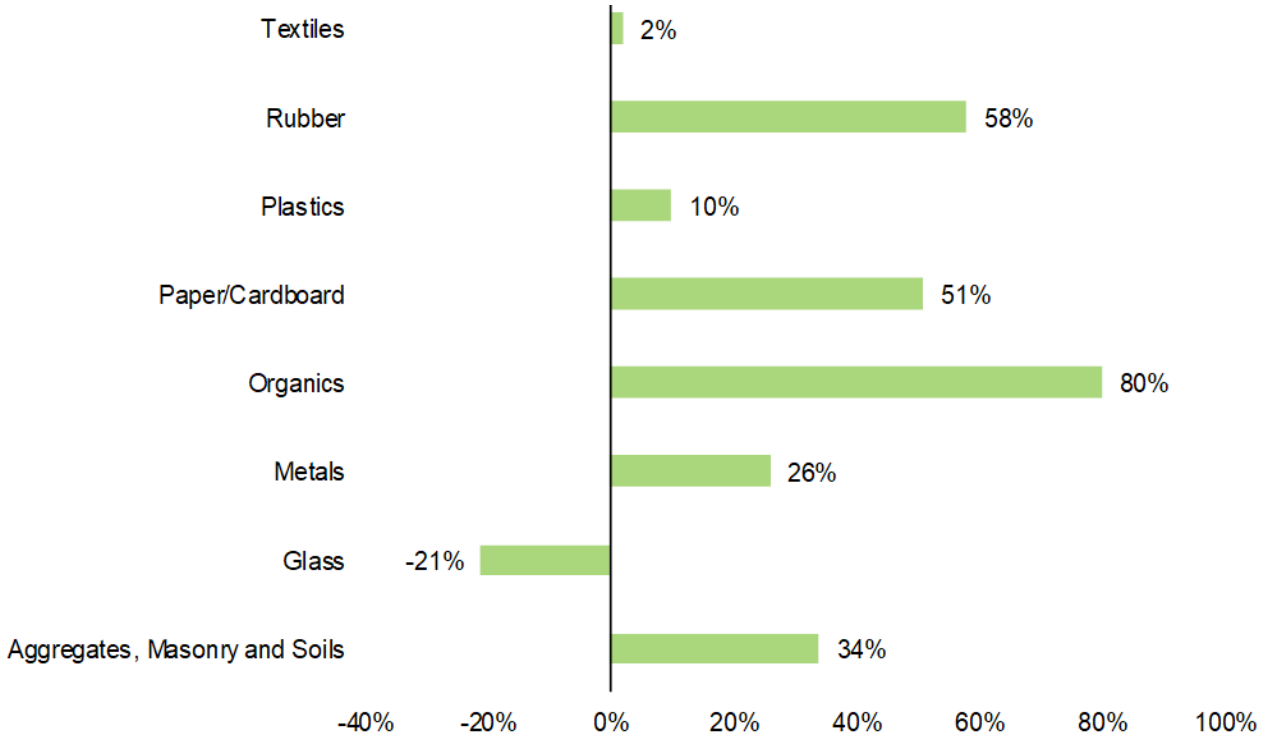


Figure W.4 Percentage change of tonnes of material types recovered for reprocessing, Victoria, 2007–08 to 2016–17

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
W:02 Generation of municipal waste per capita	○	○	●	○	→	DATA QUALITY Good

Data Custodian Victorian Local Government Annual Survey (SV) and ABS Population Figure

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.

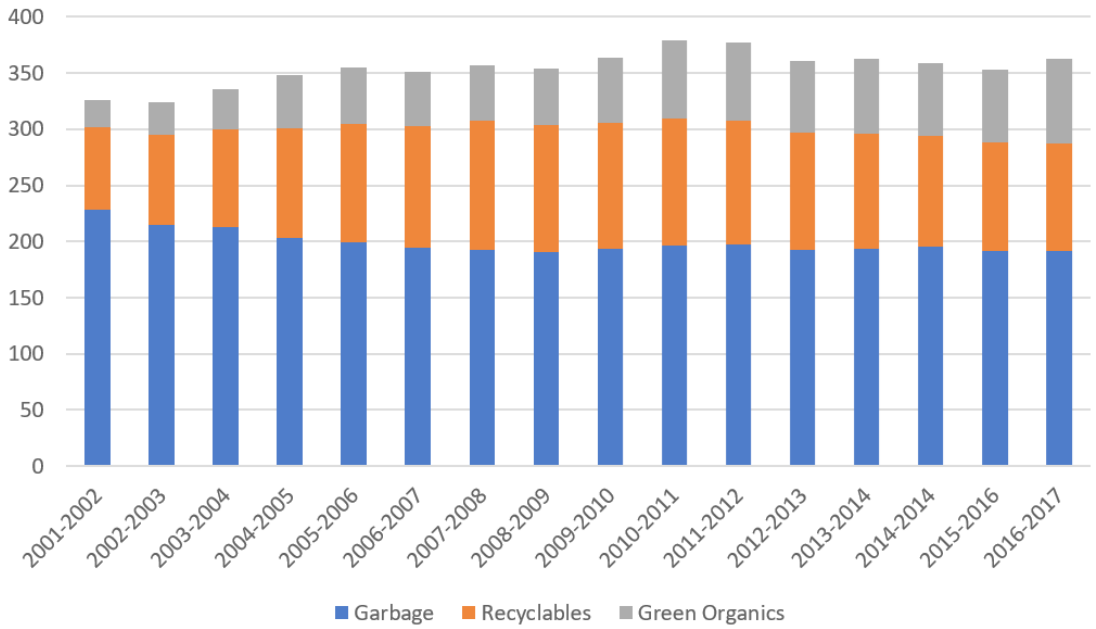


Figure W.5 Municipal solid waste per capita, 2001–02 to 2016–17 (kg) [16]

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 light-weighting 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 behaviour.

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 (CO_2-e) in a year, or equivalent to taking 125,759 cars off the road[19] for an entire year
- saving 3,747,243 gigajoules of energy – enough to provide power to almost a million Victorian households for a month

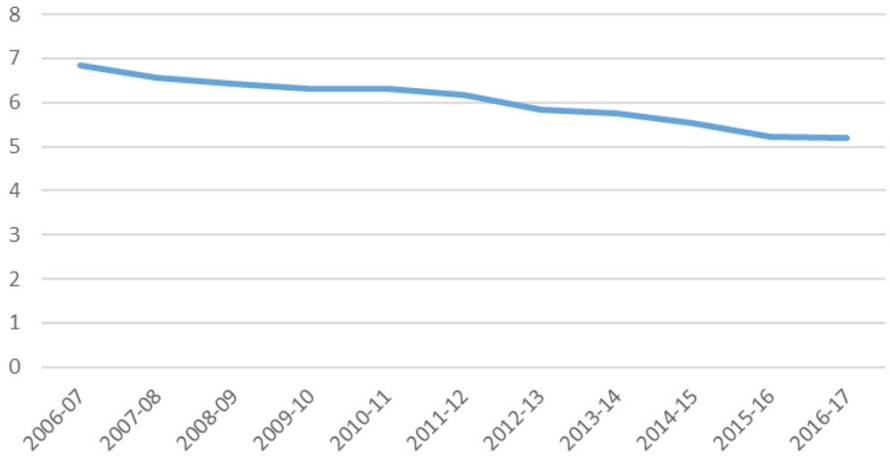


Figure W.6 The amount in tonnes (y-axis) of municipal solid waste generation per capita from 2006–07 to 2016–17 [17]

17. Sustainability Victoria 2018, 'Victorian Local Government Annual Waste Services Report 2016-17', Melbourne, Victoria.

18. Sustainability Victoria 2018, 'Lifecycle assessment of kerbside recycling', Melbourne, Victoria https://www.sustainability.vic.gov.au/Government/Victorian-Waste-data-portal/Lifecycle-assessment-of-kerbside-recyclables-in-Victoria Accessed 3 December 2018.

19. Australian Bureau of Statistics 2018, '9208.0 - Survey of motor vehicle use, Australia, 12 months ended 30 June 2016', http://www.abs.gov.au/ausstats/abs@.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.au/system/files/resources/e30b1895-4870-4a1f-9b32-3a590de3dddf/files/national-greenhouse-accounts-factors-august-2016.pdf Accessed 4 December 2018.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
W:03 Total Waste Generated	○	●	○	○	→	DATA QUALITY: Good

Data Custodian SV 2009 landfill audit

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 state[20] – 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.

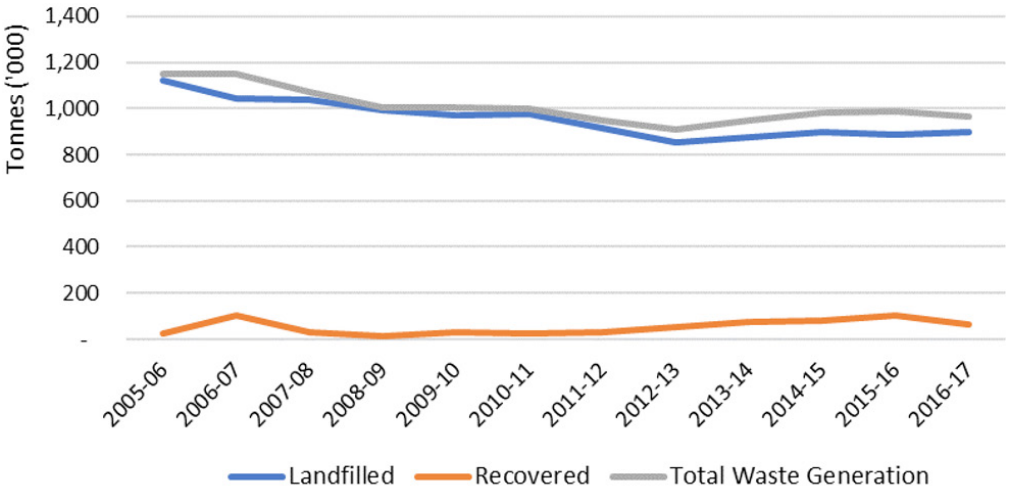


Figure W.7 Food organics, recovered and landfilled, Victoria, 2005–06 to 2016–17 [21]

20. Sustainability Victoria 2018, 'Statewide Waste and Resource Recovery Infrastructure Plan', Melbourne, Australia.

21. Sustainability Victoria 2018, 'Waste projection model', Melbourne, Victoria https://www.sustainability.vic.gov.au/Government/Victorian-Waste-data-portal/Interactive-waste-data-mapping/Waste-projection-model# Accessed 3 December 2018.

Indicator	Status	Trend	Data Quality
	UNKNOWN POOR FAIR GOOD		
W:04 Diverson Rate	○ ○ ● ○	→	DATA QUALITY Good

Data Custodian EPA Victoria and Victorian Recycling Industry Annual Survey (SV)

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.

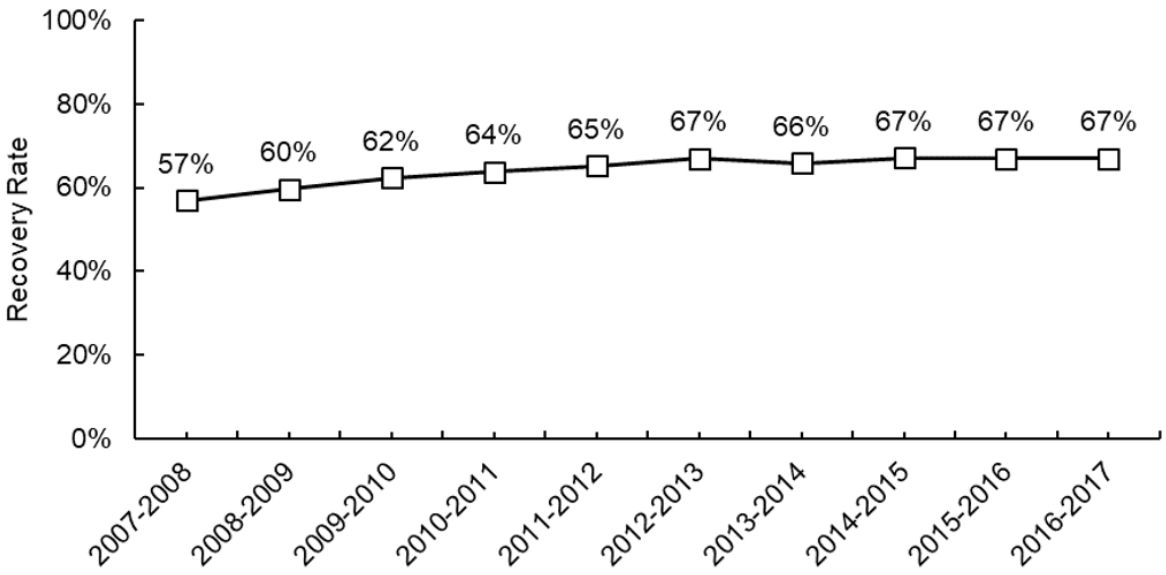


Figure W.8 Resource Recovery; Diversion rate of solid waste, Victoria, 2007–08 to 2016–17 [22]

22. Sustainability Victoria 2018, 'Victorian Recycling Annual Survey Report 2016–17', Melbourne, Australia.

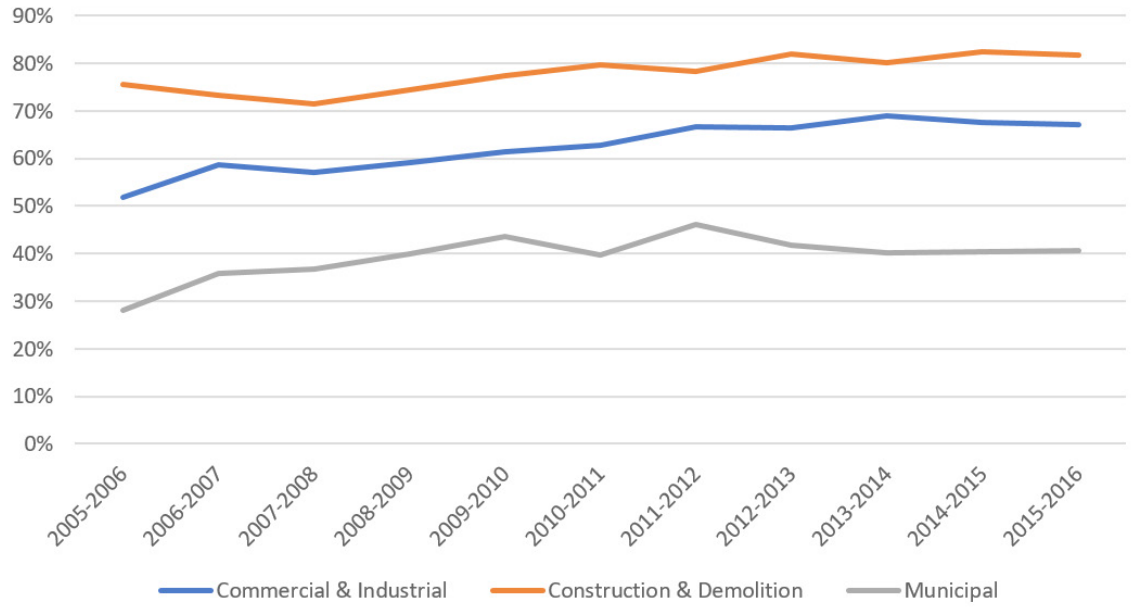


Figure W.9 Annual diversion rate by source sector, Victoria, 2005–06 to 2015–16[23]

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.

23. Ibid

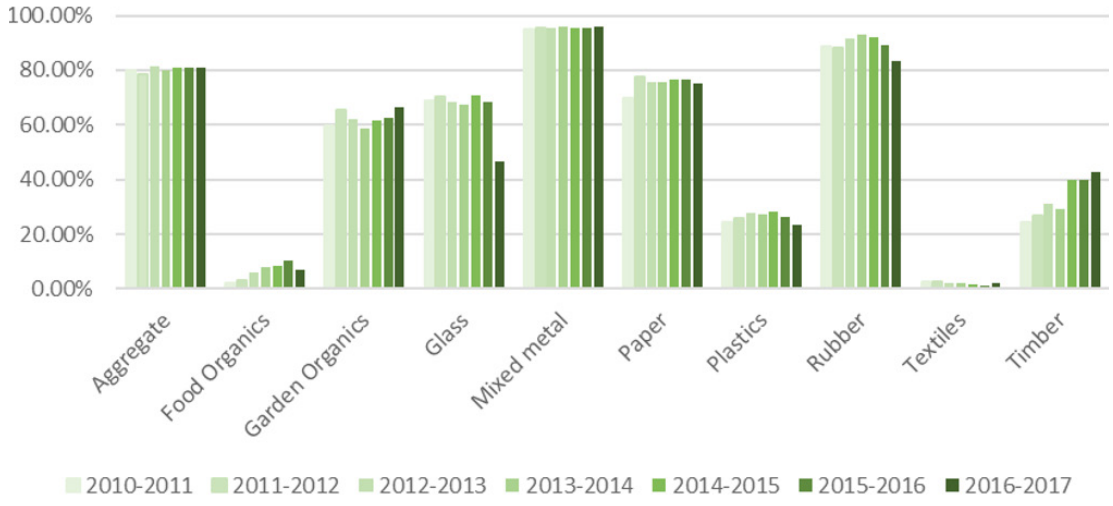


Figure W.10 Recovery rate by material type in Victoria from 2010–11 to 2016–17 [27]

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.

Aggregates[24] (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]

24. Excluding contaminated soils, which are considered hazardous.
25. Sustainability Victoria 2018, 'Victorian Recycling Annual Survey Report 2016–17', Melbourne, Victoria.
26. 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.
27. Sustainability Victoria 2018, 'Victorian Recycling Annual Survey Report 2016–17', Melbourne, Australia.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
W:05 Litter and Illegal Dumping	○	○	○	●	↗	DATA QUALITY Poor
Data Custodian National Litter Index (Keep Australia Beautiful) SV						

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.

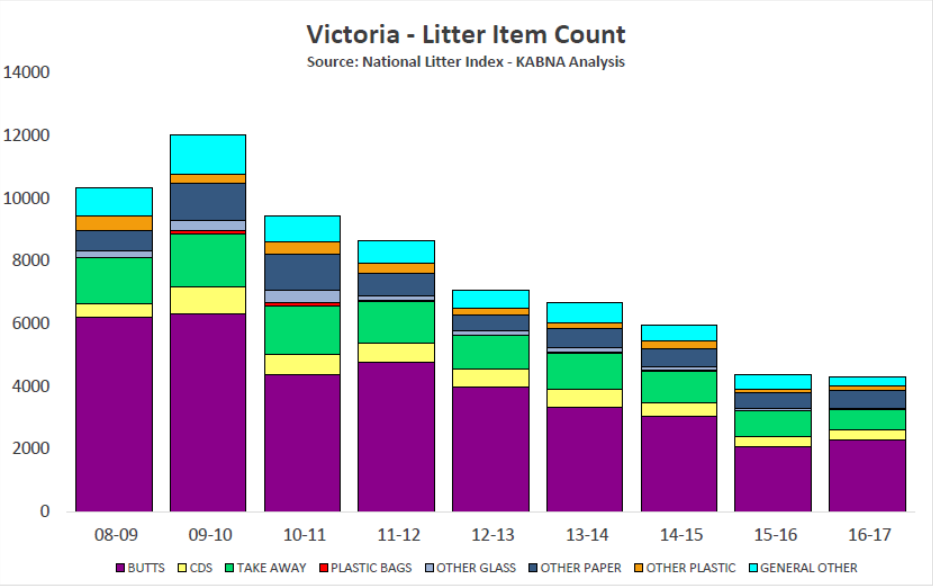


Figure W.11 Litter item count trends in Victoria from 2008–09 to 2016–17. Note: The numbers on the y-axis refer to the number of items counted [28]

28. Keep Australia Beautiful 2017, 'National Litter Index, 2016-17, Victoria Results', Newtown, New South Wales http://kab.org.au/wp-content/uploads/2018/02/1802_KAB_nli_report_v2_2016-17.pdf Accessed 4 December 2018.

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.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
W:06 Total Hazardous Waste managed	○	○	●	○	→	DATA QUALITY Fair

Data Custodian Dept.Environment and Energy 2017, EPA Victoria

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 materials[30] and could be related to a decline in manufacturing in Victoria during this period.



Figure W.12 Hazardous waste arising in Victoria

(Data source: Derived from Hazardous Waste in Australia 2017 (Dept. Environment and Energy 2017))

29. 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.
30. 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-fluoroalkyl 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. m^3 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.

31. 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.

33. 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 circular-economy 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 (T)

SCIENTIFIC ASSESSMENTS Part III

Commissioner *for* Environmental Sustainability Victoria

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 motor-vehicle 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]

1. Australian Department of the Energy and Environment, 'Australian Greenhouse Emissions Information System', Canberra, Australia http://ageis.climatechange.gov.au/ Accessed 3 December 2018.
2. 'Australian Bureau of Statistics, 'Population by Age and Sex, Victoria June 2002 Canberra, Australia.
3. Australian Bureau of Statistics, '2016 Census QuickStats', Canberra, Australia Accessed 3 December 2018.
4. Australian Bureau of Statistics 2017, 'Survey of Motor Vehicle Use, Australia, 12 months ended 30 June 2016', Canberra, Australia http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/9208.012%20months%20ended%2030%20June%202016?OpenDocument Accessed 3 December 2018.
5. DELWP 2016, 'Victoria in Future 2016', East Melbourne, Victoria https://www.planning.vic.gov.au/__data/assets/pdf_file/0014/14036/Victoria-in-Future-2016-FINAL-web.pdf Accessed 3 December 2018.
6. Infrastructure Victoria 2016, 'The Road Ahead: How an efficient, fair and sustainable pricing regime can help tackle congestion', Melbourne, Victoria http://www.infrastructurevictoria.com.au/sites/default/files/images/The%20road%20ahead%20final%20web.pdf Accessed 3 December 2018.
7. Transport for Victoria 2018, 'Metropolitan Train Load Standards Survey Report May 2018', Melbourne, Victoria https://transport.vic.gov.au/-/media/tfv-documents/data/metropolitan-train-load-standards-report---may-2018-pdf-version.pdf?la=en&hash=49B109D1BA385555ADDD4D32D60EFF1F Accessed 3 December 2018.
8. Bowatte, G. et al 2018, 'Traffic related air pollution and development and persistence of asthma and low lung function', Environment International, 113, pp. 170–176.
9. EPA 2001, 'Traffic Noise Measurement – Francis Street, Yarraville, 2001', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/820.pdf Accessed 3 December 2018.
10. EPA 2013, 'Francis Street monitoring program – Final report', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1546%201.pdf Accessed 3 December 2018.
11. VicRoads, 'Truck curfews and the Inner West', Melbourne, Victoria https://www.vicroads.vic.gov.au/business-and-industry/heavy-vehicle-industry/registration-permits-curfews-and-compliance/truck-curfews/truck-curfews-in-the-inner-west Accessed 3 December 2018.

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.

12. Transport for Victoria, 'Transport Integration Act', Melbourne, Victoria https://transport.vic.gov.au/about/legislation/transport-integration-act Accessed 3 December 2018.
13. 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 3 December 2018.

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 zero-emissions 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://infrastructurevictoria.com.au/sites/default/files/images/Five-year%20focus%20-%20Immediate%20actions%20to%20tackle%20congestion%20-%20April%202018.pdf Accessed 3 December 2018.
15. Ibid
16. 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%20Advice%20-%20Evidence%20Base%20Report%20August%202018.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.

Poor
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

Poor
Evidence and consensus too low to make an assessment

Fair
Limited evidence or limited consensus

Good
Adequate high-quality evidence and high level of consensus

	Summary	Status	Trend
		UNKNOWN POOR FAIR GOOD	

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.

DATA QUALITY

Good

	Summary	Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **T:02** Greenhouse gas emission and emission intensities from transport **Region** 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	Transport GHG emissions have grown by 39% from 1990 to 2016, making it the sector with the highest increase in emissions in Victoria over this period. Transport emissions have increased in line with population growth since 2009.	 DATA QUALITY Good	
Indicator **T:03** Air pollution from transport **Region** Victoria **Measures** Air-quality concentrations measured near major roads and other transport activity centres **Data custodian** EPA Victoria	Air pollution is being measured in association with motor vehicle traffic in Melbourne at only one roadside station. Decreasing vehicle pollution has been linked to improved air-quality.	 Fair for motor vehicles and Unknown for rail and shipping DATA QUALITY Poor (Only one major roadside air monitoring station and no air-quality monitoring data available for rail and shipping)	 Improving for motor vehicles and Unclear for rail and shipping

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
T:01 Travel demand	○	●	○	○	↘	DATA QUALITY: Good
Data Custodian ABS, TfV						

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).

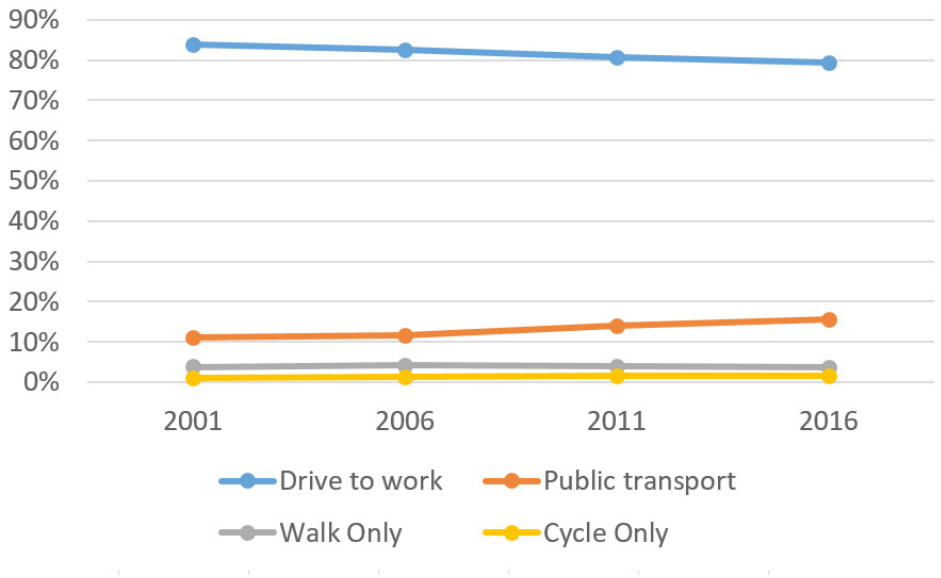


Figure T.1 Percentage of journeys to work by transport mode (Victoria)
(Data source: TfV)

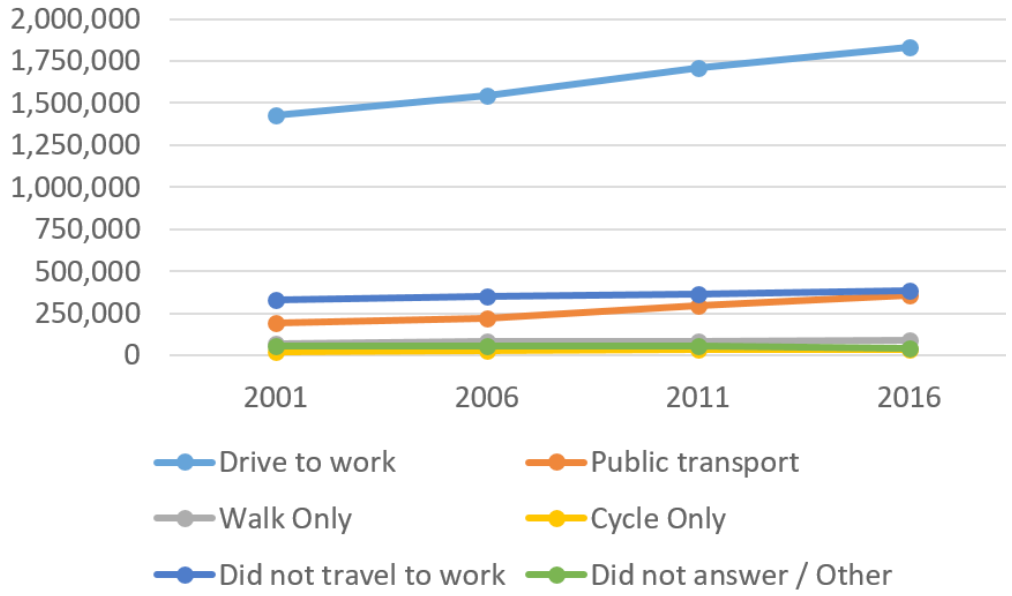


Figure T.2 Number of journeys to work, by transport mode (Victoria)
(Data source: TfV, 2018)

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://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/9208.012%20months%20ended%2030%20June%202016?OpenDocument Accessed 3 December 2018.
18. Australian Bureau of Statistics 2008, '3235.0 - Population by Age and Sex, Regions of Australia, 2007', Canberra, Australia http://www.abs.gov.au/ausstats/abs@.nsf/Products/3235.0~2007~Main+Features~Victoria?OpenDocument Accessed 3 December 2018.
19. Australian Bureau of Statistics 2017, '2016 Census: Victoria', Canberra, Australia http://www.abs.gov.au/ausstats/abs@.nsf/MediaRealesesByCatalogue/C508DD213FD43EA7CA258148000C6BBE?OpenDocument Accessed 3 December 2018.
20. Australian Department of Infrastructure and Regional Development 2015, 'Traffic congestion and cost trends for Australian capital cities', Canberra, Australia https://bitre.gov.au/publications/2015/files/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		→	DATA QUALITY: Good

Data Custodian TfV

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).

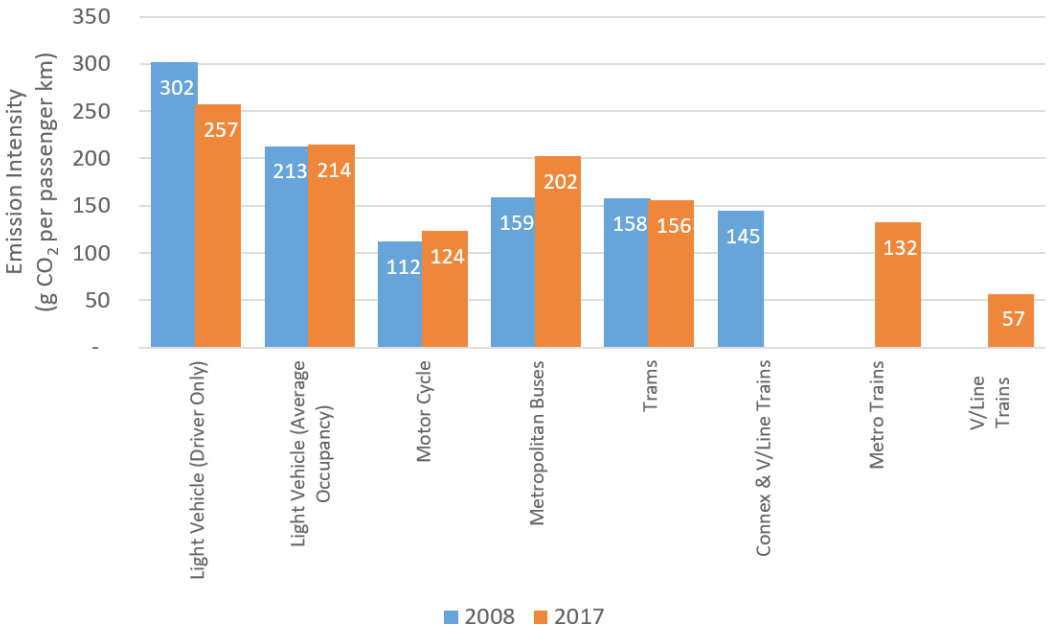


Figure T.3 Estimated GHG emissions intensity (grams CO_2-e per passenger kilometre) for 2008 and 2017
(Data source: TfV, 2018)

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.

21. DELWP, 'Victoria In Future one page profiles', East Melbourne, Victoria https://www.planning.vic.gov.au/land-use-and-population-research/victoria-in-future-2016/victoria-in-future-one-page-profiles Accessed 3 December 2018.
22. 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 3 December 2018.

Indicator	Status	Trend	Data Quality
T:03 Air pollution from transport	 Fair for motor vehicles and Unknown for rail and shipping	 Trend: Improving (motor vehicles); Unclear (rail and shipping)	 DATA QUALITY Poor (only one major roadside air-monitoring station; no air-quality monitoring data available for rail and shipping)

Data Custodian EPA Victoria

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 motor-vehicle 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 noise-monitoring 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 $PM_{2.5}$ 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 air-pollution hotspot in terms of the number of days exceeding air-quality standards (see indicator AQ:03 Particle pollution (PM_{10} and $PM_{2.5}$)). 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.

23. EPA 2013, 'Francis Street monitoring program – Final report', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1546%201.pdf Accessed 3 December 2018.
24. EPA 2001, 'Air Monitoring at Francis Street, Yarraville', Carlton, Victoria.
25. EPA 2001, 'Traffic Noise Measurement – Francis Street, Yarraville, 2001', Carlton, Victoria https://www.epa.vic.gov.au/~/media/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 https://www.epa.vic.gov.au/~/media/Publications/897.pdf Accessed 3 December 2018.
28. EPA 2013, 'Francis Street monitoring program – Final report', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1546%201.pdf Accessed 3 December 2018.
29. Ibid
30. Ibid
31. Ibid
32. VicRoads, 'Truck curfews and the Inner West', Melbourne, Victoria, https://www.vicroads.vic.gov.au/business-and-industry/heavy-vehicle-industry/registration-permits-curfews-and-compliance/truck-curfews/truck-curfews-in-the-inner-west Accessed 3 December 2018.
33. EPA 2016, 'Brooklyn air quality update: effectiveness of road sealing', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/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, Victoria https://www.epa.vic.gov.au/~/media/Publications/1535.pdf 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 air-monitoring 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 air-emissions 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 (E)

SCIENTIFIC ASSESSMENTS Part III

Commissioner *for* Environmental Sustainability Victoria



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] For[7] example, the energy efficiency of Victoria's building stock is low when compared to world best practice[8,9] 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).

1. Grubb M 2014, 'Planetary Economics', Routledge, London, United Kingdom.
2. Ayers RU, Ayers EH 2009, 'Crossing the energy divide', Pearson FT Press, London United Kingdom.
3. Productivity Commission 2003, 'Trends in Australian Manufacturing', Canberra, Australia https://www.pc.gov.au/research/completed/manufacturing/tiam.pdf Accessed 4 December 2018.
4. The McKell Institute Victoria, 'The Place to Make: The Future of Manufacturing in Victoria', Melbourne, Victoria https://mckellinstitute.org.au/app/uploads/McKell_VIC_Manufacturing_SPREADS_WEB.pdf Accessed 4 December 2018.
5. IEA 2017, 'Energy Efficiency 2017', Paris, France.
6. American Council for an Energy-Efficient Economy 2018, 'The 2018 International Energy Efficiency Scorecard'.
7. 7
8. IEA 2017, 'Energy efficiency indicators', Paris, France.
9. Sustainability Victoria 2015, 'Energy Efficiency Upgrade Potential of Existing Victorian Houses', Melbourne, Victoria https://www.sustainability.vic.gov.au/About-Us/Publications/Retrofit-Trial-Energy-Efficiency-Upgrade-Potential Accessed 4 December 2018.
10. Demographia 2018, 'World Urban Areas 14th Annual Edition: 201804'.

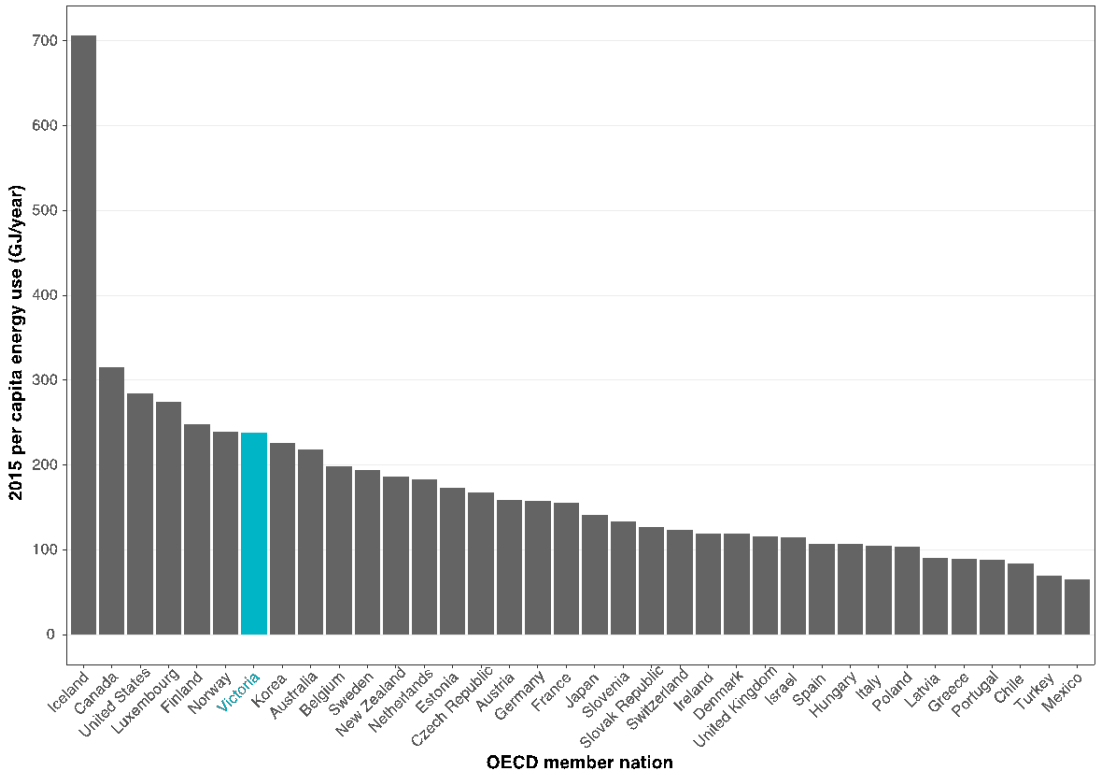


Figure E.1 Per capita energy use in Victoria, compared to OECD nations, 2015[11,12,13]

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.

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 CO_2-e (carbon dioxide equivalent). Emissions from energy, including fuel combustion and fugitive emissions, contributed around 103 Mt of CO_2-e, or 90% of this total (Figure E.2), representing almost one-quarter of Australia's total emissions from energy.[23]

11. IEA 2017, 'CO_2 Emissions from Fuel Combustion', Paris, France.
12. Australian Bureau of Statistics 2018, '3101.0 - Australian Demographic Statistics, Dec 2017 issue', Canberra, Australia.
13. Australia Department of the Environment and Energy 2017, 'Australian Energy Updated 2017', Canberra, Australia.
14. Geoscience Australia, 'Brown Coal', Canberra, Australia http://www.ga.gov.au/data-pubs/data-and-publications-search/publications/gimr/brown-coal Accessed 4 December 2018.
15. Geoscience Australia 2012, 'Shaping a Nation: A Geology of Australia', ANU Press.
16. Geoscience Australia, 'Australian Energy Resource Assessment', Canberra, Australia http://aera.ga.gov.au/ Accessed 4 December 2018.
17. DEDJTR, 'Petroleum', Melbourne, Victoria http://earthresources.vic.gov.au/earth-resources/victorias-earth-resources/petroleum Accessed 4 December 2018.
18. Hughes L, McMichael T 2011, 'The Critical Decade: Climate Change and Health', Climate Commission Secretariat (Department of Climate Change, Canberra, Australia.
19. Climate Council and Climate and Health Alliance 2014, 'Climate Council: Joint Statement on the Health Effects of Coal in Australia', http://www.climatecouncil.org.au/uploads/800f051ad0cb-47d1554179635d9f4070.pdf Accessed 4 December 2018.
20. 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.
21. Garnaut R, 2008, 'The Garnaut climate change review', Cambridge University Press, Cambridge, United Kingdom.
22. Garnaut R, 2011, 'The Garnaut review 2011: Australia in the global response to climate change', Cambridge University Press, Cambridge, United Kingdom.

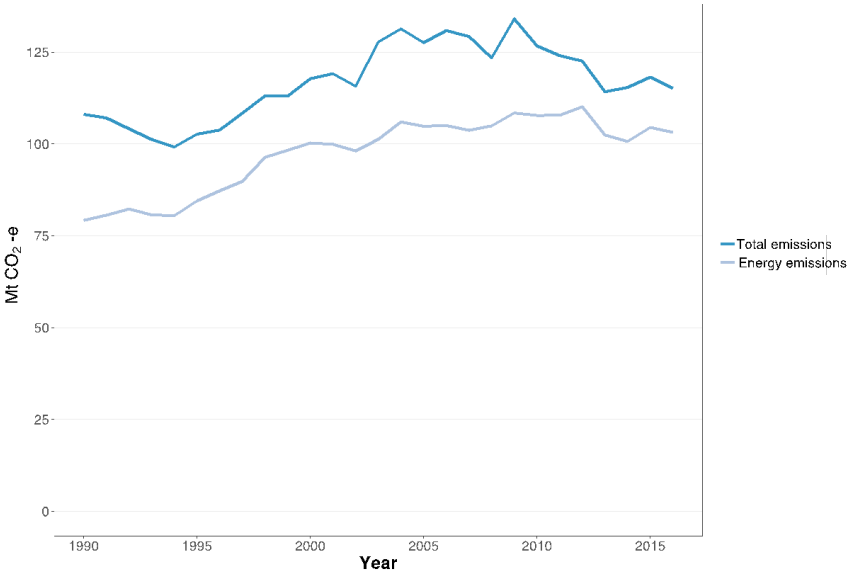


Figure E.2 Victorian energy GHG emissions compared to Victorian total GHG emissions[24]

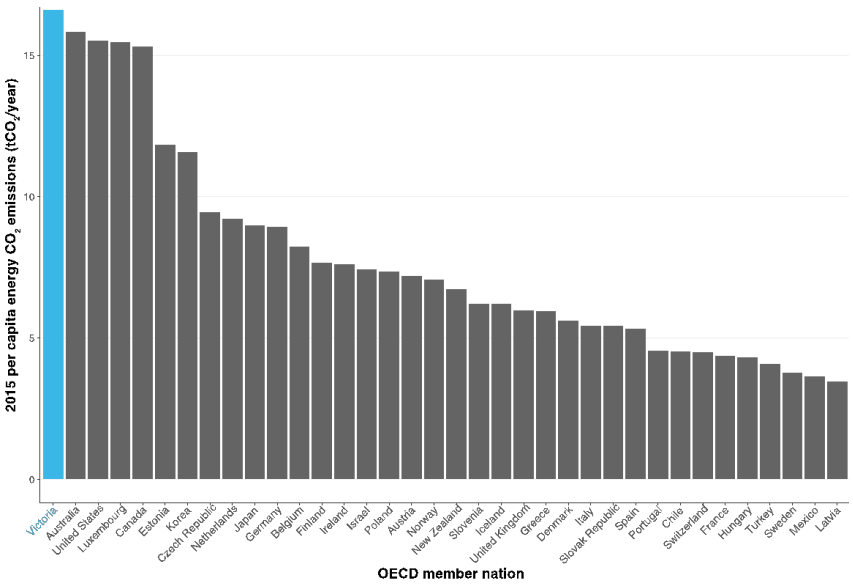


Figure E.3 Per capita energy emissions in Victoria, compared to OECD nations, 2015[25,26,27]

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).

23. Australian Department of the Environment and Energy, 'Australian Greenhouse Emissions Information System', Canberra, Australia http://ageis.climatechange.gov.au Accessed 4 December 2018.
24. Ibid.
25. IEA, 'CO_2 Emissions from Fuel Combustion', Paris, France.
26. Australian Bureau of Statistics 2018, '3101.0 - Australian Demographic Statistics, Dec 2017 issue', Canberra, Australia.
27. Australian Department of the Environment and Energy, 'Australian Greenhouse Emissions Information System', Canberra, Australia http://ageis.climatechange.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 zero-emissions 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 CO_2-e emissions from energy have declined from their mid-2000s high to around 90% of their 1990 level. However, total energy use and total CO_2-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 cl imb 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.
29. 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/f932b66241ecf1b7ca256e92000e23be/05736C89E5B8C7C0CA2580D50006FF95/$FILE/17-005aa%20authorised.pdf Accessed 4 December 2018.

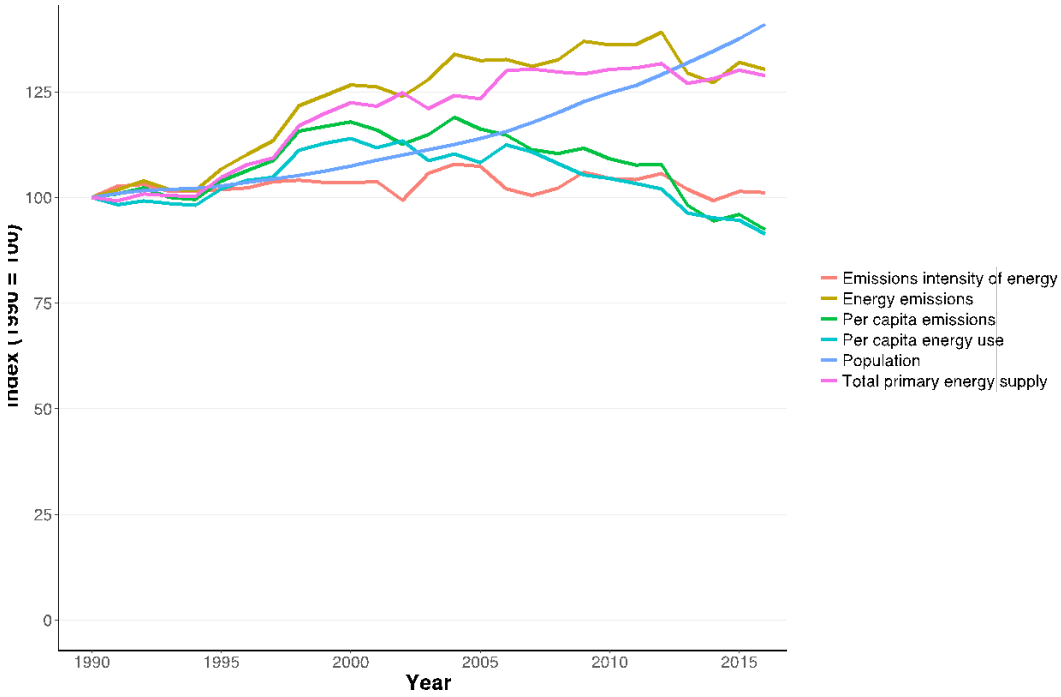


Figure E.4 Victorian population, energy use and energy emissions, changes 1990 to 2016[30,31,32]

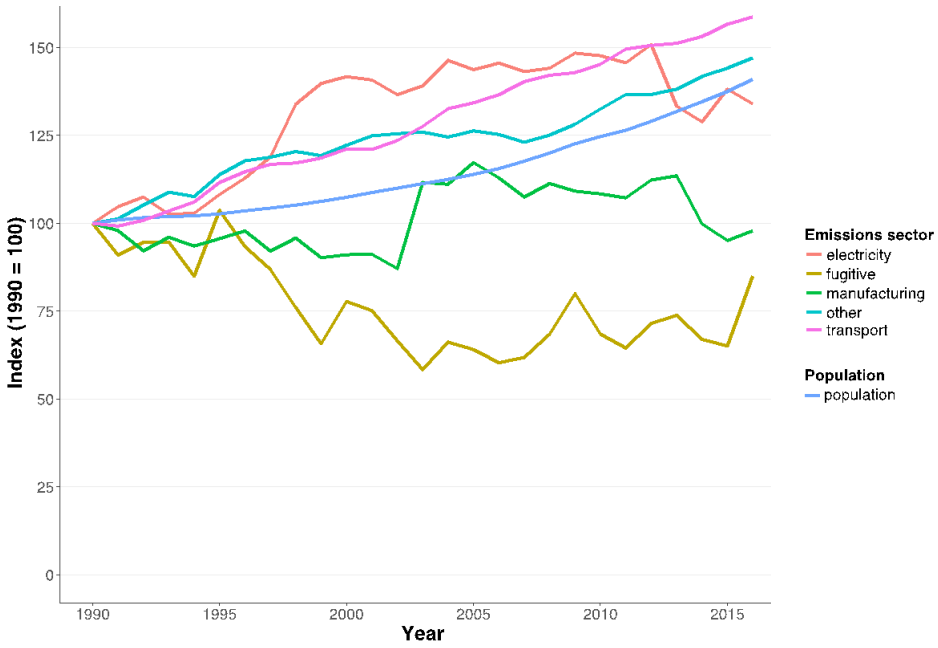


Figure E.5 Energy emissions by sector 1990 to 2016 with population growth[33]

30. Australian Bureau of Statistics 2018, '3101.0 - Australian Demographic Statistics, Dec 2017 issue', Canberra, Australia.
31. Australian Department of the Environment and Energy, 'Australian Greenhouse Emissions Information System', Canberra, Australia http://ageis.climatechange.gov.au Accessed 4 December 2018.
32. Australia Department of the Environment and Energy 2017, 'Australian Energy Updated 2017', Canberra, Australia.
33. 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

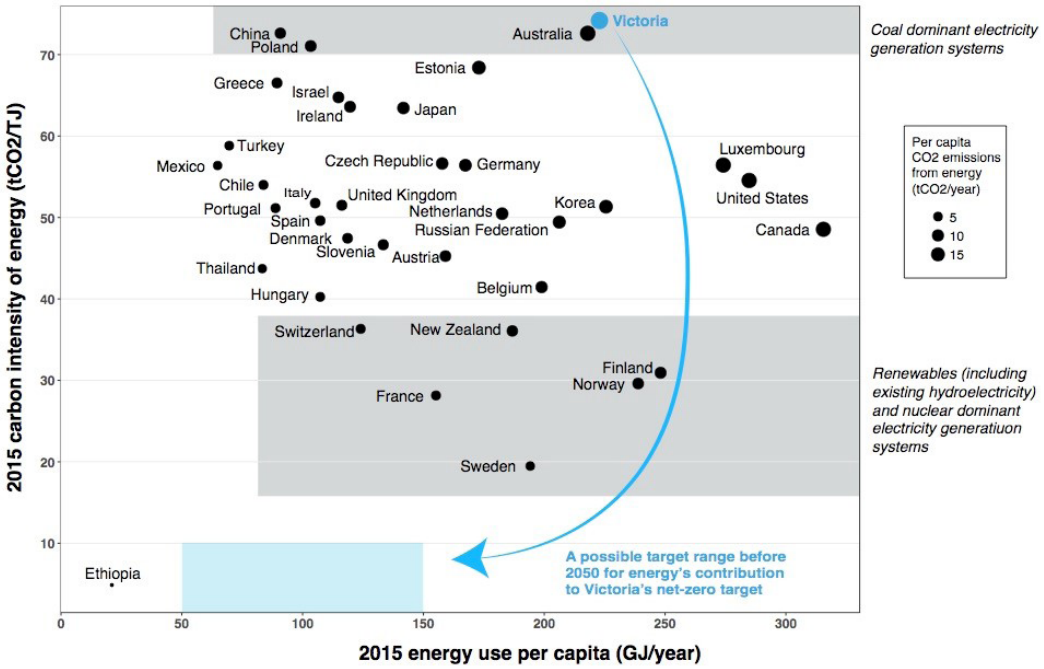


Figure E.6 Victoria's energy transition challenge to 2050[36,37,38,39]

34. Millar RJ, Fuglestvedt JS, Friedlingstein P, Rogelj J, Grubb MJ, Matthews 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.
36. IEA, 'CO_2 Emissions from Fuel Combustion', Paris, France.
37. Australian Bureau of Statistics 2018, '3101.0 - Australian Demographic Statistics, Dec 2017 issue', Canberra, Australia.
38. Australian Department of the Environment and Energy, 'Australian Greenhouse Emissions Information System', Canberra, Australia http://ageis.climatechange.gov.au Accessed 4 December 2018.
39. Australia Department of the Environment and Energy 2017, 'Australian Energy Updated 2017', Canberra, Australia.
40. IEA 2017, 'Energy Technology Perspectives 2017', Paris, France.
41. IEA 2017, 'Real-world policy packages for sustainable energy transitions', Paris, France.
42. 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.

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]

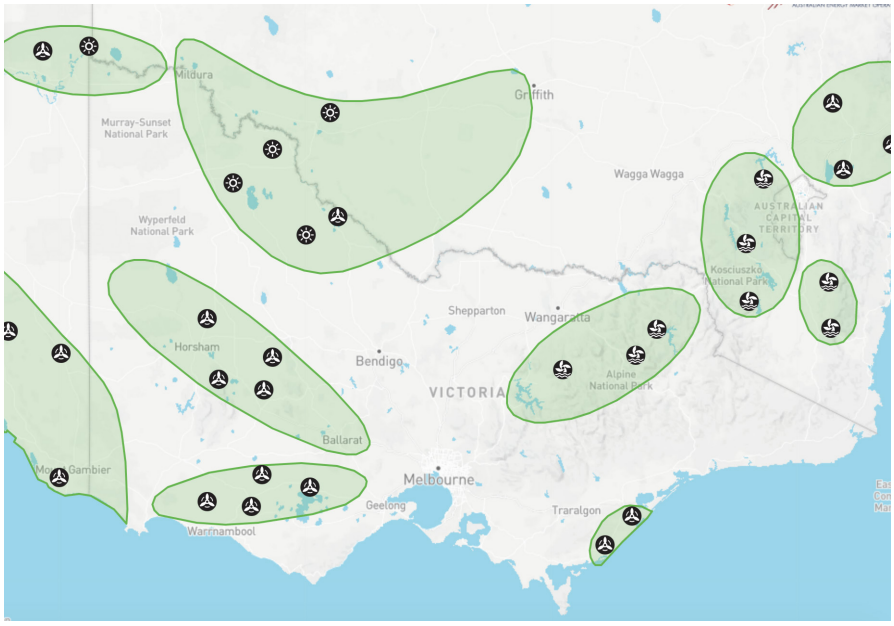


Figure E.7 Australian Energy Market Operator's renewable energy zones in Victoria

(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.
44. Australian Energy Market Operator, 'Generator Information Page', Melbourne, Victoria http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information Accessed 12 September 2018.
45. 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/F9B4F84D96E4E65ACA2581D2001B3DC7/$FILE/17-056aa%20authorised.pdf Accessed 4 December 2018.
46. Clean Energy Regulator, 'Postcode data for small-scale installations', Canberra, Australia http://www.cleanenergyregulator.gov.au/RET/Forms-and-resources/postcode-data-for-small-scale-installations Accessed 11 September 2018.
47. Australian Energy Market Commission 2018, 'Annual Market Performance Review 2017: Final report', Sydney South, New South Wales https://www.aemc.gov.au/sites/default/files/2018-03/Final%20report.pdf Accessed 4 December 2018.
48. Australian Energy Market Operator 2016, 'National Electricity Forecasting Report: for the National Electricity Market', Melbourne, Victoria.
49. 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/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2018/Integrated-System-Plan-2018_final.pdf Accessed 4 December 2018.

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 brown-coal-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 around 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 brown-coal-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]

51. Australian Energy Market Operator, 'Generator Information Page', Melbourne, Victoria http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information 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.
53. Australian Energy Market Operator, 'AEMO Map', http://www.aemo.com.au/aemo/apps/visualisations/map.html Accessed 11 September 2018.
54. 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 2018.
55. Deloitte Access Economics 2018, 'Megatrends and the Victorian Environment', Melbourne Victoria.
56. Australian Energy Market Operator, 'AEMO Map', *neutral scenario,* http://www.aemo.com.au/aemo/apps/visualisations/map.html Accessed 11 September 2018.

58. 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.
59. AGL Energy Limited 2017, 'Rehabilitation: AGL's Approach to rehabilitation of power generation infrastructure', http://agl2017.reportonline.com.au/sites/agl2017.reportonline.com.au/files/rehabilitation_report.pdf Accessed 4 December 2018.
60. IEA, 'Electricity Information 2018', Paris, France.

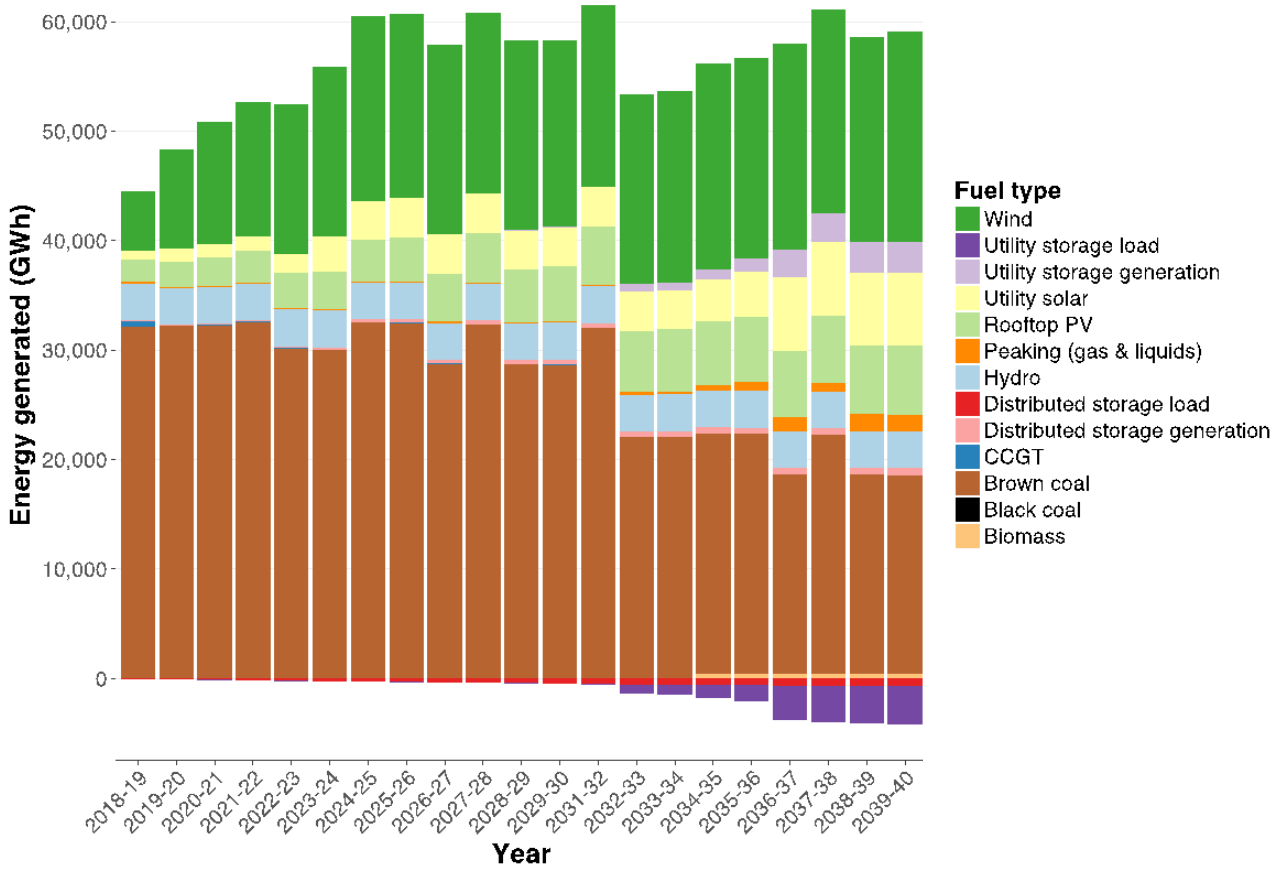


Figure E.8 AEMO Integrated System Plan electricity generation outlook projections for Victoria to 2040[57]

57. Ibid.

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

	Fossil-fuelled system legacy	Transformation challenges
Electricity **50%** of Victoria's total 2016 emissions	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).	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

	Fossil-fuelled system legacy	Transformation challenges
Transport **20%** of Victoria's total 2016 emissions 	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.	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 scale[71] • 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 years[72]) • Significant investments in improved infrastructure will be needed, for example refuelling infrastructure for non-ICE vehicles, increased public and active transport investments[73] and changes to land use such as increased urban densities in activity centres well serviced by public and active transport.

64. IEA, 'CO2 Emissions from fuel combustion 2017', Paris, France.
65. Australian Department of the Environment and Energy, 'Australian Greenhouse Emissions Information System', Canberra, Australia http://ageis.climatechange.gov.au Accessed 4 December 2018.
66. National Transport Commission 2017, 'Carbon Dioxide Emissions Intensity for New Australian Light Vehicles 2016', Melbourne, Victoria https://www.ntc.gov.au/Media/Reports/(35220AEE-C4EA-9AC6-1BB6-88D8C66D80F5).pdf Accessed 4 December 2018.
67. IEA 2017, 'Energy Technology Perspectives 2017', Paris, France.
68. IEA 2017, 'Real-world policy packages for sustainable energy transitions', Paris, France.
69. Energeia 2018, Australian Electric Vehicle Market Study: Prepared for ARENA and CEFC.
70. Australian Energy Market Operator 2016, 'AEMO Insights: Electric Vehicles', Melbourne, Victoria.
71. Keith DW, Holmes G, St. Angelo D, Heidel K 2018, 'A Process for Capturing CO2 from the Atmosphere', *Joule*, 2(8), pp. 1573-1594.
72. Australian Bureau of Statistics 2018, '9309.0 Motor Vehicle Census, Australia, 31 Jan 2018', Canberra, Australia.
73. Climate Council of Australia Limited 2018, 'Waiting for the greenlight: transport solutions to climate change', Potts Point, New South Wales.

Table E.3 Energy system decarbonisation challenges – other sectors

Remaining energy 20% of Victoria's total 2016 emissions	Fossil-fuelled system legacy	Transformation challenges
	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.	This is a more challenging area likely to require many specific solutions. Electrification of heating in buildings and other non-electricity 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 total 2016 emissions	
	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 CO_2-e in 2016 from what they would be if LULUCF sinks are not included in this total emissions calculation.

74. IEA 2017, 'Energy Technology Perspectives 2017', Paris, France.
75. IEA 2017, 'Real-world policy packages for sustainable energy transitions', Paris, France.
76. Energy Networks Australia 2017, 'Decarbonising Australia's gas networks', Melbourne, Victoria.
77. Energy Networks Australia 2017, Vision 2050: Reliable, secure energy and cost-effective carbon reduction', Melbourne, Victoria.
78. 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 low-emission 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).

79. Millar RJ, Fuglestvedt JS, Friedlingstein P, Rogelj J, Grubb MJ, Matthews 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.
80. Meinshausen M, Meinshausen N, Hare W, Raper SCB, Frieler K, Knutti R, Frame DJ, Allen MR 2009, 'Greenhouse-gas emission targets for limiting global warming to 2 °C', *Nature*, 458, pp. 1158–1162.
81. Victorian State Government 2016, 'Latrobe Valley Set To Be World Leader On Hydrogen', Melbourne, Victoria, https://www.premier.vic.gov.au/latrobe-valley-set-to-be-world-leader-on-hydrogen/ Accessed 4 December 2018.
82. IEA 2017, 'Energy Technology Perspectives 2017', Paris, France.
83. 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.
85. DELWP 2017, 'Energy Efficiency and Productivity Strategy', East Melbourne, Victoria https://www.energy.vic.gov.au/__data/assets/pdf_file/0030/89292/Energy-Efficiency-and-Productivity-Strategy-Web.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 systems[86]
- 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]
- 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 grid[93]
- 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 Fund[94]
- 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 2030[95]
- legislating energy savings targets under the *Victorian Energy Efficiency Target Act 2007*[96]

86. DELWP 2017, 'Victorian Budget 2017/18 Factsheet: Energy', East Melbourne https://www2.delwp.vic.gov.au/__data/assets/pdf_file/0026/63827/Budget-2017-18-Fact-Sheet-Energy-.pdf Accessed 4 December 2018.
87. 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/f932b66241ecf1b7ca256e92000e23be/05736C89E5B8C7C0CA2580D50006FF95/$FILE/17-005aa%20authorised.pdf Accessed 4 December 2018.
88. Office of the Chief Parliamentary Counsel Victoria 2017, 'Renewable Energy (Jobs and Investment) Act 2017', Melbourne, Victoria http://www.legislation.vic.gov.au/Domino/Web_Notes/LDMS/PubStatbook.nsf/51dea49770555ea6ca256da4001b90cd/F9B4F84D96E4E65ACA2581D2001B3DC7/$FILE/17-056aa%20authorised.pdf Accessed 4 December 2018.
89. 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.
90. 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.
91. Victorian State Government 2018, 'Construction begins on Bulgana green power hub', Melbourne, Victoria https://www.premier.vic.gov.au/wp-content/uploads/2018/05/180516-Construction-Begins-On-Bulgana-Green-Power-Hub.pdf Accessed 4 December 2018.
92. DELWP, 'Victorian Renewable Energy Auction Scheme', East Melbourne, Victoria https://www.energy.vic.gov.au/__data/assets/pdf_file/0014/80510/VRET-fact-sheet-Auction.pdf Accessed 4 December 2018.
93. 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.
94. 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_version_-_20160308.PDF Accessed 4 December 2018.
95. DELWP 2017, 'Energy Efficiency and Productivity Strategy', East Melbourne, Victoria https://www.energy.vic.gov.au/__data/assets/pdf_file/0030/89292/Energy-Efficiency-and-Productivity-Strategy-Web.pdf Accessed 4 December 2018.
96. 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/f932b66241ecf1b7ca256e92000e23be/05736C89E5B8C7C0CA2580D50006FF95/$FILE/17-005aa%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 emissions[97]
- 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 annually[98]
- 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 program[99]
- supporting 50 poorly performing commercial buildings and tenancies to implement energy efficiency improvements through the Better Commercial Buildings grants program[100]
- supporting the Victorian households most in need to undertake energy upgrades through the $17 million Home Energy Assist program[101]
- implementing the $25 million Energy Storage Initiative, which includes funding for two large-scale 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]

97. DELWP, 'Victorian Energy Upgrades', East Melbourne, Melbourne https://www.energy.vic.gov.au/energy-efficiency/victorian-energy-upgrades Accessed 4 December 2018.
98. Victorian State Government 2016, 'Greener Government Buildings to Save $100 million', Melbourne, Victoria https://www.premier.vic.gov.au/greener-government-buildings-to-save-100-million/ Accessed 4 December 2018.
99. Sustainability Victoria, 'Grants for Businesses', Melbourne, Victoria https://www.sustainability.vic.gov.au/business/efficient-business-operations/boosting-business-productivity Accessed 4 December 2018.
100. Sustainability Victoria, 'Better Commercial Buildings', Melbourne, Victoria https://www.sustainability.vic.gov.au/betterbuildings Accessed 4 December 2018.
101. DELWP, 'Home Energy Assist Program, Victoria State Government', East Melbourne, Victoria, https://www.victorianenergysaver.vic.gov.au/get-help-with-your-bills/concessions-and-rebates/home-energy-assist-program Accessed 4 December 2018.
102. DELWP 2018, 'Renewable Energy Technology: energy storage - large-scale batteries, East Melbourne, Victoria https://www.energy.vic.gov.au/__data/assets/pdf_file/0016/123406/Large-scale-battery-storage-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%20Energy%20Productivity%20Plan%20release%20version%20FINAL_0.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.[105] 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.
105. Parliament of Victoria 2018, 'Inquiry into electric vehicles', Melbourne, Victoria https://parliament.vic.gov.au/909-eic/inquiry-into-electric-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.

Poor
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

Poor
Evidence and consensus too low to make an assessment

Fair
Limited evidence or limited consensus

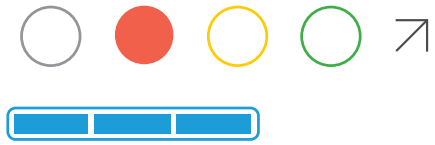
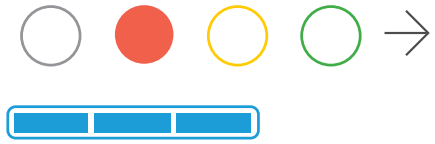
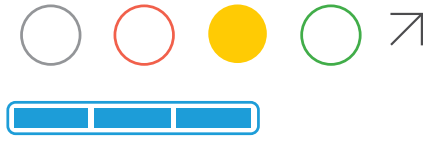
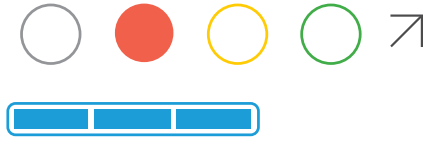
Good
Adequate high-quality evidence and high level of consensus

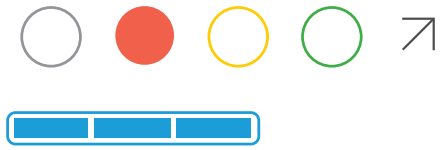
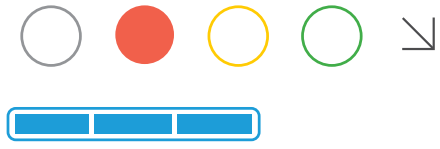
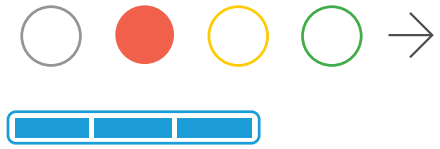
ENERGY

	Summary	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend
Indicator **E:01** Energy use per capita **Region** Victoria **Measures** GJ **Data custodian** DEE	Energy use per capita is declining and is slightly below 1990 levels but remains high by global standards.		↗
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

DATA QUALITY
Good

	Summary	Status UNKNOWN POOR FAIR GOOD	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 UNKNOWN POOR FAIR GOOD	Trend
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 (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
E:01 Energy use per capita			 DATA QUALITY: Good

Data Custodian DEE

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 2015–16[106]

Sector	Energy consumption 1989–90		Energy consumption 2015–16		Difference 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 Data Custodian DEE		→	DATA QUALITY Good
E: 03 Consumption of renewable energy as a share of total energy consumption Data Custodian DEE		↗	DATA QUALITY 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.[107] 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.

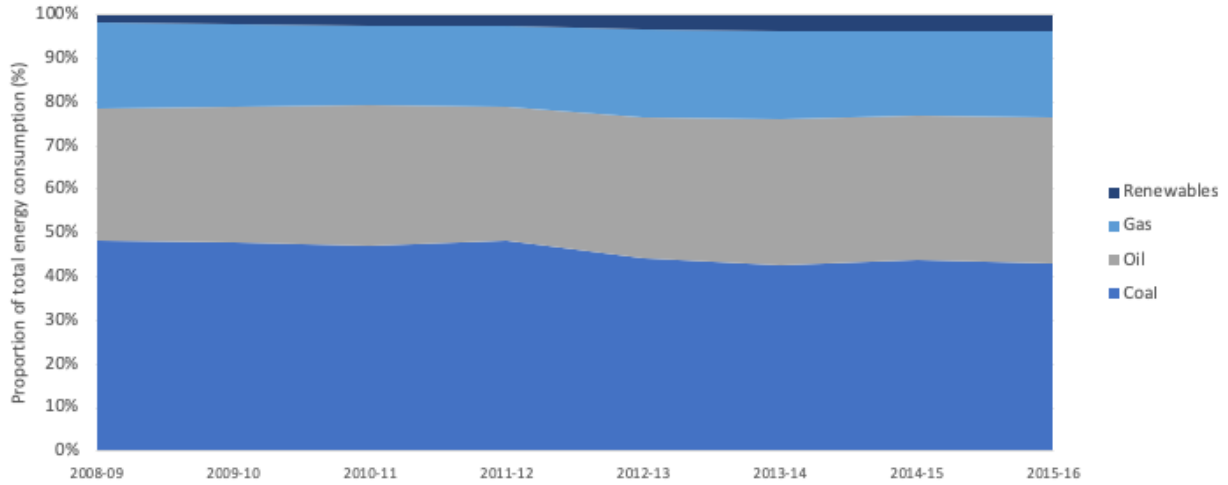


Figure E.9 Proportion of Victoria's energy consumption by fuel type[108]

107. Australian Energy Market Operator, 'Generator Information Page', Melbourne, Victoria http://www.aemo.com.au/Electricity/National-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 non-domestic 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 2015–16[109]

Fuel type	Energy consumption 2008–09		Energy consumption 2015–16		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

109. Ibid.

110. DHHS 2017, 'Annual Report 2016-17', Melbourne, Victoria https://dhhs.vic.gov.au/sites/default/files/documents/201710/DHHS-annual-report-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	○ ● ○ ○	→	DATA QUALITY: Good

Data Custodian DEE

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.

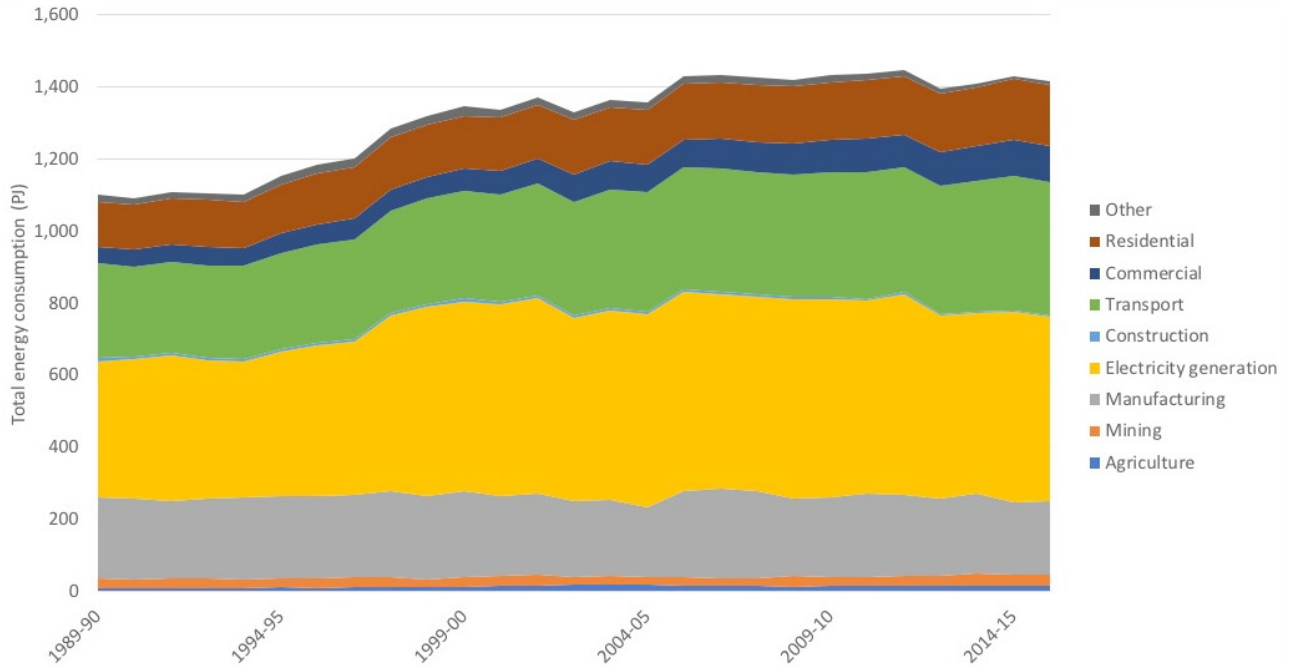


Figure E.10 Energy consumption by industry sector in Victoria, 1989–90 to 2015–16[111]

111. 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 (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
E:05 Total electricity consumption			 DATA QUALITY 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.

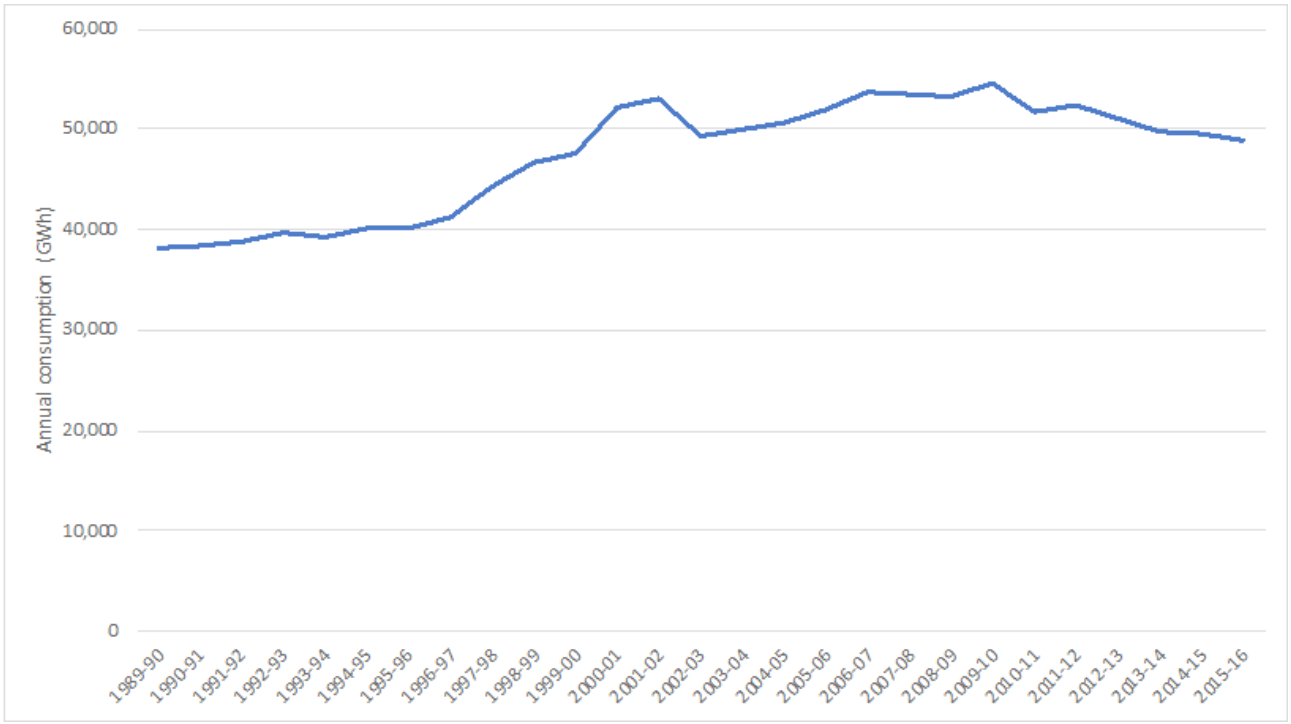


Figure E.11 Total annual electricity consumption, Victoria, 1989–90 to 2015–16[112]

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.

112. Department of Environment and Energy 2017, 'Australian Energy Statistics 2017: Table L', Canberra, Australia.
113. Australian Energy Market Operator 2017, Electricity Forecasting Insights: for the national electricity market, Melbourne, Victoria https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_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 Data Custodian DELWP, NEM Review, Metered Generation and DELWP estimates		↗	DATA QUALITY Good
E:07 Share of renewable energy generation of total electricity generation Data Custodian DELWP, NEM Review, Metered Generation and DELWP estimates		↗	DATA QUALITY 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).

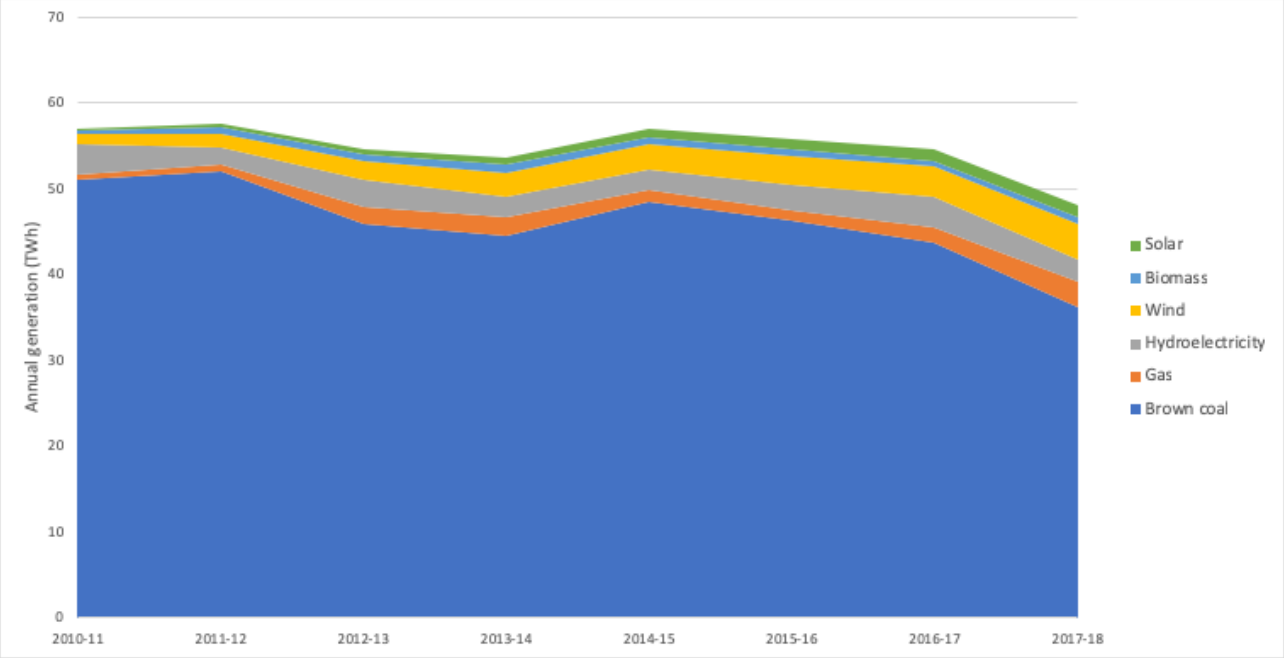


Figure E.12 Victoria's annual electricity generation by fuel type, 2010–11 to 2017–18[114]

114. 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 2017–18[115]

	Electricity generation 2010–11		Electricity generation 2017–18		Difference 2010–11 to 2017–18
	TWh	Share (%)	TWh	Share (%)	TWh
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
Renewable 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

115. Ibid.

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]

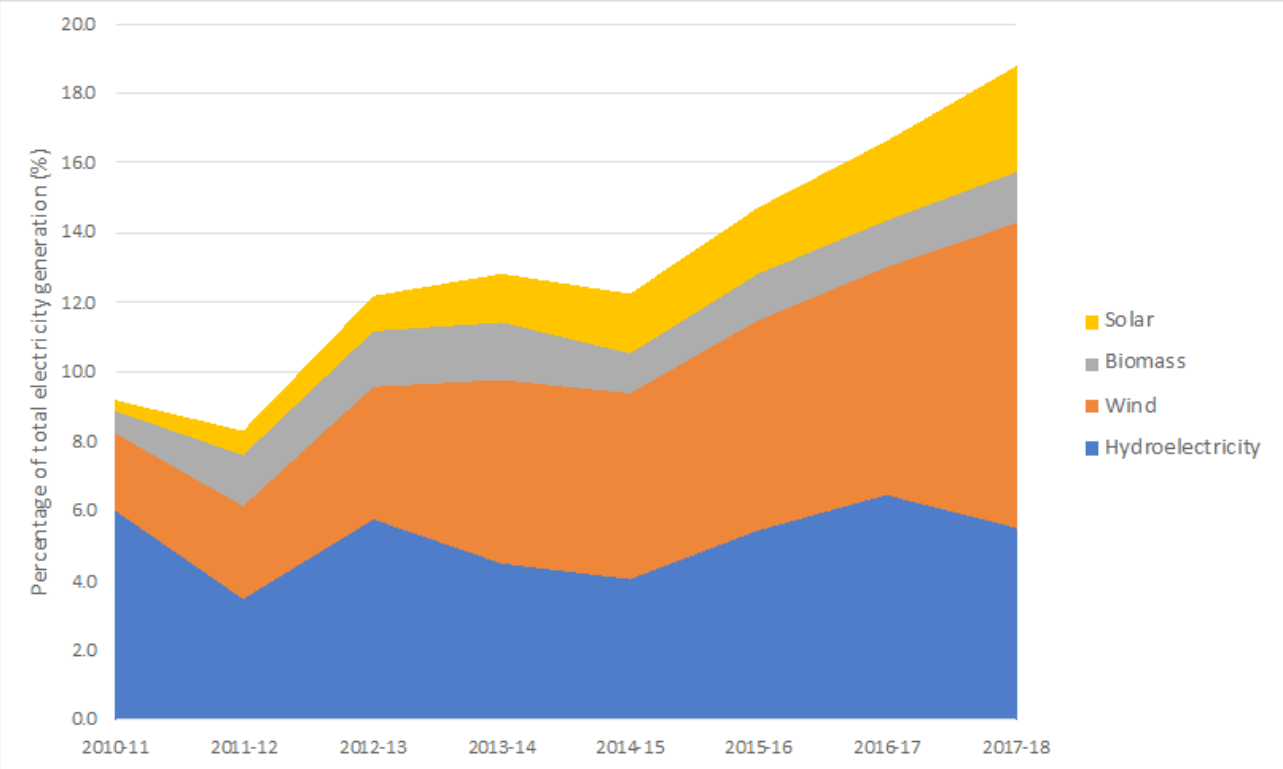


Figure E.13 Proportion of renewable electricity generation by fuel type, as a percentage of total electricity generation in Victoria, 2010–11 to 2017–18[117]

116. 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.

117. 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, 2007–2017[121]

	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

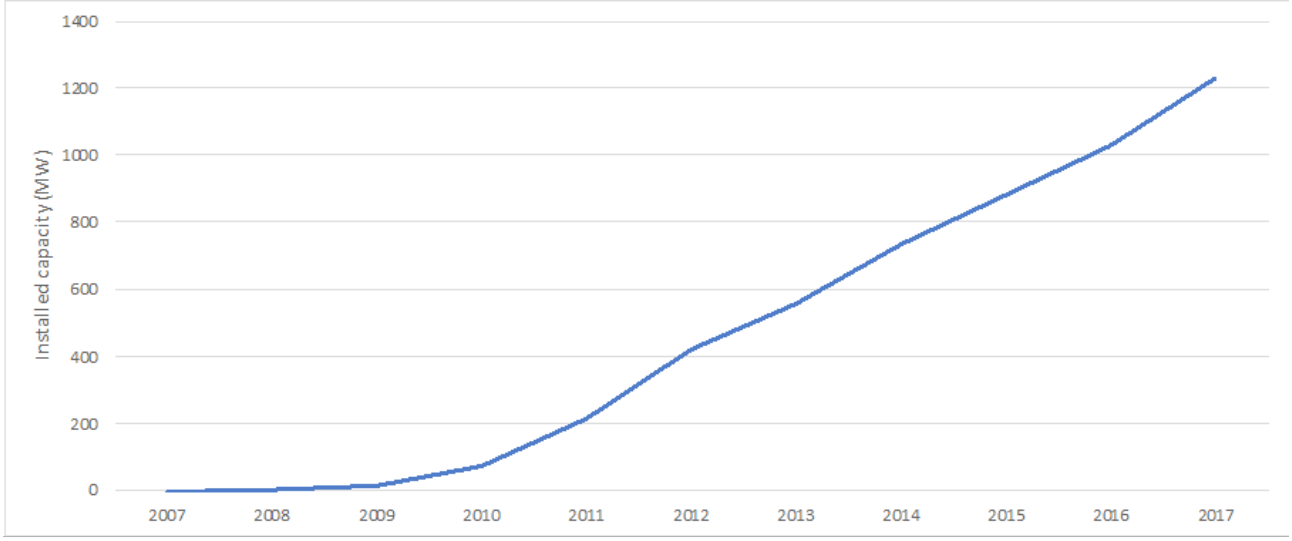


Figure E.14 Cumulative capacity of small-scale solar PV installations in Victoria, 2007–2017[122]

118. 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/ESOO/2017/2017-WEM-ESOO-Methodology-Report---Projections-of-Uptake-of-Small-scale-Systems.pdf Accessed 4 December 2018.
120. 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. Ibid.
122. Ibid.

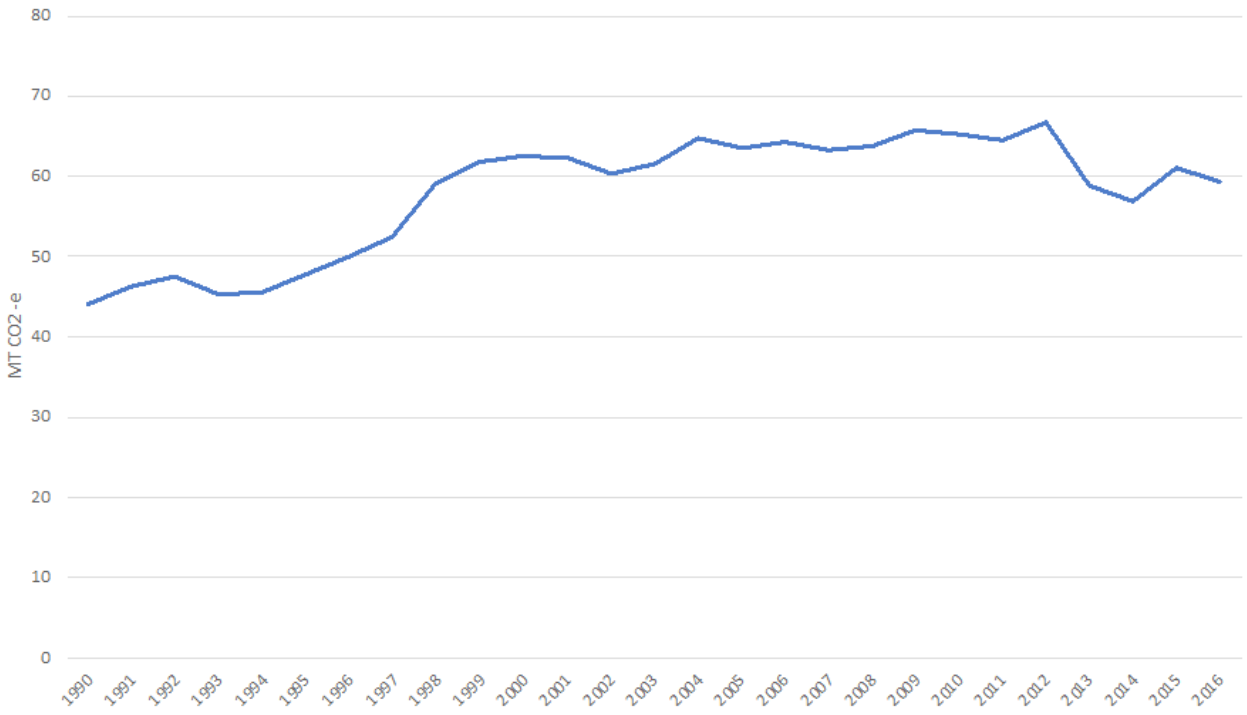


Figure E.15 Annual emissions from public electricity in Victoria, 1990–2016[123,124]

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).

123. Australian Department of the Environment and Energy, 'Australian Greenhouse Emissions Information System', Canberra, Australia http://ageis.climatechange.gov.au Accessed 4 December 2018.
124. Australian Government Department of the Environment and Energy 2018, 'National Inventory Report 2016: Volume 1', Canberra, Australia http://www.environment.gov.au/system/files/resources/02bcfbd1-38b2-4e7c-88bd-b2b7624051da/files/national-inventory-report-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 Data Custodian Department of Environment and Energy, National Greenhouse Gas Inventory			 DATA QUALITY Good
E:09 Per capita transport energy use Data Custodian DEE, National Greenhouse Gas Inventorys Inventory			 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 2015–16[125]

	Energy consumption 1989–90		Energy consumption 2015–16		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

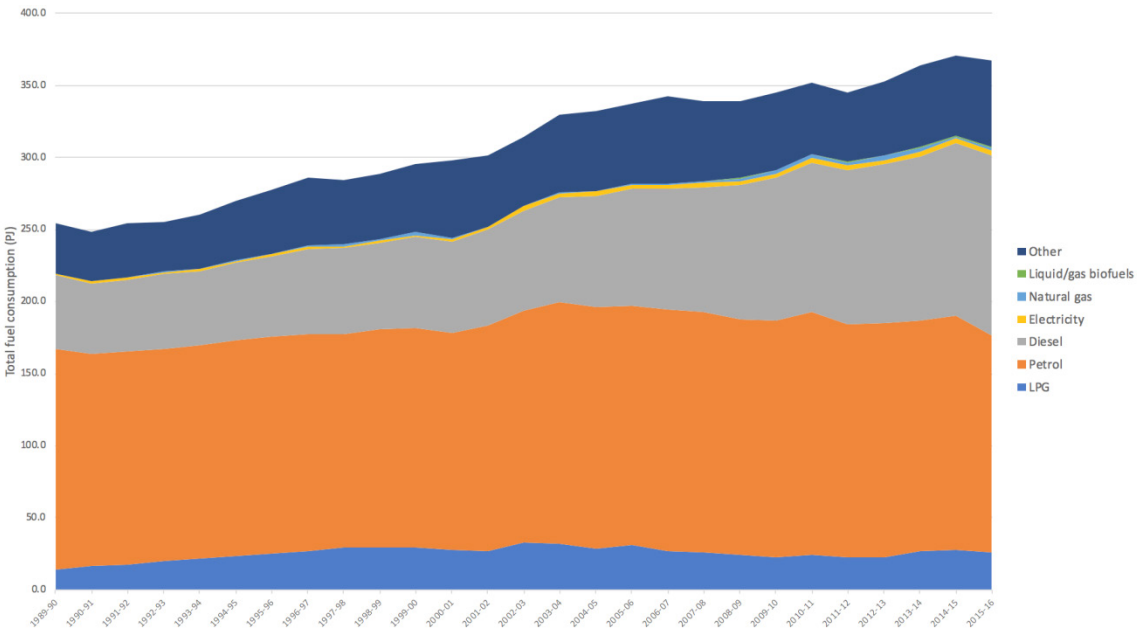


Figure E.16 Energy consumption in the transport sector by fuel type, Victoria, 1989–90 to 2015–16[126]

125. 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 and turbine fuel).

126. 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.

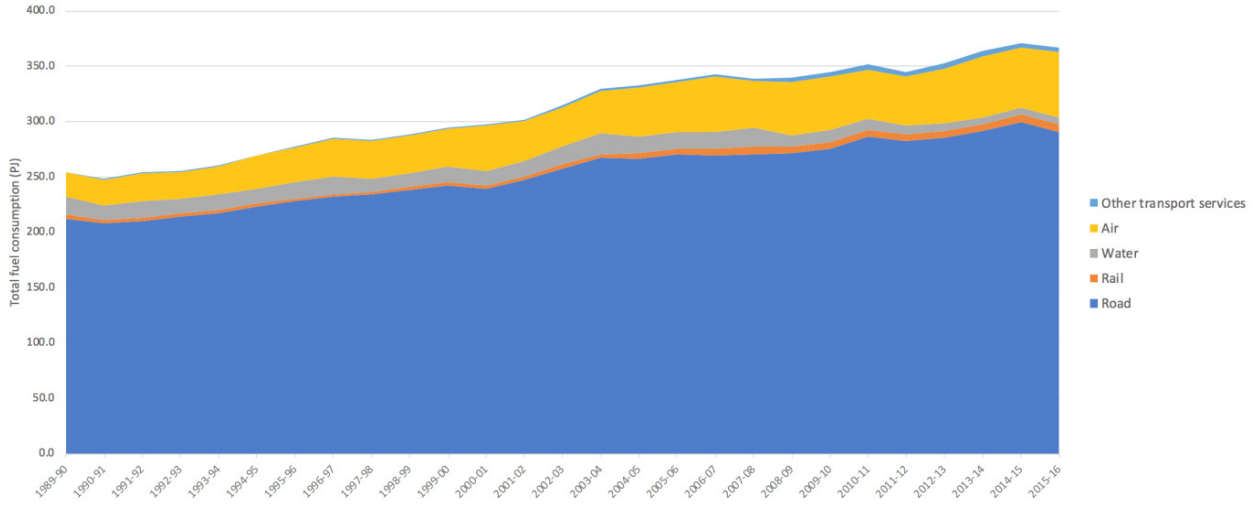


Figure E.17 Total fuel consumption by transport subsector, Victoria, 1989–90 to 2015–16[127]

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.

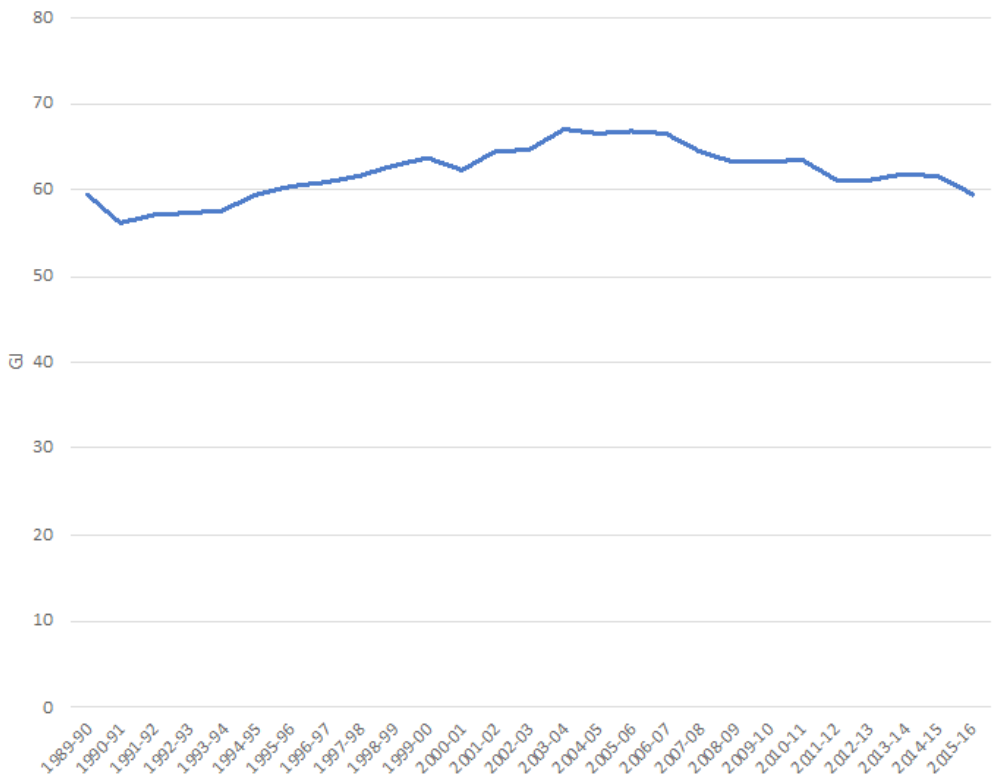


Figure E.18 Per capita transport energy use, Victoria, 1989–90 to 2015–16[128,129]

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.

128. Department of Environment and Energy 2017, 'Australian Energy Statistics 2017: Table E3', Canberra, Australia.
129. 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?OpenDocument Accessed 4 December 2018.

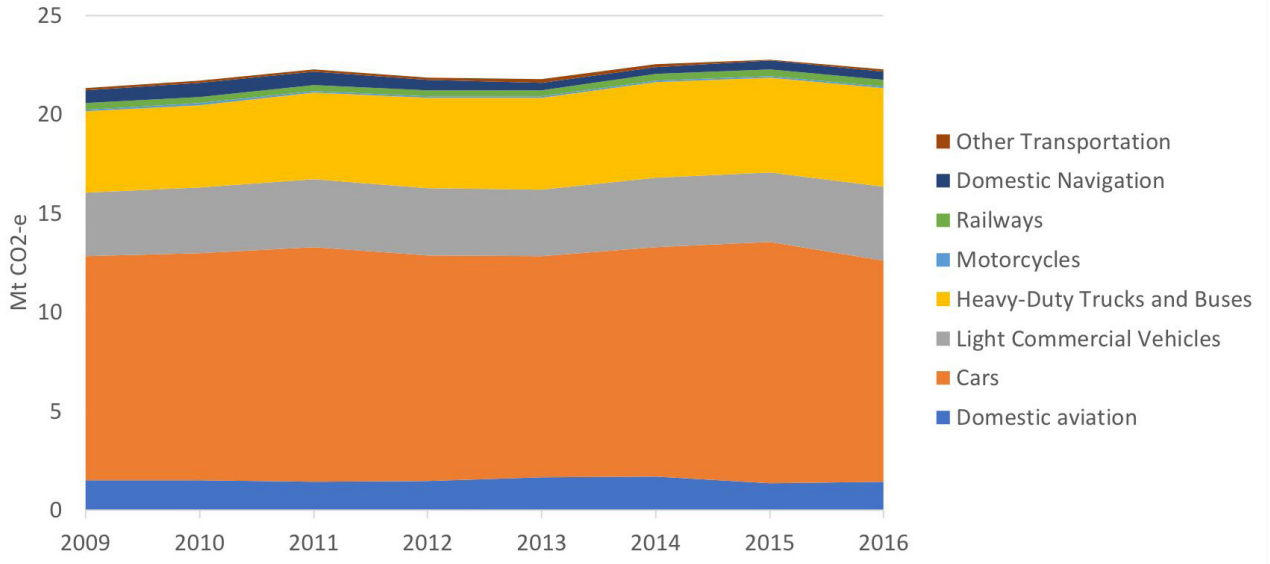


Figure E.19 Energy emissions from the transport sector by type of transport, 2009–2016[130]

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.

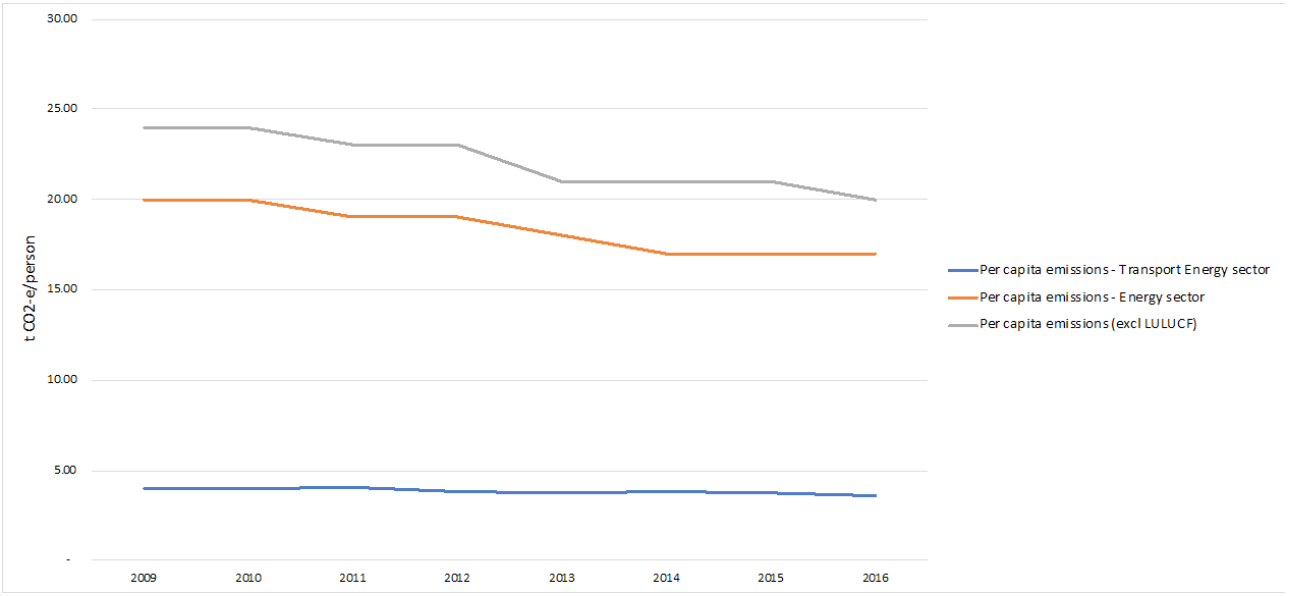


Figure E.20 Transport sector emissions per capita compared to total energy sector and overall emissions between 2009 and 2016[131,132]

130. Australian Department of the Environment and Energy, 'Australian Greenhouse Emissions Information System', Canberra, Australia http://ageis.climatechange.gov.au Accessed 4 December 2018.
131. Ibid.
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?OpenDocument 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', https://www.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 net-zero 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 cost-effective 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 end-use 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 low-carbon 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.

134. United Nations 2015, 'Paris Agreement', https://unfccc.int/sites/default/files/english_paris_agreement.pdf Accessed 4 December 2018.
135. 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/f932b66241ecf1b7ca256e92000e23be/05736C89E5B8C7C0CA2580D50006FF95/$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 https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0019/121924/Issues-Paper_28-03-2018.pdf Accessed 4 December 2018.
137. 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.
138. Australian Energy Market Operator and Energy Networks Australia 2018, 'Open Energy Networks: consultation paper', https://www.energynetworks.com.au/sites/default/files/open_energy_networks_consultation_paper.pdf Accessed 4 December 2018.
139. Ibid.
140. Green Building Council of Australia, 'Neighbourhoods and community', Barangaroo, New South Wales https://new.gbca.org.au/green-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 zero-emissions electricity generation**
- **the associated markets, governance and business models.**

141. 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).
142. Darby S, Liddell C, Hills D, Drabble D 2015, 'Smart Metering Early Learning Project: Synthesis report', Department of Energy & Climate Change, London, United Kingdom.
143. 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, Australia.
144. Ibid.
145. Nelson T, Orton F, Chappel T 2017, 'Electricity market design in a decarbonised energy system', working paper.
146. 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.
147. 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.
148. 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.

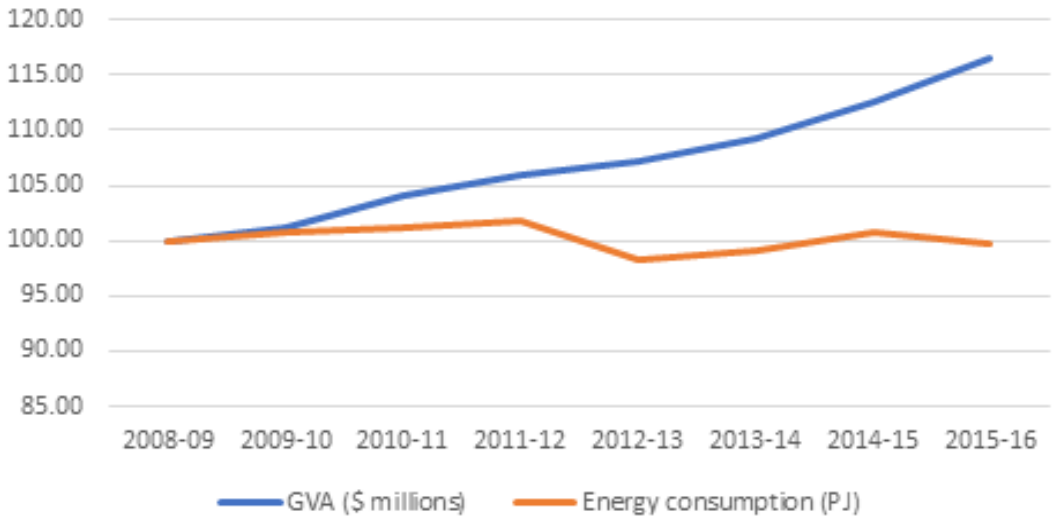


Figure E.21 Victoria industry gross value add vs energy consumption

Index: 2008–09 = 100

149. DELWP 2017, 'Energy Efficiency and Productivity Strategy', East Melbourne, Victoria https://www.energy.vic.gov.au/__data/assets/pdf_file/0030/89292/Energy-Efficiency-and-Productivity-Strategy-Web.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).

150. Australian Bureau of Statistics, '5220.0 Australian National Accounts: State Accounts', Canberra, Australia.
151. Department of Environment and Energy 2017, 'Australian Energy Statistics 2017: Table C3', Canberra, Australia.



SOE 2018 CLIMATE CHANGE ADAPTATION INDICATORS

SCIENTIFIC ASSESSMENTS Part III

Commissioner *for* Environmental Sustainability Victoria

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.

Poor
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

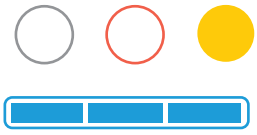
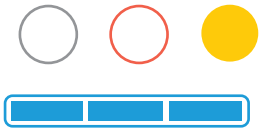
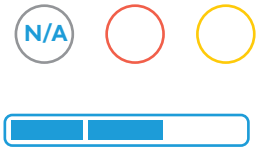
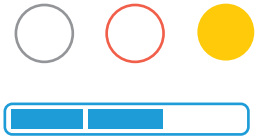
Data quality

Poor
Evidence and consensus too low to make an assessment

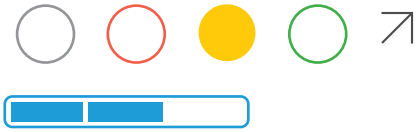
Fair
Limited evidence or limited consensus

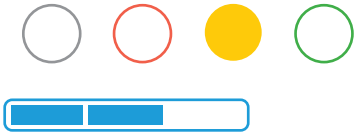
Good
Adequate high-quality evidence and high level of consensus

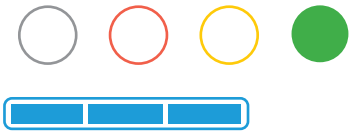
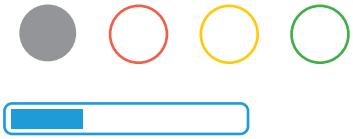
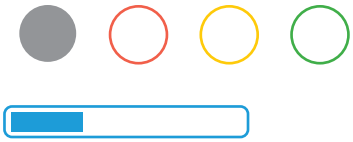
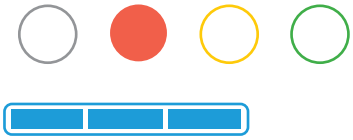
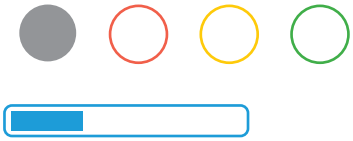
Chapter	Summary	Description	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend
Air	**Indicator** **A:05** Stratospheric ozone	The long-term changes in stratospheric ozone due to ozone depleting substances over a mid-latitude location such as Victoria are small compared to natural variations. Melbourne's ultraviolet levels have generally been stable since the 1980's.		
			DATA QUALITY Good	
Climate Change	**Indicator** **CC:01** Observed average rainfall	Victoria has received below average to record low cool season rainfall for the most recent 30 years from 1985-2015. This has been influenced by declining cool season rainfall.		
			DATA QUALITY Good	

Chapter	Summary	Description	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend
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.	 DATA 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.	 DATA QUALITY: Good	
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)	

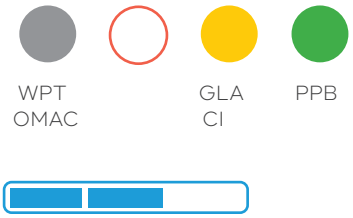
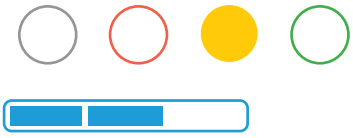
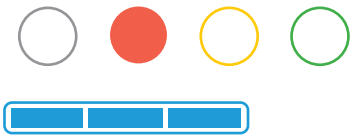
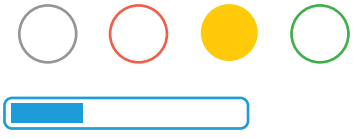
Chapter	Summary	Description	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend
Climate Change	**Indicator** **CC:08** Projected sea level	Further mean sea level rises and an increase in the frequency of extreme inundation events are projected.	N/A DATA QUALITY Good	↘
Climate Change	**Indicator** **CC:09** Sea-surface 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 (UNKNOWN / POOR / FAIR / GOOD)	Trend
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.	 DATA 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 Unknown (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 (UNKNOWN / POOR / FAIR / GOOD)	Trend
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 (UNKNOWN / POOR / FAIR / GOOD)	Trend
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.	 DATA QUALITY 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.	 DATA QUALITY 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.	 DATA QUALITY Poor	?

Chapter	Summary	Description	Status UNKNOWN POOR 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. **Corner Inlet and Nooramunga Mangroves** are at their southern-most limit in Corner Inlet and Nooramunga where 80% of the pre-1750s cover remains. **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	 CI NMCP WPT OMAC  DATA QUALITY Good WPT & CI & NMCP & OMAC	?
Marine and Coastal Environments	**MC:02** Saltmarsh extent	**Port Phillip Bay** About 50% of Port Phillip Bay's pre-1750s saltmarsh cover of 3710 ha remains today. **Western Port** In Western Port, 90–95% of saltmarsh that once covered 1460 ha remains today. **Gippsland Lakes** Historical mapping of the various lakes indicates that between 80 and 100% of pre-1750s saltmarsh has been retained. **Other marine and coastal areas** 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.	 OMAC PPB GLA WPT  DATA QUALITY Fair - PPB & WPT  DATA QUALITY Poor - GLA & OMAC	OMAC ? PPB → GLA ? WPT ↘

Chapter	Summary	Description	Status UNKNOWN POOR FAIR GOOD	Trend
Marine and Coastal Environments	**MC:03** Seagrass condition	**Port Phillip Bay** 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 reveal that it declined on average by 0.5 km^2 per year between 1965 and 2013, with algal blooms and turbidity both impacting on light penetration. There is limited data on density and epiphytes.	 DATA QUALITY Fair	WPT ? GLA ? PPB → OMAC ? CI ↘
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	↗
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	↘

Authorised by the Commissioner
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Spatial data is sourced from the Victorian Spatial Data Library.

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