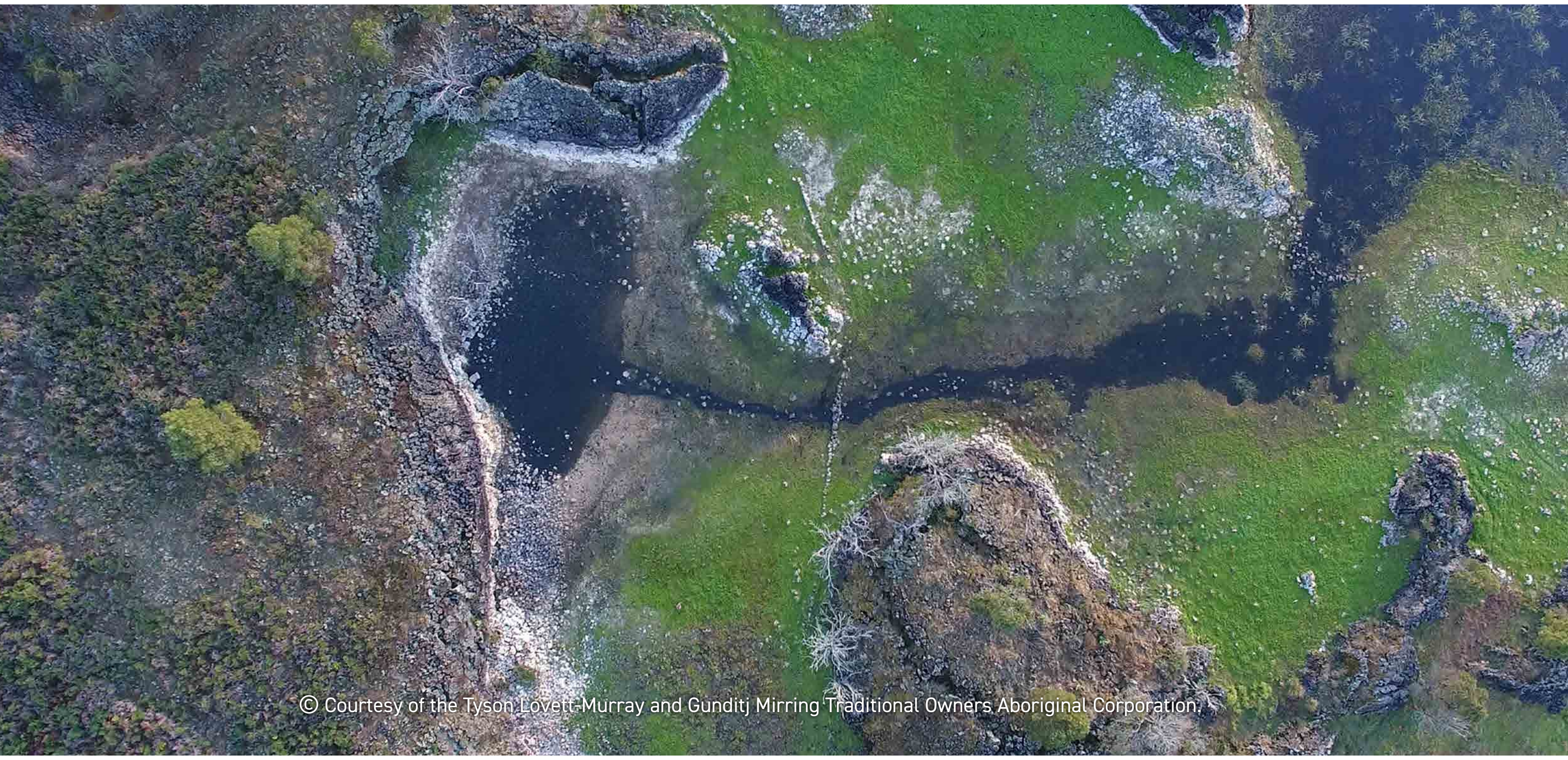
Commissioner
for Environmental
Sustainability
Victoria

Victorian State of the Environment 2023 Report
Scientific Assessments Volume 1

VICTORIA
State
Government


© Courtesy of the Tyson Lovett-Murray and Gunditj Mirring Traditional Owners Aboriginal Corporation.

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

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

Traditional Owners

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

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

Commissioner *for* Environmental Sustainability Victoria

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Guide to indicator assessments

Each indicator report card includes the following information.

Measures

These are the specific measurements and data sets used to inform the status and trend assessments.

Region

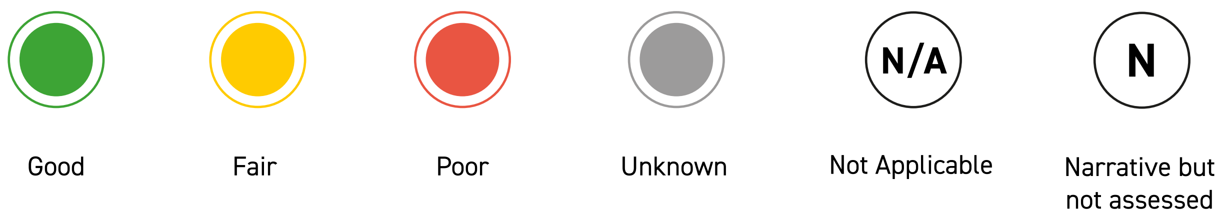
The assessments have been conducted on a statewide and/or regional scale based on the localisation of the impacts associated with each indicator and/or the spatial scale of the evidence supporting the assessment.

Status

The status summary presents an overall analysis of the assessment for each indicator. An indicator can be assessed as having a good, fair or poor status (see status thresholds below). Where there is insufficient data, the indicator status is assessed as unknown. Note that some indicators may not show discernible changes over the 5-year period that is used for state of the environment reporting, thus, the assessment for these indicators incorporate changes in environmental condition over longer time scales (e.g. decadal).

The legend for status in the report card is:

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

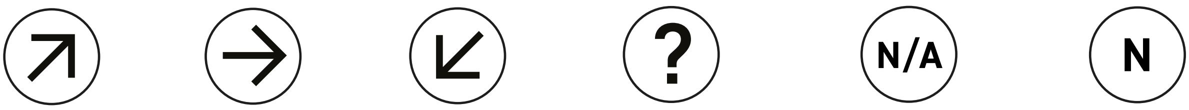


Trend

The trend summary presents an overall analysis of the trend assessments for each selected indicator. The trend identifies whether the status of the indicator is deteriorating, improving or remaining stable. Importantly, trend does not represent whether the measure used to assess the indicator is increasing or decreasing (e.g. increasing waste generation) but instead reflects whether the change in the indicator measure denotes an improved or deteriorating environmental outcome.

The legend for trend in the report card is:

- **Improving**
- **Stable**
- **Deteriorating**
- **Unclear**
- **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.



Improving | Stable | Deteriorating | Unclear | Not Applicable | Narrative but not assessed

Confidence

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

Note that in the SoE 2018 Report, the quality of data for each indicator was assessed as either good, fair or poor. The ratings given to data quality in 2018 are included in the summary table for each indicator in this chapter. However, the 2023 assessment does not refer to data quality in the summary table. Instead, it refers to confidence in the assessment of status and trend, rating it as either low, moderate, high or insufficient. The change to providing an assessment of indicator confidence rather than data quality in 2023 has been made to reflect that data quality is one of several components that inform the confidence of indicator status and trend assessments – other components include the level of scientific consensus and the presence of scientifically-developed thresholds, legislative objectives or existing reporting frameworks.

The legend for confidence in the report card is:

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

High | Moderate | Low | Insufficient | Not Applicable | Narrative but not assessed

Cultural landscape health and management (CL)

Victorian State of the Environment 2023 Report

Aboriginal farming enterprise, Healesville 2021.
Creator: Anthony Webster, Imagine Pictures.
Credit: Department of Jobs Precincts and Regions.
© Agriculture Victoria.

Cultural landscape health and management (CL)

Background

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

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

Aboriginal cultural heritage in Victoria is protected under the Victoria's *Aboriginal Heritage Act 2006* (Aboriginal Heritage Act). The Aboriginal Heritage Act establishes a framework and mechanisms for the management and protection of Aboriginal cultural heritage. These mechanisms include cultural heritage management plans, cultural heritage permits, protection declarations and Aboriginal cultural heritage land management agreements.

The status of 'Registered Aboriginal Parties' is provided under the Aboriginal Heritage Act to Traditional Owner organisations that hold decision-making powers under the Aboriginal Heritage Act for the protection and management of Aboriginal cultural heritage within a specified geographic area.

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

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

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

1. Parks Victoria (PV) 2018, 'Managing Country together', Melbourne, Victoria.
2. Ibid.
3. Federation of Victorian Traditional Owner Corporations. 2021. 'Victorian Traditional Owner cultural landscapes Strategy', Melbourne, Victoria.
4. Ibid.

Victorian Government progress on recommendations made in the State of the Environment 2018 Report

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

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

Recommendation 1 of the SoE 2018 Report recommended:

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

<u>Government response in 2020:</u>
SUPPORT IN PRINCIPLE

'The Victorian Government is committed to supporting Aboriginal self-determination and Traditional Owner aspirations for culture and Country. The Government will support Traditional Owners to identify cultural indicators for biocultural landscape health within the principles of self-determination, as outlined in the Victorian Government's Aboriginal Affairs Framework 2018-2023.' [5]

'Responding to the Government's new Self-Determination Reform Framework, the Department of Environment, Land, Water and Planning (DELWP) is developing a strategy for transforming its systems and structures to support self-determination. DELWP is currently working to support Traditional Owners' capacity to actively pursue their natural resource interests. This support includes:

- Twenty-three Aboriginal Water Officer positions across Victoria to support Traditional Owners and Aboriginal Victorians to have better involvement in the water sector.
- Gunditji Mirring Traditional Owners Aboriginal Corporation's Killara Kooyang Water Project. Funded through the Aboriginal Water Program's Economic Development Initiative, this project will pilot the access and use of water for an aquaculture facility in the Budj Bim Cultural Landscape.
- Partnership and Engagement Coordinators in 11 Traditional Owner Corporations to support Traditional Owners to meaningfully participate in the Forest Reform process and support cultural values assessments.
- Liaison officers within Traditional Owner Corporations to help coordinate work with the Department in managing the state's natural resources.' [6]

5. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Victorian Government response to the state of the environment 2018 report', Melbourne, Victoria.
6. Ibid.

Cultural landscape health and management (CL)

Progress made since 2018

Since the State of the Environment 2018 Report was released in 2019, the Victorian Government has undertaken a significant process of social change in response to the rapidly shifting environment surrounding Aboriginal self-determination and First Peoples' rights and interests. In alignment with the Victorian Aboriginal Affairs Framework (VAAF) 2018-2023 (Figure CL1), the Department of Energy, Environment and Climate Action (DEECA) has progressed from an approach of Aboriginal inclusion towards self-determination, Truth Telling and future Treaty. DEECA's alignment of self-determination commitments with the VAAF and broader Whole of Victorian Government Self Determination Reform Framework has resulted in closer and more equal partnerships with Traditional Owners and Aboriginal Victorians to advance and remove barriers to self-determination, with project and program objectives increasingly being determined by Traditional Owners.

Figure CL1: The Victorian Government's Aboriginal Affairs Framework 2018-2023.[7]

Working in partnership, DEECA has taken a step back to listen, and be directed by, the voice and priorities of Traditional Owners in response to their rights and obligations to care for Country. For Traditional Owners, the priority has been to focus on removing structural and systematic barriers which negatively impact Traditional Owners ability to fulfil their rights and obligations to care for Country. Government has worked in partnership to lay this foundation, as articulated in:

- Water is Life: Traditional Owner Access to Water Roadmap (2022) [8]
- Marine and Coastal Strategy 2022 [9]
- Victorian Traditional Owner Cultural Landscapes Strategy 2021 [10]
- Victoria Traditional Owner Cultural Fire Strategy 2019. [11]

DEECA also continues to partner in several initiatives centred around the revitalisation of Traditional Ecological Knowledge, enabling Aboriginal decision-making and supporting cultural and intellectual property rights and data sovereignty. Examples of how this work is building Traditional Owners' capability to develop contemporary cultural indicators is included in Table CL2 on the next page.

This work is also helping Traditional Owners to articulate key outcomes and objectives for managing Country, develop new or update existing Country plans, joint management plans and relevant sub-strategies, and to effectively partner with public land managers. Importantly, the integration of cultural health indicators into future state of the environment reporting will need to be determined by Traditional Owners and aligned with the principles of Indigenous Data Sovereignty.

7. Victorian Government 2018, 'Victorian Aboriginal affairs framework 2018-2023', Melbourne, Victoria.
8. Department of Environment, Land, Water and Planning (DELWP) 2022, 'Water is life: Traditional Owner access to water roadmap', Melbourne, Victoria, https://www.water.vic.gov.au/__data/assets/pdf_file/0033/599505/Water-is-Life-Summary.pdf Accessed 8 July 2023.
9. Department of Environment, Land, Water and Planning (DELWP) 2022, 'Marine and coastal strategy', Melbourne, Victoria, https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0029/571817/Marine-and-Coastal-Strategy_May-2022.pdf Accessed 8 July 2023.
10. Federation of Victorian Traditional Owner Corporations 2021, 'Victorian Traditional Owner cultural landscapes strategy', Melbourne, Victoria.
11. Victorian Traditional Owner Cultural Fire Knowledge Group 2019, 'Victoria Traditional Owner cultural fire strategy', Melbourne, Victoria, fireplusstrategyplusfinal.pdf (aidr.org.au) accessed 8 July 2023.

Cultural landscape health and management (CL)

Killawarra Scar Tree, Warby-Ovens National Park 2011.
Credit: Geoffrey Burrows.

Some recent examples of projects that have integrated cultural indicators to assess, monitor, and heal Country are highlighted below:

- Joint Management Plan for the Dja Dja Wurrung Parks with Dja Dja Wurrung Aboriginal Corporation[12]
- Final Hanging Rock Strategic Plan in partnership Wurundjeri Woi Wurrung, Dja Dja Wurrung and Taungurung[13]
- Gunaikurnai and Victorian Government Joint Management Plan joint management of 10 public parks and reserves in Gippsland[14]
- Budj Bim Cultural Landscape Master Plan 2022-2030 with Gunditj Mirring Traditional Owner Aboriginal Corporation[15]
- Joint Management Plan for Barmah National Park with Yorta Yorta Nation Aboriginal Corporation[16]
- DJAARA Forest Gardening Strategy 2022-2034[17]
- Wadawurrung Healthy Country Plan 2020-2030.[18]

In the Victorian Government's response to the SoE 2018 cultural landscape health and management recommendation, several supports provided by DEECA were referenced that are assisting Traditional Owners to actively pursue their natural resource interests.

Updates on the progress against each of these actions is provided in Table CL1 on the next page.

12. Dhelkunya Dja Land Management Board 2018, 'Joint management plan for the Dja Dja Wurrung Parks: Strategy. Melbourne, Australia: Dhelkunya Dja Land Management Board, Oct-18-Strategy.pdf (dhelkunyadja.org.au) Accessed 8 July 2023.
13. Department of Environment, Land, Water and Planning (DELWP) 2018, 'Hanging Rock strategic plan', Melbourne, Victoria, Final-Hanging-Rock-Strategic-Plan.pdf (forestsandreserves.vic.gov.au) Accessed 8 July 2023.
14. Gunaikurnai Traditional Owner Land Management Board (GKTOLMB) 2018, 'Gunaikurnai and Victorian Government joint management plan', Bairnsdale, Victoria, Microsoft Word - JMP09_Tarra–Bulga_LO.docx (gunaikurnai.org) Accessed 8 July 2023.
15. Arup, Earthcheck, PwC Indegenous Consulting, Porter L, Extent, WT Costing 2022, 'Budj Bim: Cultural landscape master plan 2022-2030', budj-bim-master-plan-2022-2030.pdf (contentedninja-media.s3-ap-southeast-2.amazonaws.com) Accessed 8 July 2023.
16. Yorta Yorta Traditional Owner Land Management Board, Yorta Yorta Nation Aboriginal Corporation 2020 'Joint management plan for Barmah National Park', Minister-Approved-Final-Barmah-NP-JMP.pdf (yytolmb.com.au) Accessed 8 July 2023.
17. Dja Dja Wurrung Clans Aboriginal Corporation 2022, 'DJAARA Forest Gardening Strategy', Bendigo, Victoria, https://djadjawurrung.com.au/djaara-launches-forest-gardening-strategy-to-heal-country/ Accessed 8 July 2023.
18. Wadawurrung Traditional Owners Aboriginal Corporation 2020, 'Wadawurrung healthy Country plan', d96c4e_72611327c6a54d3198c0499ac5c26e54.pdf (wadawurrung.org.au) Accessed 8 July 2023.

Cultural landscape health and management (CL)

Table CL1: Victorian Government response to 2018 SoE report – Supporting actions.

2018 State of the Environment Report – Supporting Actions	Progress or completion of this activity against the Governments response
23 Aboriginal Water Officer positions	This program is ongoing, and the Department currently funds 25 Aboriginal Water officers. This work has enabled Traditional Owner organisations to build a foundation and strengthen their capacity to reclaim and connect to cultural knowledge around water and water landscapes. This funding has also enabled partnership in the key elements of the Aboriginal Water Program. Continuation of this work past June 2024 is dependent upon funding through the next round of Environmental Contribution business cases.
Gunditj Mirring Traditional Owners Aboriginal Corporation's (GMTOAC) Killara Kooyang Water Project. Funded through the Aboriginal Water Program's Economic Development Initiative.	This project piloted the access and use of water for an aquaculture facility in the Budj Bim Cultural Landscape. The project is fully completed. GMTOAC will further investigate the potential to farm and/or produce Kooyang (eels) within Lake Condah, along with commercial production and processing as part of the newly constructed Aquaculture Centre at Lake Condah.
Partnership and Engagement Coordinators in 11 Traditional Owner Corporations to support Traditional Owners to meaningfully participate in the Forest Reform process and support cultural values assessments.	This investment has supported Traditional Owner participation in renewal of Regional Forest Agreements, the development of a Victorian Traditional Cultural Landscape Strategy and funding to undertake cultural mapping projects. This work has sought to restore Traditional Ecological Knowledge and supported the development of seasonal calendars, developing language databases, cultural mapping, historical landscapes reviews and program logic's for caring for Country. Traditional Owner groups will maintain data sovereignty over this information, meaning that they will have control over information and knowledge, including how it can be shared with Government and used in the future. These specific positions have now concluded, with subsequent resourcing arrangements supporting the Traditional Owners to participate in decision-making that directly impacts on the Forest and Fire Management Planning and Operations projects and the implementation of each Nations Cultural Landscapes Strategy priorities.
DEECA Liaison Officers within Traditional Owner Corporations to help coordinate work with the Department in managing the state's natural resources.	Under the program, Departmental Liaison Officers coordinate between DEECA's staff and Traditional Owner Corporation staff and members to ensure effective and efficient engagement between the Department and Traditional Owner corporations. The position's accountabilities include ensuring that their organisations are appropriately consulted and involved in the portfolio matters relevant to them. DEECA funded 13 Traditional Owner organisations in 2022-23 and is seeking ongoing funding to support this work.

Cultural landscape health and management (CL)

Table CL2 below outlines a number of DEECA initiatives that support Recommendation 1 of the SoE 2018 Report. All of the projects in the below table support the establishment of a culturally appropriate and self-determined foundation necessary for Traditional Owners to conduct assessments, monitoring, and reporting on health of Country.

Table CL2: DEECA Initiatives that support Recommendation 1 of the SoE 2018 Report.

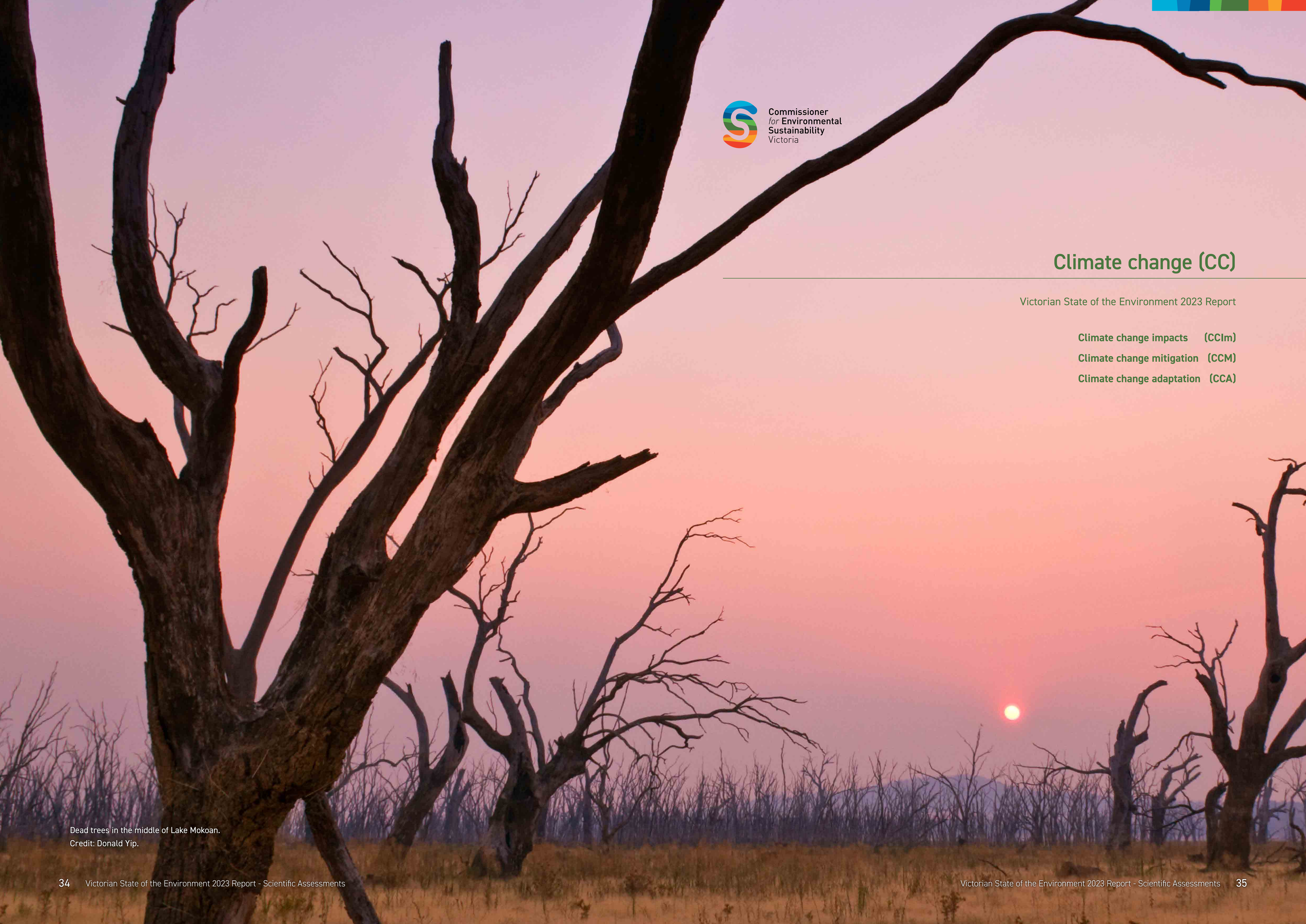
DEECA Initiatives	How this work advances development of contemporary cultural indicators?
Pupangarli Marnmarnepu Owning Our Future, Achieving Together Self-Determination Reform Strategy 2020-2025[19]	The Department has established a quarterly state-wide Caring for Country Partnership Forum (the Forum) in partnership with the 11 formally recognised Traditional Owner Corporations. The Forum functions as a Traditional Owner-led mechanism to hold the Department accountable for the implementation of Pupangarli Marnmarnepu and the Department's commitment to enable Aboriginal self-determination. The Forum tracks Traditional Owners' satisfaction against reform actions conducted both at state and at place-based actions directed at Traditional Owner priorities.
Aboriginal Water Program/Water is Life co-development of Water is Life: Traditional Owner Access to Water Roadmap supporting self-determined water projects and providing funding for Aboriginal Water Officers	The Water, Country and Community Program supports self-determined water projects, including Aboriginal Waterway Assessments (AWAs). AWA is a tool which can be used to measure and prioritise waterway health so that Traditional Owners can more effectively participate in future water planning and management. This tool incorporates cultural health indicators, and consistent with Indigenous Data Sovereignty principles, all data will remain the intellectual property of each Traditional Owner group.
Birndap Birrarung burndap umarkoo (Yarra Strategic Plan) was released in February 2022. The plan was developed in partnership with Wurundjeri Woi Wurrung, and commits to collaborative governance and delivery, in partnership with Wurundjeri and Bunurong as the Traditional Owners of the Birrarung	The Yarra Strategic Plan (YSP) has created opportunities for the development of cultural indicators, including funding for the Birrarung Rangers priority project. This initiative is to be led by Wurundjeri and establish a pathway for building capacity and capability for Birrarung rangers to provide existing and future cultural and natural heritage management services into the future. An integrated monitoring and evaluation framework for the YSP is in development. The plan incorporates 'success measures' for each of the four performance objectives that will inform the monitoring and evaluation framework.
Protecting Victoria's Environment – Biodiversity 2037 (Biodiversity 2037) is Victoria's twenty-year plan for the future of Victoria's biodiversity. DEECA is supporting Traditional Owners in a Strengthening/Healing Country Program to support Traditional Owners build a shared understanding of outcomes for Country, and support learning and knowledge transfer.	Through this program, Traditional Owners have undertaken actions to heal Country using cultural and conventional practice, described seasonal calendars to support management, and reading Country through a range of tools they use, including developing their own healthy Country assessments and surveying species using eDNA, drone and remote camera monitoring. Reclaiming cultural knowledge and practice to restore and manage culturally significant species (food and fibre plants, totemic/spirit animals) provides an important foundation to better understand changes in Country and reporting back to the community based on cultural knowledge of Country. This program is continuing to work with Traditional Owners to understand what cultural indicators they use, and how DEECA's reporting can support this to reflect Traditional Owner priorities in a manner that also supports data sovereignty and Indigenous Cultural Intellectual Property principles.

19. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Pupangarli Marnmarnepu Owning our future, achieving together self-determination reform strategy 2020-2025', Melbourne, Victoria, Pupangarli-Marnmarnepu-Owning-Our-Future-Aboriginal-Self-Determination-Reform-Strategy-2020-2025.pdf (delwp.vic.gov.au) Accessed 8 July 2023.

Cultural landscape health and management (CL)

DEECA Initiatives	How this work advances development of contemporary cultural indicators?
In 2020, Victoria modernised six Regional Forest Agreements (RFAs). The new RFAs include clauses recognising Traditional Owner rights that Traditional Owners were involved in drafting and reflect Traditional Owner rights and aspirations. RFAs commit the Victorian Government to actively seek to implement the Traditional Owner Cultural Landscapes Strategy, including by identifying opportunities to partner and have an active role in the management of forests on public land on Country	Each RFA now clearly recognises the rights and responsibilities of Traditional Owners with Country, including forests. New additions to the RFA include: • Genuine and meaningful partnership with Traditional Owners to support the protection and management of Country, foster sustainable land, water and forest management practices, and maintain the continuation of spiritual and cultural practices. • Involvement of Traditional Owners in decision making, and the active incorporation of Traditional Owner knowledge when making decisions regarding management of forests. • The assessment and evaluation of outcomes relating to matters of importance to Traditional Owners will be undertaken in five-yearly reviews.
In line with commitments in Victoria's modernised RFAs, DEECA has initiated a review of Victoria's Criteria and Indicators for sustainable forest management. DEECA is preparing a consultation paper for the Cultural Landscapes Co-Governance Group to consider and decide a path forward for delivering this. Project is led by the WOVG RFA Implementation Steering Committee	The review of Victoria's criteria and indicators for sustainable forest management will provide a foundation for sharing western science-based knowledge with Traditional Owners, and to enable Traditional Owner input to the review of non-indigenous indicators. A connected piece of work is being established for Traditional Owners to self-determine relevant cultural indicators. This aims to balance the need for scalable, statewide data with the rights of Traditional Owners to self-determine cultural indicators for their own Country.
In line with commitments in Victoria's modernised RFAs commitments, DEECA is updating Victoria's regional state forest management plans. The new plans will support the Department to actively manage state forests across a range of contemporary values and uses in partnership with Traditional Owners.	A program is underway to deliver six new regional forest management plans in partnership with Victorian Traditional Owners, and the opportunity to embed Traditional Owners cultural objectives, actions and indicators within new forest management plans. Forest management plans will be complemented by the implementation of the activities supported by the Cultural Landscapes Strategy and Co-Governance Group (see below).
Victorian Traditional Owner Cultural Landscapes Strategy – A Cultural Landscapes Co-Governance Group formed in 2019 to lead the delivery of the Victorian Traditional Owner Cultural Landscapes Strategy. It has been re-established with the intent to support government to guide the implementation of the strategy.	The Cultural Landscapes Co-Governance Group will meet in March 2023 to reset the terms of reference and propose priorities for implementation of the strategy. The revitalization of knowledge, and enabling cultural landscapes, is a key objective of the Cultural Landscapes Strategy. This objective will be supported by the development of Reading Country programs and systems development to assist with assessing the health of Country, including cultural indicators.
Victorian Traditional Owner Cultural Fire Strategy – Implementation of the Victorian Traditional Owner Cultural Fire Strategy currently provides support to partnership between Traditional Owners and government land managers.	Ongoing implementation led by Traditional Owners is across three main areas: • governance: establishing a co-governance arrangement with government agencies • policy reform: to remove barriers to cultural fire • operations: partnership with Traditional Owners to identify, nominate and deliver cultural fire as part of the Joint Fuel Management Program. This work supports the foundational structures and processes that would allow Traditional Owners to restore practice and knowledge in their communities to the extent that cultural indicators could be developed and agreed. In addition to this work, the Department's Forest, Fire and Regions Group also measures the number of cultural burns undertaken on the department's Fuel Management System, and reports on this as part of the VAAF Country Domain and annual reporting through DEECA's Bushfire Risk Management Report. In 2021-22, the Department supported Traditional Owners to deliver 13 cultural burns.

Stone huts on the Budj Bim Cultural Landscape, the first site in Australia to be inscribed on the UNESCO World Heritage List purely for its Aboriginal cultural significance.
Credit: CES.



Dead trees in the middle of Lake Mokoan.
Credit: Donald Yip.

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Climate change (CC)

Victorian State of the Environment 2023 Report

Climate change impacts (CCIm)

Climate change mitigation (CCM)

Climate change adaptation (CCA)

Key findings

Assessments of the 13 indicators in the 'Climate change' chapter are generally made with high confidence and highlight poor environmental status with a deteriorating trend (Table CC1). None of the 13 indicators have been assessed as having a good status. These assessments are generally similar to the results for the corresponding indicators in the State of the Environment (SoE) 2018 Report.

Climate change impacts

The assessments of indicators CCIm:01 to CCIm:10 were generally consistent with the SoE 2018 indicator assessments, where the same 10 indicators were assessed as deteriorating. The only change was the stable snow-cover trend for higher altitude alpine resorts based on fresh analysis completed for this report.

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

The assessment of indicator 'CCIm:01 Observed surface temperature' shows that annual average temperatures for Melbourne are approaching a 1.5°C increase from an indicative pre-industrial era temperature. Indeed, some years are now more than 1.5°C warmer than the indicative pre-industrial era baseline.[20] The results of this comparison with an indicative pre-industrial era temperature are consistent with recent Australian research that found Australia had warmed by approximately 1.5°C from 1850 to 2019.[21] The warming in Melbourne reflects both broader climate change and the impacts of urbanisation. On a decadal basis, Melbourne has warmed by 0.99°C from an average of 19.6°C (1992–2001) to 20.5°C (2012–2021). If the rate of temperature increase was to continue at its current trajectory of nearly 0.5°C per decade (Melbourne's temperatures increased by 0.99°C from the 1990s to the 2010s), temperatures in Melbourne will increase by approximately 2.5°C from pre-industrial levels by the 2040s. The Technical Report for the Victorian Climate Projections 2019 project found that, based on ACORN-SAT temperature data, the mean annual temperature across Victoria had increased by 1.2°C between 1910 and 2018.[22]

The observed temperature increase is particularly significant in the context of Australia being a signatory to the Paris Agreement, which aims to keep global temperature rise during this century well below 2°C above pre-industrial levels (the pre-industrial period was defined as 1850–1900) and to pursue efforts to limit the temperature increase even further to 1.5°C. However, it is important to note that warming assessed in this report is representative of land-based warming, while the Paris Agreement aim includes both land and ocean temperatures. Globally, land is warming faster than oceans, with Intergovernmental Panel on Climate Change (IPCC) assessments determining land warming at 1.6°C, ocean warming at 0.9°C and the combined land–ocean warming at 1.1°C.[23]

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

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

The financial cost of natural disasters is increasing in Victoria and is projected to be at least $185 billion cumulatively between 2020 and 2060.[24] Further detail is provided in indicator 'CCIm:10 Occurrence and impacts of extreme weather'.

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

Climate change

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

Inland regions of Victoria are projected to warm by a greater amount (2.4°C) compared to coastal regions (1.9°C) by the 2050s, while the number of very hot days is projected to double across the state by the 2050s, relative to the 1986–2005 reference period and under a high-emissions pathway.[25] The assessments for the 'Climate projections' indicators are generally based on results from the Victorian Climate Projections (VCP19) project. Since then, a new generation of global climate models have been developed as part of the Coupled Model Intercomparison Projects Phase 6 (CMIP6). These were featured in the IPCC Sixth Assessment Report (AR6), which included a new set of emission scenarios. The new modelling and scenarios are yet to be downscaled and applied for Victoria.

While the impact of global warming on Victoria's rainfall is expected to increase throughout the 21st century, significant natural variability will occur. In some years and decades this natural variability will exacerbate the underlying drying, while in other periods the underlying drying will be balanced out by natural climatic events such as La Niña.[26] By the 2050s, Victoria is likely to experience more extreme, short-duration rainfall despite an overall decrease in rainfall.[27, 28]

Tidal gauge data provided by BOM shows that mean and maximum sea levels are gradually increasing, and this is exerting pressure on human coastal settlements and infrastructure. Future rises are projected with high confidence, with sea levels expected to rise about 12 cm by 2030 at some places along Victoria's coastline, and 40 cm by 2070.[29] These projections are based on a high-emissions scenario (RCP8.5) and are relative to the levels observed for the 1986-2005 reference period.

Climate change mitigation

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

Climate change adaptation

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

25. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019', https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0029/442964/Victorias-Climate-Science-Report-2019.pdf Accessed 8 June 2023.
26. Department of Environment, Land, Water and Planning (DELWP), BOM, CSIRO, The University of Melbourne 2020, 'Victoria's water in a changing climate', https://apo.org.au/node/312270 Accessed on 8 June 2023.
27. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019', https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0029/442964/Victorias-Climate-Science-Report-2019.pdf Accessed 8 June 2023.
28. Clarke JM, Grose M, Thatcher M, Hernaman V, Heady C, Round V, Rafter T, Trenham C, Wilson L 2019, 'Victorian Climate Projections 2019: Technical report', CSIRO, Melbourne.
29. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019', https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0029/442964/Victorias-Climate-Science-Report-2019.pdf Accessed 8 June 2023.

Climate change

Successful climate change adaptation:

- is fundamental to our ongoing ability to function and achieve other climate goals, including GHG mitigation
- requires 'interventions that intentionally address the impacts and risks of climate change on natural and human systems' [30]
- reduces the negative consequences of interactions among existing systems and emergent climatic shifts, hazards and their flow-on effects
- includes not only the management of increasingly frequent and severe disasters, but also anticipation and prevention or mitigation of larger, longer-term, aggregate future threats.

Dead trees next to the pink salt lake in the Murray-Sunset National Park.
Credit: Brendan Markovich.

30. Pearce-Higgins JW, Antão LH, Bates RE, Bowgen KM, Bradshaw CD, Duffield SJ, Ffoulkes C, Franco AMA, Geschke J, Gregory RD, Harley MJ, Hodgson JA, Jenkins RLM, Kapos V, Maltby KM, Watts O, Willis SG, Morecroft MD 2022, 'A framework for climate change adaptation indicators for the natural environment', *Ecological Indicators*, 136, article no. 108690, https://www.sciencedirect.com/science/article/pii/S1470160X22001613 Accessed 9 June 2023.

Table CC1: Climate change indicators assessed in this chapter with comparisons to SoE 2018 assessments.

Climate change - Impacts

2023 Indicator	2023 status	2023 trend	2023 confidence	2018 Indicator	2018 status	2018 trend	2018 data quality
Climate							
CCIm:01 Observed surface temperature	🔴	↙	🟢	CC:03 Observed surface temperature	🟡	↙	🟢
CCIm:02 Observed average rainfall	🔴	↙	🟢	CC:01 Observed average rainfall	🔴	↙	🟢
CCIm:03 Snow cover	🟡 (Falls Creek, Mount Buller, Mount Hotham) 🔴 (Mount Baw Baw, Lake Mountain)	→ (Falls Creek, Mount Buller, Mount Hotham) ↙ (Mount Baw Baw, Lake Mountain)	🟡	CC:02 Snow cover	🟡	↙	🟢
CCIm:04 Sea level and coastal inundation	🟡	↙	🟢	CC:07 Observed sea level	🟡	↙	🟡 (at Victorian sites until 1993 because data until 1993 has not been formally standardised) 🟢 (at Victorian sites since 1993)
CCIm:05 Sea-surface temperature	🔴	→	🟢	CC:09 Sea-surface temperature	🔴	↙	🟢
Climate projections							
CCIm:06 Projected changes in temperature	N/A	↙	🟢	CC:04 Projected changes in temperature	N/A	↙	🟢

Climate change - Impacts

2023 Indicator	2023 status	2023 trend	2023 confidence	2018 Indicator	2018 status	2018 trend	2018 data quality
Climate projections							
CCIm:07 Projected changes to average rainfall	N/A	↙	Green	CC:05 Projected changes to average rainfall	N/A	↙	Yellow
CCIm:08 Regional climate projections	N/A	↙	Green	CC:06 Regional climate projections	N/A	↙	Green
CCIm:09 Projected sea level	N/A	↙	Green	CC:08 Projected sea level	N/A	↙	Green
CCIm:10 Occurrence and impacts of extreme weather	Red	↙	Green	CC:12 Occurrence and impacts of extreme weather	Red	↙	Green
Climate change - Mitigation							
CCM:11 Annual greenhouse gas emissions	Yellow	↗	Green	CC:10 Annual greenhouse gas emissions	Red	↗	Green
CCM:12 Victorian ecosystem carbon stocks	Yellow (land sector) Red (marine and coastal sector)	?	Red (land sector) Yellow (marine and coastal sector)	CC:11 Victorian ecosystem carbon stocks	Yellow (land sector) Grey (marine and coastal sector)	→ (land sector) ? (marine and coastal sector)	Yellow
CCM:13 Stratospheric ozone	Yellow	→	Green	A:05 Stratospheric ozone	Yellow	→	Green

Victorian Government progress on State of the Environment 2018 Report recommendations

The SoE 2018 Report included recommendations to the Victorian Government to improve environmental sustainability outcomes. Presented below is the recommendation specific to this chapter's themes as well as:

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

Recommendation 2 of the SoE 2018 Report recommended:

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

Government response in 2020:
SUPPORT

31. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Victorian Government response to the state of the environment 2018 report', Melbourne, Victoria.

'The Victorian Government supports the development of science, including improved projections and guidance to improve the useability of projections, to support decision-making across all regions of Victoria. The Government acknowledges the value of localised climate projections, noting however that localised projections do not reduce the large uncertainty in rainfall projections, because the large uncertainty in rainfall projections is a feature of the source global climate models.' [31]

'The Government has made a significant investment in improved climate projections, and in improved understanding of Victoria's climate variability through the following work streams:

- The Victorian Climate Initiative (VicCI) was a collaboration between the Department of Environment, Land, Water and Planning (DELWP), the Bureau of Meteorology (BOM), and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) that produced a set of climate and streamflow projections based on 42 global climate models, which have been used by all water corporations across Victoria when assessing the impacts of climate change on water availability.
- The Victorian Water and Climate Initiative (VicWaCI) is a collaboration between DELWP, BOM, CSIRO and the University of Melbourne, which builds on the VicCI by looking at the changes in catchment runoff response across Victoria, and better understanding how changes in Victorian rainfall over recent decades fits with projections of future rainfall declines. Like VicCI, the findings will support many actions including the development of guidelines issued by DELWP to water corporations for the application of VicWaCI findings to long-term climate change adaptation planning within the water sector.
- The Victorian Climate Projections project (VCP19) is a collaboration between DELWP and CSIRO that has produced new local-scale climate projections for the entire state of Victoria for medium- and high-emissions pathways, including rainfall. VCP19 has made a significant contribution to improved understanding of rainfall in Victoria through

localised scaled models that improve the simulation of rainfall, in part due to better representation of topography such as mountain ranges and coastlines. Key to this program is support by CSIRO climate scientists to assist users in understanding and applying the new data to different situations, which aids with the integration of data into decision-making.' [32]

'These are user-driven, collaborative research programs that focus on improving scientific understanding of changes in climate and increasing the capacity of users to apply the research outputs, which supports environmental decision-making informed by data and evidence. The existing research activities and products provide improved localised projections, along with supporting science that assists stakeholders to understand the range of uncertainties in projections so that they are able to make robust decisions.' [33]

'The work that DELWP has already undertaken fulfils this recommendation. Continued efforts will be required to further improve the understanding of the physical impacts of climate change on Victoria, including better understanding of the uncertainties associated with projections of future climate. Any investment in additional research and product development will be subject to stakeholder needs, including through the application of the next round of Intergovernmental Panel on Climate Change global climate models.' [34]

Progress made since 2018

The Victorian Government have fulfilled this recommendation, primarily through the completion of the Victorian Climate Projections project in 2019 that was a collaboration between DELWP and CSIRO.[35] The project produced new local-scale climate projections for the entire state of Victoria for medium- and high-emissions pathways, including rainfall. The project developed a set of 5 km datasets for use in impact/risk assessment. The datasets are accompanied by a set of products (e.g. Victoria's Future Climate Tool) designed to build the capacity of state and local government, business and the community to understand and apply climate change data and information.[36, 37]

Victoria's Climate Science Report 2019 brought together the latest knowledge gained from the Victorian Government's investment in climate science. The report provided insights into how our climate is changing and what it means for Victoria's future.[38]

The VicWaCI is a collaboration between DELWP, BOM, CSIRO and the University of Melbourne, and has investigated the changes in catchment runoff response across Victoria, to better understand how changes in Victorian rainfall over recent decades fits with projections of future rainfall declines. A key output from VicWaCI was the release of Victoria's Water in a Changing Climate in 2020 (amended February 2021), which provided a key source of information on the impact of climate on Victoria's water resources — the Victorian water sector is able to use this resource to inform future planning and policy decisions. The new findings were used to develop the 2020 edition of the Guidelines for Assessing the Impact of Climate Change on Water Availability in Victoria, and they provide a foundation for regional sustainable water strategies, urban water strategies, and informing water resource planning decisions.[39]

The Victorian Climate Projections 2019, Climate Science Report 2019 and the VicWaCI findings are incorporated within several indicator assessments and narratives of this SoE 2023 Report.

In 2020, the Victorian Government noted that continued efforts will be required to further improve the understanding of the physical impacts of climate change on Victoria, including better understanding of the uncertainties associated with projections of future climate.[40]

32. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Victorian Government response to the state of the environment 2018 report', Melbourne, Victoria.
33. Ibid.
34. Ibid.
35. Commonwealth Scientific and Industrial Research Organisation (CSIRO), 'Victorian climate projections 2019', https://www.climatechangeinaustralia.gov.au/en/projects/victorian-climate-projections-2019/ Accessed 22 July 2022.
36. Ibid.
37. Department of Environment, Land, Water and Planning (DELWP), 'Victoria's future climate tool', https://vicfutureclimatetool.indraweb.io/project Accessed 21 November 2022.
38. Department of Environment, Land, Water and Planning (DELWP), 'Victoria's changing climate', https://www.climatechange.vic.gov.au/victorias-changing-climate Accessed 21 November 2022.
39. Department of Environment, Land, Water and Planning (DELWP), 'Victorian water and climate initiative (2017–2024)', https://www.water.vic.gov.au/climate-change/climate-and-water-resources-research/the-victorian-water-and-climate-initiative Accessed 22 July 2022.
40. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Victorian Government response to the state of the environment 2018 report', https://www.environment.vic.gov.au/__data/assets/pdf_file/0017/504008/Victorian-Government-response-to-the-State-of-the-Environment-2018-report.pdf Accessed 22 July 2022.

Background

> 'The cumulative scientific evidence is unequivocal: Climate change is a threat to human well-being and planetary health. Any further delay in concerted anticipatory global action on adaptation and mitigation will miss a brief and rapidly closing window of opportunity to secure a liveable and sustainable future for all.' [41]

Climate research continues to show that temperatures, sea levels and sea-surface temperatures are rising in Australia.[42] 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.[43, 44] This SoE 2023 Report summarises 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, with the IPCC reporting in 2021 that human activities are responsible for approximately 1.1°C of global warming since the period of 1850 to 1900.[45]

The link between increasing GHG concentrations and climate change has been a growing area of focus for policy-makers since countries adopted the United Nations Framework Convention on Climate Change in 1992, which was a precursor to the adoption of the Kyoto Protocol in 1997 and the Paris Agreement in 2015.[46, 47, 48]

The challenges associated with mitigating and adapting to climate change impacts are significant. Rising to these challenges is a current and critical need as the magnitude of climate change, and its associated adverse impacts, are being increasingly experienced.

For Victoria, the Climate Science Report 2019 followed on from the findings and assessments made in the 'Climate change impacts' chapter of the SoE 2018 Report — highlighting the observed trends and local-scale projections of increased intensity and frequency of climate extremes such as heatwaves, high fire danger days and intense rainfall in the future.[49] The Climate Science Report 2019 report also built on the knowledge gained from the Victorian Government's investment in climate science, including the Victorian Climate Projections 2019 that were based on the global models that informed the IPCC 5th Assessment Report.[50] Key findings from the Victorian Climate Science Report 2019 and Victorian Climate Projections 2019 have been incorporated in the indicator assessments within the 'Climate change impacts' themes in this chapter.

The IPCC 6th Assessment Synthesis Report was released in 2023 — following earlier releases of contributions from Working Groups I, II and III in 2021 and 2022 — and it is expected to inform Victoria's next Climate Science Report that is due in 2024, ensuring the best available science informs climate action in Victoria.[51] It is imperative that planning and policy development continues to leverage climate science to enable decision-making that fully prepares Victoria to manage climate change impacts.

41. Intergovernmental Panel on Climate Change (IPCC) 2022', 'Summary for policymakers', [H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. In: *Climate change 2022: Impacts, adaptation, and vulnerability*, Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press.
42. Bureau of Meteorology (BOM), Commonwealth Scientific and Industrial Research Organisation (CSIRO) 2022, 'State of the climate 2022', http://www.bom.gov.au/state-of-the-climate/2022/documents/2022-state-of-the-climate-web.pdf Accessed 29 November 2022.
43. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Fact sheet 7: Climate change', Melbourne, Victoria, https://www.delwp.vic.gov.au/__data/assets/pdf_file/0022/416407/7-Climate-change-fact-sheet-FINAL.pdf Accessed 22 July 2022.
44. Commonwealth Scientific and Industrial Research Organisation (CSIRO) 2019, 'Victorian climate projections 2019: Technical Report'.
45. Intergovernmental Panel on Climate Change (IPCC) 2021, Climate Change 2021: The Physical Science Basis.', Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
46. United Nations (UN) 1998, 'Kyoto Protocol to the United Nations Framework Convention on Climate Change'.
47. United Nations (UN) 1992, 'United Nations framework convention on climate change'.
48. United Nations (UN) 2015, 'Paris Agreement'.
49. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019', Melbourne, https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0029/442964/Victorias-Climate-Science-Report-2019.pdf Accessed 22 July 2022.
50. Clarke JM, Grose M, Thatcher M, Hernaman V, Heady C, Round V, Rafter T, Trenham C, Wilson L 2019, 'Victorian climate projections 2019 technical report', Commonwealth Scientific and Industrial Research Organisation (CSIRO), Melbourne, Australia.
51. Intergovernmental Panel on Climate Change (IPCC), 'Sixth assessment report', https://www.ipcc.ch/assessment-report/ar6/ Accessed 10 May 2023.

Climate change

Climate change adaptation

This is the first time that the Victorian state of the environment reporting has included climate change adaptation as a standalone theme. Previous reports have highlighted or acknowledged indicators that have included a climate change adaptation component but not included a section committed to a climate change adaptation narrative.

Presented here is a framework for reporting on climate change adaptation progress in Victoria in future reports. The framework is a set of indicators designed to help secure Victoria by advancing climate change adaptation for, of and with the natural environment. The framework incorporates ten new indicators, as well as pre-existing indicators elsewhere in this report. The new indicators proposed here are not assessed.

Rooted in the inseparability of environmental sustainability and positive adaptation outcomes, the indicator framework will help track and monitor progress against the Victoria Government's seven inter-related AAPs (Figure CC1) and guide ongoing work on the RASs. Note that this is not an evaluation framework for the AAPs, but rather a guide to the data and information that needs to be collected in order to establish the scientific evidence-base for tracking progress on how Victoria, its communities and its natural environment are adapting to climate change.

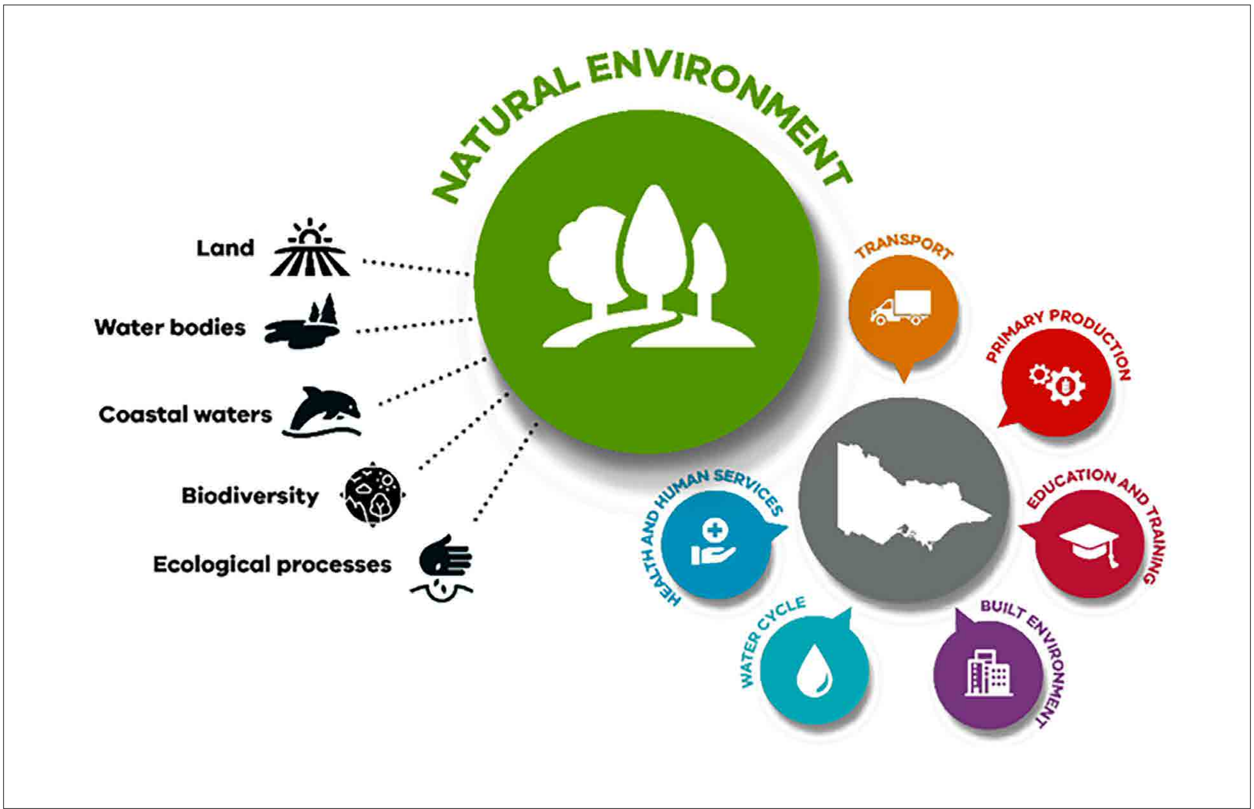

Figure CC1: The seven systems or sectors used to structure climate change adaptation in Victoria via a related series of Adaptation Action Plans. Each coloured circle represents a system. The natural environment system is centred here, but environmental sustainability is fundamental to all the systems.

The framework emphasises that the natural environment is the foundation of all the other systems, shaping the climate change risk we face and the success of our adaptation efforts. The natural environment (consisting of air, land, water, plants, animals) fundamentally provides not only the context in which human systems and regions exist, but specific ecological services that enable human life and activities to occur. A high-level overview of the ecological services that the AAP systems in Victoria rely upon is provided in Table CC2.

Table CC2: Examples of the ecological services that Victoria's seven adaptation systems rely on.

System	Example ecological services the system relies on to operate			
	Provisioning	Supporting	Regulating	Cultural
Natural environment (sector)	Iconic plants and animals High amenity landscapes and tourism destinations Water and food resources for participants Wood resources for infrastructure	Habitat for biodiversity Water and nutrient cycling Genetic diversity	Microclimate & global climate regulation Pest and disease control	Connection to Country and place Shared sense of identity for Victorians
Transport	Water and food resources for participants Water resources for equipment Destinations for travellers Commodities transported Wood resources for infrastructure	Stable foundations for transport infrastructure Drainage and flood control	Air quality for workers and travellers Microclimate for equipment function	Mental health Desire to travel
Primary production	Commodity species Land resources Water resources for production Bioenergy resources Wood resources for infrastructure Water and food resources for participants	Water and nutrient cycling Stable foundations for operations Genetic diversity Habitat for biodiversity Pollination	Microclimate and global climate regulation Pest and disease control Decomposition and soil formation	Connection to place Mental health
Education and training	Water and food resources for participants Amenity for staff and students	Water and nutrient cycling Drainage and flood control Stable foundations for operations	Microclimate and global climate regulation Disease control (including COVID-19)	Learning opportunities Connection to place Mental health Shared sense of identity
Built environment	Water and food resources for participants Land resources Energy resources Wood resources for infrastructure	Water and nutrient cycling Drainage and flood control Stable foundations for operations	Microclimate and global climate regulation Disease control (including COVID-19)	Connection to place Mental health Shared sense of identit
Water cycle	Water and food resources for participants Land resources Energy resources	Water and nutrient cycling, including land application of biosolids Drainage and flood control	Microclimate and global climate regulation Pathogen and disease control (including in biosolids management)	Cultural water flows and connection to Country
Health and human services	Water and food resources for participants Open space for physical exercise	Water and nutrient cycling Drainage and flood control Stable foundations for operations	Microclimate and global climate regulation Pathogen and disease control	Mental health and wellbeing

Climate change

Successful climate change adaptation is fundamental to our ongoing ability to function or achieve any other goal, including greenhouse gas mitigation. It involves 'interventions that intentionally address the impacts and risks of climate change on natural and human systems'.[52] It reduces the negative consequences of interactions between all existing systems and emergent climatic shifts, hazards and their flow-on effects. It includes not only the management of increasingly frequent and severe disasters but anticipation and avoidance of larger, longer-term, aggregate future threats.

Adaptation for, of and with the natural environment needs to comprehensively take account of the dynamic changes, needs and risks that the multidirectional interaction of natural and human systems creates. Environmental degradation is a climate impact engine. By undermining current systems, degraded environments convert climate-related pressures into serious impacts for human and natural systems alike, driving further degradation. Under climate change, environmental degradation is both a lag and lead indicator of adaptation success. Improving and monitoring the state of our environment is therefore more vital than ever.

International initiatives such as the IPBES Global Assessment Report on Biodiversity and Ecosystem Services and the new Taskforce on Nature-Related Financial Disclosures all emphasise that natural systems are essential to human survival and wellbeing, as well as to greenhouse gas mitigation and carbon sequestration. Yet, environmental considerations are not yet comprehensively incorporated into climate change adaptation, nor is adaptation yet comprehensively incorporated into environmental and sustainability work. This SoE report begins to redress this need by including this new chapter on adaptation.

Policy and legislative settings

The *Climate Change Act 2017* (CC Act) took effect on 1 November 2017 establishing a long-term emissions reduction target for Victoria of net zero by 2050. The CC Act provides a legislative framework to adapt statewide systems to address the impacts of climate change and transition Victoria to a climate-resilient community and economy.[53]

The CC Act requires Government to:

- produce periodic reports, including annual GHG emissions reports as well as standalone reports on the science and data relevant to climate change in Victoria.[54]
- develop a Climate Change Strategy every five years from 2020. That strategy must include five-yearly interim GHG emission reduction targets, five-yearly sector pledges to reduce emissions to achieve those targets and adaptation priorities.
- develop Adaptation Action Plans every five years from 2021 for key systems vulnerable to the impacts of climate change that are highlighted in the Climate Change Strategy.

The first Climate Science Report was released in 2019 and synthesised the latest climate change science and its implications for Victoria. The report uses the Victorian Climate Projections 2019 that were developed in association with Recommendation 2 from the SoE 2018 Report to present local-scale projections. By continually improving models and updating projections, Victoria's climate science reporting serves as the evidence base for taking informed and robust action to adapt to the range of potential climate futures and build resiliency among the Victorian community against climate change impacts.

Victoria's roadmap to net-zero and climate resilience

Victoria's first Climate Change Strategy was published in 2021 and is a 5-year roadmap to net-zero emissions by 2050.[55, 56] The plan outlines GHG emission reduction targets for 2025 and 2030 along with the actions for achieving those targets.

The interim GHG emissions reduction targets are required to be set for 5-year periods to keep Victoria on track to meet the long-term net zero target. Victoria's interim target for 2020 was to reduce emissions by 15% to 20% below 2005 levels.[57] Shortly before the publication of the SoE 2018 Report, the Victorian

52. Pearce-Higgins J W, Antão L H, Bates R E, Bowgen K M, Bradshaw C D, Duffield S J, Ffoulkes C, Franco A M A, Geschke J, Gregory R D, Harley M J, Hodgson J A, Jenkins R L M, Kapos V, Maltby K M, Watts O, Willis S G, Morecroft M D 2022, 'A framework for climate change adaptation indicators for the natural environment', Ecological Indicators, 136, 108690, https://doi.org/https://doi.org/10.1016/j.ecolind.2022.108690 Accessed 5 July 2023.
53. Office of the Chief Parliamentary Counsel Victoria 2017, '*Climate Change Act 2017*', Melbourne, Victoria, https://content.legislation.vic.gov.au/sites/default/files/2020-05/17-5aa005%20authorised.pdf Accessed 1 September 2022.
54. Department of Environment, Land, Water and Planning (DELWP), *'Climate Change Act 2017'*, https://www.climatechange.vic.gov.au/legislation/climate-change-act-2017 Accessed 22 July 2022.
55. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Victoria's climate change strategy', Melbourne, Victoria, https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0026/521297/Victorian-Climate-Change-Strategy.pdf Accessed 1 September 2022.
56. Since the release of *Victoria's Climate Change Strategy* in 2021, the Victorian Government had moved forward the net-zero emissions target to 2045.
57. Department of Environment, Land, Water and Planning (DELWP), 'Victoria's greenhouse gas emissions and targets', https://www.climatechange.vic.gov.au/victorias-greenhouse-gas-emissions-and-targets Accessed 22 July 2022.

Climate change

Government determined interim targets to reduce emissions by 28% to 33% below 2005 levels by 2025, and 45% to 50% by 2030.[58] In 2022, the Victorian Government committed to an emissions reduction target of 75% to 80% by 2035, and to bring forward its net zero emissions target by five years to 2045.[59] The government intends to legislate the 2035 and 2045 targets in 2023.[60]

To help meet these targets, the Victorian Government prepared emissions reduction pledges for the period from 2021 to 2025 — the first in a progression of five-yearly pledges required under the CC Act.[61] The emissions reduction pledges for the period from 2021 to 2025 are detailed in Table CC3.

Table CC3: Victoria's emissions reduction pledges for the period from 2021 to 2025.[62]

Sector	Pledge summary
Agriculture	This pledge will deliver foundational actions that will ensure farmers are preparing to achieve emissions reductions towards 2030. New technologies and practices will be tested for the Victorian context, and farmers will be supported to use information and tools that will help realise emissions reduction opportunities on-farm.
Energy	This pledge will accelerate Victoria's transition to a clean and efficient energy future, ensuring that 50% of Victoria's electricity will come from renewable sources by 2030. Rebates will be provided to 778,500 households for solar panels, solar hot water systems and batteries, and 15,000 small businesses will receive rebates for solar panels. Note that further information on policies and legislation relating to the energy sector can be found in the 'Energy' chapter of this report.
Industrial processes and product use	This pledge will improve the maintenance and management of refrigeration and air conditioning equipment to reduce leakage of refrigerant gases.
Land use, land use change and forestry	This pledge reflects that, from 2030, commercial native timber harvesting in Victoria's state forests will cease – protecting an area of native forest greater than the landmass of Tasmania. The pledge will also lead to the restoration of degraded landscapes and the planting of up to 30 million trees, helping to remove emissions from the atmosphere. The Victorian Forestry Plan will assist the forestry industry as it manages its gradual transition away from native forest harvesting to a plantation-based timber supply.[63] Note that further information on policies and legislation relating to the forestry sector can be found in the 'Forests' chapter of this report.
Transport	This pledge will accelerate the transition to zero-emission vehicles (ZEVs) by setting a 50% ZEV target for all new light-vehicle sales by 2030. A $100 million package of new policies and programs will ensure Victoria is a leader in the adoption of ZEVs in Australia and position the state to take full advantage of the emerging global shift towards this new technology. Victoria committed to ensuring all new public buses are ZEVs from 2025 and to increase active transport (cycling and walking) to 25% of all trips by 2030.[64] In November 2021, Victoria was a signatory to the Conference of the Parties 26 (COP26) declaration on accelerating the transition to 100% zero emission cars and vans.[65]
Waste	This pledge will halve the amount of organic waste going to landfill by 2030, while supporting emerging waste and recycling industries and economic opportunities across the state. Note that further information on policies and legislation relating to the waste sector can be found in the 'Waste and resource recovery' chapter of this report.
Whole of Victorian Government	This pledge will see all Victorian Government operations — including schools, hospitals and metropolitan trains and trams — powered by 100% renewable electricity by 2025. The Victorian Government will also cut emissions with more energy-efficient buildings and infrastructure and bring 400 ZEVs into the government fleet by 2023.

58. Department of Environment, Land, Water and Planning (DELWP), 'Climate action targets', https://www.climatechange.vic.gov.au/climate-action-targets Accessed 20 October 2022.
59. The Hon Daniel Andrews MP 2022, 'Putting power back in the hands of Victorians', Media Release 20 October 2022.
60. Department of Environment, Land, Water and Planning (DELWP), 'Climate action targets', https://www.climatechange.vic.gov.au/climate-action-targets Accessed 20 October 2022.
61. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Victoria's climate change strategy', Melbourne, Victoria, https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0026/521297/Victorian-Climate-Change-Strategy.pdf Accessed 22 July 2022.
62. Department of Environment, Land, Water and Planning (DELWP), 'Victorian Government action on climate change', Melbourne, Victoria, https://www.climatechange.vic.gov.au/victorian-government-action-on-climate-change#pledges Accessed 22 July 2022.
63. Department of Jobs, Precincts and Regions (DJPR) 2021, 'Victorian forestry plan', https://djpr.vic.gov.au/__data/assets/pdf_file/0012/2042040/13318-VIC-Forestry-Plan_V2_FA_WEB.pdf Accessed 28 October 2022.
64. Department of Transport (DOT), 'Transport sector emissions reduction pledge', https://transport.vic.gov.au/our-transport-future/climate-change/transport-sector-emissions-reduction-pledge Accessed 18 November 2022.
65. Department of Environment, Land, Water and Planning (DELWP) 2022, 'Clean air for all Victorians', Melbourne, Victoria, https://www.environment.vic.gov.au/__data/assets/pdf_file/0032/603977/Victorias-air-quality-strategy.pdf Accessed 10 February 2023.

Climate change

Additional to the whole-of-government pledge summarised in Table CC3, local governments were encouraged to make voluntary pledges associated with actions that will reduce emissions related to the performance of a council's powers and duties under the *Local Government Act 2020*.[66] As at 26 July 2022, 21 Victorian councils had submitted Council Pledges under Victoria's CC Act.[67]

Climate change adaptation

The Climate Change Strategy also provides a pathway for Victoria becoming climate resilient by 2050 by identifying Victoria's adaptation priorities to address current climate change impacts, reduce barriers and establish the foundations for transformational adaptation. Together, these actions are aimed at supporting Victorian communities and businesses for achieving the 2050 objectives of:

- Climate-resilient built and natural environments
- Prosperous, liveable and healthy communities
- An orderly and just adaptation process.

Climate change responses are being integrated into federal, state and local government policies and strategies across many sectors. There are notable examples of this in the marine and coastal sector, with the Marine and Coastal Policy 2020 which identifies climate change as a key threat to the marine and coastal environment and requires decision makers to strengthen resilience to climate change.[68] Furthermore, there was a designated action to adapt to climate change in the Marine and Coastal Strategy 2022.[69] Examples from beyond the marine and coastal sector include a Building Victoria's Climate Resilience report detailing what Victoria is doing to adapt and build resilience to our changing climate, Victoria's zero emissions vehicle roadmap, Victoria's gas substitution roadmap, and the Victorian Renewable Hydrogen Industry Development Plan.[70, 71, 72]

System-based adaptation

The first AAPs were published in 2022 have been developed for seven key systems that are either vulnerable to climate impacts or critical to Victoria's climate resilience. The seven systems, and what they capture, include:

- Built environment: physical structures and assets, built and natural assets, and how people interact with them.
- Education and training: early childhood, school education, higher education and training and skills sectors.
- Health and human services: public health and wellbeing services and assets, social housing infrastructure, and support for vulnerable community members.
- Natural environment: land-based, aquatic, coastal, and marine ecosystems.
- Primary production: agricultural industries, plantation forestry, productive fisheries and the infrastructure, workforce, and communities supporting them.
- Transport: transport users, freight services, transport networks, facilities, systems and vehicles, and those that plan, design, operate and manage them.
- Water cycle: the collection, storage, treatment, delivery and supply of water, and the management of wastewater, drainage and flooding.

The seven AAPS were informed by system experts as well as public consultation and have been prepared by nominated Ministers. Under the CCA Act, the AAPs are required to be updated every five years to guide government action towards achieving the 5-year priorities and 2050 vision set out in *Victoria's Climate Change Strategy*. Each plan outlines the system-specific challenges of climate change, key risks, and adaptation actions for the next five years.

66. Department of Environment, Land, Water and Planning (DELWP), 'Council pledges', https://www.climatechange.vic.gov.au/local-government/council-pledges Accessed 28 November 2022.
67. Department of Environment, Land, Water and Planning (DELWP), 'Submitted council pledges', https://www.climatechange.vic.gov.au/local-government/council-pledges/submitted-council-pledges Accessed 28 November 2022.
68. Department of Environment, Land, Water and Planning (DELWP) 2020, "Marine and coastal policy', Melbourne, Victoria, https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0027/456534/Marine-and-Coastal-Policy_Full.pdf Accessed 18 November 2022.
69. Department of Environment, Land, Water and Planning (DELWP) 2022, 'Marine and coastal strategy', Melbourne, Victoria, https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0029/571817/Marine-and-Coastal-Strategy_May-2022.pdf Accessed 22 July 2022.
70. Department of Environment, Land, Water and Planning 2022, 'Gas substitution roadmap', Melbourne, Victoria, https://www.energy.vic.gov.au/__data/assets/pdf_file/0025/586411/Victorias-Gas-Substitution-Roadmap.pdf Accessed 20 October 2022.
71. State of Victoria 2022, 'Building Victoria's climate resilience', Melbourne, Victoria, https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0023/558140/BuildingVictoriaClimateResilience.pdf Accessed 22 July 2022.
72. Department of Environment, Land, Water and Planning (DELWP) 2021, Victorian renewable hydrogen industry development plan', Melbourne, Victoria, https://www.energy.vic.gov.au/data/assets/pdf_file/0021/513345/Victorian-Renewable-Hydrogen-Industry-Development-Plan.pdf Accessed 20 October 2022.

Climate change

During the 2022 to 2026 period, the key priorities of the AAPs are focused on:

- improving policies, standards and system-wide capacity to promote greater climate preparedness and resilience among public assets and government services, including infrastructure and services for highly exposed and vulnerable Victorians
- providing information, tools and capacity that enables climate ready decision-making, enhances skillsets as well as facilitates the development of new technologies and innovations in order to respond to a changing climate and build climate resilience of value chains
- establishing the practices, systems and knowledge that enables Victoria's natural environments to effectively adapt to climate impacts
- ensuring that the social and economic opportunities and benefits of a climate-resilient Victoria are available to all communities and individuals across the state now and into the future.[73]

Regional adaptation

RASs are community-led plans developed across six regions of Victoria which aim to strengthen resilience to climate change by building adaptive capacity and preparedness and delivering place-based, locally relevant adaptation action during the five-year period spanning from 2020 to 2025.[74] Regional climate projections and targeted guidance informed the strategies which complement the system-based Adaptation Action Plans by endeavouring to ensure that adaptation action is locally integrated and caters to the diversity of community needs, values and priorities across the state's different regions. The development of the RASs and initial implementation of priority projects was funded by the Supporting our Regions to Adapt program through the state's Sustainability Fund.

The key themes within the RASs include:

- preparing for and recovering from emergencies
- caring for the natural environment
- improving health and wellbeing
- strengthening the economy and workforce
- improving resilience of our built environment
- embracing renewable energy.

Local adaptation

Local governments play a critical role in supporting their communities to adapt to climate change as they are the first to respond to localised climate change impacts and their strong connections to the community and local knowledge mean they are often best placed to recognise the need for adaptation at a local scale.

On 24 March 2020, the Victorian *Local Government Act* was put into effect which amended the previous 1989 Act by strengthening the mandate for councils to consider climate change in their decision-making processes.[75] In accordance with the overarching and supporting principles defined in the *Local Government Act 2020*, Councils are required to:

- mitigate and plan for climate change risks
- give priority to achieving the best outcomes for the municipal community, including future generations.
- Incorporate regional, state, and national plans and policies into strategic planning processes.

To assist local government decision-makers understand the scope and deliver on their roles and responsibilities for adaptation under current Victorian legislation, the *Local Government Climate Change Adaptation Roles and Responsibilities Under Victorian Legislation* was developed in 2020.[76] This guidance brief sets out the duties of council staff under Victorian legislation in relation to climate change and describes a process for discharging those duties with appropriate due diligence.

73. Department of Environment, Land, Water and Planning (DELWP) 2022, 'Building Victoria's climate resilience', https://www.climatechange.vic.gov.au/building-victorias-climate-resilience/our-commitment-to-adapt-to-climate-change/adaptation-action-plans-a-major-step-forward-for-climate-resilience-in-victoria Accessed 1 September 2022.
74. Department of Environment, Land, Water and Planning (DELWP) 2022 'Supporting local action on climate change' https://www.climatechange.vic.gov.au/supporting-local-action-on-climate-change Accessed 1 September 2022.
75. Office of the Chief Parliamentary Counsel Victoria 2020, '*Local Government Act* 2020', Melbourne, Victoria, https://www.legislation.vic.gov.au/as-made/acts/local-government-act-2020 Accessed 1 September 2022.
76. DELWP 2020, 'Local government climate change adaptation roles and responsibilities under Victorian legislation', Melbourne, Victoria, https://www.climatechange.vic.gov.au/data/assets/pdf_file/0030/490476/Local-Government-Roles-and-Responsibilities-for-Adaptation-under-Victorian-Legislation_Guidance-Brief.pdf Accessed 18 October 2022

Monitoring evaluation, reporting and improvement framework for adaptation

Victoria's adaptation priorities to 2025 under Victoria's Climate Change Strategy includes the development and implementation of a long-term climate change adaptation Monitoring, Evaluation, Reporting and Improvement framework based on state-wide risk assessments. Insights gained will inform the development of the next climate change strategy and 5-yearly AAPs.

Indicator assessments

Refer to 'Guide to the indicator assessments' at the start of Part 3 for the accompanying definitions and legends related to the indicator assessment summary tables.

SoE indicator suite adjustments

State of the environment indicators are the foundational tools for evaluating and communicating the impact our activities have on the environment. The assessments of SoE 2018 indicators provided a scientific baseline of the state of Victoria's environment from which future SoE reports build upon.

However, as new pressures, challenges and data sources emerge, the SoE indicator suite must also evolve to ensure their collective assessments provide a comprehensive account of the condition of Victoria's natural values. The SoE 2023 indicator suite has been adjusted, with some new indicators being introduced and some existing indicators either being disaggregated to improve the focus of assessments, merged to enable inter-connected indicators to be evaluated as a whole, superseded, or modified in terms of the scope, breadth of measures or to align with policy targets. Refer to Appendix C of the Summary Report for a complete account of the changes that have been made to the SoE 2018 indicator suite in this report.

Changes to the indicator suite for this chapter are outlined below.

- The SoE 2018 indicators 'CC:14 Community awareness of climate risks and associated responsibilities', 'CC:15 Councils (or other organisations) with urban forestry plans or urban greening or cooling-related strategies', 'CC:16 Considering climate change risks in land-use planning (including the coastal zone)' and 'CC:17 Percentage of agri-businesses using long-term weather and climate change projections' have now been superseded by the indicators proposed within the new Climate Change Adaptation Framework introduced within this chapter.

Picnic table underwater at Hattah-Kulkyne National Park.
Credit: Nick Esser. © Parks Victoria.

Climate change — Impacts

Climate

Indicator CCIm:01 Observed surface temperature

CCIm:01 Observed surface temperature						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		↙			↙	

Data source(s):	BOM
Measure(s):	Victorian annual mean temperature anomaly Victorian annual maximum temperature anomaly Victorian annual minimum temperature anomaly Change in annual mean daily maximum temperatures since the pre-industrial period (1850–1900)

Why this indicator?

The global climate has changed relative to the pre-industrial period, and there are several lines of evidence that these changes have had impacts on organisms and ecosystems, as well as on human systems and wellbeing.

Australia is a signatory to the Paris Agreement, which has a central aim of strengthening the global response to the threat of climate change by keeping a global temperature rise this century well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase even further, to 1.5°C.

As a global average, human-induced warming reached approximately 1°C above pre-industrial levels in 2017. Warming greater than the global average has already been experienced in many regions and seasons, with higher average warming over land than over the ocean.

NB: This SoE 2023 indicator was 'CC:03 Observed surface temperature' in the SoE 2018 Report.

Why this assessment in 2023?

Victoria's temperature increases identified in the SoE 2018 Report have continued.

Each year since 1997 has been warmer in Victoria than the average for the 1961 to 1990 period. Furthermore, seven years during the past decade (2013–22) have been in the top 10 warmest years on record for Victoria.

Across Victoria, the mean annual temperature has increased by 1.4°C (within a range of 1.0–1.8°C) between the pre-industrial era and the most recent decade (2011–20). In Melbourne, annual average temperatures are approaching a 1.5°C increase from an indicative pre-industrial era temperature. Some years are now more than 1.5°C warmer than the indicative pre-industrial era baseline.

If the recent rate of temperature increase continues at the current trajectory of nearly 0.5°C per decade, temperatures in Melbourne will increase by approximately 2.5°C from pre-industrial levels by 2040.

Summary of State of the Environment 2018 Report assessment

- 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.

Critical data used for the 2023 assessment

- Climate Change – Trends and Extremes
- Long-term Temperature Record

2023 assessment

The climate of Victoria has been warming since the 1950s (Figure CCIm2). Each year since 1997 has been warmer in Victoria than the average for the period from 1961 to 1990. Furthermore, seven years during the past decade (2013-2022) have been in the top-ten warmest years on record for Victoria. The warmest year measured in Victoria was 2007, which was 1.24°C warmer than the average for 1961 to 1990.[77]

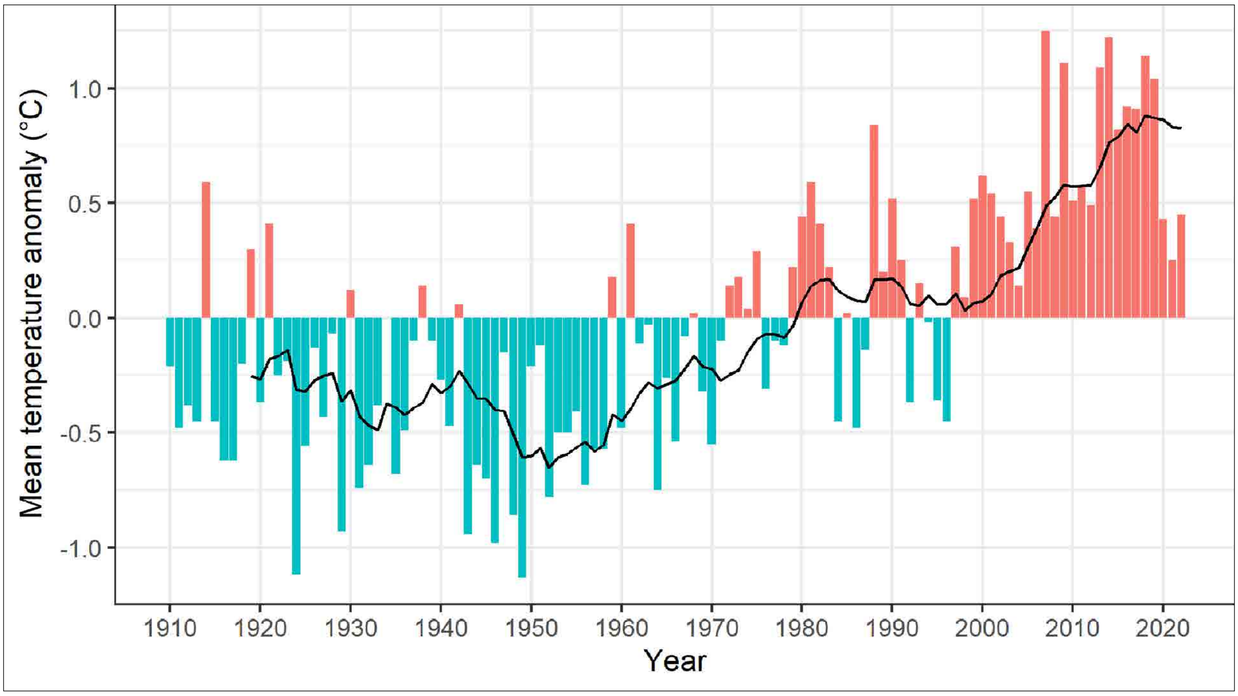

Figure CCIm2: Victorian mean temperature anomaly 1910 to 2022 (based on a 30-year climatology of 1961-1990 with a 10-year rolling average shown as the black line).[78, 79]

The greatest warming, measured as the linear trend across Victoria from 1910 to 2022, has been observed in summer (+0.15°C per decade), with the least warming observed in winter (+0.08°C per decade) - parts of south-east Australia have seen significant cool-season drying, and hence more clear winter nights.[80, 81] The warming has been observed in both maximum (daytime) and minimum (overnight) temperatures.

All parts of Victoria have warmed since the 1950s (Figure CCIm3 to Figure CCIm5). The most warming during daytime has generally occurred in northern regions, while overnight temperatures have warmed the most across south-western coastal areas.

77. Bureau of Meteorology (BOM), 'Climate change – Trends and extremes', http://www.bom.gov.au/climate/change indextml#tabs=Tracker&tracker=timeseries&tQ=graph%3Dtmean%26area%3Daus%26season%3D0112%26ave_yr%3D0 Accessed 11 April 2022.
78. Bureau of Meteorology (BOM), 'Climate change – Trends and extremes', http://www.bom.gov.au/climate/change/index.shtml#tabs=Tracker&tracker=timeseries&tQ=graph%3Dtmean%26area%3Dvic%26season%3D0112%26ave_yr%3D0 Accessed 13 February 2023.
79. The average for 1961 to 1990 is 14.1°C.
80. Bureau of Meteorology (BOM), 'Climate change – Trends and extremes', http://www.bom.gov.au/climate/change/index.shtml#tabs=Tracker&tracker=timeseries Accessed 11 April 2022.
81. Commonwealth Scientific and Industrial Research Organisation (CSIRO), Bureau of Meteorology (BOM) 2022, 'State of the climate 2022', http://www.bom.gov.au/state-of-the-climate/2022/documents/2022-state-of-the-climate-web.pdf Accessed 29 November 2022.

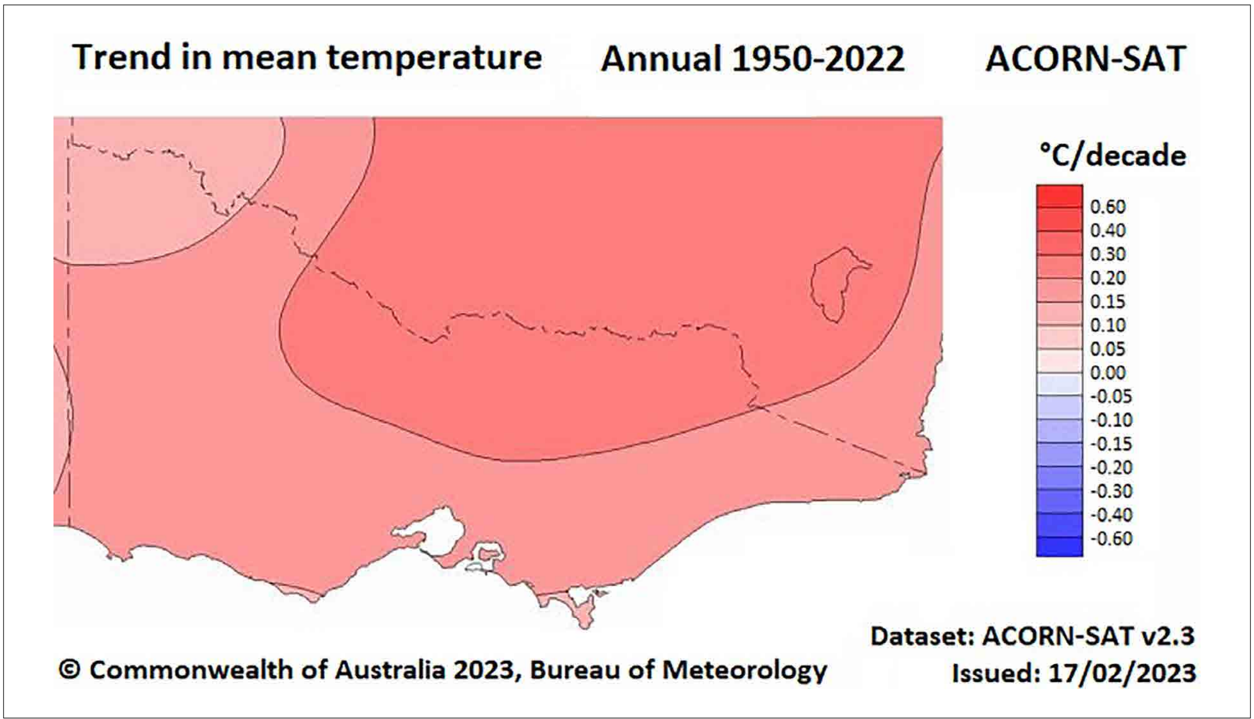

Figure CCIm3: Trends in Victorian mean temperatures for the period between 1950 and 2022.[82]

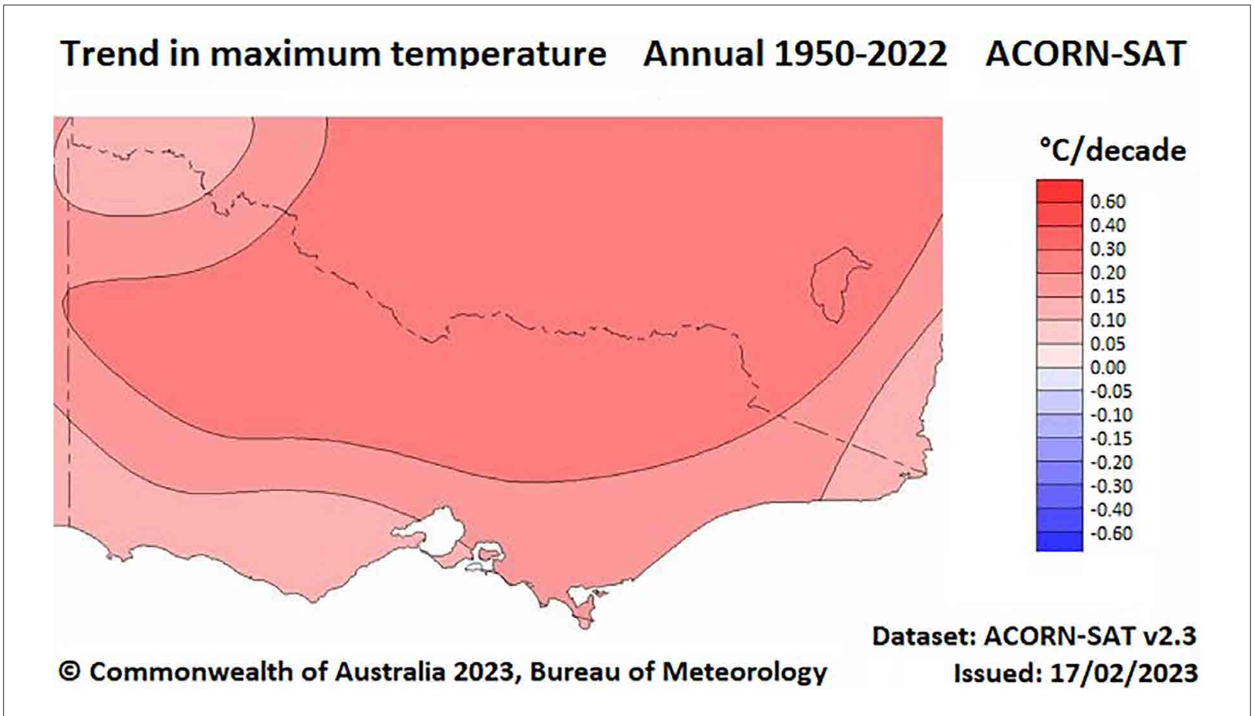

Figure CCIm4: Trends in Victorian maximum temperatures for the period between 1950 and 2022.[83]

82. Bureau of Meteorology (BOM), 'Climate change – Trends and extremes', http://www.bom.gov.au/climate/change/#tabs=Tracker&tracker=trend-maps&tQ=map%3Dtmean%26area%3Dvic%26season%3D0112%26period%3D1950 Accessed 13 February 2023.
83. Bureau of Meteorology (BOM), 'Climate change – Trends and extremes', http://www.bom.gov.au/climate/change/#tabs=Tracker&tracker=trend-maps&tQ=map%3Dtmax%26area%3Dvic%26season%3D0112%26period%3D1950 Accessed 13 February 2023.

Climate change — Impacts

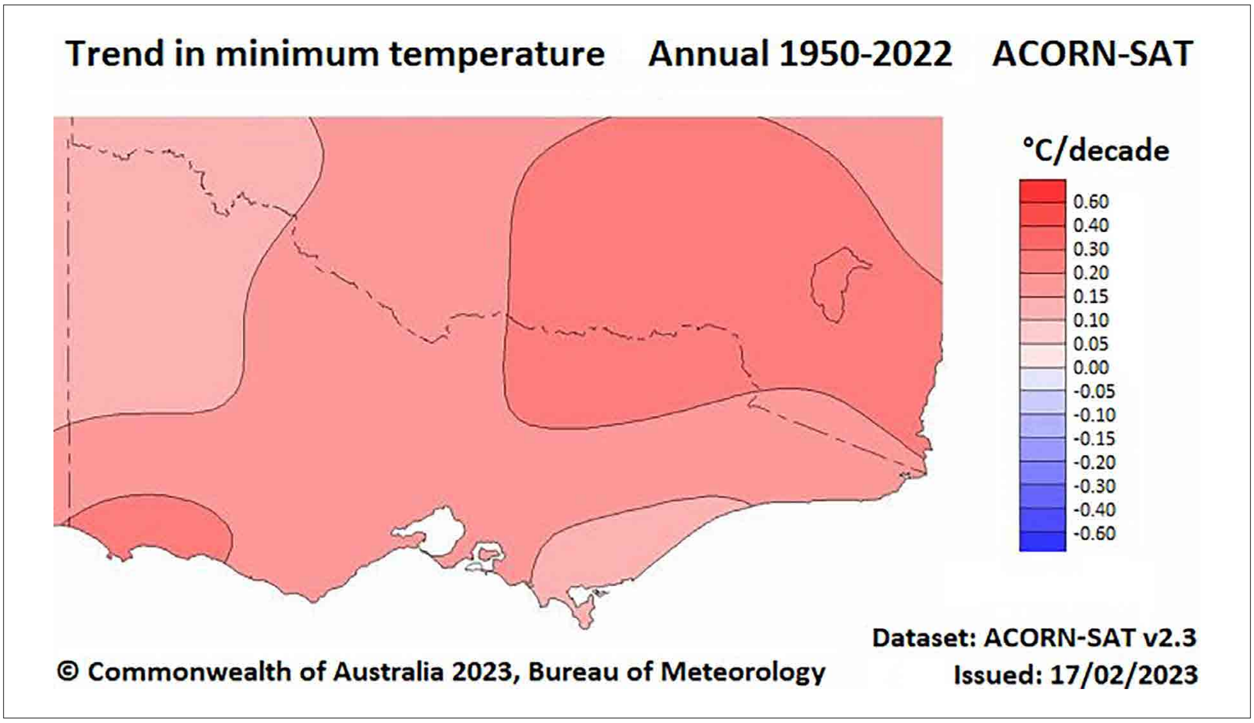

Figure CCIm5: Trends in Victorian minimum temperatures for the period between 1950 and 2022.[84]

Australia is a signatory to the Paris Agreement, which has a central aim of strengthening the global response to the threat of climate change by keeping global temperature rise this century well below 2°C above pre-industrial levels (the pre-industrial period was defined as 1850-1900) and to pursue efforts to limit the temperature increase even further to 1.5°C.[85] However, it is important to note that the warming assessed in this indicator is representative of land-based warming. The Paris Agreement aim includes both land and ocean temperatures. Globally, land is warming faster than oceans, with IPCC assessments determining land warming at 1.59°C for the 2011 to 2020 period compared to 1850 to 1900 period, while ocean warming was at 0.88°C and the combined land/ocean warming at 1.09°C.[86]

The ACORN-SAT is the dataset used by BOM to monitor long-term temperature trends in Australia. ACORN-SAT uses observations from 11 weather stations across Victoria, selected for the quality and length of their available temperature data.[87] Via the ACORN-SAT network, temperature data are available for eight locations across Victoria since 1910 — the locations are: Cape Otway, Gabo Island, Kerang, Melbourne, Mildura, Nhill, Sale and Wilsons Promontory.

Reliable temperature records are not available for Melbourne prior to 1910, however, indicative temperature measurements were recorded at BOM's Melbourne Regional Office from 1855. Analysis of these data for the Melbourne Regional Office weather station indicates that the average of annual mean daily maximum temperatures during the pre-industrial period to 1900 was within 0.1°C of the average for the period 1910 to 1959 (the first 50-year period of ACORN-SAT data). Hence, we assume the first 50 years of ACORN-SAT temperature data for Melbourne is reasonably representative of the 'pre-industrial' temperature levels. Therefore, a temperature of 19.06°C (the average of the ACORN-SAT temperatures for Melbourne from 1910-1959) has been used as an indicative reference value for Melbourne's pre-industrial temperature,

84. Bureau of Meteorology (BOM), 'Climate change – Trends and extremes', http://www.bom.gov.au/climate/change/#tabs=Tracker&tracker=trend-maps&tQ=map%3Dtmax%26area%3Dvic%26season%3D0112%26period%3D1950 Accessed 13 February 2023.
85. United Nations (UN) 2015, 'Paris agreement'.
86. Intergovernmental Panel on Climate Change (IPCC) 2021, 'Climate change 2021: The physical science basis.', Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
87. Bureau of Meteorology (BOM) 2021, 'Long-term temperature record', http://www.bom.gov.au/climate/data/acorn-sat/ Accessed 10 November 2022.

Climate change — Impacts

which enables an indicative assessment of how temperature levels in Melbourne are tracking against the 1.5°C and 2°C targets in the Paris Agreement.

The average of annual mean daily maximum temperatures for Melbourne during the most recent decade (2012-2021) was 20.55°C, which means that current temperatures are approaching a 1.5°C degree increase from the indicative pre-industrial era temperature.[88] Indeed, some years are now more than 1.5°C warmer than the indicative pre-industrial era baseline, with nine of the most recent 20 years (that is, during the period of 2002-2021) being more than 1.5°C warmer than the indicative pre-industrial era temperature. Furthermore, four of the past five years (during the period of 2017-2021) were more than 1.65°C warmer than the indicative pre-industrial era temperature.

On a decadal basis, Melbourne has warmed by 0.99°C from an average of 19.55°C (1992-2001) to 20.53°C (2012-2021). If the recent rate of temperature increase continues at the current trajectory of nearly 1°C across a 20-year period, temperatures in Melbourne will have increased by approximately 2.5°C from pre-industrial levels by the 2040s.

Across Victoria, research published in 2023 details that the mean annual temperature has increased by 1.4°C (within a range of 1.0°C to 1.8°C) between the pre-industrial era (1850-1900) and the most recent decade (2011-2020).[89]

Indicator CCIm:02 Observed average rainfall

CCIm:02 Observed average rainfall

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	●	↙	●	●	↙	●
Data source(s):	BOM					
Measure(s):	Victorian annual rainfall anomaly Victorian rainfall deciles for the warm and cool seasons					

Why this indicator?

Rainfall strongly influences the agriculture and water resources sectors as it is important for many crops and for replenishing reservoirs. The timing and intensity of rainfall can influence the severity of pluvial and riverine floods, which have social and community impacts, as well as environmental impacts for sediment and pollutants entering bays.

NB: This SoE 2023 indicator was 'CC:01 Observed average rainfall' in the SoE 2018 Report.

Why this assessment in 2023?

Despite the year-to-year rainfall variability, below-average rainfall has been recorded most years since the late 1990s, which highlights an emerging drying trend. This has been influenced by declining cool-season rainfall. Above-average rainfall (relative to the period 1961–1990) has only been recorded for six of the past 25 years in Victoria.

88. As at February 2023, ACORN-SAT data for Melbourne was available up until the end of 2021.
89. Grose MR, Boschat G, Trewin B, Round V, Ashcroft L, King AD, Narsey S, Hawkins E 2023, 'Australian climate warming: observed change from 1850 and global temperature targets', *Journal of Southern Hemisphere Earth Systems Science*, https://doi.org/10.1071/ES22018 Accessed 20 February 2023.

Climate change — Impacts

Summary of State of the Environment 2018 Report assessment

- 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.

Critical data used for the 2023 assessment

- Climate Change – Trends and Extremes

2023 assessment

Rainfall over Victoria is highly variable from year-to-year in response to large-scale climate drivers, such as the El Niño-Southern Oscillation, and a range of weather systems over different timescales.[90]

Since the publication of SoE 2018, there were two very dry years in 2018 and 2019 before three years that were influenced by La Niña events, including the very wet year of 2022 and the slightly wetter than average years of 2020 and 2021.

Despite the year-to-year rainfall variability, there is an emerging drying trend which means below-average rainfall has been recorded most years since the late 1990s. The below-average rainfall conditions have dominated the climate and extended the overall drying pattern affecting the state. Above-average rainfall (relative to the period from 1961-1990) has only been recorded for six of the past 25 years in Victoria (Figure CCIm6). Exceptions of wetter years have occurred during La Niña events (2010-2011 and 2020-2022) and in association with a strong negative Indian Ocean Dipole (2016).

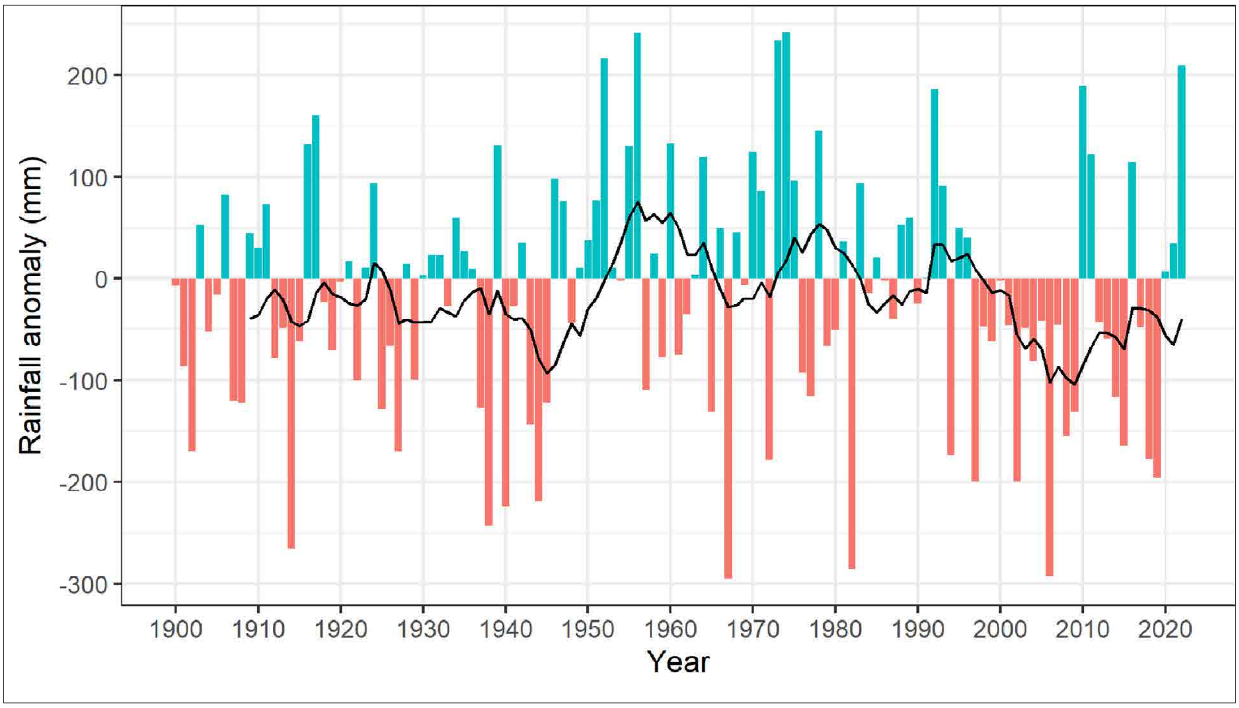

Figure CCIm6: Victorian mean rainfall anomaly from 1900 to 2022 (based on a 30-year climatology of 1961-1990 with a 10-year rolling average shown as the black line).[91, 92]

90. Department of Environment, Land, Water and Planning (DELWP), Bureau of Meteorology (BOM), Commonwealth Scientific and Industrial Research Organisation (CSIRO), University of Melbourne 2020, 'Victoria's water in a changing climate', https://www.water.vic.gov.au/__data/assets/pdf_file/0024/503718/VICWACI_VictoriasWaterInAChangingClimate_FINAL.pdf Accessed 11 April 2022.
91. Bureau of Meteorology (BOM), 'Climate change – Trends and extremes', http://www.bom.gov.au/climate/change/index.shtml#tabs=Tracker&tracker=timeseries&tQ=graph%3Drranom%26area%3Dvic%26season%3D0112%26ave_yr%3D11 Accessed 18 July 2022.
92. The average rainfall for 1961-1990 is 663.4 mm.

Climate change — Impacts

The variability and timing of extremes differ by season. Around two-thirds of Victoria's total annual rain falls during the cool season (April to October). The drying climate during this century has mainly been affecting the cool season, with Figure CCIm7 showing most of Victoria having received between below-average to record low cool-season rainfall for the period since the start of the Millennium Drought in 1997. The decline in cool-season rainfall has consequences for agriculture, water resources and water quality, as this rainfall is important for many crops and for replenishing reservoirs.[93, 94]

Cool-season rainfall was the lowest on record when averaged across the state during the Millennium Drought (1997–2009; top centre of Figure CCIm7). It has continued to be low across the state (top right of Figure CCIm7) and, for many locations, the 23 years from 1997-2019 have had the lowest cool-season rainfall compared to any other 23-year period which ended with increased rainfall from 2020-2022 that occurred in association with a La Niña state.[95] Despite the increased rainfall from 2020, the significant decline in the cool season across the period since the start of the Millennium Drought has led to the status assessment of deteriorating for this indicator.

A key finding from the Victorian Water and Climate Initiative during 2020 was that the decline in cool-season rainfall in recent decades is unlikely to have been as large without the influence from increasing levels of atmospheric GHGs.[96, 97] This means the declining rainfall experienced during the past two decades may be indicative of a longer-term change.

Since the beginning of the Millennium Drought in 1997, warm-season (November to March) rainfall has generally been above average in northern Victoria and below average in southern Victoria (Figure CCIm7).

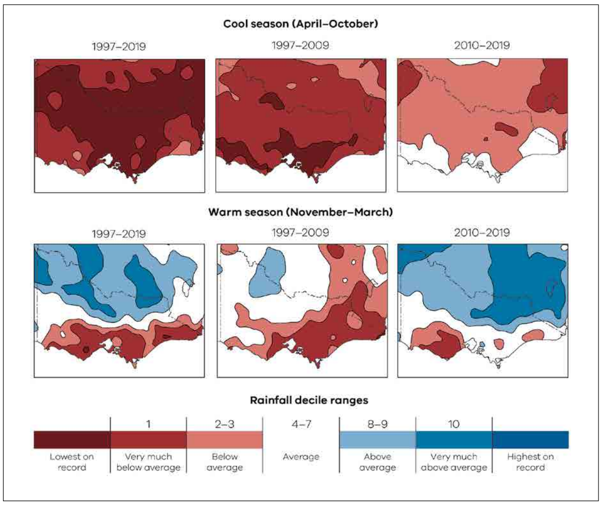

Figure CCIm7: Rainfall decile maps for the cool season (April–October, top row) and warm season (November–March, bottom row) in Victoria for the period since the start of the Millennium Drought (1997-2019), during the Millennium Drought (1997-2009) and the years following the Millennium Drought (2010-2019).[98, 99, 100]

93. Delage FPD, Power SB 2020, 'The impact of global warming and the El Niño-Southern Oscillation on seasonal precipitation extremes in Australia', *Climate Dynamics*, 54, pp. 4367-4377.
94. Rauniyar SP, Power SB 2020, 'The impact of anthropogenic forcing and natural processes on past, present and future rainfall over Victoria, Australia', *Journal of Climate*.
95. Department of Environment, Land, Water and Planning (DELWP), Bureau of Meteorology (BOM), Commonwealth Scientific and Industrial Research Organisation (CSIRO), University of Melbourne 2020, 'Victoria's water in a changing climate', https://www.water.vic.gov.au/__data/assets/pdf_file/0024/503718/VICWACI_VictoriasWaterInAChangingClimate_FINAL.pdf Accessed 11 April 2022.
96. The Victorian Water and Climate Initiative is a partnership between the Victorian Department of Environment Land, Water and Planning (DELWP), the Bureau of Meteorology (BOM), University of Melbourne and the Commonwealth Scientific and Industrial Research Organisation (CSIRO
97. Department of Environment, Land, Water and Planning (DELWP), Bureau of Meteorology (BOM), Commonwealth Scientific and Industrial Research Organisation (CSIRO), University of Melbourne 2020, 'Victoria's water in a changing climate', https://www.water.vic.gov.au/data/assets/pdf_file/0024/503718/VICWACI_VictoriasWaterInAChangingClimate_FINAL.pdf Accessed 11 April 2022.
98. Department of Environment, Land, Water and Planning (DELWP), Bureau of Meteorology (BOM), Commonwealth Scientific and Industrial Research Organisation (CSIRO), University of Melbourne 2020, 'Victoria's water in a changing climate', https://www.water.vic.gov.au/data/assets/pdf_file/0024/503718/VICWACI_VictoriasWaterInAChangingClimate_FINAL.pdf Accessed 11 April 2022.
99. Evans A, Jones D, Smalley R, Lellyett S 2020, 'An enhanced gridded rainfall analysis scheme for Australia', Bureau Research Report – BRR041.
100. The graphs in the left column represent the full period since the start of the Millennium Drought in 1997 (1997–2019), relative to all other 23-year periods. The graphs in the middle column represent the Millennium Drought years (1997–2009), relative to all other 13-year periods. The graphs in the right column represent the years following the Millennium Drought (2010–2019), relative to all other 10-year periods.

Indicator CCIm:03 Snow cover

CCIm:03 Snow cover						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Victoria's alpine region	(Falls Creek, Mount Buller, Mount Hotham) (Mount Baw Baw, Lake Mountain)	(Falls Creek, Mount Buller, Mount Hotham) (Mount Baw Baw, Lake Mountain)				
Data source(s):	Academic researchers, DELWP					
Measure(s):	Average natural snow depths at Victorian alpine resorts					

Why this indicator?

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

NB: This SoE 2023 indicator was 'CC:02 Snow cover' in the SoE 2018 Report.

Why this assessment in 2023?

Natural snow depths in July and August have been generally stable at the higher-altitude resorts of Falls Creek, Mount Buller and Mount Hotham. Results at these locations for July and August 2011 to 2020 are within 10% of the depths for 1993 to 2002, with slight increases in natural snow depth measured at Falls Creek and Mount Buller.

For the lower altitude alpine resort locations (Lake Mountain and Mount Baw Baw), the observations show a gradual, but steady, deterioration in natural snow depth.

Summary of State of the Environment 2018 Report assessment

- 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 to 2099.

Critical data used for the 2023 assessment

- Victorian Alpine Resorts - Daily Snow Depth Records

2023 assessment

As reported in the SoE 2018 Report, a decline in snow accumulation has been observed at several locations across the Victorian Alps since the 1950s.[101, 102] Similarly, observations have shown a decline in the frequency of the smaller daily snowfall events (less than 10 cm) across the Victorian Alps in the 30 years to 2015.[103] These changes are closely linked to maximum temperatures in winter, indicating the role of anthropogenic climate change in reducing snow cover.[104] Snow depth is also influenced by large-scale drivers such as the El Nino Southern Oscillation and Indian Ocean Dipole.[105]

101. Fiddes S, Pezza A, Barras V 2015, 'A new perspective on Australian snow', *Atmospheric Science Letters*, 16(3), pp. 246–252.
102. Timbal B, Ekstrom M, Fiddes SL, Grose M, Kirono DGC, Lim E, Lucas C, Wilson L 2016, 'Climate change science and Victoria', Bureau Research Report No. 014.
103. Fiddes S, Pezza A, Barras V 2015, 'A new perspective on Australian snow', *Atmospheric Science Letters*, 16(3), 246–252.
104. Ibid.
105. 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.

In the absence of any published research or analysis during the past five years focussing on snow cover in Victorian alpine regions, daily snow depth records from Victorian alpine resorts have been collated and analysed for this report.[106, 107, 108, 109, 110, 111] Natural snow depth data are available from 1993 to 2020. Analysis has been limited to Falls Creek, Lake Mountain, Mount Baw Baw, Mount Buller and Mount Hotham during the months of July and August — data for June, September and October as well as all data from Mount Stirling have been excluded due to gaps in the data record.

Much like the year-to-year variability for rainfall (see indicator 'CCIm:02: Observed average rainfall'), natural snow depth can fluctuate significantly on an annual basis due to large-scale climate drivers, such as the El Niño-Southern Oscillation, and a range of weather systems over different timescales. Figure CCIm8 highlights this annual variability showing the average daily natural snow depth across five Victorian alpine resorts in July and August from 1993 to 2020. The higher altitude resorts of Mount Buller, Falls Creek and Mount Hotham alpine resorts record more natural snow depth compared to the lower peaks at Mount Baw Baw and Lake Mountain.

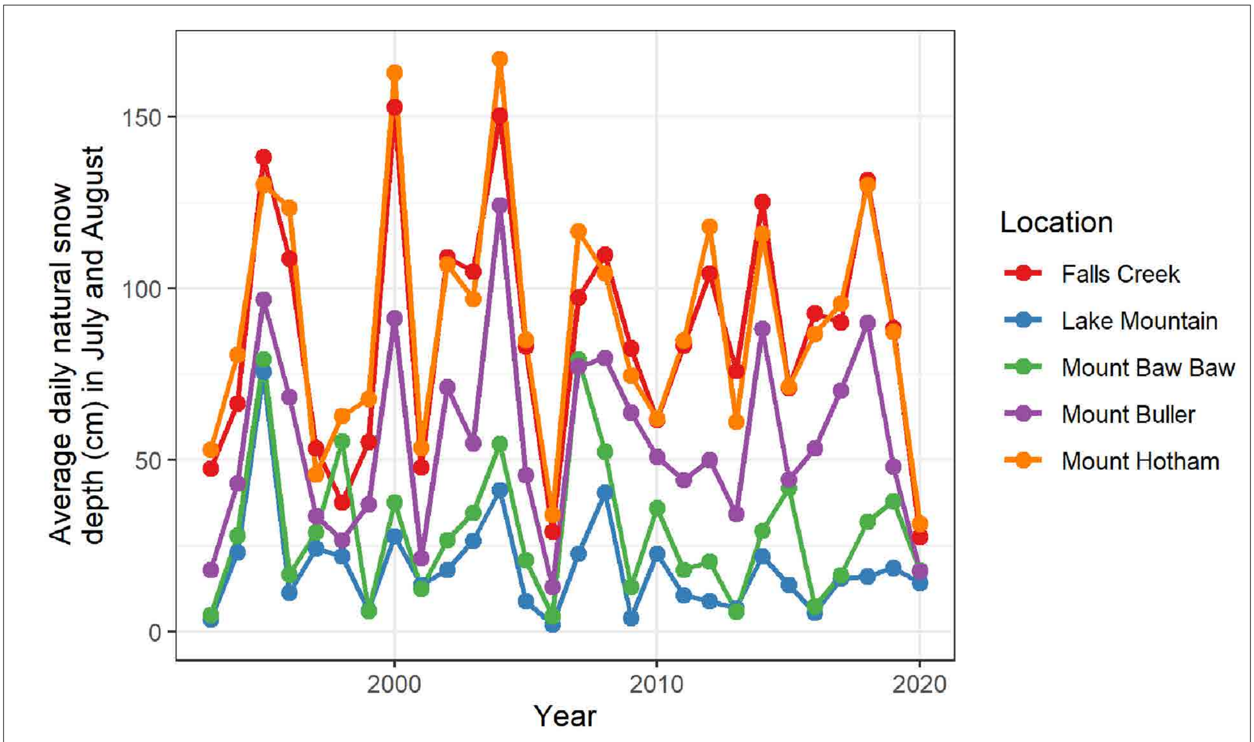

Figure CCIm8: Average natural snow depths at Victorian alpine resorts for July and August from 1993 to 2020.[112, 113, 114, 115, 116]

106. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Victorian alpine resorts - Daily snow depth records Falls Creek', https://discover.data.vic.gov.au/dataset/victorian-alpine-resorts-daily-snow-depth-records-falls-creek Accessed 19 July 2022.
107. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Victorian alpine resorts - Daily snow depth records Lake Mountain', https://discover.data.vic.gov.au/dataset/victorian-alpine-resorts-daily-snow-depth-records-lake-mountain Accessed 19 July 2022.
108. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Victorian alpine resorts - Daily snow depth records Mount Baw Baw', https://discover.data.vic.gov.au/dataset/victorian-alpine-resorts-daily-snow-depth-records-mount-baw-baw Accessed 19 July 2022.
109. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Victorian alpine resorts - Daily snow depth records Mount Buller', https://discover.data.vic.gov.au/dataset/victorian-alpine-resorts-daily-snow-depth-records-mount-buller Accessed 19 July 2022.
110. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Victorian alpine resorts - Daily snow depth records Mount Hotham', https://discover.data.vic.gov.au/dataset/victorian-alpine-resorts-daily-snow-depth-records-mount-hotham Accessed 19 July 2022.
111. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Victorian alpine resorts - Daily snow depth records Mount Stirling', https://discover.data.vic.gov.au/dataset/victorian-alpine-resorts-daily-snow-depth-records-mount-stirling Accessed 19 July 2022.
112. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Victorian alpine resorts - Daily snow depth records Falls Creek', https://discover.data.vic.gov.au/dataset/victorian-alpine-resorts-daily-snow-depth-records-falls-creek Accessed 19 July 2022.
113. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Victorian alpine resorts - Daily snow depth records Lake Mountain', https://discover.data.vic.gov.au/dataset/victorian-alpine-resorts-daily-snow-depth-records-lake-mountain Accessed 19 July 2022.
114. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Victorian alpine resorts - Daily snow depth records Mount Baw Baw', https://discover.data.vic.gov.au/dataset/victorian-alpine-resorts-daily-snow-depth-records-mount-baw-baw Accessed 19 July 2022.
115. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Victorian alpine resorts - Daily snow depth records Mount Buller', https://discover.data.vic.gov.au/dataset/victorian-alpine-resorts-daily-snow-depth-records-mount-buller Accessed 19 July 2022.
116. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Victorian alpine resorts - Daily snow depth records Mount Hotham', https://discover.data.vic.gov.au/dataset/victorian-alpine-resorts-daily-snow-depth-records-mount-hotham Accessed 19 July 2022.

The medium-term (averaged over 10 years) natural snow depth data have been used to investigate underlying snow cover trends across Victoria's alpine regions. The 10-year rolling average natural snow depths from the first 10-year period in the data record (1993-2002) until the most recent decade (2011-2020) are shown in Figure CCIm9.

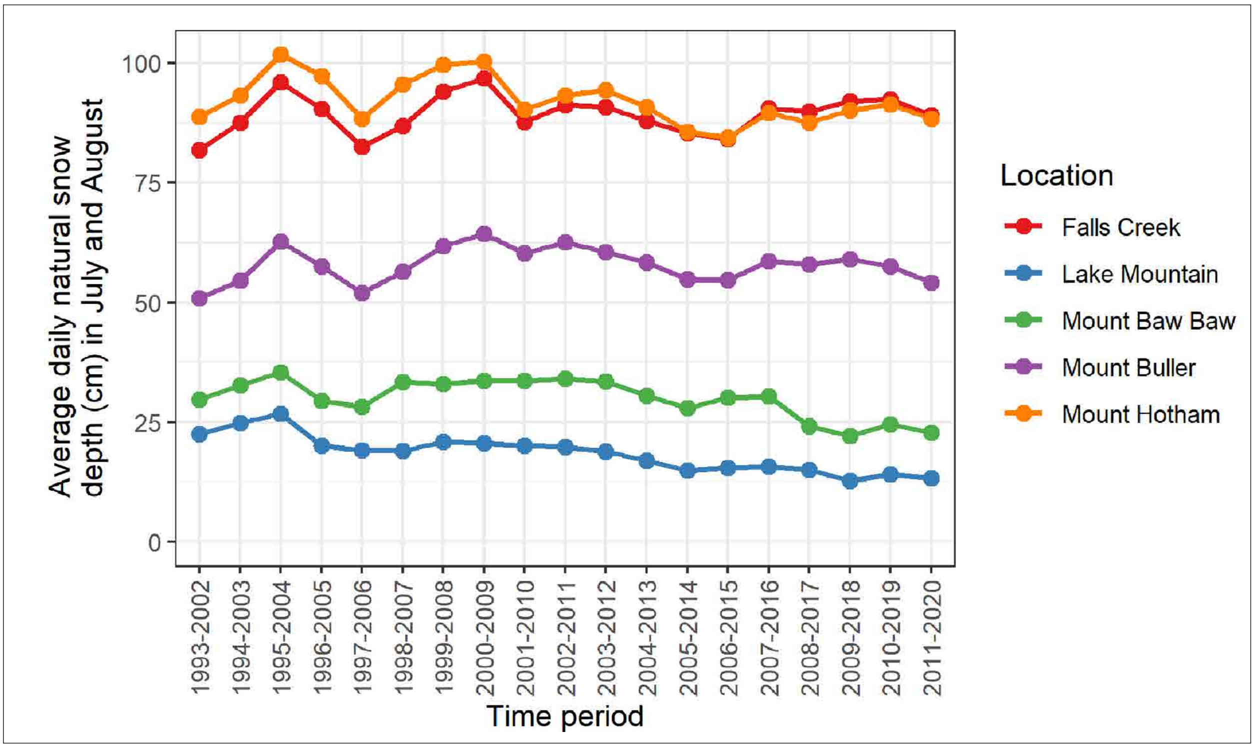

Figure CCIm9: Ten-year rolling average of average natural snow depths at Victorian alpine resorts for July and August from 1993 to 2020.[117, 118, 119, 120, 121]

Table CCIm4 presents the daily natural snow depths for July and August averaged across the 10-year periods at the start and end of the data record. The results from Figure CCIm9Figure CCIm9 and Table CCIm4 show that natural snow depths in July and August have been generally stable at the higher altitude resorts of Mount Buller, Falls Creek and Mount Hotham. Results at these locations for July and August from 2011 to 2020 are within 10% of the depths from 1993 to 2002, with slight increases in natural snow depth measured at Falls Creek and Mount Buller.

For the lower altitude alpine resort locations (Lake Mountain and Mount Baw Baw), the observations show a gradual, but steady, deterioration in natural snow depth. Lake Mountain has recorded 41% less natural snow depth for July and August across the period from 2011 to 2020 compared with the same months in 1993 to 2002. At Lake Mountain, in every single one of the past 10 years (2011-2020) there has been less natural snow depth averaged across July and August compared with the average for the period of 1993 to 2002 when the data record commenced.

117. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Victorian alpine resorts - Daily snow depth records Falls Creek', https://discover.data.vic.gov.au/dataset/victorian-alpine-resorts-daily-snow-depth-records-falls-creek Accessed 19 July 2022.
118. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Victorian alpine resorts - Daily snow depth records Lake Mountain', https://discover.data.vic.gov.au/dataset/victorian-alpine-resorts-daily-snow-depth-records-lake-mountain Accessed 19 July 2022.
119. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Victorian alpine resorts - Daily snow depth records Mount Baw Baw', https://discover.data.vic.gov.au/dataset/victorian-alpine-resorts-daily-snow-depth-records-mount-baw-baw Accessed 19 July 2022.
120. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Victorian alpine resorts - Daily snow depth records Mount Buller', https://discover.data.vic.gov.au/dataset/victorian-alpine-resorts-daily-snow-depth-records-mount-buller Accessed 19 July 2022.
121. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Victorian alpine resorts - Daily snow depth records Mount Hotham', https://discover.data.vic.gov.au/dataset/victorian-alpine-resorts-daily-snow-depth-records-mount-hotham Accessed 19 July 2022.

Climate change — Impacts

Table CCIm4: Daily natural snow depths for July and August averaged across the 10-year periods at the start and end of the data record (1993-2002 and 2011-2020).[122, 123, 124, 125, 126]

Alpine resort	10-year rolling average (1993-2002) of average daily natural snow depth (cm) in July and August	10-year rolling average (2011-2020) of average daily natural snow depth (cm) in July and August	Change (%) in natural snow depth in July and August from 1993-2002 to 2011-2020
Falls Creek	81.8	89.1	9%
Lake Mountain	22.6	13.3	-41%
Mount Baw Baw	29.7	22.8	-23%
Mount Buller	50.9	54.1	6%
Mount Hotham	88.8	88.3	-1%

In addition to ground-based observations for snow depth, researchers have been utilising modern technology to assess snow cover. The SoE 2018 Report highlighted that satellite remote sensing was used to observe a reduction in snow cover in the Australian Alps from 2000 to 2014.[127] During the past 5 years there has been no published research or advance on using remote sensing to detect snow cover changes specific to Victorian alpine regions. However, research published in 2022 showcased that snow cover changes had been detected over the Snowy Mountains in New South Wales using dynamic object-based image algorithms.[128]

There is a considerable inter-annual 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 at the state's alpine locations.

As presented in the SoE 2018 Report, future projections of snow in Australia have been produced 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 as well as an acceleration in snowmelt and, thus, reduced snow season length, particularly at low elevations.[129, 130, 131, 132, 133] No new analysis of projected changes to snow cover or snow depth was presented as part of the Victorian Climate Projections 2019.[134]

Snow cover and volume will decline to the extent that eventually only the highest peaks will experience any seasonal snow cover by 2070 to 2099 under a high-emissions scenario, with smaller but still substantial declines in snow cover under lower emissions scenarios.[135] These changes are likely to have a large impact on natural ecosystems and recreational use in the region.

122. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Victorian alpine resorts - Daily snow depth records Falls Creek', https://discover.data.vic.gov.au/dataset/victorian-alpine-resorts-daily-snow-depth-records-falls-creek Accessed 19 July 2022.
123. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Victorian alpine resorts - Daily snow depth records Lake Mountain', https://discover.data.vic.gov.au/dataset/victorian-alpine-resorts-daily-snow-depth-records-lake-mountain Accessed 19 July 2022.
124. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Victorian alpine resorts - Daily snow depth records Mount Baw Baw', https://discover.data.vic.gov.au/dataset/victorian-alpine-resorts-daily-snow-depth-records-mount-baw-baw Accessed 19 July 2022.
125. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Victorian alpine resorts - Daily snow depth records Mount Buller', https://discover.data.vic.gov.au/dataset/victorian-alpine-resorts-daily-snow-depth-records-mount-buller Accessed 19 July 2022.
126. Department of Environment, Land, Water and Planning (DELWP) 2021, 'Victorian alpine resorts - Daily snow depth records Mount Hotham', https://discover.data.vic.gov.au/dataset/victorian-alpine-resorts-daily-snow-depth-records-mount-hotham Accessed 19 July 2022.
127. Thompson J 2016, 'A MODIS-derived snow climatology (2000–2014) for the Australian Alps', *Climate Research* 68(1), pp. 25–38.
128. Rasouli AA, Cheung KKW, Mohammadzadeh Alajujeh K, Ji F 2022, 'On the detection of snow cover changes over the Australian Snowy Mountains using a dynamic OBIA approach', *Atmosphere*, 13(5), pp. 826.
129. Commonwealth Scientific and Industrial Research Organisation (CSIRO), Bureau of Meteorology (BOM) 2015, 'Climate change in Australia: Information for Australia's natural resource management regions: technical report', Australia.
130. Di Luca A, Evans JP, Ji F 2017, 'Australian snowpack in the NARCliM ensemble: evaluation, bias correction and future projections', *Climate Dynamics*.
131. Timbal B, Ekstrom M, Fiddes SL, Grose M, Kirono DGC, Lim E, Lucas C, Wilson L 2016, 'Climate change science and Victoria', Bureau Research Report No. 014.
132. Bhend J, Bathols JM and Hennessy KJ 2012, 'Climate change impacts on snow in Victoria', CAWCR Research Report, Centre for Australian Weather and Climate Research, 42 pp.
133. 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.
134. Clarke JM, Grose M, Thatcher M, Hernaman V, Heady C, Round V, Rafter T, Trenham C, Wilson L 2019, 'Victorian climate projections 2019 technical report', Commonwealth Scientific and Industrial Research Organisation (CSIRO), Melbourne, Australia.
135. Antarctic Climate and Ecosystems Cooperative Research Centre 2016, 'The potential impacts of climate change on Victorian alpine resorts' http://www.arcc.vic.gov.au/uploads/publications-and-research/The%20Potential%20Impact%20of%20Climate%20Change%20on%20Victorian%20Alpine%20Resorts%20Study_FINAL.pdf Accessed 22 July 2022.

Climate change — Impacts

Through a research project entitled Mountain Champions: Building Resilience into Alpine Environments for a Low-snow Future, academics from a range of Australian universities have begun collaborating to investigate how the Australian Alps will fare with declines in snow cover. Specifically, the research group will assess whether alpine species have the regeneration and adaptive capacity to thrive under new climates, as well determining their tolerances to the extreme temperatures they will face in the future.[136]

Indicator CCIm:04 Sea level and coastal inundation

CCIm:04 Sea level and coastal inundation						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Victoria's coastline						(Victorian sites until 1993)* (Victorian sites since 1993)
Data source(s):	BOM					
Measure(s):	Annual mean sea level Annual maximum sea levels					

Why this indicator?

Sea-level rise is one of the biggest threats associated with climate change to marine and coastal environments. Coastal communities in Victoria are already experiencing some of the impacts associated with sea-level rise. These impacts are expected to intensify this century and include:

- more frequent and extensive inundation of low-lying areas, with the impacts exacerbated by storm surges
- loss of coastal habitat, such as roosting and nesting sites for shorebirds and seabirds
- accelerated cliff retreat and shoreline recession altered saltmarsh and mangrove habitats
- coastal erosion.

NB: This SoE 2023 was 'CC:07 Observed sea level' in the SoE 2018 Report.

Why this assessment in 2023?

The status and trend assessments of fair and deteriorating, respectively, reflect the gradual but consistently increasing mean and maximum sea levels that are exerting pressure on human coastal settlements and infrastructure.

** Sea level data up to 1993 have not been formally standardised.*

Summary of State of the Environment 2018 Report assessment

- There have been rises of mean and maximum sea levels, as well as an increasing frequency of very high sea levels.

Critical data used for the 2023 assessment

- 2021 Australian National Collection of Homogenised Observations of Relative Sea Level (ANCHORS)
- Coastal Risk Australia
- CoastKit
- Sea Level Rise 2100 StormTide (82cm) - WMS

136. Research Centre for Applied Alpine Ecology, 'Why should we care about snow in the mountains?', https://rcaae.org/2020/11/17/why-should-we-care-about-snow-in-the-mountains/ Accessed 9 May 2022.

2023 assessment

As the ocean warms it expands and sea-level rises. This thermal expansion has contributed about one third of the sea-level rise observed globally. Ice loss from glaciers and polar ice sheets, together with changes in the amount of water stored on the land, contribute the remaining two thirds of the observed global sea-level rise. Ice loss from Greenland, Antarctica and glaciers has been the dominant contributor to global sea-level rise since 1993.[137]

Global mean sea level has risen by around 25 cm since 1880.[138] Half of this rise has occurred since 1970, providing confirmation that global mean sea-level rise is accelerating.

Australia, like other nations, is experiencing sea-level rise. Sea level varies from year to year and from place to place, partly due to the natural variability of the climate system from the effect of climate drivers, such as El Niño and La Niña. Based on satellite altimetry observations since 1993, the rates of sea-level rise in some areas to the north and southeast of Australia (Figure CCIm10) have been significantly higher than the global average.[139]

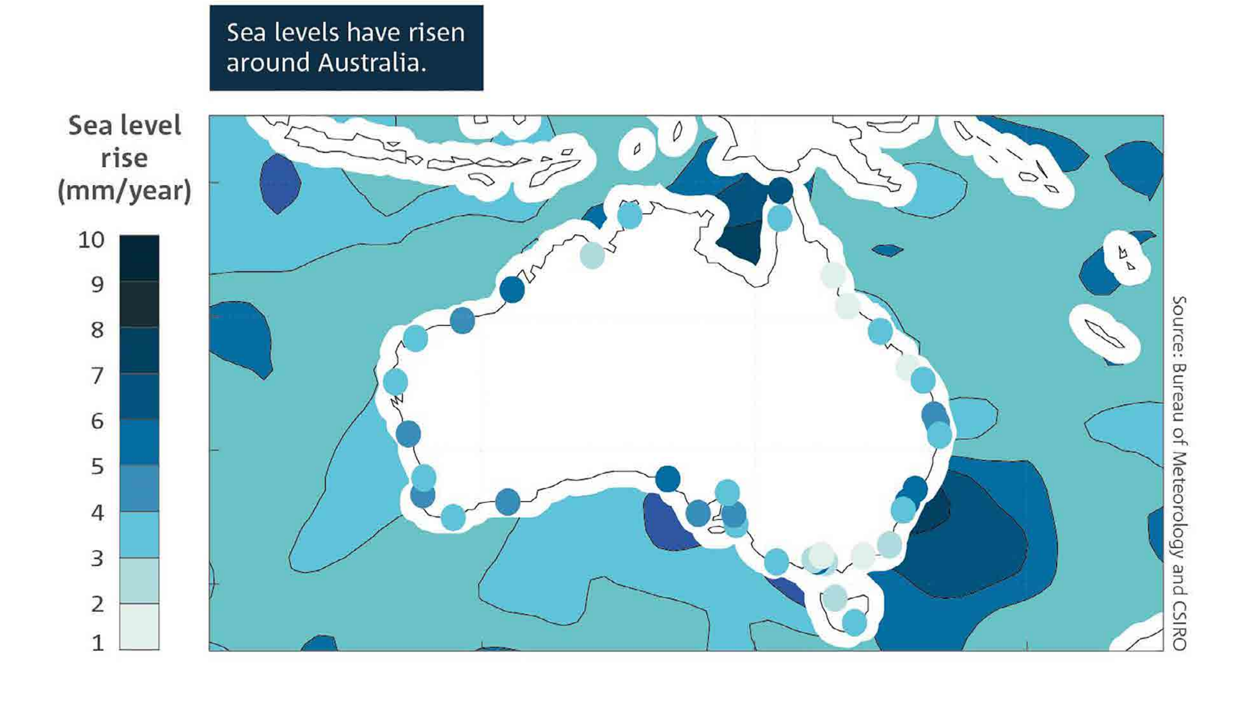

Figure CCIm10: The rate of offshore sea-level rise around Australia from 1993 to 2020.[140, 141]

137. Bureau of Meteorology (BOM), Commonwealth Scientific and Industrial Research Organisation (CSIRO) 2022, 'State of the climate 2022', http://www.bom.gov.au/state-of-the-climate/2022/documents/2022-state-of-the-climate-web.pdf Accessed 29 November 2022.
138. Ibid.
139. Bureau of Meteorology (BOM), Commonwealth Scientific and Industrial Research Organisation (CSIRO) 2022, 'State of the climate 2022', http://www.bom.gov.au/state-of-the-climate/2022/documents/2022-state-of-the-climate-web.pdf Accessed 29 November 2022.
140. Ibid.
141. The map displays data measured using satellite altimetry from 1993–2020 and onshore rate of sea level rise (coastal points) from the ANCHORS multi-decadal tide gauge dataset. The colour scale applies to both the contour (satellite altimetry) and dots (tide gauges) observations.

Sea-level data from a tide gauge has been collected by BOM at several currently monitored locations along the Victorian coastline, with data available from the 1960s.[142] In 2021, BOM homogenised tide gauge-based sea-level datasets around Australia — the new dataset is called the Australian National Collection of Homogenized Observations of Relative Sea Level (ANCHORS) and provides coastal sea levels at hourly resolution with homogenisation performed on annual means.[143] ANCHORS is intended to be a national tide gauge-based sea-level dataset to monitor changes in mean sea level and resultant coastal flood frequency changes around Australia. Data for Victorian locations in ANCHORS up until the end of 2019 has been used in the following analysis.[144]

Given sea-level rise is occurring at a rate of approximately a few centimetres per decade, the time series of annual mean sea levels across Victoria shows, within the interannual variability, a very gradual but consistently increasing sea level (Figure CCIm11).

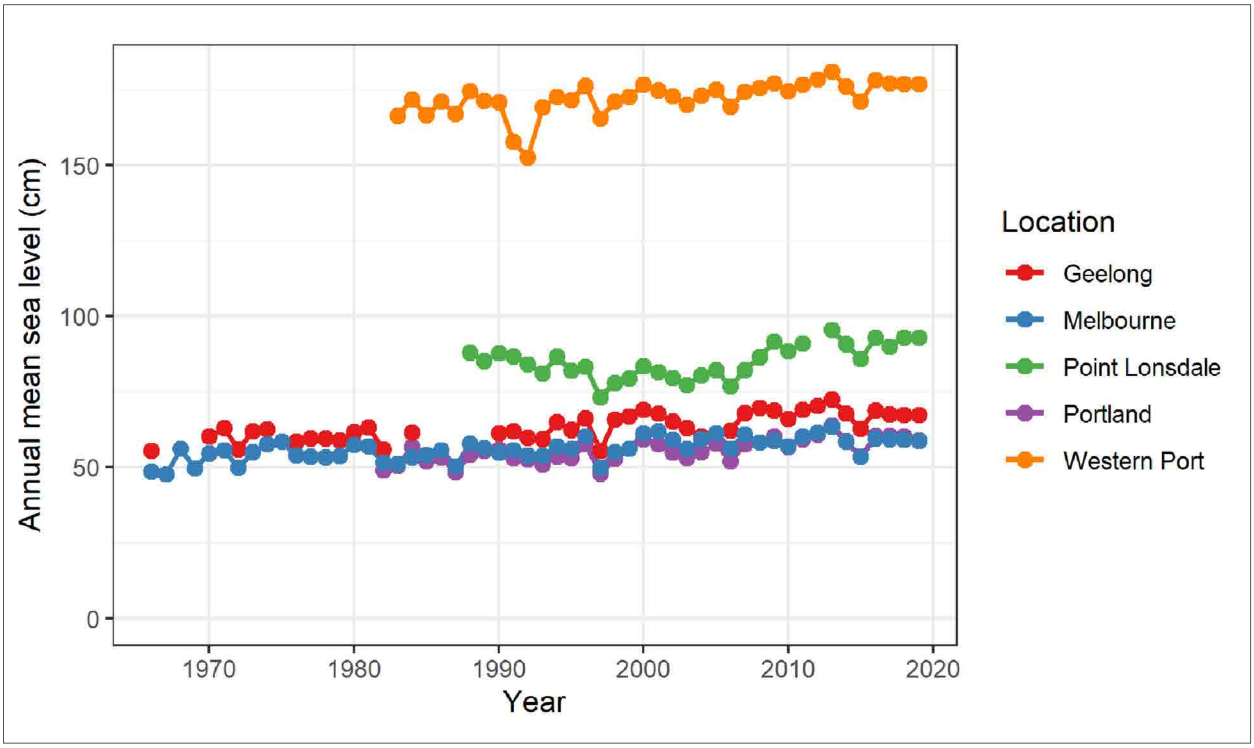

Figure CCIm11: Annual mean sea levels at Victorian locations from 1966 to 2019.[145, 146]

Table CCIm5 shows the average sea level at Victorian locations for each decade.[147] Local coastal processes, the effects of vertical land motion, and changes in site and/or reference levels affect local estimates of sea-level change. However, there is consistency across all high-quality datasets that sea levels have increased by between 2.0 cm and 4.5 cm per decade since the 1990s.

It is notable that Point Lonsdale's annual mean sea level during the most recent decade (2010-2019) was 8.9 cm higher than the previous decade (2000-2009), which indicates that sea levels at Port Phillip Heads have just experienced the most dramatic decadal increase in sea levels since measurement began. This change is likely due to a combination of climate change and local factors (e.g. dredging).

142. Bureau of Meteorology (BOM), 'Tide gauge metadata and observed monthly sea levels and statistics', http://www.bom.gov.au/oceanography/projects/ntc/monthly/ Accessed 22 May 2021.
143. Hague BS, Jones DA, Trewin B, Jakob D, Murphy BF, Martin D, Braganza K 2021, 'ANCHORS: A multi-decadal tide gauge dataset to monitor Australian relative sea level changes', *Geoscience Data Journal*, 00, pp. 1– 17.
144. Only ANCHORS data that has been categorised as 'higher' quality data have been used in the analysis for this report.
145. National Computational Infrastructure, Bureau of Meteorology (BOM) 2021, 'Australian national collection of homogenised observations of relative sea level (ANCHORS)', https://dx.doi.org/10.25914/6142dff37250b Accessed 20 July 2022.
146. Note that even though it appears sea level is higher in Western Port, this is due to a result of 0 being defined as the lowest tide and the tidal range in Western Port is broader than the other locations included in the graph. This is not indicative of Western Port being at more, or less, risk to coastal inundation than the other locations.
147. There are some gaps in Table CCIm5 when there was no data collected, only 'lower'-quality data were available or there weren't enough years of monitoring completed in the decade to constitute a representative 10-year average.

Table CCIm5: Ten-year average of annual mean sea level (cm) at Victorian locations from the 1970s to 2010s.[148]

Decade	Portland	Geelong	Point Lonsdale	Melbourne	Western Port
1970s	-	60.0	-	54.6	-
1980s	52.5	-	-	54.5	-
1990s	53.4	62.5	82.2	55.2	168.0
2000s	56.6	66.0	82.2	59.3	173.9
2010s	59.3	67.9	91.2	59.1	176.7
Change	3.0 cm per decade from the 1990s to the 2010s	2.7 cm per decade from the 1990s to the 2010s	4.5 cm per decade from the 1990s to the 2010s	2.0 cm per decade from the 1990s to the 2010s	4.4 cm per decade from the 1990s to the 2010s

The frequency of very high sea levels has also increased, with statistically significant increases in the frequency at which the Highest Astronomical Tide is being exceeded at Williamstown and Geelong.[149]

Table CCIm6 shows the average annual maximum sea level at Victorian locations for each decade. Across Port Phillip Heads, Port Phillip Bay and Western Port, there is consistency that annual maximum sea levels have increased by between 2.9 cm and 6.2 cm per decade since the 1990s, while the changes have been less on the south-western coastline at Portland.

Table CCIm6: Ten-year average of annual maximum sea level (m) at Victorian locations from the 1970s to 2010s.[150]

Decade	Portland	Geelong	Point Lonsdale	Melbourne	Western Port
1970s	-	1.440	-	1.388	-
1980s	1.405	-	-	1.357	-
1990s	1.436	1.449	1.902	1.393	3.439
2000s	1.485	1.519	1.898	1.460	3.462
2010s	1.446	1.573	1.977	1.451	3.507
Change from the 1990s to the 2010s	0.5 cm per decade from the 1990s to the 2010s	6.2 cm per decade from the 1990s to the 2010s	3.8 cm per decade from the 1990s to the 2010s	2.9 cm per decade from the 1990s to the 2010s	3.4 cm per decade from the 1990s to the 2010s

Note: There are some data gaps for some locations and time periods as a result of no data being collected, only low-quality data available (for Portland, Geelong, Point Lonsdale, Melbourne and Western Port) or there weren't enough years of monitoring completed in the decade to constitute a representative 10-year average

148. National Computational Infrastructure, Bureau of Meteorology (BOM) 2021, 'Australian national collection of homogenised observations of relative sea level (ANCHORS)', https://dx.doi.org/10.25914/6142dff37250b Accessed 20 July 2022.
149. Commissioner for Environmental Sustainability (CES) 2021, 'State of the marine and coastal environment 2021 report', Melbourne, Victoria.
150. National Computational Infrastructure, Bureau of Meteorology (BOM) 2021, 'Australian national collection of homogenised observations of relative sea level (ANCHORS)', https://dx.doi.org/10.25914/6142dff37250b Accessed 20 July 2022.

Coastal inundation

Recent coastal inundation has primarily occurred when storm surges have coincided with high astronomical tides (e.g. king tides or spring tides), which are higher than in the past due to sea-level rise.

To visualise the possible impacts of coastal inundation, Figure CCIm12 shows the extensive flooding (shaded in blue) that would occur in Point Lonsdale and Queenscliff alongside Port Phillip Heads, Cowes on Phillip Island, Port Franklin near Corner Inlet and Lakes Entrance near the Gippsland Lakes in 2100 during a high tide under a high-emissions scenario, which assumes a median sea-level rise of 0.84 m relative to the sea level during the 1986-2005 reference period. This visualisation shows the considerable risk sea-level rise and coastal inundation poses to property along the Victorian coastline. The image was developed assuming average weather conditions (e.g. no storm surges), which means that more extensive inundation is likely when sea levels are elevated above the normal high tide mark (e.g. during a storm surge). In Queenscliff, the Highest Astronomical Tide was exceeded in all but two of the 24 months from 2018 to 2019. The image also does not account for any erosion that might happen between now and 2100, which would lead to changes in shoreline position.

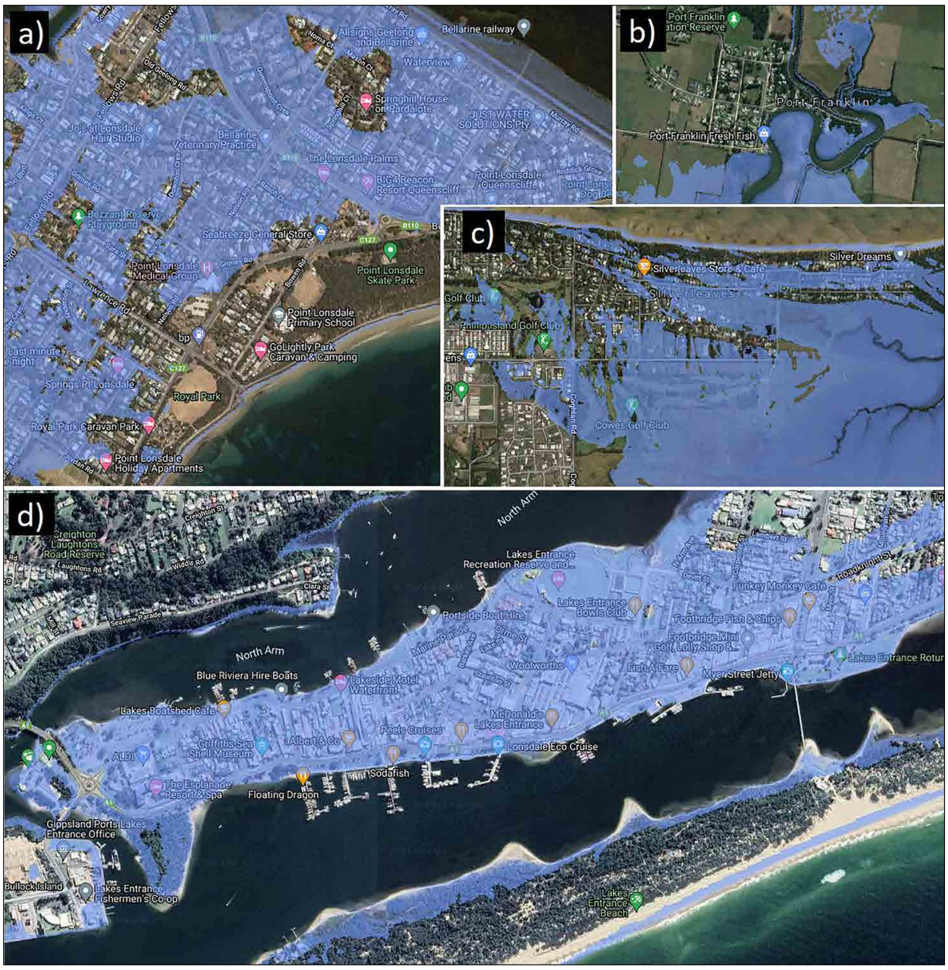

Figure CCIm12: Estimated coastal inundation at high tide assuming a 84-cm sea-level rise relative to the sea level during the 1986-2005 reference period). a) Point Lonsdale and Queenscliff; b) Cowes, Phillip Island; c) Port Franklin; d) Lakes Entrance.[151, 152]

151. Cooperative Research Centre for Spatial Information, NGIS, 'Coastal risk Australia', http://www.coastalrisk.com.au/ Accessed 20 July 2022.
152. The highest astronomical tide values along the Australian coast have been computed by Coastal Risk Australia from the CANUTE tide model relative to mean sea level. The CANUTE model has been developed by Antarctic Climate and Ecosystems Cooperative Research Centre and provides estimates for 12,000 'virtual tide gauges' spaced approximately every 2.5 km around the coast.

Climate change — Impacts

Indicator CCIm:05 Sea-surface temperature

CCIm:05 Sea-surface temperature						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Victoria's marine environment	🔴	→	🟢	🔴	↙	🟢
Data source(s):	BOM, CSIRO					
Measure(s):	Australian region sea-surface temperatures Australian sea-surface temperature anomaly – southern region					

Why this indicator?

Oceans play an important role in the global climate system, absorbing more than 90% of the excess heat trapped by GHGs. Water temperature is important for all marine life, which serve environmental (e.g. biodiversity), economic (e.g. commercial fisheries) and social (e.g. recreational fishing) functions.

NB: This SoE 2023 indicator was 'CC:09 Sea-surface temperature' in the SoE 2018 Report.

Why this assessment in 2023?

The increasing frequency of marine heatwaves around Australia in recent years has caused permanent impacts on marine ecosystem health, and marine habitats and species. These impacts include depletion of kelp forests and seagrasses, a poleward shift in some marine species, and increased occurrence of disease. This information is the basis of the status assessment of poor.

The trend for this indicator has been assessed as stable rather than deteriorating (as it was rated in the SoE 2018 Report). This is because the sea-surface temperature anomaly in the southern region has not increased further during the past five years, even though each year has been at least 0.35°C warmer than the 30-year climatology of the 1961 to 1990 period.

Summary of State of the Environment 2018 Report assessment

- Sea surface temperatures in the Australian region have been observed at record warm-levels in recent years.

Critical data used for the 2023 assessment

- Climate Change – Trends and Extremes

2023 assessment

Oceans play an important role in the global climate system, absorbing more than 90% of the excess heat trapped by GHGs.[153] Water temperature is important for all marine life, which serve environmental (e.g. biodiversity), economic (e.g. commercial fisheries) and social (e.g. recreational fishing) functions.

Unusually high ocean water temperatures are referred to as marine heatwaves due to their persistence and intensity. They can have devastating and long-term impacts on Australia's coastal ecosystems, economy and communities, including industries such as fisheries, aquaculture and tourism.[154]

Ocean temperature monitoring programs are crucial for identifying marine heatwaves. Australia's Integrated Marine Observing System (IMOS) incorporates ocean data systems from multiple data streams to provide near real-time summaries of many parameters, including sea-surface temperature. The IMOS data offers region-specific information for monitoring marine heatwaves. This information can be valuable for the public aquaculture industries and tourism operators in the marine environment, while it is also used by researchers, weather and hazard forecasters, and as an input to future climate projections.

153. Intergovernmental Panel on Climate Change (IPCC) 2013, 'Climate change 2013: the physical science basis', Working Group I contribution to the IPCC Fifth Assessment Report, Cambridge University Press, Cambridge, United Kingdom
154. National Environmental Science Programme (NESP), 'Marine heatwaves: changes, causes and impacts', https://nespclimate.com.au/marine-heatwaves-changes-causes-and-impacts/ Accessed 13 April 2022.

Average sea surface temperature in the Australian region has warmed by more than 1°C since 1900, with nine of the ten warmest years on record occurring since 2010.[155] In the southern region (30°S–46°S, 94°E–174°E), recent years have also been warmer than average, with all 12 years from 2010 to 2021 being in the top 20 warmest years on record (Figure CCIm13). The trend for this indicator has been assessed as stable rather than poor (as it was rated in the SoE 2018 Report). This is because, as shown by Figure CCIm13, the sea-surface temperature anomaly in the southern region has not increased further during the past five years even though each year has been at least 0.35°C warmer than the 30-year climatology of 1961 to 1990.

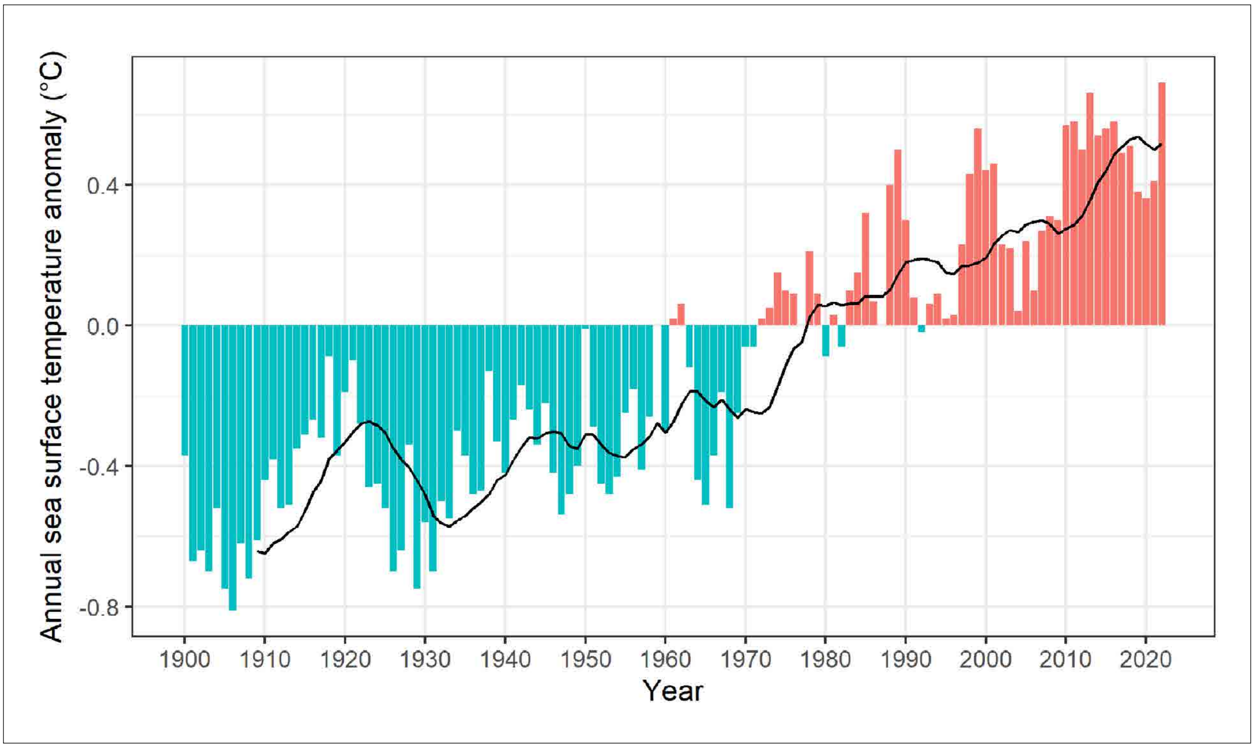

Figure CCIm13: Australian sea surface temperature anomaly – Southern Region from 1900 to 2022 (based on a 30-year climatology of 1961-1990 with a 10-year rolling average shown as the black line).[156]

The greatest ocean warming in the Australian region since 1970 has occurred around south-eastern Australia and Tasmania (Figure CCIm14). The East Australian Current now extends further south, creating an area of more rapid warming in the Tasman Sea where the warming rate is now twice the global average.[157]

155. Bureau of Meteorology (BOM) and CSIRO 2020, 'State of the climate 2020'.
156. Bureau of Meteorology (BOM), 'Climate change – Trends and extremes', http://www.bom.gov.au/climate/change/index.shtml#tabs=Tracker&tracker=timeseries&tQ=graph%3Dsst%26area%3Dsth%26season%3D0112%26ave_yr%3D0 Accessed 22 July 2022.
157. Bureau of Meteorology (BOM), Commonwealth Scientific and Industrial Research Organisation (CSIRO) 2022, 'State of the climate 2022', http://www.bom.gov.au/state-of-the-climate/2022/documents/2022-state-of-the-climate-web.pdf Accessed 29 November 2022.

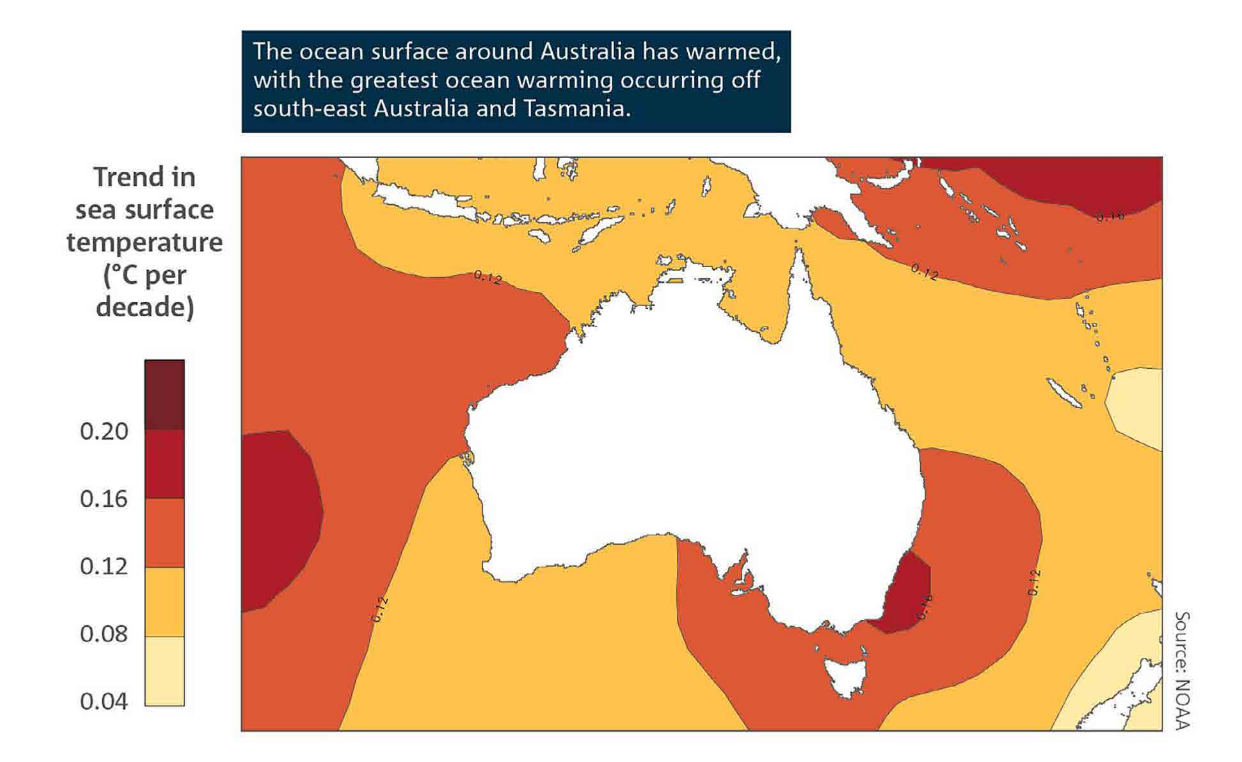

Figure CCIm14: Trends in sea surface temperatures in the Australian region (4–46° S and 94–174° E) from 1950 to 2021.[158]

Warming of the ocean has contributed to longer and more frequent marine heatwaves. Heatwaves in the ocean often persist much longer than heatwaves on land, sometimes spanning multiple months or even years. The increasing frequency of marine heatwaves around Australia in recent years has caused permanent impacts on marine ecosystem health, habitats and species. These impacts include depleting kelp forests and seagrasses, a poleward shift in some marine species, and increased occurrence of disease.[159]

Temperate reefs from around the world are becoming tropicalised as warm-water species shift their distribution towards the poles in response to warming. This is already causing profound shifts in dominant foundation species and associated ecological communities as canopy seaweeds, such as kelp, are replaced by tropical species.[160]

A 2019 international study involving Australian researchers found that marine heatwaves alter the fundamental structure of some marine ecosystems across the world, posing challenges for the industries that rely on them and threatening global biodiversity.[161] The study also found that marine heatwaves will likely intensify further with ongoing climate change, threatening many species living near the upper end of their tolerable temperature range. The ocean off southeast Australia was identified as being particularly vulnerable to marine heatwaves.

This research was extended in 2020, analysing the links between enhanced predictions of marine heatwaves and marine conservation, fisheries and aquaculture management.

158. Bureau of Meteorology (BOM), Commonwealth Scientific and Industrial Research Organisation (CSIRO) 2022, 'State of the climate 2022', http://www.bom.gov.au/state-of-the-climate/2022/documents/2022-state-of-the-climate-web.pdf Accessed 29 November 2022.
159. Ibid.
160. Vergés A, McCosker E, Mayer-Pinto M, Coleman MA, Wernberg T, Ainsworth T, Steinberg PD 2019, 'Tropicalisation of temperate reefs: implications for ecosystem functions and management actions', *Functional Ecology*, 33(6), pp. 1000–1013.
161. Smale DA, Wernberg T, Oliver ECJ, Thomsen M, Harvey BP, Straub SC, Burrows MT, Alexander LV, Benthuysen JA, Donat MG, Feng M, Hobday AJ, Holbrook NJ, Perkins-Kirkpatrick SE, Scannell HA, Gupta AS, Payne BL, Moore PJ 2019, 'Marine heatwaves threaten global biodiversity and the provision of ecosystem services', *Nature Climate Change*, 9, pp. 306–312.

It found that addressing the threats posed by marine heatwaves to the health and sustainability of marine ecosystems will require significant action, including:

- a coordinated global commitment to reduce GHG emissions
- governance arrangements that support novel adaptation strategies, such as protecting refugia for foundation marine species of coral, kelp and seagrass that provide essential habitats to marine ecosystems.[162]

Research studies published in 2022 highlight the specific link between warmer marine waters driving an increase in the abundance and range of sea urchins (*Heliocidaris erythrogramma* and *Centrostephanus rodgersii*) along most parts of the Victorian coastline eastward from Cape Otway.[163] Two kelp species (*Phyllospora comosa* and *Ecklonia radiata*) that are important in terms of providing food are decreasing in percent coverage over time with multiple environmental variables contributing to these declines, including increasing temperatures and urchin populations.[164]

Climate projections

Climate scientists use emissions scenarios to project a reasonable range of possible future climates because we do not know what social, economic and technological pathways (which determine GHG emissions) will be followed over time.[165]

The assessments for the indicators in this sub-theme are generally based on results from the VCP19 — a collaboration between DELWP and CSIRO that produced new local-scale climate projections for the entire state of Victoria for medium- and high-emissions pathways. Since then, a new generation of global climate models have been developed (CMIP6) and were featured in the 2021 IPCC sixth assessment report that included a new set of emission scenarios. This new modelling and scenarios are yet to be downscaled and applied for Victoria. Therefore, the indicators in this sub-theme refer to the different emissions scenarios from the IPCC fifth assessment report. These 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'. Furthermore, in the 2021 IPCC sixth assessment report, the modern reference period has been moved to be 1995-2014, however, updated modelling for this reference period has not been completed for Victoria and the 1986-2005 reference period is used in this report as it was in the SoE 2018 Report.

162. Holbrook NJ, Sen Gupta A, Oliver ECJ, Hobday AJ, Benthuysen JA, Scannell HA, Smale DA, Wernberg T 2020, 'Keeping pace with marine heatwaves', *Nature Reviews Earth and Environment*, 1, pp. 482–493.
163. Young MA, Critchell K, Miller AD, Treml EA, Sams M, Carvalho R, Ierodiaconou D 2022, 'Mapping the impacts of multiple stressors on the decline in kelps along the coast of Victoria, Australia', *Diversity and Distributions*, 00, pp. 1–22. https://doi.org/10.1111/ddi.13654 Accessed 9 July 2023.
164. Ibid.
165. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019', Melbourne, https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0029/442964/Victorias-Climate-Science-Report-2019.pdf Accessed 22 July 2022.

Indicator CCIm:06 Projected changes in temperature

CCIm:06 Projected changes in temperature						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	N/A	↙	●	N/A	↙	●
Data source(s):	BOM, CSIRO					
Measure(s):	Annually averaged warming for various emission scenarios relative to the climate of the 1986–2005 reference period					

Why this indicator?

Projecting temperature change is important to support planning and policy decisions made by the Victorian Government, local governments and communities. Projections are also used by scientific researchers to better understand the consequences of global climate change.

NB: This SoE 2023 indicator was 'CC:04 Projected changes in temperature' in the SoE 2018 Report.

Why this assessment in 2023?

There has been no change to the assessments for this indicator since the SoE 2018 Report. Physical evidence, past trends and various models all suggest Victoria will continue warming this century, so ongoing warming is projected with high confidence.

Summary of State of the Environment 2018 Report assessment

- Physical evidence, past trends and various models all suggest Victoria will continue warming this century, thus an ongoing warming is projected with high confidence.

Critical data used for the 2023 assessment

- Victorian Climate Projections 2019

2023 assessment

At a global scale, the impact of pursuing a lower emission pathway is demonstrated by the degree of climate change expected by the mid-21st century. Higher ongoing emissions of GHGs will lead to greater warming and associated impacts, while reducing emissions will lead to less warming and fewer impacts.[166]

The observed warming measured across Victoria since the middle of the 20th century is expected to continue. The amount of increase in the second half of the current century depends on the world's GHG emissions over the coming decades.

By the 2050s, average temperatures in Victoria are projected to be 1.4°C to 2.4°C warmer under a high-emissions scenario (RCP 8.5) or 0.9°C to 1.8°C warmer under a medium-emissions scenario (RCP 4.5) compared to the 1986-2005 reference period. By the 2090s, average temperatures in Victoria are projected to be 2.8°C to 4.3°C warmer under a high-emissions scenario (RCP 8.5) or 1.3°C to 2.2°C warmer under a medium-emissions scenario (RCP 4.5) compared to the 1986-2005 reference period (high confidence).[167]

Note that these projected temperature increases described above are relative to the 1986-2005 baseline period. As discussed in indicator 'CCIm:01 Observed surface temperature', the Paris Agreement has a stated aim to keep global temperature rise for

166. Bureau of Meteorology (BOM) and CSIRO 2020, 'State of the climate 2020'.
167. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019', Melbourne, https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0029/442964/Victorias-Climate-Science-Report-2019.pdf Accessed 22 July 2022.

this century below 2°C above pre-industrial levels, with the pre-industrial period defined as being from 1850 to 1900. The Paris agreement targets viewed in a Victorian context are already close to being breached (see indicator CCIm:03 that highlights annual mean daily maximum temperatures in Melbourne are now regularly at least 1.5°C warmer than an indicative pre-industrial era baseline). Given the temperature increases that have already been observed and the very high confidence that Victoria's climate will continue to warm this century, effective and swift action is required globally to keep the targets of the Paris agreement viable.[168]

If the world succeeds in matching aspirations under the Paris Agreement to limit global warming to 2°C relative to a pre-industrial era baseline, then Victoria is also expected to warm by around 2°C in line with the global average.[169] However, it is important to note that the Paris agreement targets are based on global average temperatures, which encompass an average of temperatures over land and water. Temperatures over land are expected to warm more than those over water, which means that surface air temperatures over land are generally likely to be greater than 1.5°C if there is a global temperature increase of 1.5°C.[170]

An increase in the average temperature leads to a corresponding increase in extremely hot daily maximum temperatures and a decrease in extremely cold daily minimum temperatures, assuming no change to variability or timing of extreme temperature events.[171] Climate extremes are by definition rare events, so accurately determining their current and future frequency and intensity is difficult and highly dependent on having a long record of climate observations.[172] Despite these challenges, the predicted hotter and more frequent hot days, fewer cold days, more intense heatwaves and fewer extreme cold nights was the most important and relevant message from the 2019 Victorian climate projections and was given with very high confidence.[173]

The changes projected for Victoria as part of a high-emissions scenario for the long-term future include significant warming compared to the current climate. Under a high-emissions scenario, the projections indicate that locations within Victoria could experience days when the temperature exceeds 55°C in summer and 33°C in winter by 2080 to 2099. An example of the daily maximum temperature on an extreme day is show in Figure CCIm15.[174] Further discussion on the impacts associated with extreme temperatures is provided in indicator 'CCIm:10 Occurrence and impacts of extreme weather'.

168. Ibid.
169. Ibid.
170. Hoegh-Guldberg O, Jacob D, Taylor M, Bindi M, Brown S, Camilloni I, Diedhiou A, Djalante R, Ebi KL, Engelbrecht F, Guiot J, Hijioka Y, Mehrotra S, Payne A, Seneviratne SI, Thomas A, Warren R and Zhou G 2018, 'Impacts of 1.5°C global warming on natural and human systems', in 'Global warming of 1.5°C', an IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.
171. Clarke JM, Grose M, Thatcher M, Hernaman V, Heady C, Round V, Rafter T, Trenham C, Wilson L 2019, 'Victorian climate projections 2019 technical report', Commonwealth Scientific and Industrial Research Organisation (CSIRO), Melbourne, Australia.
172. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019', Melbourne, https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0029/442964/Victorias-Climate-Science-Report-2019.pdf Accessed 22 July 2022.
173. Clarke JM, Grose M, Thatcher M, Hernaman V, Heady C, Round V, Rafter T, Trenham C, Wilson L 2019, 'Victorian climate projections 2019 technical report', Commonwealth Scientific and Industrial Research Organisation (CSIRO), Melbourne, Australia.
174. Ibid.

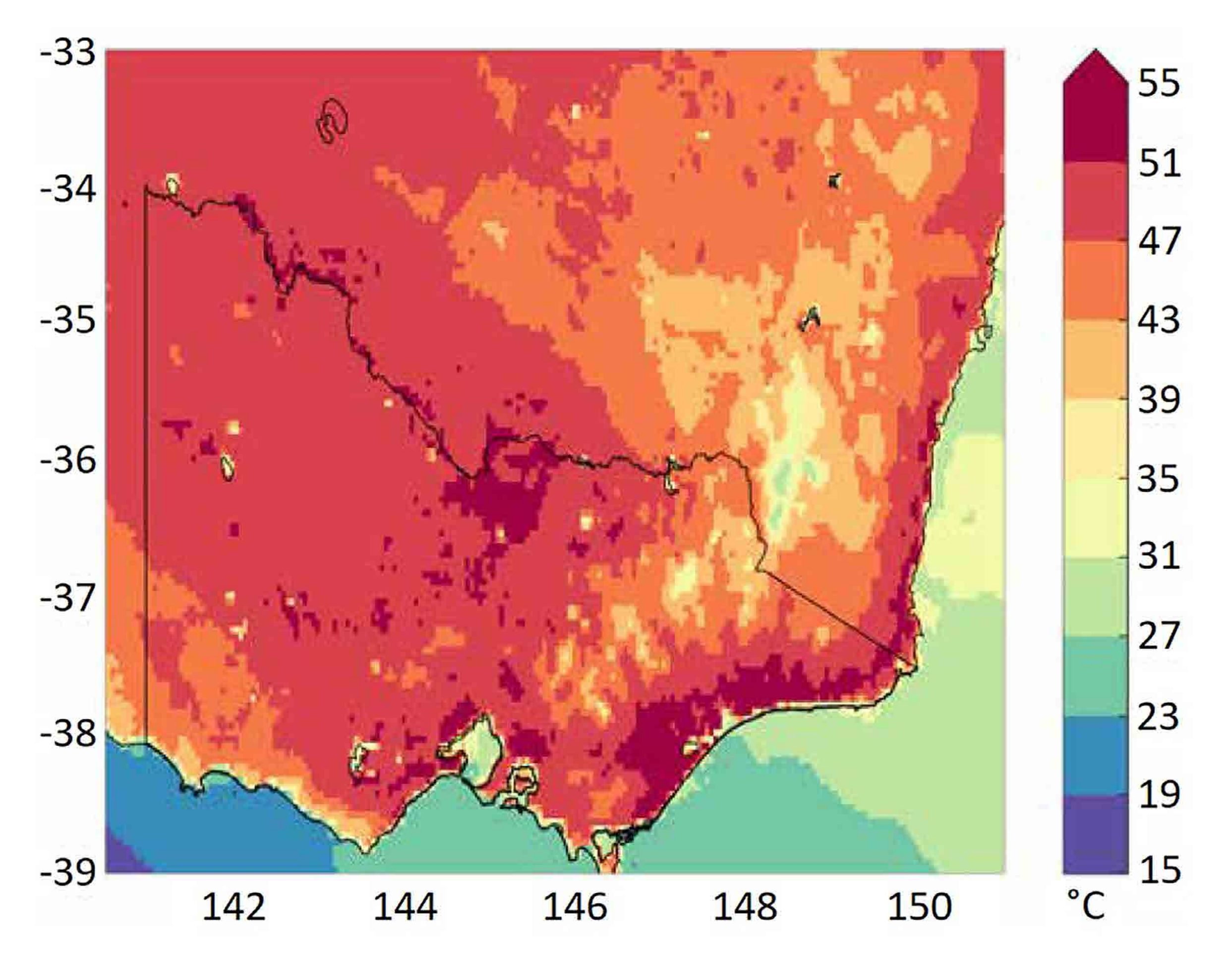

Figure CCIm15: Daily maximum temperature for an example extreme heat summer day in the 2050s simulated under a high (RCP8.5) emission scenario.[175, 176]

175. Ibid.
176. Note that the emission scenario is RCP8.5 and the image is produced for a summer day in the 2050s (HadGEM2-CC model downscaled by CCAM), where Melbourne reaches 50°C, and even higher temperatures inland. There is a warm bias in the simulation associated with the Gippsland region, so the temperature may be artificially elevated near the southeast coast. Note this is not the hottest day in simulations, it is just indicative of a very hot day in the future climate without a historical precedent.

Indicator CCIm:07 Projected changes to average rainfall

CCIm:07 Projected changes to average rainfall						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	N/A	↙	● (green)	N/A	↙	● (yellow)
Data source(s):	BOM, CSIRO					
Measure(s):	Percentage change in annual rainfall for various emission scenarios relative to the climate of the 1986–2005 reference period					

Why this indicator?

Projecting rainfall change is important to support planning and policy decisions made by the Victorian Government and communities. Projections are also used by scientific researchers to better understand the consequences of global climate change.

NB: This SoE 2023 indicator was 'CC:05 Projected changes to average rainfall' in the SoE 2018 Report.

Why this assessment in 2023?

The observed reduction in cool-season (April–October) rainfall since the 1990s is projected to continue.

While the impact of global warming on Victorian rainfall is expected to increase throughout the 21st century, large natural variability will also occur. In some years and decades, this natural variability will exacerbate the underlying drying. In other periods, the underlying drying will be balanced out by natural climatic events such as La Niña.

Summary of State of the Environment 2018 Report assessment

- The observed reduction in cool-season (April-October) rainfall during the past twenty years is projected to continue into the future.

Critical data used for the 2023 assessment

- Synthesis of published material and incorporates critical data previously analysed and reported
- Victoria's Water in a Changing Climate

2023 assessment

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

Global climate models project that the observed reduction in cool-season (April-October) rainfall since the beginning of the Millennium Drought in 1997 will continue — possibly intensifying given that current observations, which also include natural climate variability, are tracking at the drier end of these projections (Figure CCIm16).[177]

177. Department of Environment, Land, Water and Planning (DELWP), Bureau of Meteorology (BOM), Commonwealth Scientific and Industrial Research Organisation (CSIRO), University of Melbourne 2020, 'Victoria's water in a changing climate', https://www.water.vic.gov.au/__data/assets/pdf_file/0024/503718/VICWACI_VictoriasWaterInAChangingClimate_FINAL.pdf Accessed 11 April 2022.

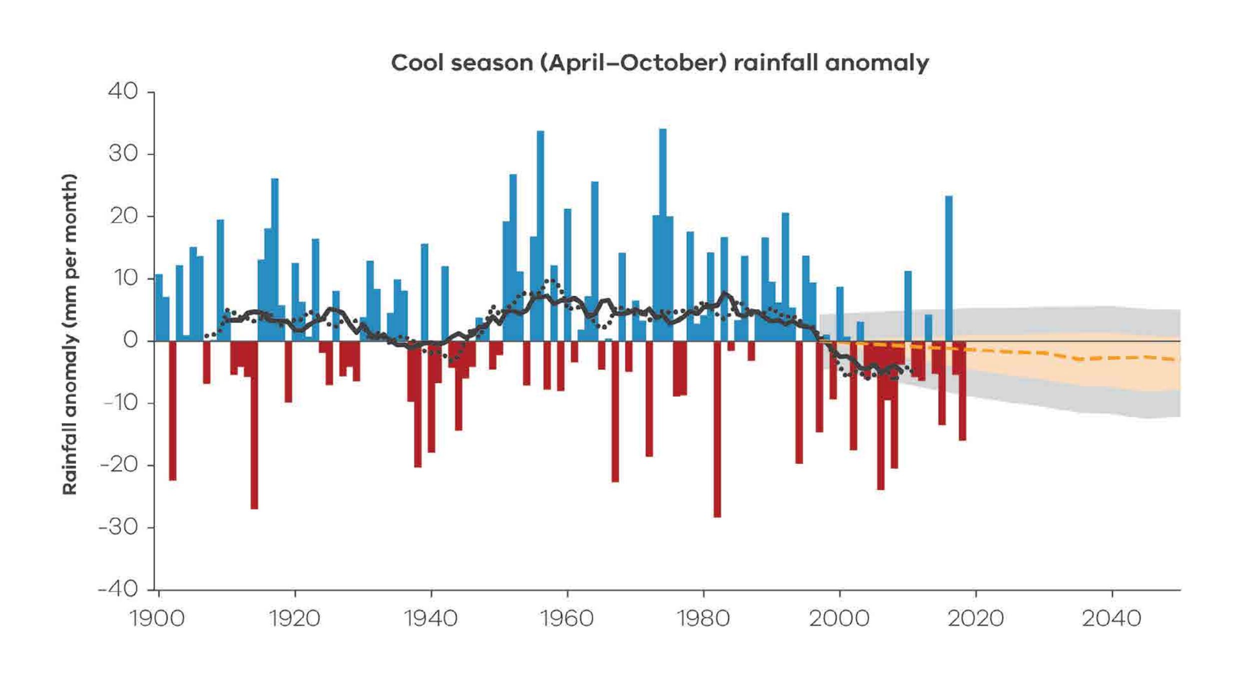

Figure CCIm16: Observed and projected cool-season rainfall anomalies for Victoria from 1900 to 2020.[178, 179]

It is important to understand the influence of natural climate variability (e.g. La Niña) and the effect of climate change (e.g. GHG increases) had on the observed rainfall reductions in recent decades. This is because any rainfall reductions due to increasing GHG concentrations are likely to continue.[180]

While the impact of global warming on Victorian rainfall is expected to increase as the 21st century unfolds, large natural variability will also occur. In some years and decades this natural variability will exacerbate the underlying drying, while in other periods the underlying drying will be balanced out by natural climatic events, such as La Niña.[181]

Climate models suggest that for the period of 2018 to 2037 there is a large chance (88%) that internal rainfall variability will not completely offset the drying due to climate change under all emissions scenarios.[182] Dry conditions are projected to become increasingly likely as the century unfolds, especially if international efforts do not have a major impact on reducing global GHG emissions.

Up to 2060, climate models project similar drying in Victoria for low-, medium- and high-emissions scenarios.[183] Beyond this, the magnitude of rainfall reduction is related to emissions, with the range of rainfall reduction projected between 6.5% to 16%, depending on the emissions scenario, when compared to the period 1900 to 1959.[184]

178. Department of Environment, Land, Water and Planning (DELWP), Bureau of Meteorology (BOM), Commonwealth Scientific and Industrial Research Organisation (CSIRO), University of Melbourne 2020, 'Victoria's water in a changing climate', https://www.water.vic.gov.au/__data/assets/pdf_file/0024/503718/VICWACI_VictoriasWaterInAChangingClimate_FINAL.pdf Accessed 11 April 2022.
179. Observed and projected cool-season rainfall anomalies from the 1975-2018 climate period serves as a reference for Victoria in mm per month (in bars). The solid and dashed lines through the observations are 20-year and 15-year running averages, respectively. The coloured wedge represents the projected rainfall across 40 GCMs (CMIP5) by scaling the observation for the 1975–2018 period with the model-based mid-decile scaling factors derived by comparing the modelled future period with the modelled 1975–2018 period for different 30-year future periods centred at 2020, 2025 and every decade afterwards to 2050. The dashed black line is the middle of the range across the 40 models and the pink shaded area shows the 10th to 90th percentiles range of the 40 models. In grey, the observed 1900–2018 decadal variability is added.
180. Department of Environment, Land, Water and Planning (DELWP), Bureau of Meteorology (BOM), Commonwealth Scientific and Industrial Research Organisation (CSIRO), University of Melbourne 2020, 'Victoria's water in a changing climate', https://www.water.vic.gov.au/__data/assets/pdf_file/0024/503718/VICWACI_VictoriasWaterInAChangingClimate_FINAL.pdf Accessed 11 April 2022.
181. Ibid.
182. Rauniyar SP and Power SB 2020, 'The impact of anthropogenic forcing and natural processes on past, present and future rainfall over Victoria, Australia', *Journal of Climate.*
183. Ibid.
184. Department of Environment, Land, Water and Planning (DELWP), Bureau of Meteorology (BOM), Commonwealth Scientific and Industrial Research Organisation (CSIRO), University of Melbourne 2020, 'Victoria's water in a changing climate', https://www.water.vic.gov.au/__data/assets/pdf_file/0024/503718/VICWACI_VictoriasWaterInAChangingClimate_FINAL.pdf Accessed 11 April 2022.

Climate change — Impacts

Indicator CCIm:08 Regional climate projections

CCIm:08 Regional climate projections						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	N/A	↙	●	N/A	↙	●
Data source(s):	BOM, CSIRO, DELWP					
Measure(s):	Projected number of hot and frost days for various emission scenarios in 2030 and 2070					

Why this indicator?

It is important to understand how the climate is projected to change across Victoria, as it may not change in the same way in every region. Looking at projected changes regionally gives additional information that can be lost in statewide averages.

NB: This SoE 2023 indicator was 'CC:06 Regional climate projections' in the SoE 2018 Report.

Why this assessment in 2023?

Inland regions of Victoria are projected to warm by a greater amount (2.4°C) than coastal regions (1.9°C) by the 2050s (relative to 1986–2005).

The number of very hot days in Victoria is projected to double across the state by the 2050s relative to the 1986–2005 reference period and under a high-emissions pathway.

By the 2050s, Victoria is likely to experience more extreme short-duration rainfall, despite an overall decrease in rainfall.

Summary of State of the Environment 2018 Report assessment

- 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.

Critical data used for the 2023 assessment

- Victorian Climate Projections 2019

2023 assessment

Regional temperature changes

Inland regions of Victoria are projected to warm by a greater amount compared to coastal regions. For example, the maximum annual temperature for inland regions such as Goulburn, Loddon Campaspe and Ovens Murray is projected to be 2.4°C warmer by the 2050s (relative to 1986-2005 and within a range of 1.6–3.1°C) following a high-emissions pathway. The projected temperature increase by the 2050s for the coastal regions of Barwon, Greater Melbourne and Great South Coast under the same high-emissions scenario is slightly lower, at 1.9°C (within a range of 1.4–2.6°C).[185]

While a 2°C increase may not sound like much of an impact, it can markedly increase the likelihood of hot days occurring.[186] For example, Figure CCIm17 shows that the number of very hot days in Victoria is projected to double across the state by the 2050s relative to the 1986-2005 reference period and under a high-emissions pathway. The thresholds for very hot days vary across Victoria due to the differences in current climate — a 40°C-day in the northwest currently occurs about as often as a 35°C-day in Melbourne.[187]

185. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019', Melbourne, https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0029/442964/Victorias-Climate-Science-Report-2019.pdf Accessed 22 July 2022.
186. Ibid.
187. Ibid

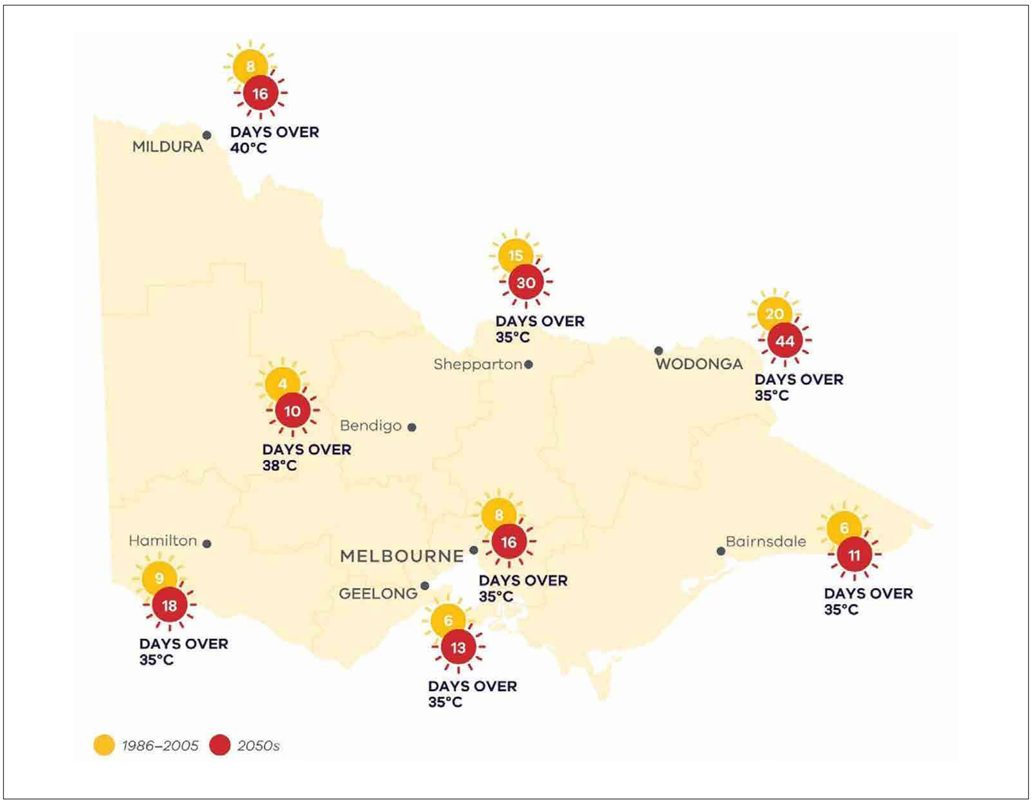

Figure CCIm17: Comparison of the median number of hot days per year during the 1986-2005 reference period and in the 2050s under high emissions (RCP8.5). Hot days have maximum temperature greater than the thresholds of 35°C, 38°C and 40°C for locations across Victoria.[188, 189]

Regional rainfall changes

Annual rainfall is likely to decline across the state by the 2050s compared with the rainfall totals recorded during the 1986-2005 reference period (Figure CCIm18).[190, 191] However, there will still be significant year-to-year rainfall variability, with Victoria likely to experience more extreme short-duration rainfall despite an overall decrease in rainfall.[192]

In response to the decline in rainfall, streamflow is also expected to decline. Streamflows over the past decades have been the lowest on record and are likely to continue to decline over coming decades.[193, 194]

The projected decline in the future is due to likely reductions in future cool-season rainfall, along with increasing temperatures and potential for evapotranspiration (the transfer of water vapour to the air directly from the soil, from open water or through plants). While future reductions in rainfall and streamflow are expected, there is a wide range of uncertainty about the timing and magnitude of these reductions.[195] Streamflow is discussed in more detail within indicator 'ER:09 Condition of flow regimes' in the 'Inland waters' chapter.

188. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019', Melbourne, https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0029/442964/Victorias-Climate-Science-Report-2019.pdf Accessed 22 July 2022.
189. Commonwealth Scientific and Industrial Research Organisation (CSIRO) 2019, 'Victorian climate projections 2019: Technical Report'.
190. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019', Melbourne, https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0029/442964/Victorias-Climate-Science-Report-2019.pdf Accessed 22 July 2022.
191. Commonwealth Scientific and Industrial Research Organisation (CSIRO) 2019, 'Victorian climate projections 2019: Technical report'.
192. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019', Melbourne, https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0029/442964/Victorias-Climate-Science-Report-2019.pdf Accessed 22 July 2022.
193. Department of Environment, Land, Water and Planning (DELWP), Bureau of Meteorology (BOM), Commonwealth Scientific and Industrial Research Organisation (CSIRO), University of Melbourne 2020, 'Victoria's water in a changing climate', https://www.water.vic.gov.au/__data/assets/pdf_file/0024/503718/VICWACI_VictoriasWaterInAChangingClimate_FINAL.pdf Accessed 11 April 2022.
194. Potter NJ, Chiew FHS, Zheng H, Ekstrom M and Zhang L 2016, 'Hydroclimate projections for Victoria at 2040 and 2065', Commonwealth Scientific and Industrial Research Organisation (CSIRO).
195. Department of Environment, Land, Water and Planning (DELWP), Bureau of Meteorology (BOM), Commonwealth Scientific and Industrial Research Organisation (CSIRO), University of Melbourne 2020, 'Victoria's water in a changing climate', https://www.water.vic.gov.au/__data/assets/pdf_file/0024/503718/VICWACI_VictoriasWaterInAChangingClimate_FINAL.pdf Accessed 11 April 2022.

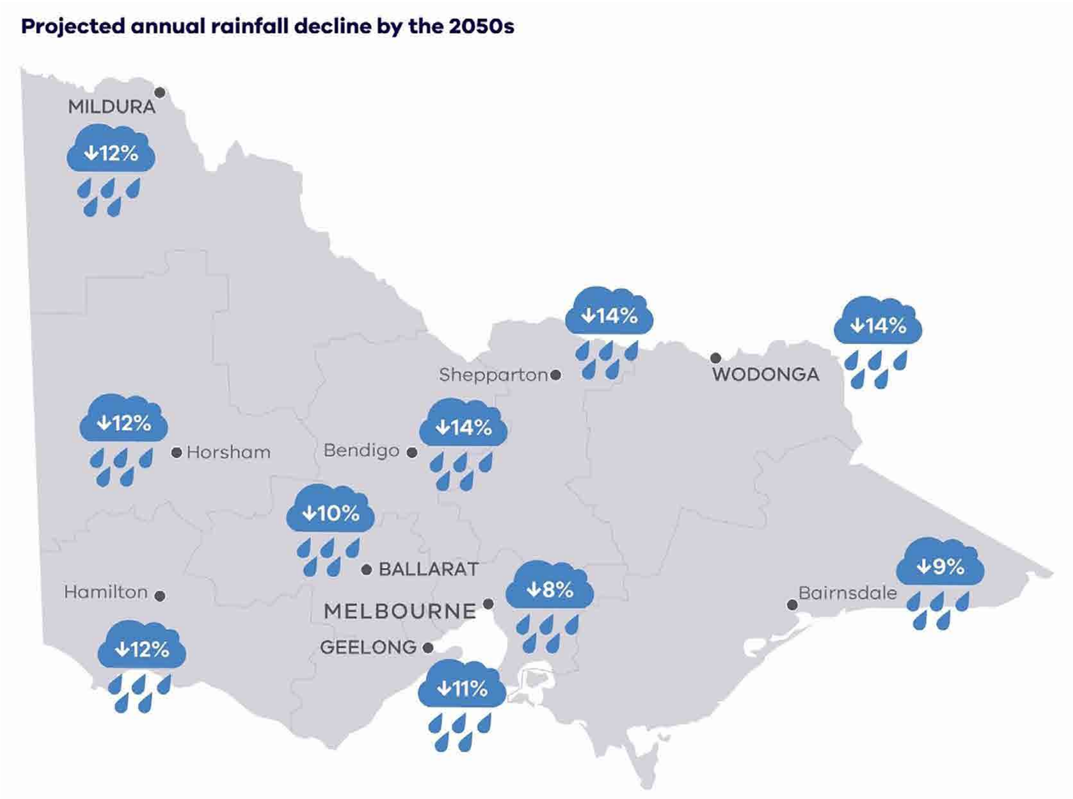

Figure CCIm18: Average percent decline in annual rainfall for locations across Victoria for the 2050s under high-emissions scenario (RCP8.5) compared to the 1986-2005 reference period.[196, 197]

196. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019', Melbourne, https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0029/442964/Victorias-Climate-Science-Report-2019.pdf Accessed 22 July 2022.
197. Commonwealth Scientific and Industrial Research Organisation (CSIRO) 2019, 'Victorian climate projections 2019: Technical report'.

Indicator CCIm:09 Projected sea level

CCIm:09 Projected sea level						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Victoria's coastline	N/A	↙	●	N/A	↙	●
Data source(s):	BOM, CSIRO					
Measure(s):	Projected mean sea level in 2030, 2050, 2070 and 2090 for all emission scenarios					

Why this indicator?

Projecting sea-level change is important to support planning and policy decisions made by the Victorian Government and communities. Projections are also used by scientific researchers to better understand the consequences of global climate change.

NB: This SoE 2023 indicator was 'CC:08 Projected sea level' in the SoE 2018 Report.

Why this assessment in 2023?

Future rises in sea level are projected with high confidence. Sea levels are expected to rise by approximately 12 cm at various places along Victoria's coastline by 2030, with a rise of approximately 40 cm projected by 2070. These projected rises are based on a high-emissions scenario (RCP8.5) and are relative to the levels observed for the 1986–2005 reference period. The trend assessment of deteriorating reflects the projected rise in sea levels and increasing pressure being exerted on human coastal settlements and infrastructure.

Summary of State of the Environment 2018 Report assessment

- Further mean sea-level rises and an increase in the frequency of extreme inundation events are projected.

Critical data used for the 2023 assessment

- A synthesis of published material and incorporated critical data previously analysed and reported
- Victoria's Climate Science Report 2019

2023 assessment

Future rises in sea level are projected with high confidence.[198] Figure CCIm19 shows sea levels are expected to rise by approximately 12 cm at various places along Victoria's coastline by the 2030s, with a rise of approximately 40 cm projected by the 2070s. These projected rises are based on a high-emissions scenario (RCP8.5) and are relative to the levels observed for the 1986-2005 reference period.

The various emissions scenarios all project a similar rise in sea level by the 2030s, with the global emissions pathway likely to have a greater impact by the 2070s. For the 2070s, sea-level rise projections vary from 32 cm (within a range of 20-46 cm) under a medium-emissions scenario (RCP4.5) to 42 cm (within a range of 26-54 cm) under a high-emissions scenario (RCP8.5).[199]

Understanding the range of projections for sea-level rise increases the robustness of climate change planning. Figure CCIm19 shows the median results associated with the modelled projections, while Table CCIm7 shows the range to provide detail about less likely, but still plausible, scenarios. The ranges in Table CCIm7 are based on the 5% to 95% range of model results for sea-level rise and were completed and first published in 2015.[200] A 2021 report by the IPCC stated that global mean sea-level rise approaching 2 m by 2100 and 5 m by 2150 under a very high GHG-emissions scenario (SSP5-8.5), even though provided with low confidence, cannot be ruled out due to deep uncertainty in ice-sheet processes.[201]

198. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019', Melbourne, https://www.climatechange.vic.gov.au/data/assets/pdf_file/0029/442964/Victorias-Climate-Science-Report-2019.pdf Accessed 22 July.
199. Commonwealth Scientific and Industrial Research Organisation (CSIRO), Bureau of Meteorology (BOM) 2015, 'Climate change in Australia: Information for Australia's natural resource management regions: Technical report', Australia.
200. Ibid
201. Intergovernmental Panel on Climate Change (IPCC) 2021, 'Climate change 2021: The physical science basis. Summary for policymakers', Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)].

Climate change — Impacts

Figure CCIm19: Sea-level rise projections (cm) relative to the baseline (1986–2005) for key Victorian locations under high (RCP8.5) emissions scenarios for the 2030s and 2070s.[202]

Table CCIm7: Likely ranges for projections of regional sea-level rise (cm) relative to the 1986–2005 period under all emissions scenarios.[203]

Locations	2030 projected sea-level rise (cm)	2050 projected sea-level rise (cm)	2070 projected sea-level rise (cm)	2090 projected sea-level rise (cm)
Geelong	6 - 17	12 - 33	18 - 54	22 - 82
Williamstown	6 - 17	12 - 32	17 - 54	22 - 81

Sea-level rise not only results in changes in mean sea level but can also change the frequency and intensity of extreme sea-level events, such as storm tides that occur when high tides combine with strong winds and low-pressure systems.[204]

The sea-level projections for Victoria are consistent with those at a national level. For example, projections published in 2015 show that, for 16 locations across Australia under a high-emissions scenario, sea levels are projected to rise (based on median modelled values) by between 59 cm and 66 cm by 2090.[205]

202. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019', Melbourne, https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0029/442964/Victorias-Climate-Science-Report-2019.pdf Accessed 22 July 2022.
203. Commonwealth Scientific and Industrial Research Organisation (CSIRO), Bureau of Meteorology (BOM) 2015, 'Climate change in Australia: Information for Australia's natural resource management regions: technical report', Australia.
204. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019', Melbourne, https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0029/442964/Victorias-Climate-Science-Report-2019.pdf Accessed 22 July.
205. Commonwealth Scientific and Industrial Research Organisation (CSIRO), Bureau of Meteorology (BOM) 2015, 'Climate change in Australia: Information for Australia's natural resource management regions: Technical report', Australia.

Impacts of climate change

Indicator CCIm:10 Occurrence and impacts of extreme weather

CCIm:10 Occurrence and impacts of extreme weather						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	Red	↙	Green	Red	↙	Green
Data source(s):	Australian Institute for Disaster Resilience, BOM, CSIRO, Deloitte Access Economics, DOH, Insurance Council of Australia					
Measure(s):	Frequency of extreme heat days Number of excess deaths associated with extreme heat days Number of dangerous fire weather days Financial cost associated with natural disasters					

Why this indicator?

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

NB: This SoE 2023 indicator was 'CC:12 Occurrence and impacts of extreme weather' in the SoE 2018 Report.

Why this assessment in 2023?

There has been a significant increase in the number of days per year of unusually high temperatures in Victoria. This is linked to increasing risks of heatwaves and bushfires. A drier climate with more intense rainfall events has also been experienced in recent years.

Several catastrophic natural disaster events have occurred since the SoE 2018 Report was published. These have had significant impacts on human life, wildlife, livestock and infrastructure.

The financial cost of natural disasters is increasing in Victoria and is projected to be at least $185 billion cumulatively from 2020 to 2060.

The human impacts of extreme heat can be catastrophic, particularly during multi-day heatwaves with oppressive overnight weather. In terms of fatalities in Australia, Victoria is most at risk from heatwaves, with 183 heatwave fatalities occurring across the state from 2001 to 2018. This number is more than half of all Australian heatwave fatalities during this period.

Summary of State of the Environment 2018 Report assessment

- 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).

Critical data used for the 2023 assessment

- BOM data on the number of days each year when the Victoria averaged daily mean temperature has been unusually warm hot
- Department of Health (DOH) data on the number of days when heat health alerts have been issued in Victoria
- The number of heat-related deaths during heatwave conditions in the National Coronial Information System (NCIS)
- Sustainability Victoria research from 2020 providing measures for community awareness and knowledge of the health impacts of climate change
- Major incidents reports
- State of the Climate 2022
- Special Report: Update to the Economic Costs of Natural Disasters in Australia
- Insurance Catastrophe Resilience Report: 2020-21.

2023 assessment

Extreme heat

The shift to a warmer climate across Victoria has been accompanied by an increase in the number of extreme heat events occurring across large areas of the state. This is illustrated by increases in the number of days per year, and particularly during the summer months, when Victorian temperatures have been unusually hot (Figure CCIm20 and Figure CCIm21). In these cases, unusually hot days are defined as those above the 99th percentile of each month (in this case from the years 1910–2021).[206, 207] This century has not seen a year without at least one unusually hot day compared to the start of the record which contains many years without unusually hot days (25% of years from 1910-1950 contained no unusually hot days). Furthermore, there has been an average of 6.6 unusually hot days per year this century, compared to 3.0 last century — there is a similar pattern for summer months, with an average of 1.9 unusually hot days per year during summer months this century compared to 0.7 unusually hot summer days per year last century. As described in Indicator 'CCIm:08 Regional climate projections', the number of very hot days in Victoria is projected to double across the state by the 2050s relative to the 1986-2005 reference period and under a high-emissions pathway.

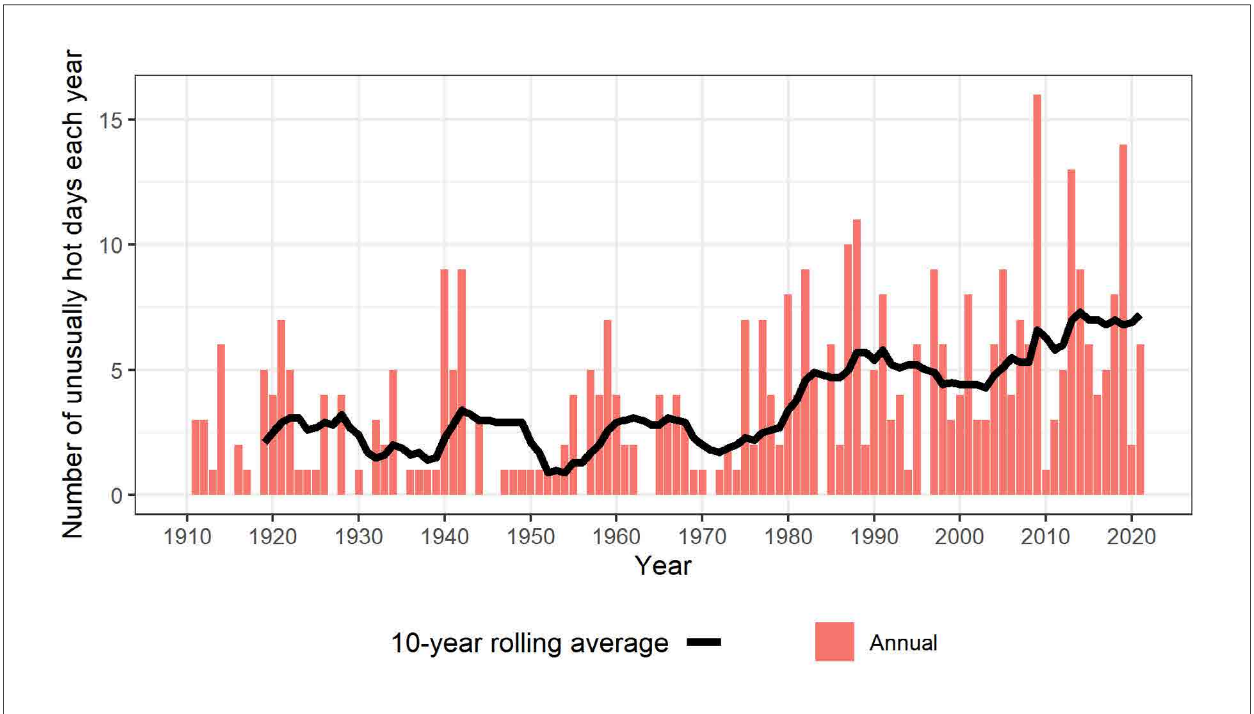

Figure CCIm20: Number of days each year when the averaged daily mean temperature in Victoria has been unusually hot between 1910 to 2020. Unusually hot days are those above the 99th percentile of each month from the years 1910 to 2021.[208]

206. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019', Melbourne, https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0029/442964/Victorias-Climate-Science-Report-2019.pdf Accessed 22 July.
207. The thresholds for very hot days vary across Victoria due to the differences in current climate: a 40°C-day in the northwest currently occurs about as often as a 35°C-day in Melbourne.
208. Bureau of Meteorology (BOM), 'Unpublished data', Australia, Accessed 2022.

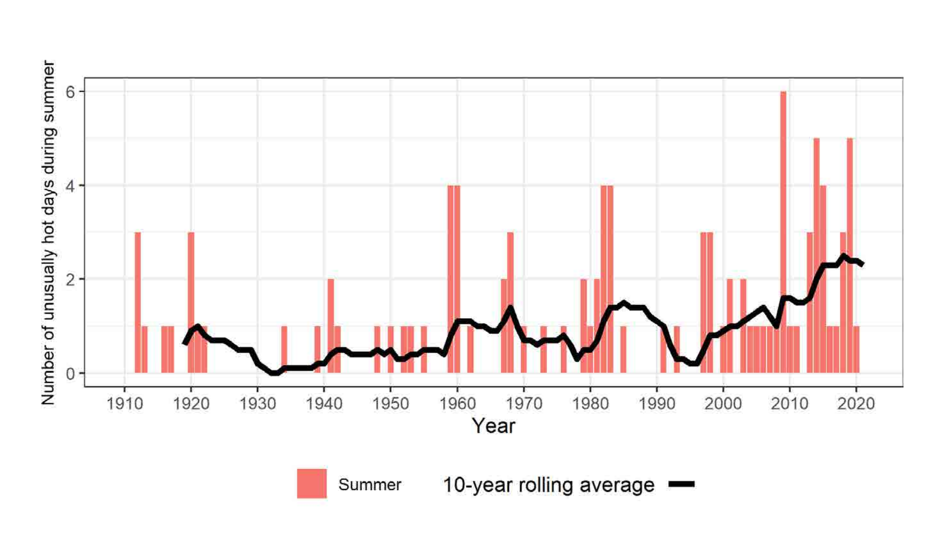

Figure CCIm21: Number of days each year during summer when the averaged daily mean temperature in Victoria has been unusually hot. Unusually hot days are those above the 99th percentile of each month from the years 1910 to 2021.[209]

Victoria's DOH operates a heat health alert system from November to March, with data on the number of heat health alerts available since 2009.[210, 211] The system is based on temperature thresholds above which heat-related illness and mortality increases. The peak year for heat health alerts was during 2019, with 84 alerts issued for 22 days of extreme heat across multiple districts. For the first five years of heat health alert data (2009-2013), there was an average of 6.8 days per year when heat health alerts were issued. For the most recent five years (2017-2021), this had increased by 50% to 10.2 days per year when heat health alerts were issued (Figure CCIm22).

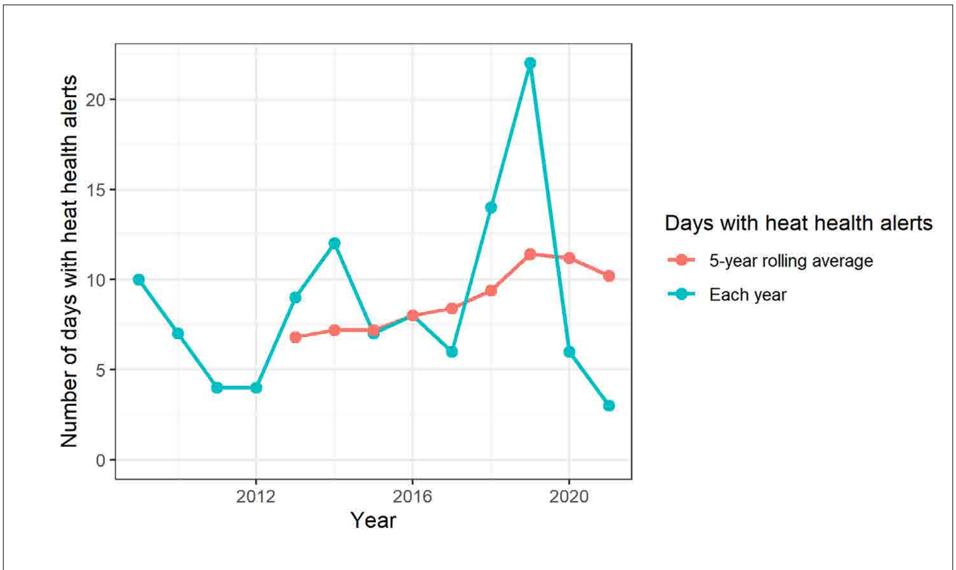

Figure CCIm22: Number of days with heat health alerts in Victoria from 2009 to 2021.[212]

209. Bureau of Meteorology (BOM), 'Unpublished data', Australia, Accessed 2022.
210. Department of Health (DOH), 'Heat health alerts', https://www.health.vic.gov.au/environmental-health/heat-health-alerts Accessed 22 July 2022.
211. Bettio L, Nairn JR, McGibbony SC, Hope P, Tupper A, Fawcett RJB 2019, 'A heatwave forecast service for Australia', Proceedings of the Royal Society of Victoria 131, 53-59.
212. Department of Health (DOH) 2022, 'Unpublished data', Melbourne, Victoria.

Climate change — Impacts

While there is good data on when the alerts are issued, there is less information available on the effect of the alerts. This was identified in the Health and Human Services Climate Change Adaptation Action Plan 2022–2026, with Action H2 of that plan focussed on improving the evidence base and monitoring of climate-related health impacts, including implementing an ongoing surveillance program which brings together data on changes in climate-related health hazards, vulnerabilities, and population health outcomes in Victoria.[213]

The impacts of extreme heat can be catastrophic, particularly during multi-day heatwaves with oppressive overnight weather. Research published in 2022 on heatwave fatalities in Australia from 2001-2018 found at least 473 heat-related deaths were reported to a coroner during the period of research, of which 354 occurred during heatwave conditions and, of these, 244 occurred within buildings.[214]

Most indoor heatwave fatalities occurred in older housing stock.[215] Older homes can also be a risk for residents in extremely cold weather. Parts of south-east Australia have seen significant cool-season drying, and hence, more clear winter nights.[216] This results in colder nights due to increased heat loss from the ground.

In terms of total heatwave fatalities in Australia, Victoria is most at risk with more than half (52%) of all Australian heatwave fatalities from 2001 to 2018 reported to coroners occurring in Victoria.[217] On a per capita basis, Victoria ranked third with 0.18 deaths per 100,000 people (behind Northern Territory and South Australia at 0.32 and 0.31 deaths, respectively). It is unclear why Victoria is more at risk than many other Australian states and territories, however, current research has highlighted that most fatalities occurred in houses built pre-2006 and without air conditioning.[218] The current threat is likely to increase with the combination of an ageing population, increasing urbanisation and the expectation of longer, more frequent and more intense heatwaves under future climatic conditions.

The most catastrophic heatwave events in Victoria, in terms of the greatest number of heat-related deaths during heatwave conditions in the NCIS database from 2001 to 2018, occurred in January to February of 2009 (66 deaths) and January 2014 (92 deaths).[219] Note that deaths reported to a coroner (NICS records) were less than excess death estimates for specific heatwave events available from the literature. In Victoria, 374 excess deaths were attributed to a January 2009 heatwave (the majority of those deaths occurring in people over 75 years of age), while there were an estimated 167 excess deaths during a January 2014 heatwave.[220, 221]

Heatwaves are exacerbated by the urban heat island (UHI) effect. Research focusing on Sydney has found that the number of heatwave days could increase fourfold (from 2006-2018 to 2080-2099) under the most extreme climate change scenario. However, the researchers concluded that greater than 90% of current heatwave days in Sydney would not breach heatwave thresholds if there was no UHI effect. Tree canopy reduces urban heat, and widespread tree planting could offset the increases in heat-attributable deaths as climate warming progresses.[222]

Despite the increasing risks and impacts associated with extreme heat, research published in 2020 by Sustainability Victoria highlighted that significant proportions of the public remain unaware of a range of health conditions that health professionals believe will become more common. In some instances, the people most likely to be unaware are those most at risk of the condition. For example, young men and older people were less likely to be aware of heatstroke and heat stress, yet it is people from these subgroups who are most vulnerable to these health conditions.[223]

213. Department of Health (DOH), Department of Families, Fairness and Housing (DFFH) 2022, 'Health and Human Services climate change adaptation action plan 2022–2026', https://www.health.vic.gov.au/sites/default/files/2022-02/health-human-services-climate-change-adaptation-action-plan-2022-2026_0.pdf Accessed 21 July 2022.
214. Coates L, van Leeuwen J, Browning S, Gissing A, Bratchell J, Avci A 2021, 'Heatwave fatalities in Australia, 2001-2018: An analysis of coronial records', *International Journal of Disaster Risk Reduction*, 67.
215. Ibid.
216. Commonwealth Scientific and Industrial Research Organisation (CSIRO), Bureau of Meteorology (BOM) 2022, 'State of the climate 2022', http://www.bom.gov.au/state-of-the-climate/2022/documents/2022-state-of-the-climate-web.pdf Accessed 29 November 2022.
217. Coates L, van Leeuwen J, Browning S, Gissing A, Bratchell J, Avci A 2021, 'Heatwave fatalities in Australia, 2001-2018: an analysis of coronial records'. *International Journal of Disaster Risk Reduction*, 67.
218. Ibid.
219. Ibid.
220. Department of Human Services (DOHS) 2009, 'January 2009 heatwave in Victoria: An assessment of health impacts' Melbourne, Victoria.
221. Department of Health (DOH) 2014, 'The health impacts of the January 2014 heatwave in Victoria'.
222. Chaston TB, Broome RA, Cooper N, Duck G, Geromboux C, Guo Y, Ji F, Perkins-Kirkpatrick S, Zhang Y, Dissanayake GS, Morgan GG, Hanigan IC 2022, 'Mortality burden of heatwaves in Sydney, Australia is exacerbated by the urban heat island and climate change: Can tree cover help mitigate the health impacts?', *Atmosphere*, 13, 714. https://doi.org/10.3390/atmos13050714 Accessed 6 July 2023.
223. Sustainability Victoria (SV) 2020, 'Linking climate change and health impacts - Social research exploring awareness among Victorians and our healthcare professionals of the health effects of climate change', https://assets.sustainability.vic.gov.au/susvic/Report-Linking-climate-change-and-health-impacts-Research-Snapshot-2020.pdf Accessed 28 November 2022.

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.[224] More detail on the effects on biodiversity from climate change is provided in indicator 'B:35 Climate-sensitive ecosystems' within the 'Biodiversity' chapter.

Extreme storms, rainfall and flooding

In 2019, Australian researchers collaborating as part of the Earth Systems and Climate Change Hub reported that extreme rainfall caused by thunderstorms is likely to increase in intensity resulting in increased flood-risk factors in some cases. Furthermore, they reported that climate models indicate a potential increase in future thunderstorm frequency for parts of eastern Australia.[225] Several severe storms have impacted Victoria since 2019, including some of the more costly ones that are detailed below.

October 2022

In mid-October 2022, severe downpours across large parts of Victoria — triggered by the third consecutive year of weather patterns impacted by a La Niña state — led to several rivers flooding their banks, inundating and isolating thousands of properties across much of the state. The complete cost and extent of damages are not included in this report as they are yet to be quantified and published. However, public reporting at the time of the floods described a catastrophic event with devastating human, animal and financial consequences.

The floods inundated 63 local government areas across regional Victoria and Melbourne. Victoria's State Emergency Service (SES) received 3,049 calls for help in a 24-hour period in mid-October, including 1,766 flood incidents and 128 rescues.[226]

The rainfall and flooding impacted much of eastern Australia, and in November 2022 the Insurance Council of Australia estimated they had generated more than 17,200 claims with estimated insured losses of $477 million across Victoria, New South Wales and Tasmania.[227]

In December 2022, Agriculture Victoria published data showing the floods had caused 15,662 livestock deaths in the state, with a further 1,937 missing. There were also thousands of kilometres of damaged fencing, more than 150,000 tonnes of hay or silage that had been destroyed and more than 200,000 hectares of field crops had been lost.[228]

June 2021

An extensive severe weather system caused significant impact and damage in June 2021, largely across the Central Highlands, Dandenong Ranges and Gippsland areas, resulting in significant wind damage and widespread flooding. Parts of Traralgon were evacuated.[229]

The weather caused major impacts to critical infrastructure, damage to properties and isolation of multiple communities across Victoria. Victoria's SES received more than 9,100 requests for assistance across the state relating to the flood and storm event.[230]

Over 160,000 properties lost power, many for over a week. Damage assessments identified at least 110 properties as uninhabitable. Two deaths were reported, and many communities remained in communications isolation for a number of days.[231]

January 2020

Severe thunderstorms developed over central and eastern Victoria that brought hailstone of up to 5.5 cm in diameter to parts of south-east Melbourne, while damaging winds, heavy rainfall and flash flooding occurred over broader areas of the state over the following days.[232]

224. Department of Environment, Land, Water and Planning (DELWP), 'Heat stress in wildlife', https://www.wildlife.vic.gov.au/wildlife-emergencies/heat-stress-in-wildlife2 Accessed 22 July 2022.
225. Earth Systems and Climate Change Hub 2019, ' Thunderstorms and climate change in Australia', https://nespclimate.com.au/wp-content/uploads/2019/11/A4_4pp_brochure_NESP_ESCC_Thunderstorms_Nov11_2019_WEB.pdf Accessed 22 November 2022.
226. Parliament of Victoria, 'Inquiry probes 2022 Victoria floods', https://new.parliament.vic.gov.au/news/environment/floodsubmissions Accessed 17 March 2023.
227. Insurance Council of Australia, 'Three-year weather bill reaches $12.3 billion', Media release 30 November 2022, https://insurancecouncil.com.au/wp-content/uploads/2022/11/221130-Three-year-weather-bill-reaches-12.3-billion.pdf Accessed 17 March 2023.
228. Agriculture Victoria, 'Flood and storm impacts in late 2022', https://agriculture.vic.gov.au/farm-management/emergency-management/floods/flood-and-storm-impacts-late-2022 Accessed 17 March 2023.
229. Australian Institute for Disaster Resilience 2020, 'Major incidents report 2020-21', https://knowledge.aidr.org.au/media/8975/aidr_major-incidents-report_2020-21.pdf Accessed 21 July 2022.
230. Ibid.
231. Ibid.
232. Ibid.

The hailstones damaged cars and homes in several south-eastern Melbourne suburbs and caused part of a supermarket ceiling to collapse. Transport networks were also significantly affected, with rail and tram services across Melbourne heavily impacted and freeway traffic brought to a standstill, including all east-bound lanes of the Princes Highway being closed at Pakenham just after 4pm on 20 January.[233]

The Victorian SES received more than 1,000 calls during a single day to attend to building damage, more than 200 calls for fallen trees and 140 calls for flooding.[234]

August 2019

West and South Gippsland and the coastal south-west sustained winds of 90 km/h to 110 km/h, with gusts of 128 km/h recorded at Wilsons Promontory and 120 km/h at Cape Otway. One person died in the Yarra Ranges when a gum tree fell onto a car.[235]

During a 24-hour period, the Victorian SES received more than 600 requests for assistance, mostly due to fallen trees and some building damage. Other impacts included the Frankston pier breaking from its moorings and drifting across the bay, while more than 45 domestic flights were cancelled in a day at Melbourne Airport.[236]

Bushfires

There is a clear trend toward more dangerous weather conditions for bushfires in southeast Australia, including significant increases in the frequency and magnitude of extreme conditions in some regions (Figure CCIm23). In 2021, the IPCC reported with high confidence that fire weather is projected to increase throughout Australia.[237] The Forest Fire Danger Index (FFDI) is used throughout Victoria by fire agencies to plan and manage

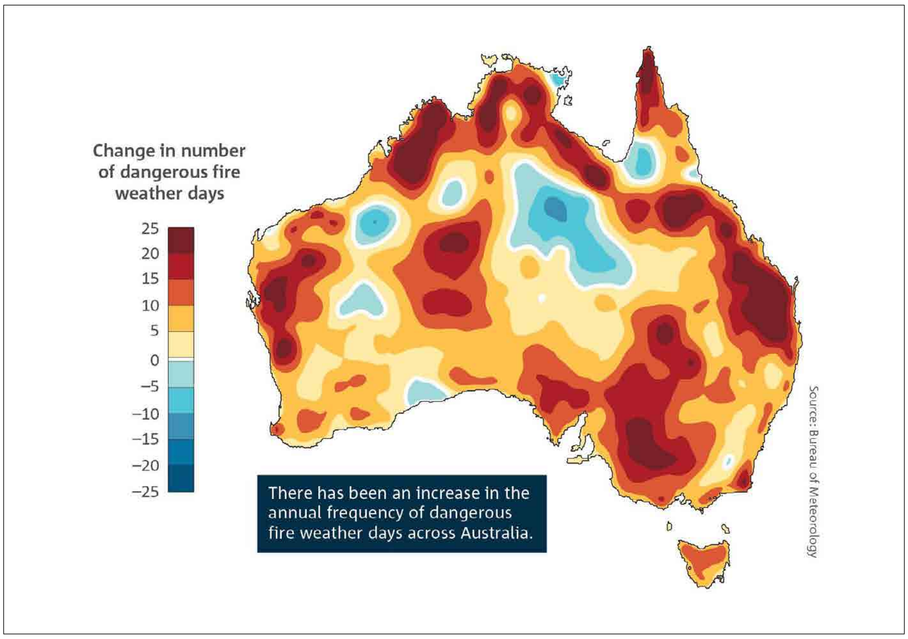

Figure CCIm23: Change in the number of days that the Forest Fire Danger Index exceeded its 90th percentile between July 1950–June 1985 and July 1985–June 2022 across Australia.[239]

233. Australian Institute for Disaster Resilience 2020, 'Major incidents report 2020-21', https://knowledge.aidr.org.au/media/8975/aidr_major-incidents-report_2020-21.pdf Accessed 21 July 2022.
234. Ibid.
235. Ibid.
236. Ibid.
237. Arias PA, Bellouin N, Coppola E, Jones RG, Krinner G, Marotzke J, Naik V, Palmer MD, Plattner GK, Rogelj J, Rojas M, Sillmann J, Storelvmo T, Thorne PW, Trewin B, Achuta Rao K, Adhikary B, Allan RP, Armour K, Bala G, Barimalala R, Berger S, Canadell JG, Cassou C, Cherchi A, Collins W, Collins WD, Connors SL, Corti S, Cruz F, Dentener FJ, Dereczynski C, Di Luca A, Diongue Niang A, Doblas-Reyes FJ, Dosio A, Douville H, Engelbrecht F, Eyring V, Fischer E, Forster P, Fox-Kemper B, Fuglestvedt JS, Fyfe JC, Gillett NP, Goldfarb L, Gorodetskaya I, Gutierrez JM, Hamdi R, Hawkins E, Hewitt HT, Hope P, Islam AS, Jones C, Kaufman DS, Kopp RE, Kosaka Y, Kossin J, Krakovska S, Lee JY, Li J, Mauritsen T, Maycock TK, Meinshausen M, Min SK, Monteiro PMS, Ngo-Duc T, Otto F, Pinto I, Pirani A, Raghavan K, Ranasinghe R, Ruane AC, Ruiz L, Sallée JB, Samset BH, Sathyendranath S, Seneviratne SI, Sörensson AA, Szopa S, Takayabu I, Tréguier AM, van den Hurk B, Vautard R, von Schuckmann K, Zaehle S, Zhang X and Zickfeld K 2021, 'Technical Summary', In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte V, Zhai P, Pirani A, Connors SL, Péan C, Berger S, Caud N, Chen Y, Goldfarb L, Gomis MI, Huang M, Leitzell K, Lonnoy E, Matthews JBR, Maycock TK, Waterfield T, Yelekçi O, Yu R and Zhou B (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 33–144. doi:10.1017/9781009157896.002.
238. Bureau of Meteorology (BOM), Commonwealth Scientific and Industrial Research Organisation (CSIRO) 2022, 'State of the climate 2022', http://www.bom.gov.au/state-of-the-climate/2022/documents/2022-state-of-the-climate-web.pdf Accessed 29 November 2022.
239. Ibid.

resources in response to the risk of bushfires. The FFDI indicates the fire danger on a given day based on observations of temperature, rainfall, humidity and wind speed. FFDI patterns have been changing over recent decades, with the strongest increases generally occurring during summer and spring. Climate change is contributing to these changes in fire weather.[238]

These changes to the springtime pattern indicate a shift towards an earlier start to the fire season, which also impacts the prescribed burning season. There is likely to be a narrower window of opportunity for prescribed burning in the future, which would most likely result in an increase in prescribed burning during winter. This is likely to mean smoke impacts from prescribed burning will be concentrated into a shorter, more intense period.[240] More information on prescribed burning is available in indicator 'Fi:01 Area of native vegetation burnt in planned fires and bushfires' of the 'Fire' chapter.

Considerable year-to-year variability in fire weather also occurs. La Niña years (e.g. 2020–21 and 2010-11) are associated with wet and cool climate anomalies and a lower number of days with high FFDI values.[241]

November 2019 to February 2020

On 21 November 2019, a total fire ban was declared for the entire state and code red (catastrophic) fire danger conditions were forecast for the state's west. One hundred and fifty fires started in Victoria that day, burning 326,000 ha.[242]

On 20 December 2019, another total fire ban was declared for Victoria and a new December maximum temperature record of 47.9°C was set at Hopetoun and Horsham. One hundred and ten new fires broke out that day. Over the following days, several smaller fires began to combine, creating large fires that threatened several communities and critical infrastructure.[243]

On 30 December 2019, another state-wide total fire ban was declared as multiple new fires started from dry lightning in the Grampians, Hume and Gippsland regions. Three fires in East Gippsland with a combined area of more than 130,000 ha remained active; some fires burned with sufficient intensity to create thunderstorms within smoke plumes that generated extremely dangerous fire conditions that included local thunder and lightning.[244]

Early in the morning of 31 December 2019, the Banana Track fire reached the coastal town of Mallacoota in the state's far east. Several thousand people were isolated in the town and more than 60 homes were destroyed. Escape routes were cut off and an estimated 4,000 people gathered on the town's foreshore, protected by the local Country Fire Authority (CFA) brigade, three CFA strike teams, Forest Fire Management Victoria firefighters and Victoria Police personnel.[245]

For December, record warmth across Australia had been accompanied by record low rainfall over eastern Australia. The monthly accumulated FFDI for December was the highest on record over most of the country, and for Australia as a whole, the December 2019 FFDI was the highest on record for any month. On 30 and 31 December, FFDI values were highest on record for December over areas of south-eastern Australia, including regions of significant fire activity in East Gippsland. By the end of December, fires had burnt 400,000 ha across the state, more than 230,000 ha in East Gippsland, and many communities remained isolated without power or telecommunications.[246]

The Snowy Complex fire in the far east of the state was the last major fire to be contained. This occurred on 27 February 2020 after it had burned 663,000 ha.[247]

The Victorian bushfires during the summer of 2019–20 caused the loss of lives of five humans and 6,632 livestock, while destroying more than 300 homes.

240. Di Virgilio G, Evans JP, Clarke H, Sharples J, Hirsch AL, Hart MA 2020, 'Climate change significantly alters future wildfire mitigation opportunities in southeastern Australia', *Geophysical Research Letters*, 47, e2020GL088893.
241. Bureau of Meteorology (BOM), Commonwealth Scientific and Industrial Research Organisation (CSIRO) 2022, 'State of the climate 2022', http://www.bom.gov.au/state-of-the-climate/2022/documents/2022-state-of-the-climate-web.pdf Accessed 29 November 2022.
242. Australian Institute for Disaster Resilience 2020, 'Major incidents report 2019-20', https://knowledge.aidr.org.au/media/8049/aidr_major-incidents-report_2019-20.pdf Accessed 21 July 2022.
243. Ibid.
244. Ibid.
245. Ibid.
246. Ibid.
247. Ibid.

The fires burned more than 1.5 million ha of public and private land, including 1.39 million ha of forests and parks, plantations and native timber assets, critical wildlife habitat and water catchments.[248] For context, the 1.5 million ha burnt in 2019-20 compares with the over 430,000 ha burnt in the 2009 Black Saturday fires, approximately 1.2 million ha burnt during the 2006-07 fire season and 1.3 million ha in 2003.[249]

A preliminary evaluation of the health burden of the Victorian 2019-20 bushfires estimated that bushfire smoke was associated with 120 excess deaths — more information on bushfire smoke and air quality is presented in the 'Air' chapter.

Cost of natural disasters

Natural disasters are currently estimated to cost Australia $38 billion per year, on average.[250] This expense is forecast to grow — in line with population growth, climate change and property value growth — to between $73 billion per year (under a low-emissions scenario) and $94 billion per year (under a high-emissions scenario by 2060.[251, 252]

The total cost of natural disasters for Victoria over the 40 years from 2020 to 2060 is estimated to be between $185 billion (under a low-emissions scenario) and $206 billion (under a high-emissions scenario).[253] These estimates highlighted that Melbourne would be particularly susceptible to the financial cost of natural disasters in a high-emissions future, with the annual cost of natural disasters for the state capital projected to nearly quadruple from $1.6 billion in 2020 to $6.2 billion in 2060 under a high-emissions scenario.

Insurance losses are one cost of natural disasters. Based on information reported by the Insurance Council of Australia, insurance claims and costs are presented below for recent natural disasters in Victoria:

- A total of 26,578 insurance claims were made with costs totalling $230 million due to storms and floods in June 2021.[254]
- The estimated cost of damage caused by storms that had struck Victoria, New South Wales and the Australian Capital Territory in January 2020 was $1.2 billion from 107,932 lodged claims, more than 60,000 of them for damaged motor vehicles. An estimated 30% of the claims arose from Victoria.[255]
- The black summer 2019-20 bushfires have been estimated to have been responsible for 304,359 insurance claims incurring a cost of $5.47 billion nationally.[256]

The insurance losses presented above do not include properties that were not insured or underinsured. These elements are important given the likelihood of rising insurance premiums alongside increasing frequency and severity of natural disasters. A 2021 report for South Australia found that, as natural disasters increase due to climate change, people whose home, contents, and/or vehicles are uninsured may face catastrophic financial losses that push them into poverty, or further entrench their poverty.[257]

248. Ibid.
249. Department of Environment, Land, Water and Planning (DELWP), 'Past bushfires', https://www.ffm.vic.gov.au/history-and-incidents/past-bushfires Accessed 18 November 2022.
250. Deloitte Access Economics 2021, 'Special report: Update to the economic costs of natural disasters in Australia', Australian Business Roundtable for Disaster Resilience and Safer Communities, https://www.iag.com.au/sites/default/files/Newsroom%20PDFs/Special%20report%20_Update%20to%20the%20economic%20costs%20of%20natural%20disasters%20in%20Australia.pdf Accessed 21 July 2022.
251. Ibid.
252. It is important to note that this economic modelling was done for natural disasters, which includes earthquakes that are not climate-related natural disasters. However, earthquakes are forecast to be a relative smaller contributor to natural disaster costs (estimated to be less than 5% of the total cost of natural disasters by 2060) compared with the other natural disasters included in the analysis (bushfires, coastal inundation, flooding, severe storms and hail, and tropical cyclones).
253. Deloitte Access Economics 2021, 'Special report: Update to the economic costs of natural disasters in Australia', Australian Business Roundtable for Disaster Resilience and Safer Communities, https://www.iag.com.au/sites/default/files/Newsroom%20PDFs/Special%20report%20_Update%20to%20the%20economic%20costs%20of%20natural%20disasters%20in%20Australia.pdf Accessed 21 July 2022.
254. Insurance Council of Australia 2021, 'Insurance catastrophe resilience report: 2020-21', https://insurancecouncil.com.au/wp-content/uploads/2021/09/ICA008_CatastropheReport_6.5_FA1_online.pdf Accessed 21 July 2022.
255. Australian Institute for Disaster Resilience 2020, 'Major incidents report 2019-20', https://knowledge.aidr.org.au/media/8049/aidr_major-incidents-report_2019-20.pdf Accessed 21 July 2022.
256. Insurance Council of Australia 2021, 'Insurance catastrophe resilience report: 2020-21', https://insurancecouncil.com.au/wp-content/uploads/2021/09/ICA008_CatastropheReport_6.5_FA1_online.pdf Accessed 21 July 2022.
257. Freeman T 2022, 'Protecting the Basics: Insurance access for people on low incomes at risk from climate emergencies', South Australian Council of Social Service, Adelaide.

Climate change — Impacts

Compound events

Compound extreme events are the combination of multiple drivers and/or hazards that contribute to societal or environmental risk. Examples are concurrent heatwaves and droughts, compound flooding (e.g. a storm surge in combination with extreme rainfall and/or river flow), compound fire weather conditions (e.g. a combination of hot, dry and windy conditions), or concurrent extremes at different locations.[258]

It should be noted that the different types of hazards presented in this indicator narrative have generally been considered in isolation, but Victoria is becoming affected by collocated changes in several types of related hazards.

One example from January 2020 is that severe thunderstorms were occurring across Victoria while 15 bushfires were still burning across the state.

The rain, humidity and cooler temperatures brought welcome relief to some firefighters, however, fire-affected catchments in East Gippsland and north-east Victoria were put on flood watch. Firefighters were withdrawn from some areas due to fears that strong winds and flash flooding could topple trees, create landslides and send debris onto roads in areas damaged by fire.[259]

The Victorian Government's Built Environment Climate Change Action Plan 2022-2026 reported that an increased incidence of landslides and erosion is an associated risk with compound events. Impacts from these types of events include damage to building footings that cause instability, damage to buried infrastructure, damage to downslope dwellings and infrastructure, and dispersal of contaminated soils if waste storage or landfills are breached.[260]

Woorookarung Regional Park.
Credit: Peter Kervarec. © Parks Victoria.

258. Intergovernmental Panel on Climate Change (IPCC) 2021, 'Climate change 2021: The physical science basis Summary for policymakers', Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V, P Zhai, A Pirani, SL Connors, C Péan, S Berger, N Caud, Y Chen, L Goldfarb, MI Gomis, M Huang, K Leitzell, E Lonnoy, JBR Matthews, TK Maycock, T Waterfield, O Yelekçi, R Yu, and B Zhou (eds)].
259. Australian Institute for Disaster Resilience 2020, 'Major incidents report 2019-20', https://knowledge.aidr.org.au/media/8049/aidr_major-incidents-report_2019-20.pdf Accessed 21 July 2022.
260. Department of Environment, Land, Water and Planning (DELWP) 2022, 'Built environment climate change adaptation action plan 2022–2026', Melbourne, Victoria, https://www.planning.vic.gov.au/__data/assets/pdf_file/0034/635965/Built-Environment-Climate-Change-Adaptation-Action-Plan-2022-2026.pdf Accessed 23 November 2022.

Climate change — Mitigation

Indicator CCM:11 Annual greenhouse gas emissions

CCM:11 Annual greenhouse gas emissions						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	🟡	↗	🟢	🔴	↗	🟢
Data source(s):	ABS, DCCEEW					
Measure(s):	Victorian annual GHG emissions (total and by sector) Victorian per capita annual GHG emissions					

Why this indicator?

Section 52 of the *Climate Change Act 2017* (CC Act) Act requires the minister administering the CC Act to prepare annual GHG emissions reports for Victoria. The CC Act requires that the reports include an overview and collation of the best practicably available information about Victoria's GHG emissions and the extent to which emissions have been reduced compared with 2005 levels (the reference year for interim emissions reduction targets under the CC Act).

NB: This SoE 2023 indicator was 'CC:10 Annual greenhouse gas emissions' in the SoE 2018 Report.

Why this assessment in 2023?

Victoria's total net GHG emissions were 30% lower in 2020 compared with 2005 levels. Most of the improvement since 2005 has occurred in the five years since 2015: emissions decreased by 27% between 2015 and 2020. These reductions have led to an upgraded status assessment of fair in this report from poor in the SoE 2018 Report.

Summary of State of the Environment 2018 Report assessment

- 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.

Critical data used for the 2023 assessment

- Australian Greenhouse Emissions Information System
- Victorian Greenhouse Gas Emissions Report 2020

2023 assessment

National and international context

Despite a relatively small population, Australia is one of the world's biggest GHG emitters. Australia emitted the 15th most GHGs in 2019 — more than the United Kingdom and France.[261] Australia's contribution is even more significant on a per capita basis, with no other country from the Organisation for Economic Co-operation and Development (OECD) emitting more GHGs per person than Australia in 2020.[262]

A state-by-state display of GHG emissions per capita is presented in Figure CCM28 within this indicator assessment.

261. Climate Watch 2021, 'Historical GHG Emissions 2021', Washington, DC: World Resources Institute, https://www.climatewatchdata.org/ghg-emissions Accessed 6 July 2022.
262. Organisation for Economic Co-operation and Development, 'Air and GHG emissions', https://data.oecd.org/air/air-and-ghg-emissions.htm Accessed 8 March 2022.

Climate change — Mitigation

Greenhouse gases

In Victoria, carbon dioxide is the most significant GHG, contributing 71% of total emissions in 2020.[263] The majority of carbon dioxide emissions come from electricity and heat production and transport. Emissions of methane and nitrous oxide in 2020, mainly from enteric fermentation (methane) and agriculture soils (nitrous oxide), also made contributions of 20% and 5%, respectively, to the total GHG emissions.

Annual GHG emissions in Victoria

Victoria's CCA Act established a long-term target of net-zero GHG emissions by 2050, and a requirement to set five-yearly interim emissions reduction targets.[264] The Victorian Government set a foundational target for emissions to be 15% to 20% below 2005 levels by 2020.[265] This has been achieved as Victoria's total net GHG emissions were 30% lower in 2020 compared with 2005 levels (Figure CCM24). These reductions have led to a trend assessment of improving for this indicator.

Most of the improvement since 2005 occurred in the decade following 2010 — when Victoria's GHG emissions peaked at 139.8 Mt CO2-e. From then, emissions fell by 40% between 2010 and 2020. This was driven primarily by the electricity generation contribution to GHG emissions decreasing from 65.3 Mt CO2-e in 2010 to 41.7 Mt CO2-e in 2020, complemented by a net sequestration of 21.1 Mt CO2-e benefit from the land use, land-use change and forestry (LULUCF) sector in 2020 compared to a net source of 11.3 Mt CO2-e from that sector in 2010.[266]

It is important to note that, even without accounting for the benefits from the increasing net sequestration of the LULUCF sector, the Victorian Government's foundational target for emissions to be 15% to 20% below 2005 levels by 2020 would have been achieved; cumulatively across all the other sectors there has been a 20% decrease in GHG emissions from 2005 to 2020.

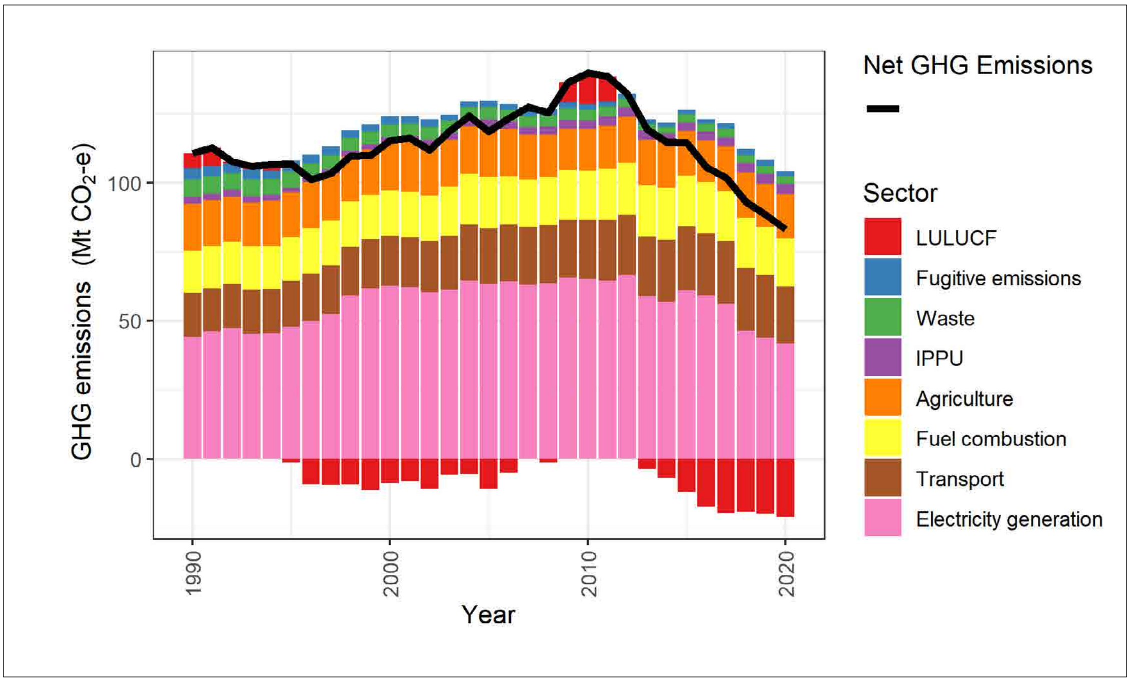

Figure CCM24: Victoria's annual GHG emissions between 1990 and 2020.[267]

263. Department of Climate Change, Energy, the Environment and Water (DCCEEW), 'Australian greenhouse emissions information system', http://ageis.climatechange.gov.au Accessed 31 October 2022.
264. In 2022, the Victorian Government committed to bring forward its net zero emissions target by five years to 2045.
265. Department of Environment, Land, Water and Planning (DELWP), 'Victorian Government action on climate change', Melbourne, Victoria https://www.climatechange.vic.gov.au/victorian-government-action-on-climate-change Accessed 31 October 2022.
266. Department of Climate Change, Energy, the Environment and Water (DCCEEW), 'Australian greenhouse emissions information system', http://ageis.climatechange.gov.au Accessed 31 October 2022.
267. Ibid.

Sector emissions

The highest contributor to GHG emissions in Victoria in 2020 was the production of electricity, responsible for 50% of the state's net emissions. The transport sector had the second largest share (25%) and was one of only two sectors with increased GHG emissions since 2005. Carbon sequestration from Victoria's land sector offset 20% of total emissions in 2020. Victoria's LULUCF sector emissions fluctuated significantly between 1990 and 2020.

During this decade, the LULUCF sector was a:

- net sink (sequestration exceeded emissions) from 1995 to 2006, 2008 and 2012 to 2020
- net source (emissions exceeded sequestration) from 1990 to 1994, 2007 and 2009 to 2011.

Figure CCM25 compares 2020 emissions by sector with emissions in 1990 (the first year that data are available) and 2005 (the reference year that Victoria's emission reduction targets are assessed against).[268] Emissions from the fuel combustion, transport, and industrial processes and product use (IPPU) sectors increased between 1990 and 2020. Transport and IPPU were the only sectors with more emissions in 2020 than in 2005.

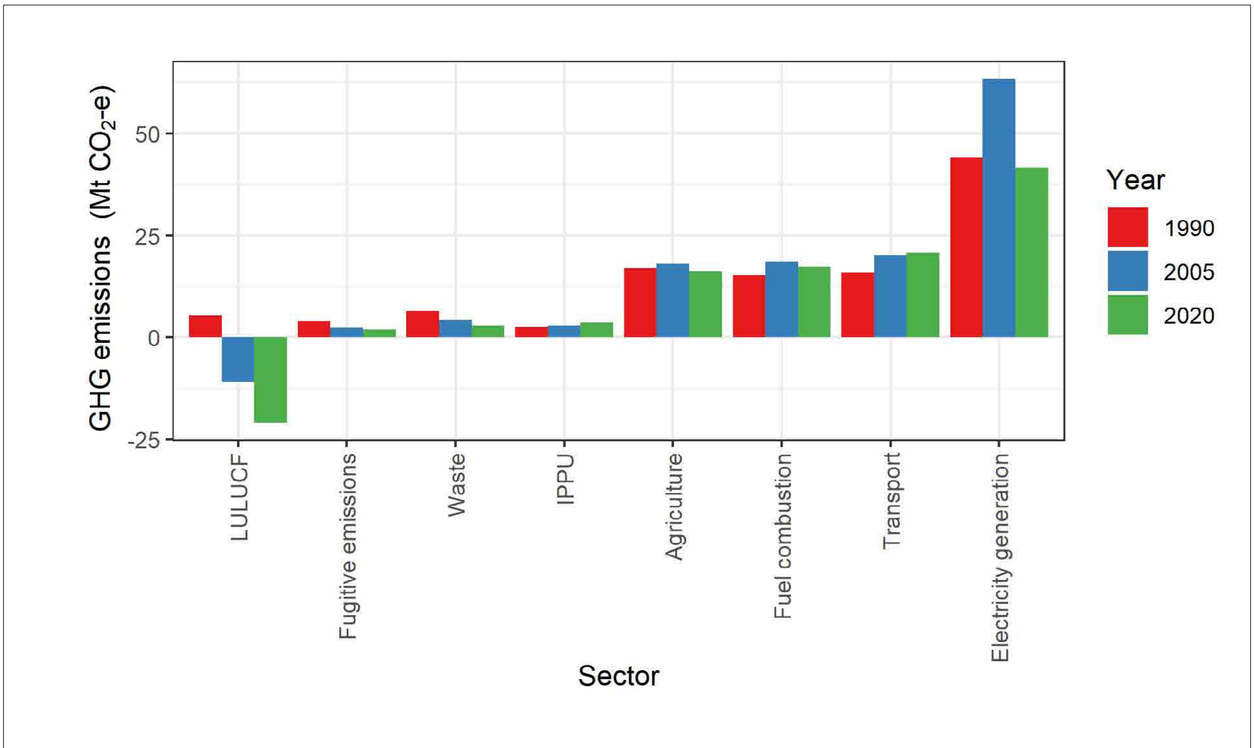

Figure CCM25: GHG emissions in Victoria by sector in 1990, 2005 and 2020.[269]

268. Office of the Chief Parliamentary Counsel Victoria 2017, '*Climate Change Act 2017*', Melbourne, Victoria, https://content.legislation.vic.gov.au/sites/default/files/2020-05/17-5aa005%20authorised.pdf Accessed 22 July 2022.
269. Department of Climate Change, Energy, the Environment and Water (DCCEEW), 'Australian greenhouse emissions information system', http://ageis.climatechange.gov.au Accessed 31 October 2022.

Energy emissions

The pronounced decrease of 36% in Victoria's electricity emissions during the past decade (2010 to 2020) is most likely to be a combination of the closure of the Hazelwood power station in 2017 and continued growth in renewable electricity generation.[270] These topics are discussed further in the 'Energy' chapter of this report.

Transport emissions

Transport emissions have grown by 31% in the last 30 years resulting in this sector having the highest increase in emissions in Victoria over this period. Road transport is the major source of emissions from the transport sector, accounting for 89% of transport GHG emissions in 2020. This is because motor vehicles are the main mode of transport for passengers and freight in Victoria. After being generally stable during this century, GHG emissions from cars dropped by 10% (1.1 Mt CO2-e) in 2020 compared to 2019 (Figure CCM26); this was likely caused by reduced transport activity due to the COVID-19 pandemic.[271] Similarly, there were significant reductions from domestic aviation as GHG emissions from that transport mode decreased by 24% (0.4 Mt CO2-e) in 2020 compared to 2019.

It is important to note that, under the United Nations Framework Convention on Climate Change (UNFCCC), domestic and international aviation are treated separately. Domestic aviation emissions are part of national and state GHG emission inventories, while international aviation emissions are dealt with separately as part of Australia's participation in the International Civil Aviation Organization (ICAO).[273] For Australia, GHG emissions from international aviation increased by more than 250% between 2002-03 and 2018-19, before a significant decrease in 2019-20 in association with the COVID-19 pandemic.[274] In 2018-19, prior to the impacts of COVID-19, Australia's international aviation sector was estimated to contribute approximately 15 Mt CO2-e, while 25% of all international flights in Australia departed from or arrived in Victoria.[275, 276] This means that international aviation travelling to and from Victoria would have likely contributed about an additional 4 Mt CO2-e per year prior to the impact of the COVID-19 pandemic

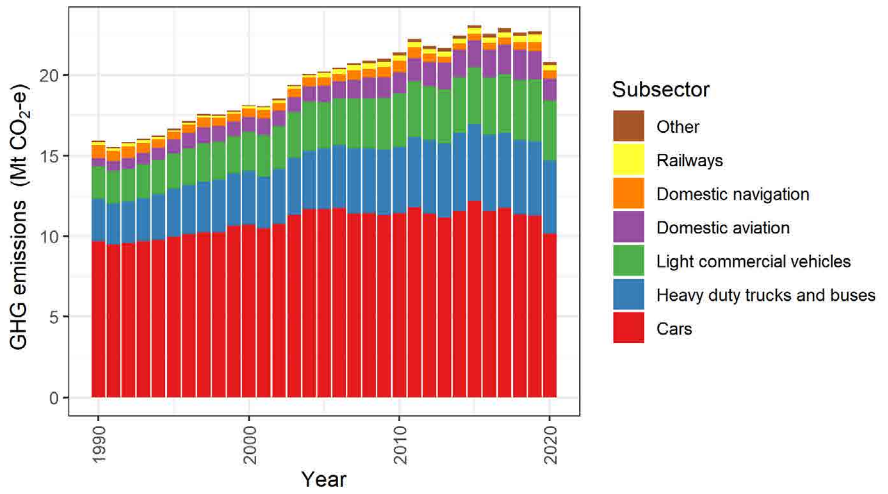

Figure CCM26: Transport GHG emissions in Victoria from 1990 to 2020.[272]

270. Department of Environment, Land, Water and Planning (DELWP) 2022, 'Victorian greenhouse gas emissions report 2020', Melbourne, Victoria, https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0036/598257/Victorian-Greenhouse-Gas-Emissions-Report-2020.pdf Accessed 24 November 2022.
271. Ibid.
272. Department of Climate Change, Energy, the Environment and Water (DCCEEW), 'Australian greenhouse emissions information system', http://ageis.climatechange.gov.au
273. Department of Infrastructure, Transport, Regional Development, Communications and the Arts, 'Aviation emissions', https://www.infrastructure.gov.au/infrastructure-transport-vehicles/aviation/aviation-safety/aviation-emissions Accessed 28 November 2022.
274. Department of Infrastructure, Transport, Regional Development, Communications and the Arts 2022, 'Australia's state action plan – International Civil Aviation Organization (ICAO) assembly resolution A37-19 on climate change October 2022', https://www.infrastructure.gov.au/sites/default/files/documents/2022-state-action-plan.pdf Accessed 28 November 2022.
275. Ibid.
276. Department of Infrastructure, Transport, Regional Development, Communications and the Arts 2020, 'Statistical report - International airline activity 2019', https://www.bitre.gov.au/sites/default/files/documents/international_airline_activity_cy2019.pdf Accessed 28 November 2022.

where the number of international flights was reduced. Including the contribution of international aviation would increase Victoria's transport GHG emissions by approximately 15% to 20% (~4 Mt CO2-e per year).

Further information on transport fuel use and GHG emissions is available in indicator 'E:06 Energy in transport' within the 'Energy' chapter of this report.

LULUCF emissions

Victoria's LULUCF sector emissions have fluctuated significantly between 1990 and 2020. During the most recent decade (2010-2020), forest land remaining forest land has generally been the LULUCF subsector influencing whether LULUCF has been a net sink (sequestration exceeded emissions) or a net source of emissions (emissions exceeded sequestration) each year.

Figure CCM27 shows the net emissions from forest land remaining forest land resulting from activities such as wildfire and prescribed burning; and other sources of emissions including changes in living biomass, dead organic matter and soil carbon in harvested native forest and other native and pre-1990 plantation forests. The years where wildfire and prescribed burning are net emissions sinks (e.g. 2015 to 2020) indicates that carbon removed through vegetation regrowth after bushfires and prescribed burns outweighed carbon released during fires in those years.

The extreme bushfires that occur in Victoria result in an amount of carbon that is initially lost in the fire that is later balanced by carbon that is re-absorbed by future regrowth. Because of this, and consistent with international guidance on GHG emission calculations, Victoria's wildfire emissions are reported on a long-term trend basis (that is, the values reported in individual years are effectively a smoothed multi-year average).[277, 278] As such, the large amount of area burnt by fires in Victoria during the 2019-20 fire season are included in the 2019 and 2020 data shown in Figure CCM27, but that 2019 and 2020 data also incorporates data from preceding years with less fire activity and stronger regrowth from years during the 2000s when there were large fires.

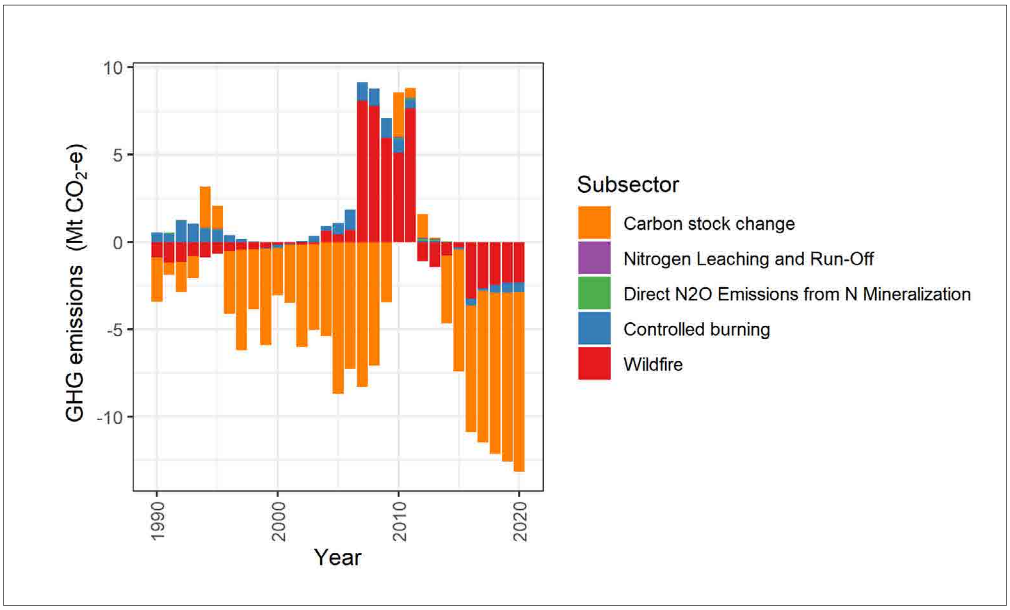

Figure CCM27: Net emissions from forest land remaining forest land sources in Victoria from 1990 to 2020.[279]

277. Department of Industry, Science, Energy and Resources 2022, 'National inventory report 2020 volume two', https://www.dcceew.gov.au/sites/default/files/documents/national-inventory-report-2020-volume-2.pdf Accessed 18 November 2022.
278. Department of Environment, Land, Water and Planning (DELWP) 2022, 'Victorian greenhouse gas emissions report 2020', Melbourne, Victoria, https://www.climatechange.vic.gov.au/data/assets/pdf_file/0036/598257/Victorian-Greenhouse-Gas-Emissions-Report-2020.pdf Accessed 24 November 2022.
279. Department of Climate Change, Energy, the Environment and Water (DCCEEW), 'Australian greenhouse emissions information system', http://ageis.climatechange.gov.au

Agricultural emissions

Agricultural sector GHG emissions have been relatively stable from 1990 to 2020, with a peak of 18.1 Mt CO2-e in 2005 and a low of 14.9 Mt CO2-e in 2010. Enteric fermentation from livestock has been the main source of GHG emissions from the agricultural sector during this period and contributed 69% of agricultural emissions in Victoria in 2020.[280, 281] Other sources in 2020 include the release of nitrous oxide from cropping and pastures (18%), while manure management (9.1%) and emissions from urea application and liming (4.1%) also contributed GHG emissions.[282]

Overall, agricultural GHG emissions have reduced by 5% from 1990 to 2020, primarily due to a decline in the sheep population since 1990 that has been attributed to seasonal and market conditions.[283]

As per the methodology specified in the National Inventory Report 2020, carbon sequestration associated with the planting of trees and vegetation or agroforestry activities are accounted for in the LULUCF sector.[284, 285] This is an important qualification because some improving farming practices (e.g. crop selection is anecdotally been increasingly based on maximising the potential for soil carbon sequestration) are being accounted for in the LULUCF sector and not the agricultural sector. Most notably, the cropland component of the LULUCF sector is now a net sink of GHG emissions in Victoria (-0.4 Mt CO2-e in 2020 compared with 2.2 Mt CO2-e in 1990), with cropland soils driving the change.[286]

Per capita emissions

Victoria's annual per capita emissions of 12.7 tonnes CO2-e per person in 2020 are lower than the national figure of 19.4 tonnes CO2-e per person (Figure CCM28). The Victorian per capita emissions have dropped by 50% since a value of 25.1 tonnes CO2-e per person was recorded in 1990 (Figure CCM29).

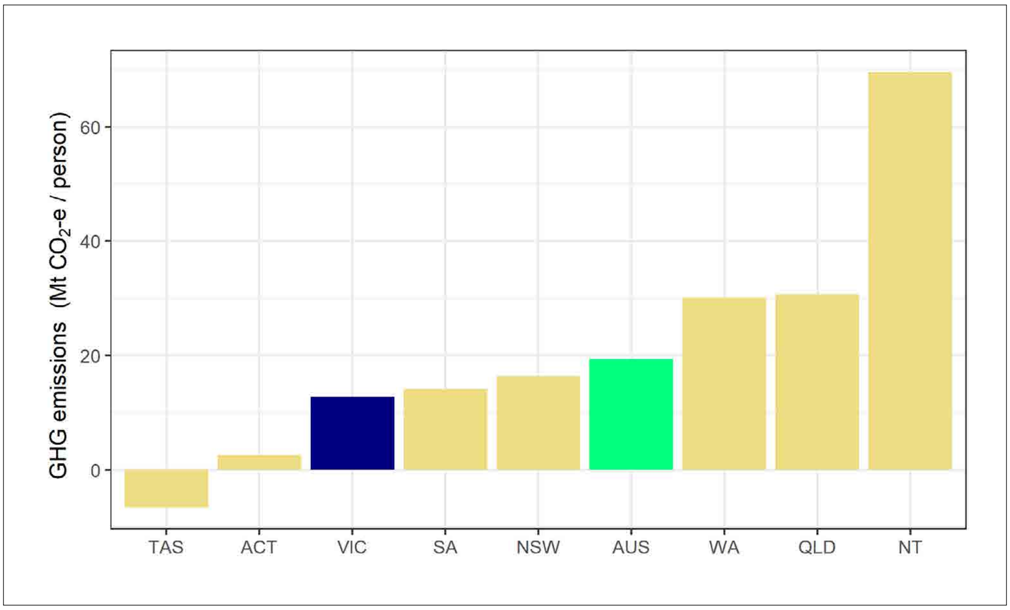

Figure CCM28: Per capita emissions in Australia by state and territory during 2020.[287, 288]

280. Enteric fermentation is a digestive process in ruminant animals, such as cows, where feed is broken down by microorganisms into simple molecules, making them available for easy digestion by the animal.
281. Department of Environment, Land, Water and Planning (DELWP) 2022, 'Victorian greenhouse gas emissions report 2020', Melbourne, Victoria, https://www.climatechange.vic.gov.au/data/assets/pdf_file/0036/598257/Victorian-Greenhouse-Gas-Emissions-Report-2020.pdf Accessed 24 November 2022.
282. Ibid.
283. Ibid.
284. Department of Industry, Science, Energy and Resources 2022, 'National inventory report 2020', https://www.dcceew.gov.au/sites/default/files/documents/national-inventory-report-2020-volume-1.pdf Accessed 31 October 2022.
285. Department of Environment, Land, Water and Planning (DELWP) 2022, 'Victorian greenhouse gas emissions report 2020', Melbourne, Victoria, https://www.climatechange.vic.gov.au/data/assets/pdf_file/0036/598257/Victorian-Greenhouse-Gas-Emissions-Report-2020.pdf Accessed 24 November 2022.
286. Department of Climate Change, Energy, the Environment and Water (DCCEEW), 'Australian greenhouse emissions information system', http://ageis.climatechange.gov.au Accessed 31 October 2022.
287. Ibid.
288. Australian Bureau of Statistics (ABS), 'National, state and territory population', Reference period: March 2022, 3101.0 National state and territory population - TABLE 4. Estimated Resident Population, State and Territories (Number), Accessed 24 November 2022.

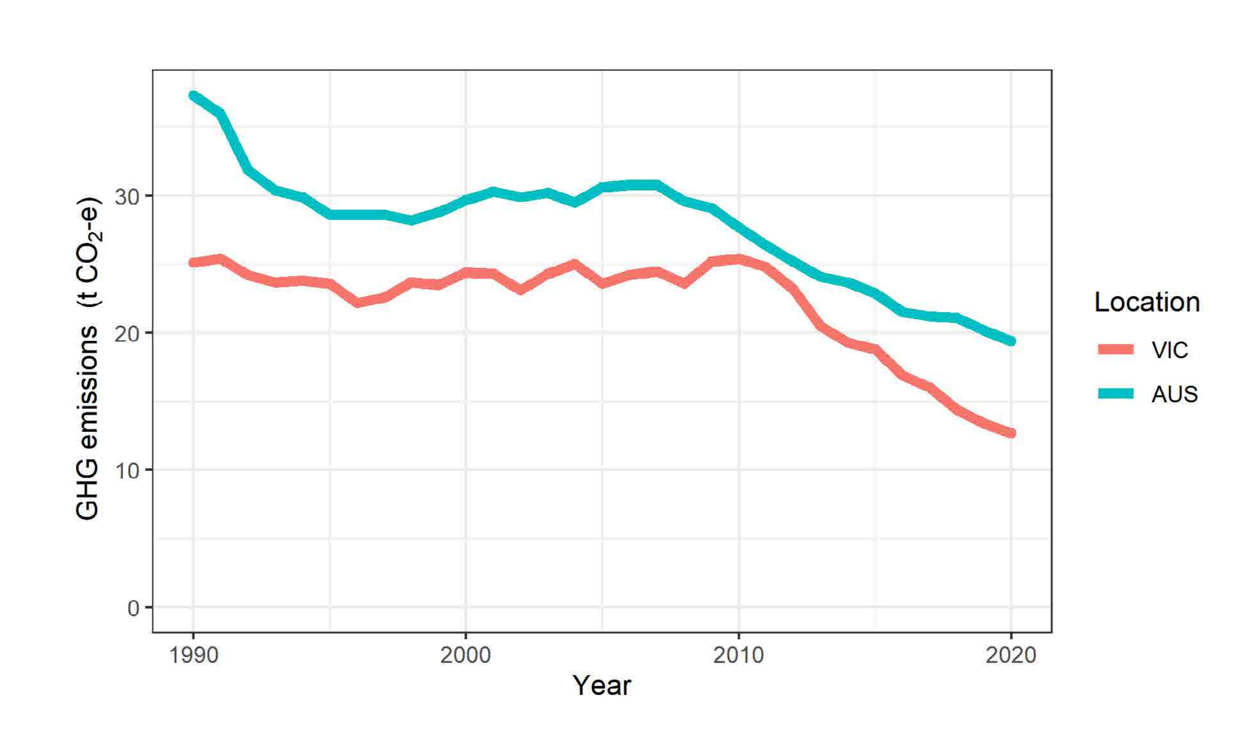

Figure CCM29: Trend in per capita emissions in Victoria and Australia from 1990 to 2020.[289, 290]

289. Department of Climate Change, Energy, the Environment and Water (DCCEEW), 'Australian greenhouse emissions information system', http://ageis.climatechange.gov.au Accessed 31 October 2022.
290. Australian Bureau of Statistics (ABS), 'National, state and territory population', Reference period: March 2022, 3101.0 National state and territory population - TABLE 4. Estimated Resident Population, State and Territories (Number), Accessed 24 November 2022.

Indicator CCM:12 Victorian ecosystem carbon stocks

CCM:12 Victorian ecosystem carbon stocks

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	(land sector) (marine and coastal sector)	?	(land sector) (marine and coastal sector)	(land sector) (marine and coastal sector)	→ (land sector) ? (marine and coastal sector)	

Data source(s):	Academic researchers, DELWP
Measure(s):	Land-sector carbon stocks Blue carbon stocks

Why this indicator?

Terrestrial-, aquatic- and marine-based carbon stocks and their trends play an important role in the global carbon cycle and GHG balance, and provide an indication of biodiversity.

NB: This SoE 2023 indicator was 'CC:11 Victorian ecosystem carbon stocks' in the SoE 2018 Report.

Why this assessment in 2023?

There was a net 1% growth in land-sector carbon stocks from 2007 to 2016, largely due to increased carbon in forests. It is unclear what effect the 2019–20 bushfires have had on Victorian land-sector carbon stocks.

The status assessment of poor for the marine and coastal sector reflects research published in 2019 that found saltmarshes, mangroves and seagrasses in Victoria are currently capturing approximately 2% of the carbon that could be captured by 2050 if coastal wetlands naturally retreat. Because this research is a 'point-in-time' assessment, the trend is unclear.

Summary of State of the Environment 2018 Report assessment

- There has been a 1% growth in carbon stocks from 2007 to 2016.

Critical data used for the 2023 assessment

- State and Territory Greenhouse Gas Inventories 2016 Australia's National Greenhouse Accounts.
- Mapping Ocean Wealth Australia: The Value of Coastal Wetlands to People and Nature.

2023 assessment

This indicator looks at the important role ecosystems play in the global carbon cycle and global GHG balance by storing carbon in trees, soil and aquatic environments. Carbon stocks are found in marine and freshwater ecosystems (blue carbon) and terrestrial ecosystems (green carbon).

Carbon stocks in Victoria are vulnerable to climatic variation and the occurrence of bushfires, which have temporarily decreased carbon stocks in some areas (e.g. during the 2019-20 bushfires). This has important implications for the management of Victoria's carbon stocks — the ability of forests to take up carbon is vital for the mitigation of climate change.

Green carbon

Victoria's forests store a considerable amount of carbon, but carbon stocks have been impacted by periods of drought and fire risk. Figure CCM30 shows declines in carbon stocks from 2002 to 2003 and 2006 to 2007 that were directly attributable to bushfire events, although there was a consistently upward trend in land sector carbon stocks from 2007 to 2016, which is the last year of available data. The y-axis of the graph in Figure CCM30 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 was only 1%. The growth was due to net growth of carbon stocks in forests, which has been occurring at a rate of nearly 2% per year. There had been a decay of carbon stocks in non-forests.

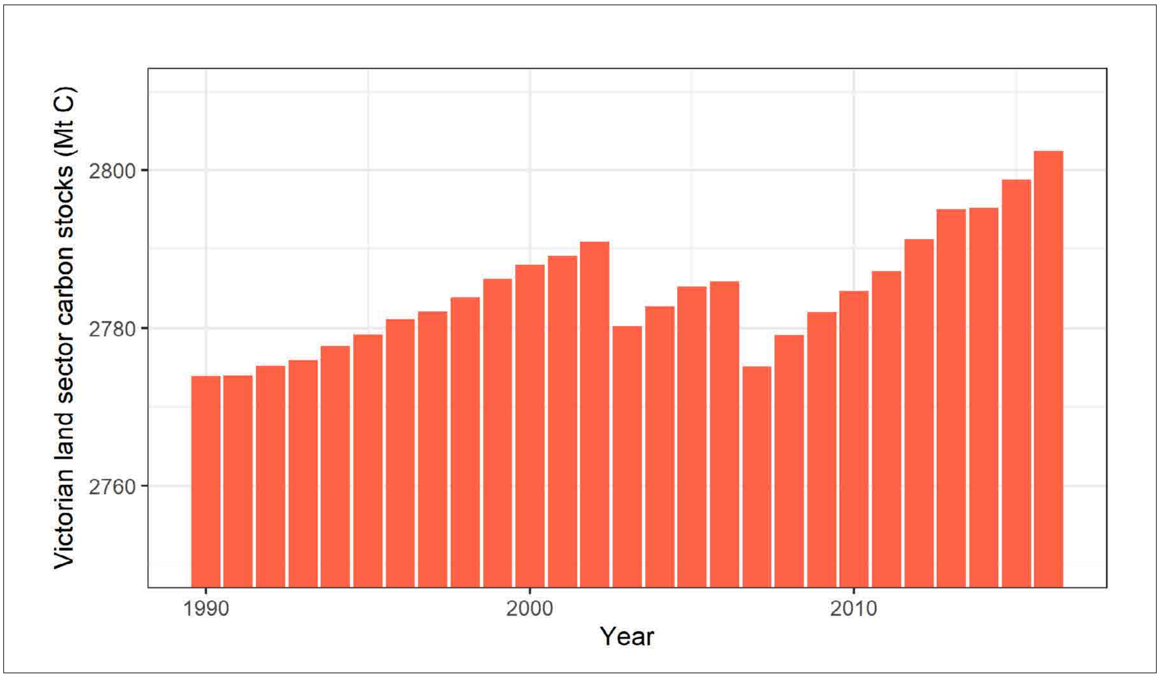

Figure CCM30: Victorian land sector carbon stocks from 1990 to 2016.[291]

Maximising land sector carbon stocks is an important element for Victoria achieving the goal of net-zero GHG emissions by 2050. In 2020, University of Melbourne researchers reviewed land-based carbon dioxide removal options for Victoria and reported that, although the land sector has been operating as a net carbon sink in recent years, it is projected to decline over the next decade.[292] This highlights a vulnerability in Victoria's path to net-zero GHG emissions and a need to increase carbon dioxide removal. The researchers proposed four options which include native forest regeneration, carbon and environmental planting, soil carbon removal and restoration of degraded lands.

Estimates of carbon stocks largely focus on public land. Victoria's Trust for Nature commissioned research on the amount of carbon storage in covenanted properties and in its reserves.[293] The research found that covenanted properties stored 9.76 million carbon equivalents, while reserves stored 2.31 million carbon equivalents.

Blue carbon

Based on an estimate of an average passenger car in Victoria emitting 2.886 tonnes of CO2-e per year, the estimated 36,000 tonnes of carbon captured by saltmarshes, mangroves and seagrasses each year in Victoria and New South Wales is equivalent to offsetting the annual emissions of more than 12,000 cars.[294, 295, 296, 297] In Victoria, it is estimated this could expand to 1.6 million tonnes of carbon by 2050 if coastal wetlands can naturally retreat in a landward direction.[298]

291. Department of the Environment and Energy (DEE) 2018, 'State and territory greenhouse gas inventories 2016 Australia's national greenhouse accounts', https://www.dcceew.gov.au/sites/default/files/documents/nga-state-and-territory-greenhouse-gas-inventories-2016.pdf Accessed 1 December 2022.
292. Dooley K, Christoff P, Burdon R 2020, 'Land-based carbon dioxide removal options for Victoria, review paper', Melbourne Sustainable Society Institute, University of Melbourne, Melbourne, Victoria
293. Rimmer L, Young V 2016, 'Conserving carbon: a desktop assessment of forest carbon stocks in properties and covenants owned or managed by Trust for Nature Victoria', Melbourne, Victoria.
294. This estimate uses research published in 2022 that calculated an average passenger vehicle in Victoria emits 260 g CO2-e per km. The Australian Survey of Motor Vehicle Use for 2019-20 estimated the average number of kilometres travelled by a passenger vehicle in Australia is 11,100 km per year. A value of 2.886 tonnes (or 2,886,000 g) is calculated by multiply 260 g / km by 11,100 km.
295. Smit R, Kennedy DW 2022, 'Greenhouse gas emissions performance of electric and fossil-fueled passenger vehicles with uncertainty estimates using a probabilistic life-cycle assessment', *Sustainability*, 14, pp. 3444. https://doi.org/10.3390/su14063444 Accessed 24 November 2022.
296. Australian Bureau of Statistics (ABS) 2020, 'Survey of motor vehicle use, Australia', Reference period: 12 Months ended 30 June 2020, 92080DO001_202006 Survey of Motor Vehicle Use, Australia, 12 months ended 30 June 2020, Table 1, https://www.abs.gov.au/statistics/industry/tourism-and-transport/survey-motor-vehicle-use-australia/latest-release Accessed 25 November 2022.
297. Carnell PE, Reeves SE, Nicholson E, Macreadie P, Ierodiaconou D, Young M, Kelvin J, Janes H, Navarro A, Fitzsimons J, Gillies CL 2019, 'Mapping ocean wealth Australia: the value of coastal wetlands to people and nature', The Nature Conservancy, Melbourne.
298. Ibid.

The carbon already stored in coastal wetland soils can range from 40 tonnes to 600 tonnes of carbon per hectare, with an estimated 26 million tonnes of carbon stored in mangroves, saltmarshes and seagrass across both Victoria and New South Wales (Figure CCM31). Mangrove ecosystems store the largest amount of carbon followed by saltmarsh and seagrass systems.[299]

To harness the power of coastal wetlands to combat climate change, in 2019 researchers used possible future management actions or inactions that would lead to expansion or contraction of coastal wetlands across Victoria in order to determine how much carbon will be sequestered (or lost) with the change in wetland extent.[301]

Removing levees now, and allowing natural tidal exchange to occur, would provide an additional 1.65 million tonnes of carbon sequestration. When this research was completed in 2019, this amount of carbon sequestration was valued at $67 million using average carbon prices paid via the Australian Emission Reduction Fund (ERF).[302]

Allowing blue carbon ecosystems to naturally colonise into landward areas (that will be inundated by sea-level rise in the future) would sequester 1.6 million tonnes of carbon by 2050, which was valued at $65 million. This would increase to 5.7 million tonnes, and be worth $159 million, by 2100.[303]

While sea-level rise will inundate a greater area than targeted levee removal, a levee removal strategy would allow for restoration to begin sooner in some locations, generating up to 14,000 additional tonnes of sequestration and $2.9 million in ERF value by 2030.[304]

In a coastal wetland loss scenario, if future erosion removes coastal wetlands and no action is taken to allow natural retreat, the carbon released from soils would exceed any sequestration gain from the remaining coastal wetland. By 2100, erosion of Victoria's blue carbon ecosystems would release a net 6.3 million tonnes of carbon into the atmosphere, after accounting for sequestration by remaining ecosystems. These emissions equate to $8.5 billion using the ERF price.[305] These costings only account for the direct GHG emissions impact associated with erosion removing coastal wetlands — the potential erosion of coastal wetlands increases flooding risk and extreme flooding events have been shown to also cause large-scale losses of seagrass habitat.[306]

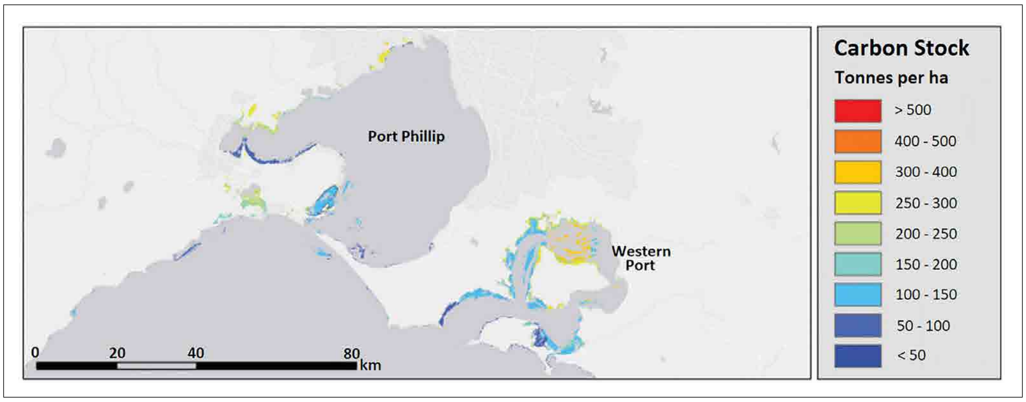

Figure CCM31: Examples of soil carbon stocks (tonnes of organic carbon per hectare) in saltmarsh, mangrove and seagrass ecosystems mapped across Victoria.[300]

299. Carnell PE, Reeves SE, Nicholson E, Macreadie P, Ierodiaconou D, Young M, Kelvin J, Janes H, Navarro A, Fitzsimons J, Gillies CL 2019, 'Mapping ocean wealth Australia: the value of coastal wetlands to people and nature', The Nature Conservancy, Melbourne.
300. Ibid.
301. Ibid.
302. Ibid.
303. Ibid.
304. Ibid.
305. Ibid.
306. Oppenheimer M, Glavovic BC, Hinkel J, van de Wal R, Magnan AK, Abd-Elgawad A, Cai R, Cifuentes-Jara M, DeConto RM, Ghosh T, Hay J, Isla F, Marzeion B, Meyssignac B, Sebesvari Z 2019, 'Sea level rise and implications for low-lying islands, coasts and communities', In: *IPCC special report on the ocean and cryosphere in a changing climate* [Pörtner H-O, Roberts DC, Masson-Delmotte V, Zhai P, Tignor M, Poloczanska E, Mintenbeck K, Alegría A, Nicolai M, Okem A, Petzold J, Rama B, Weyer NM (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 321–445. https://doi.org/10.1017/9781009157964.006 Accessed 9 July 2023.

Indicator CCM:13 Stratospheric ozone

CCM:13 Stratospheric ozone						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		→			→	
Data source(s):	BOM, CSRIO					
Measure(s):	UV index Average total column ozone Emissions of ozone-depleting substances					

Why this indicator?

Stratospheric ozone impacts on ultraviolet (UV) radiation, with less stratospheric ozone meaning more UV radiation reaches the Earth's surface.

NB: This SoE 2023 indicator was 'A:05 Stratospheric ozone' in the SoE 2018 Report.

Why this assessment in 2023?

The long-term changes in stratospheric ozone due to ozone-depleting substances over a mid-latitude location, such as Victoria, are small compared to natural variations. There was a small, but clear, decreasing trend in ozone during the 1980s and 1990s. This was followed by an increase this century that provides some evidence of a gradual stratospheric ozone recovery.

Summary of State of the Environment 2018 Report assessment

- 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 1980s.

Critical data used for the 2023 assessment

- BOM data on average total column ozone and UV index for Melbourne

2023 assessment

Ozone depletion and global action

Overwhelming scientific evidence accumulated over more than two decades of study by the international research community has shown that human-made chemicals, such as chlorofluorocarbons (CFCs), are responsible for the observed depletion in the ozone layer over Antarctica and likely play a major role in stratospheric ozone losses.[307]

Ozone is the major absorber of UV in the wavelength range 280 to 320 nanometres in sunlight, absorbing approximately 90% of it. Many experimental studies of plants and animals and clinical studies of humans have shown the harmful effect of excessive exposure to UV.[308]

Ozone depletion is an iconic example of the world taking action to address environmental damage caused by human activity. 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. Every four years, the World Meteorological Organisation and the United Nations Environment Programme review the state of the ozone layer. The 2018 review highlighted that the abundance of ozone depleting chemicals in the atmosphere is now declining, and the ozone layer is expected to recover to pre-1980 levels over the mid-latitudes by 2050 and over the Antarctic by 2065.[309]

307. Bureau of Meteorology (BOM), 'Climate glossary ozone', http://www.bom.gov.au/climate/glossary/ozone.shtml Accessed 29 June 2022.
308. Ibid.
309. World Meteorological Organization (WMO) 2018, 'Scientific assessment of ozone depletion: 2018', Global Ozone Research and Monitoring Project–Report No. 58, 588 pp., Geneva, Switzerland.

CSIRO researchers were involved in the 2020 creation and publication of a time series of Australian CFC emissions from 1960 to 2017, which included estimating atmospheric CFC trends and emissions based on observations made at Aspendale in Melbourne from 2004 to 2018.[310]

Significant Australian emissions of CFCs commenced in the early 1960s, reaching a peak in the late-1980s. Since the late-1980s, Australian CFC emissions have declined by more than 90% thanks to Australia's early and effective control of production, imports and consumption of CFCs in accordance with Montreal Protocol obligations. The temporal pattern of Victorian and Australian CFC emissions is similar to observed global emissions, with Australian emissions being less than 1% of global emissions over the entire emission history.[311]

Stratospheric ozone in Victoria

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 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 small, but clear, decreasing trend in ozone during the 1980s and 1990s, followed by an increase this century (Figure CCM32) that provides some evidence of a gradual stratospheric ozone recovery. Note that, because only gradual changes in stratospheric ozone are associated with significant impacts, the y-axes of the graphs in Figure CCM32 and Figure CCM33 have been constrained to a narrow range that most clearly shows the trends in total column ozone.

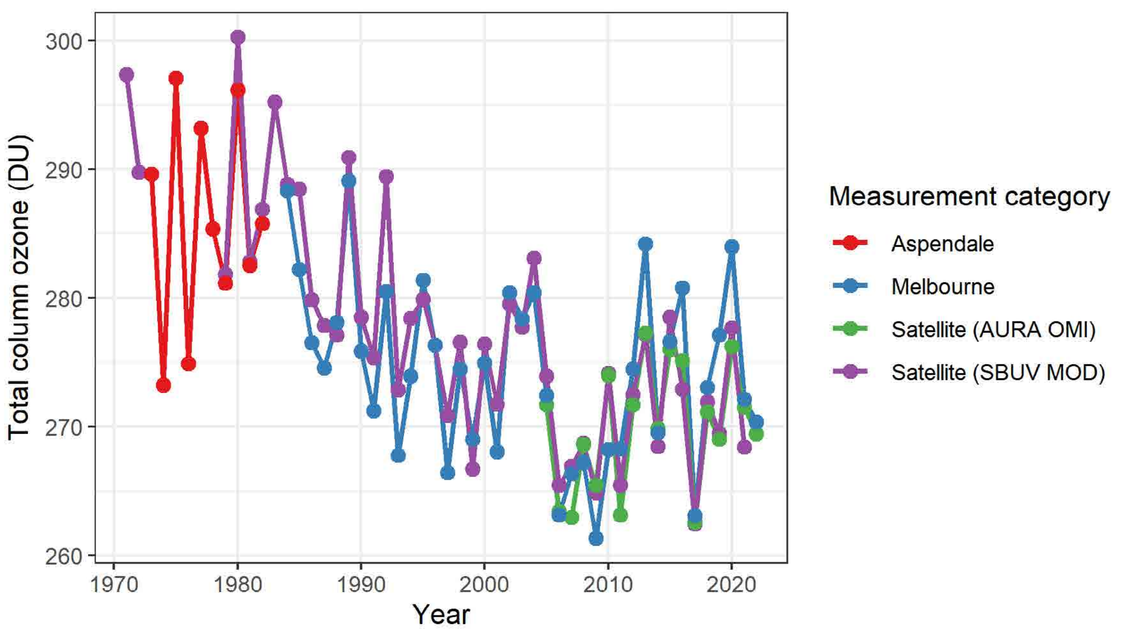

Figure CCM32: Average total column ozone for Melbourne in the month of January during 1973 to 2022.[312, 313]

310. Fraser PJ, Dunse BL, Krummel PB, Steele LP, Derek N, Mitrevski, B, Allison CE, Loh Z, Manning AJ, Redington A, Rigby M 2020, 'Australian chlorofluorocarbon (CFC) emissions: 1960–2017', *Environmental Chemistry*, 17, pp. 525–544.
311. Ibid.
312. Bureau of Meteorology (BOM) 2022, 'Unpublished data', Australia.
313. Note: Ozone is measured in Dobson Units (DU). 100 DU is equivalent to a 1 mm-thick layer of pure ozone at sea level temperature and pressure.

The 10-year rolling averages of total column ozone data (Figure CCM33) more clearly show the trend of ozone depletion from the 1980s to the 2000s before total column ozone stabilised and has begun to recover during the most recent decade.

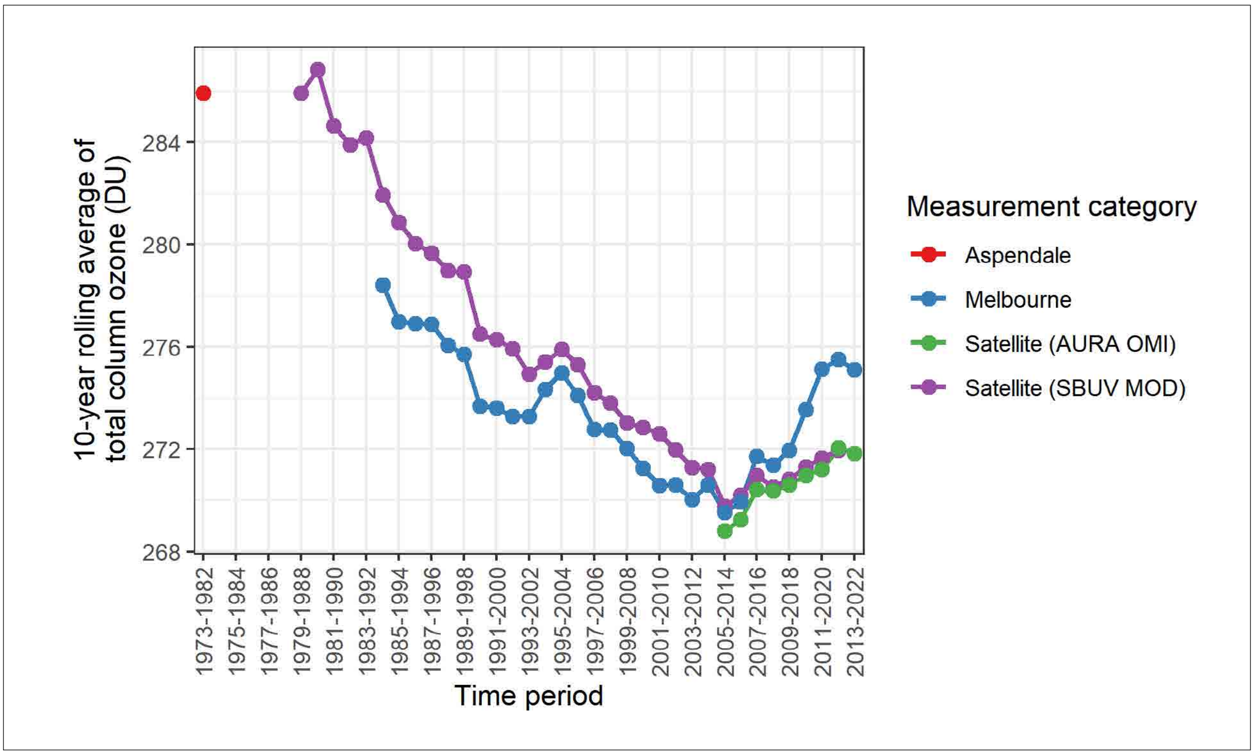

Figure CCM33: Ten-year rolling average of average total column ozone for Melbourne in the month of January from 1973-82 to 2013–22.[314, 315]

UV levels in Victoria

January is generally the month of greatest stratospheric ozone impact in Victoria as more people are on holidays and outside in the sun and UV levels are greatest. Figure CCM34 shows Melbourne's average UV levels in January since 1979. Measurement of the long-term trend includes satellite-based observations of UV levels without the impact of clouds (shown as the blue and black lines in Figure CCM34). 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 (shown as the green line in Figure CCM34). Melbourne's UV levels have been generally stable since the 1980s, with a slight increase during the final two decades of the 20th century.

314. Bureau of Meteorology (BOM) 2022, 'Unpublished data', Australia.
315. Note: Ozone is measured in Dobson Units (DU). 100 DU is equivalent to a 1 mm-thick layer of pure ozone at sea level temperature and pressure.

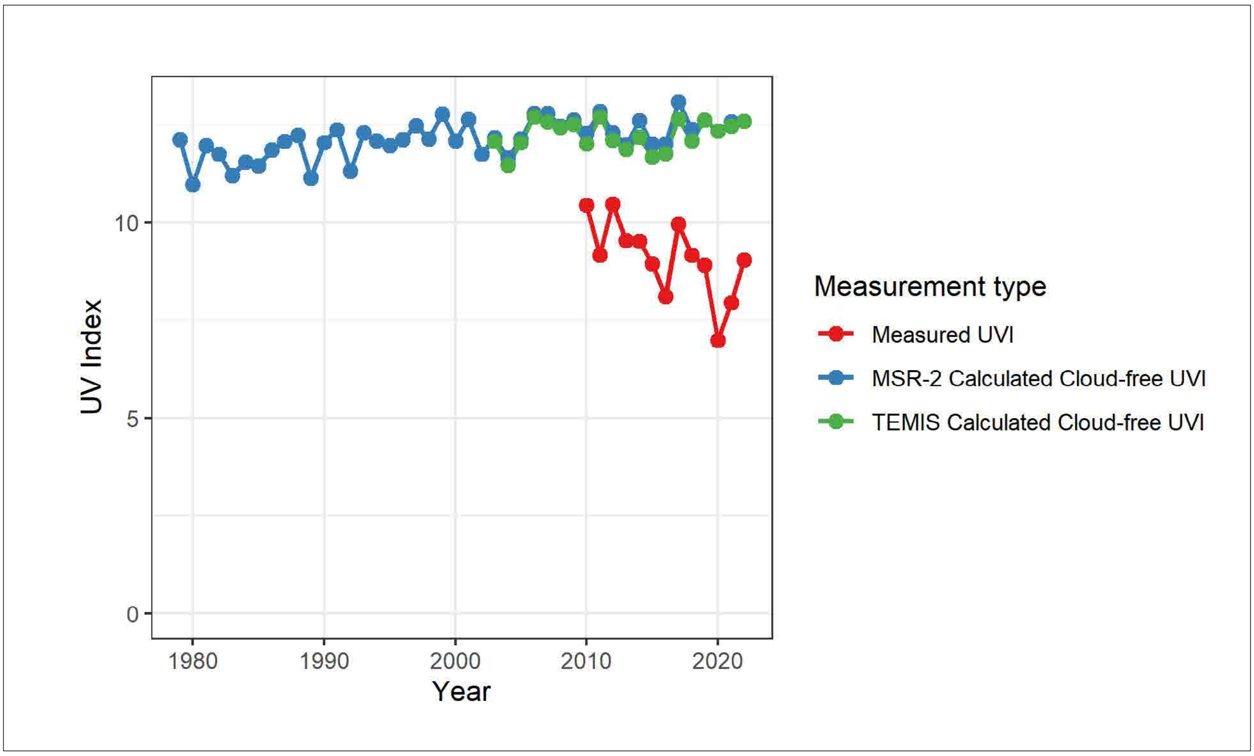

Figure CCM34: Average UV index for Melbourne in the month of January from 1979 to 2022.[316]

Bushfires posing a risk to stratospheric ozone

As detailed in indicator 'CCIm:10 Occurrence and impacts of extreme weather' and the 'Fire' chapter of this report, Victoria's changing climate means that bushfire seasons are likely to be longer and more severe. This poses a significant risk to stratospheric ozone recovery, with research published during 2022 highlighting that the smoke from the large bushfires in south-east Australia during the summer of 2019-20 contained compounds that were transported into the stratosphere that have the potential to destroy ozone.[317]

316. Bureau of Meteorology (BOM) 2022, 'Unpublished data', Australia.
317. Bernath P, Boone C, Crouse J 2022, 'Wildfire smoke destroys stratospheric ozone', *Science*, 375(6586), pp. 1292-1295.

Climate change — Adaptation

The framework underlying the indicators

The framework presents a novel nature-centred approach to climate change adaptation. There are five main ways that the natural environment relates to climate change adaptation (Table CCA8). This section outlines these relationships and the associated indicators, before discussing key adaptation challenges and providing more information about each of the new indicators and their relationship to the AAPs.

Table CCA8: Five ways the natural environment (NE) relates to climate change adaptation.

Relationship	Description	Implications for adaptation
NE as an enabler of human adaptation	From local to global scales, all human life and activities, including adaptation, rely on ecological services. Conversely, dysfunctional natural environments are disruptive and make humans more vulnerable to climate change impacts	Adaptation needs to be integrated into sustainability programs to help ensure their long-term success. Sustainability goals need to be integrated into adaptation programs (e.g. reducing resource consumption and pollution are criteria of successful adaptation).
NE as an adaptation tool	Particular aspects and components of natural systems provide adaptation benefits or services	Ecosystem-based adaptation approaches utilise aspects of ecosystem to generate specific outcomes (e.g. hazard risk reduction) for humans. For example: • use of trees and 'green infrastructure' in the urban landscape to provide cooling • restoration of coastal habitat to help mitigate storm surge and coastal erosion
NE as impacted and actively adapting	All elements of the natural environment are changing autonomously and directionally in response to climatic changes and their flow-on effects	Human adaptation needs to accommodate and manage the non-stationarity and dynamics of natural systems, including: • geophysical, hydrological geo-morphological changes (e.g. changes in soil) • ecological changes (e.g. altered seasonality, migration and range shifts) • biological changes (e.g. altered chemistry, disease loads, genetics)
NE as a target of adaptation	Valued parts and aspects of nature (e.g. protected areas) are increasingly impacted by climate change. Human adaptation can try to assist by prioritising them in adaptation initiatives and inserting adaptation into environmental management.	Adaptation to protect specific aspects or elements of natural systems (including those being used for climate action) can facilitate autonomous adaptation or intervene more strongly (e.g. relocate a population).
NE as threatened by adaptation initiatives	Human adaptation actions can have direct and indirect negative environmental impacts. This is a form of maladaptation.	Adaptation projects (especially those involving hard infrastructure) need to be designed and assessed (e.g. through application of environmental impact assessment processes) to try to avoid direct and indirect harms to biodiversity and natural systems.

Natural environment as an enabler of human adaptation

Biodiversity and healthy natural systems are essential for all human life and activities, including successful climate change mitigation and adaptation.[318] Environmental health is a pillar of adaptive capacity for any system. At planetary and local scales, a lack of environmental integrity and related ecological services (e.g. clean water) dramatically increases the vulnerability of humans and non-humans (e.g. fish) to climate change-related stresses. Improving environmental quality and ecosystem health (e.g. reducing air pollution, planting riparian vegetation) and redressing environmental injustices reduces climate-related hazards (e.g. flood risk) and environment-related vulnerabilities to climate change impacts (e.g. worsened respiratory disease).[319]

The importance of environmental conditions to climate change adaptation means that efforts to improve environmental sustainability need to be part of society's climate change adaptation and, in particular, embedded in each of the seven AAPs (not just the Natural Environment one) and all RASs. At a high level, this means that the whole SoE Report provides a window into not only how successfully many elements of the environment are adapting (discussed below), but our collective adaptive capacity.

Because positive adaptation outcomes rely on healthy environments, this component of the framework informs all of the new state of the environment indicators. To begin with, there is a need to expand and actively adapt environmental sustainability work to facilitate its success under changing climatic conditions and, thereby, reduce pressures on and restore the natural systems human survival relies on (Indicator CCA:01). Initiatives that utilise specific natural assets for their adaptation services (CCA:02) and anticipate, accommodate and support natural systems' autonomous adaptation to a changing climate (CCA:03) are also needed to enhance environmental outcomes. To further foster environmental health, and thus alleviate climate vulnerabilities, environmental sustainability needs to be incorporated as a fundamental criteria of good climate change adaptation (CCA:04). This includes centring sustainability in adaptation-related monitoring, evaluation and research (CCA:05 and CCA:06), changes to governance, policies and laws including the operationalisation of all seven of Victoria's AAPs, and adaptation activities at the community and regional scales (CCA:07 and CCA:08). As a key pillar of human adaptive capacity, natural systems and sustainability efforts need to be embedded into adaptive capacity-building initiatives, while such initiatives need to include ecological literacy as part of the efforts to improve the decision-makers' literacy in climate change and systems and futures thinking (CCA:09). Modifying this indicator to underline the foundational role of environmental conditions in generating and responding to climate risks, and to attend to associated responsibilities, would further help enhance environmental outcomes and improve adaptation outcomes.

Natural environment as an adaptation tool

In addition to relying on natural systems in general, human climate change adaptation depends on specific natural systems for targeted outcomes known as ecosystem-based adaptation (EBA). A 'nature-based solution' to climate change, EBA recognises nature as a type of critical infrastructure. It manages particular elements of nature — notably trees, reeds, soil, water, increasingly referred to as green and blue infrastructure — in ways that provide ecological services with adaptation benefits for society.[320, 321, 322] These 'adaptation services' (e.g. shading, water storage and coastal protection) avoid or reduce climate-related risks such as aridity, flood or heat and their flow-on effects at local and regional scales, and include latent and novel ecological

318. Morecroft MD, Duffield S, Harley M, Pearce-Higgins JW, Stevens N, Watts O, Whitaker J 2019, 'Measuring the success of climate change adaptation and mitigation in terrestrial ecosystems', *Science*, 13;366(6471).
319. Schlosberg D, Collins LB 2014, 'From environmental to climate justice: climate change and the discourse of environmental justice' *Wiley Interdisciplinary Reviews: Climate Change*, 5(3), pp. 359-374.
320. Kunapo J, Fletcher TD, Ladson AR, Cunningham L, Burns MJ 2018, 'A spatially explicit framework for climate adaptation', *Urban Water Journal*, 15(2), pp. 159-166, https://doi.org/10.1080/1573062X.2018.1424216 Accessed 5 July 2023.
321. Newton PW, Newman PW, Glackin S, Thomson G, Newton PW, Newman PW, Glackin S, Thomson G 2022, 'Climate resilience and regeneration: How precincts can adapt to and mitigate climate change', Greening the greyfields: New models for regenerating the middle suburbs of low-density cities, pp. 105-120.
322. Seddon N, Daniels E, Davis R, Chausson A, Harris R, Hou-Jones X, Huq S, Kapos V, Mace GM, Rizvi A R 2020, 'Global recognition of the importance of nature-based solutions to the impacts of climate change', *Global Sustainability*, 3, e15.

services that will potentially emerge as ecosystems and human needs evolve.[323, 324] An advantage of such critical natural infrastructure is that it does not tend to catastrophically fail as grey (built) infrastructure can do — propagating far-reaching impacts and undermining climate change adaptation as it does.[325] However, if ecosystems do fail — as Lindenmayer and Taylor (2020) argue is increasingly evident under climate change and other pressures — critical natural infrastructure not only ceases to provide essential ecological services but can become a major threat to human wellbeing.[326] For example, mass fish kills in the Murray Darling Basin indicate not only that some of the ecological services provided by the associated rivers are failing, but that the water has become toxic and unsuitable for numerous human uses.

EBA can benefit natural systems by providing space for certain natural components and avoiding more environmentally harmful means of achieving similar adaptation benefits. This is especially apparent in the case of cooling. Due to global warming and the trapping of heat in highly developed, asphalted urban areas, deliberately lowering temperatures is an increasing issue. Compared to the mechanical air-conditioning of indoor spaces, which displaces heat into (public) outdoor areas and directly and indirectly generates greenhouse gas emissions, tree canopies cool areas in far less environmentally damaging ways. They also provide important human health, ecosystem and other adaptation benefits, such as helping protect estuaries from polluted runoff following fires and floods.[327, 328] The co-benefits of such EBA means that — while issues remain to be resolved — they are increasingly being applied in adaptation efforts around the world (e.g. Canada and Europe).[329, 330, 331] Widespread usage is essential as it is only at scale that EBA and other NBS are likely to really achieve their potential in terms of generating ecological services and persisting over time.[332]

The direct and indirect benefits of EBA mean that its level of use is an important indicator of climate change adaptation progress (CCA:02). To foster the successful implementation and upscaling of EBA, a range of adaptation best practice is needed (CCA:05 to CCA:09), as is close attention to how the natural systems being harnessed for adaptation (e.g. a particular tree species) may be impacted by, and adapt to, changing climatic conditions (CCA:03). Capacities, incentives and other support for well-adapted EBA needs to be built into adaptation efforts across all sectors.[333] This includes the built environment and transport systems, where integrating EBA with grey infrastructure provides multiple benefits (e.g. denser, drought-tolerant plantings along transport routes and around buildings to provide cooling and thus reduce human heat exposure and the risk of infrastructure degrading and malfunctioning in hotter conditions), yet still often struggles to compete for space.[334, 335, 336] The sustainability co-benefits of EBA mean that its prioritisation in adaptation efforts helps embed sustainability criteria into adaptation work and generate wider beneficial outcomes (CCA:04).

EBA, and the related adaptation services, are an important tool for Victoria's seven system AAPs (Table CCA9). There are particular synergies between EBA and the primary production and water systems. Although the term 'ecosystem-based adaptation' is uncommon in Australian agriculture, the multiple benefits of biodiverse on-farm plantings,

323. Lavorel S, Colloff MJ, Locatelli B, Gorddard R, Prober SM, Gabillet M, Devaux C, Laforgue D, Peyrache-Gadeau V 2019, 'Mustering the power of ecosystems for adaptation to climate change', *Environmental Science and Policy*, 92, pp. 87-97.
324. Lavorel S, Colloff MJ, Mcintyre S, Doherty MD, Murphy HT, Metcalfe DJ, Dunlop M, Williams RJ, Wise RM, Williams K J 2015, 'Ecological mechanisms underpinning climate adaptation services', *Global Change Biology*, 21(1), pp. 12-31.
325. Nelson DR, Bledsoe BP, Ferreira S, Nibbelink NP 2020, 'Challenges to realizing the potential of nature-based solutions', *Current Opinion in Environmental Sustainability*, 45, pp. 49-55. https://doi.org/https://doi.org/10.1016/j.cosust.2020.09.001 Accessed 5 July 2023.
326. Lindenmayer DB, Taylor C 2020, 'New spatial analyses of Australian wildfires highlight the need for new fire, resource, and conservation policies', *Proceedings of the National Academy of Sciences*, 117(22), pp. 12481-12485, https://doi.org/doi:10.1073/pnas.2002269117 Accessed 5 July 2023.
327. Astell-Burt T, Feng X 2019, 'Association of urban green space with mental health and general health among adults in Australia' *JAMA*, 2(7), e198209-e198209.
328. Bracewell S A, Barros TL, Mayer-Pinto M, Dafforn KA, Simpson SL, Johnston EL 2023, 'Contaminant pulse following wildfire is associated with shifts in estuarine benthic communities', *Environmental Pollution*, 316, p. 120533. https://doi.org/https://doi.org/10.1016/j.envpol.2022.120533 Accessed 5 July 2023.
329. Seddon N 2022, 'Harnessing the potential of nature-based solutions for mitigating and adapting to climate change', *Science*, 376(6600), pp. 1410-1416, https://doi.org/doi:10.1126/science.abn9668 Accessed 5 July 2023.
330. Hayes AT, Jandaghian Z, Lacasse MA, Gaur A, Lu H, Laouadi A, Ge H, Wang L 2022, 'Nature-based solutions (NBSs) to mitigate urban heat island (UHI) effects in Canadian cities', *Buildings*, 12(7), p. 925
331. Cortinovis C, Olsson P, Boke-Olén N, Hedlund K 2022, 'Scaling up nature-based solutions for climate-change adaptation: Potential and benefits in three European cities', *Urban Forestry and Urban Greening*, 67, p. 127450, https://doi.org/https://doi.org/10.1016/j.ufug.2021.127450 Accessed 5 July 2023.
332. Xing Y, Jones P, Donnison I 2017 'Characterisation of nature-based solutions for the built environment', *Sustainability*, 9(1), p. 149.
333. Nelson DR, Bledsoe BP, Ferreira S, Nibbelink NP 2020, 'Challenges to realizing the potential of nature-based solutions', *Current Opinion in Environmental Sustainability*, 45, pp. 49-55. https://doi.org/https://doi.org/10.1016/j.cosust.2020.09.001 Accessed 5 July 2023.
334. Blackwood L, Renaud FG, Gillespie S 2022, 'Nature-based solutions as climate change adaptation measures for rail infrastructure', Nature-Based Solutions, 2, p. 100013, https://www.sciencedirect.com/science/article/pii/S2772411522000052?via%3Dihub Accessed 5 July 2023.
335. Jamei E, Rajagopalan P, Seyedmahmoudian M, Jamei Y 2016, 'Review on the impact of urban geometry and pedestrian level greening on outdoor thermal comfort', *Renewable and Sustainable Energy Reviews*, 54, pp. 1002-1017.
336. Dorst H, van der Jagt A, Toxopeus H, Tozer L, Raven R, Runhaar H 2022, 'What's behind the barriers? Uncovering structural conditions working against urban nature-based solutions', *Landscape and Urban Planning*, 220, p. 104335. https://doi.org/https://doi.org/10.1016/j.landurbplan.2021.104335 Accessed 5 July 2023.

for example, have long been recognised, and the associated adaptation services such as shade and shelter for livestock are increasingly valued.[337] The water sector similarly recognises the potential to complement and help protect grey infrastructure with more systemic, nature-based ones (blue and green infrastructure) that produce important co-benefits.[338, 339] There are also notable synergies between EBA and the health and education systems, given the health, wellbeing, cognitive and pedagogical benefits of natural areas.[340]

For humans in all sectors and systems, plants provide a raft of benefits, including regulation of air quality — a service which is more important than ever in a changing climate due to the risk of pollutants such as near-surface ozone worsening under hotter conditions.[341, 342] Parks and other open green space also provide social infrastructure by increasing opportunities for people to connect, network and thereby build the social capital that primarily determines disaster resilience.[343]

Table CCA9: Examples of EBD and related adaptation services for Victoria's seven adaptation systems.

System	Example ecosystem-based adaptation	Adaptation services provided
Natural environment (sector)	Management of soil organic matter Riparian vegetation Biodiverse habitat Shelter belts Open green space	Soil moisture retention, wat er drainage, erosion control Flood protection, water quality regulation Pest management, genetic diversity for breeding programs Microclimate (temperature and wind) management Recreation, tourism and social connections
Transport	Tree plantings and waterbodies along transport routes Vegetation and soil management to stabilise transport infrastructure	Shading, microclimate control and air quality regulation, especially for active transport routes Reduced risk of landslides and slips, flooding
Primary production	Management of soil organic matter Riparian vegetation Biodiverse habitat Shelter belts	Soil moisture retention, watera drainage, erosion control Flood protection, water quality regulation Pest management, genetic diversity for breeding programs Temperature and wind management
Education & training	Tree plantings and water bodies Open green space Biodiverse habitat	Shading and microclimate control, air quality regulation Recreation and physical health opportunities, social connections Mental health, cognitive function, ecological literacy opportunities
Built environment	Green infrastructure Open green space Blue infrastructure Coastal protection	Shading and microclimate control, mental health, social connections Recreation and physical health opportunities Microclimate control, flood protection, mental health, social connections Flood protection, erosion reduction
Water cycle	Catchment and riparian vegetation Green and blue infrastructure	Flood protection, water quality regulation, reduced evaporation Reduced stormwater, reduced erosion, reduced drying and cracking
Health and human services	Tree plantings and water bodies Open green space Biodiverse habitat	Shading and microclimate control, air quality regulation Recreation and physical health opportunities, social connections Mental health, cognitive function, ecological literacy opportunities

337. England JR, O'Grady AP, Fleming A, Marais Z, Mendham D 2020, 'Trees on farms to support natural capital: An evidence-based review for grazed dairy systems', *Science of The Total Environment*, 704, p. 135345, https://doi.org/https://doi.org/10.1016/j.scitotenv.2019.135345 Accessed 5 July 2023.
338. Frantzeskaki N, Bush J 2021, 'Governance of nature-based solutions through intermediaries for urban transitions–A case study from Melbourne, Australia', *Urban Forestry and Urban Greening*, 64, p. 127262.
339. Wild T, Henneberry J, Gill L 2017 'Comprehending the multiple 'values' of green infrastructure–Valuing nature-based solutions for urban water management from multiple perspectives', *Environmental Research*, 158, pp. 179-187.
340. Vella-Brodrick D A, Gilowska K 2022 'Effects of Nature (Greenspace) on Cognitive Functioning in School Children and Adolescents: a Systematic Review' *Educational Psychology Review*, 34(3), pp. 1217-1254, https://doi.org/10.1007/s10648-022-09658-5 Accessed 5 July 2023.
341. Ramon M, Ribeiro AP, Theophilo CYS, Moreira EG, de Camargo PB, de Bragança Pereira CA, Saraiva EF, dos Reis Tavares A, Dias AG, Nowak D, Ferreira ML 2023, 'Assessment of four urban forest as environmental indicator of air quality: a study in a brazilian megacity', *Urban Ecosystems*, 26(1), pp. 197-207, https://doi.org/10.1007/s11252-022-01296-7 Accessed 5 July 2023.
342. Li H, Yang Y, Jin J, Wang H, Li K, Wang P, Liao H 2023, 'Climate-driven deterioration of future ozone pollution in Asia predicted by machine learning with multi-source data', *Atmospheric Chemistry and Physics*, 23(2), pp. 1131-1145. https://doi.org/10.5194/acp-23-1131-2023 Accessed 5 July 2023.
343. Aldrich DP 2023, 'How social infrastructure saves lives: a quantitative analysis of Japan's 3/11 disasters' Japanese *Journal of Political Science*, 24(1), pp. 30-40, https://doi.org/10.1017/S1468109922000366 Accessed 5 July 2023.

Climate change — Adaptation

Natural environment as impacted and actively adapting

All elements of the natural environment (living and non-living) are altering under climate change. Any human climate change response that specifically utilises natural systems is, therefore, vulnerable to the degrading and disrupting effects of climate-related stressors (e.g. storms, floods, droughts, fires, flow-on effects such as pests and disease) on those systems. The delivery of adaptation services relies on the functional persistence of ecosystems and continual reassembly of ecological communities under climate change and variability. Analysis of ecosystems, including grassy woodlands, montane forests and floodplains, in Victoria indicates that this, in turn, requires the maintenance of vegetation structural diversity, the presence of keystone species or functional groups, varied ways of responding to disturbance among species, and landscape connectivity.[344] To help sustain such qualities, targeted investment and management is needed. Many greening initiatives do not yet take adequate account of future climates.[345] Similarly, repairing green infrastructure is often overlooked in post-disaster rebuilding efforts.[346] The latest Parks Victoria State of the Parks report found, for example, that 'natural values often have low priority in fire recovery'.[347] Inadequate disaster recovery has far-reaching impacts. A recent global stocktake of adaptation underlines that accumulating environmental damage from climate change is compounding climate change impacts for humans in the near and long term.[348] This reflects the fact that healthy natural systems mediate climate change risks to humans and their adaptation options. Although humans continuously adapt to many socio-environmental changes, such as the arrival of invasive species or the collapse of ecosystems, climate change is amplifying and complicating these existing dynamics and will do so far more in the future. All of this reinforces the need for sophisticated adaptation.[349, 350, 351, 352]

Many natural systems are already vulnerable to additional stress due to negative human influences, as this SoE report documents. For these and other reasons, natural systems themselves need to be the object (and not just a tool) of focused adaptation interventions. Non-human organisms and species continuously and automatically adapt through natural mechanisms such as altered behaviour and phenology, migration to new areas or genetic evolution. Because of this autonomous, biological adaptation, it is sometimes assumed that non-human species need little assistance adapting to shifting conditions. However, the pace, novelty and flow-on effects of human-induced climate change combined with other stressors on natural systems is increasingly straining many species' adaptive capacity at the individual, population and species scales. Many are at risk of dying out or changing beyond recognition. For example, simply to track the long-term geographical shifts in climatic zones occurring in Victoria (see 'Climate change impacts' in this chapter), it is estimated that species will need to migrate up to 50 times faster than they have moved in the past, and to do so across fragmented habitats.[353] Concurrently, many species will not be able to breed quickly enough to physically adapt to new conditions in each location, while populations and ecological communities are increasingly threatened by more frequent, severe, widespread and compounding extreme climatic events. As the Black Summer fires demonstrated, climate change-related destruction of forests and other natural systems can generate severe, wider environmental problems.

344. Lavorel S, Colloff MJ, Locatelli B, Gorddard R, Prober SM, Gabillet M, Devaux C, Laforgue D, Peyrache-Gadeau V 2019, 'Mustering the power of ecosystems for adaptation to climate change', *Environmental Science and Policy*, 92, pp. 87-97.
345. Seddon N, Chausson A, Berry P, Girardin CAJ, Smith A, Turner B 2020, 'Understanding the value and limits of nature-based solutions to climate change and other global challenges', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 375(1794), 20190120, https://doi.org/doi:10.1098/rstb.2019.0120 Accessed 5 July 2023.
346. Miller S 2020, 'Greenspace after a disaster: The need to close the gap with recovery for greater resilience', *Journal of the American Planning Association*, 86(3), pp. 339-348, https://doi.org/10.1080/01944363.2020.1730223 Accessed 5 July 2023.
347. Parks Victoria (PV) 2018, 'State of the parks 2018 report', Melbourne, Victoria.
348. Simpson NP, Williams PA, Mach K J, Berrang-Ford L, Biesbroek R, Haasnoot M, Segnon AC, Campbell D, Musah-Surugu J I, Joe E T 2023, 'Adaptation to compound climate risks: a systematic global stocktake', *iScience*.
349. Howard L 2019, 'Human adaptation to invasive species: A conceptual framework based on a case study metasynthesis', *Ambio*, 48(12), pp. 1401-1430. https://doi.org/10.1007/s13280-019-01297-5 Accessed 5 July 2023.
350. Bergstrom DM, Wienecke BC, van den Hoff J, Hughes L, Lindenmayer DB, Ainsworth TD, Baker CM, Bland L, Bowman DM, Brooks ST 2021, 'Combating ecosystem collapse from the tropics to the Antarctic', *Global Change Biology*, 27(9), pp. 1692-1703.
351. Cumming GS 2018, 'A review of social dilemmas and social-ecological traps in conservation and natural resource management', *Conservation Letters*, 11(1), e12376.
352. Cumming GS, Olsson P, Chapin FS, Holling CS 2013, 'Resilience, experimentation, and scale mismatches in social-ecological landscapes', *Landscape Ecology*, 28(6), pp. 1139-1150, https://doi.org/10.1007/s10980-012-9725-4 Accessed 5 July 2023.
353. Department of Environment, Land, Water and Planning (DELWP) 2022, 'Natural environment climate change adaptation action plan 2022–2026', Melbourne, Victoria, https://www.environment.vic.gov.au/__data/assets/pdf_file/0030/558264/Natural-environment-Climate-Change-Adaptation-Action-Plan-2022.pdf Accessed7 July 2023.

This includes impacts of runoff in marine ecosystems and large pulses of greenhouse gases into the atmosphere, turning carbon sinks into sources of worsening climate change.[354, 355] More insidiously, climatic changes are interacting with associated and independent biophysical conditions such as ocean acidification or elevated carbon dioxide atmospheric concentrations to alter organisms at a molecular level, such as reducing the protein levels of wheat and perhaps other grass species, and bleaching corals.[356, 357]

The dynamic and potentially more stressed and risky character of natural systems under climate change holds far-reaching implications for human society, including its adaptation efforts. Acknowledgement of, and support for, natural systems' autonomous adaptations need to be built into human adaptation initiatives, challenging the assumption that such systems are stationary (CCA:03). At the same time, climate change is not an excuse for complacency about ecological change. The additional stress of climate change upon natural systems increases the importance of environmental sustainability work and the related need to actively adapt such work — both to update its assumptions about natural systems and improve its own resilience (CCA:01) — and to build it into climate adaptation programs (CCA:04). EBA efforts particularly need to accommodate and facilitate positive changes in the natural systems they are working with. In choosing new plantings, for instance, not only does species choice need to reflect shifting climatic conditions, but potential indirect climate change effects such as altered competitive relationships or disease risks (indicator CCA:02), as well as the risks that natural systems can pose to humans (e.g. falling trees). Tracking ecological changes and evaluating the effects of and on different adaptations is critical (CCA:05), including changes in distant natural systems affected by adaptations via relations such as supply chains (CCA:04). Research into how and why natural systems are changing, and may change, under climate change is needed to help inform intelligent adaptations (CCA:06). The dynamic character of natural systems demands a more adaptive policy and regulatory environment as, for instance, climatic impacts on an ecosystem means that previously allowable extraction or pollution limits generate more ecological damage (CCA:07). To facilitate species' ability to track shifting climatic zones, large areas of habitat are needed, which requires large-scale, coordinated ecosystem management across locations (CCA:08). Such work underlines the need for adaptive capacity to include ecological literacy (CCA:09), and the means for systematically tracking change, such as citizen science (CCA:05 and CCA:06).

Natural environment as a target of adaptation

In addition to using natural systems for adaptation or allowing for natural adaptation under climate change, humans need to actively intervene to help protect and sustain valued, existing natural assets, whether a beloved tree, a rare species, a beautiful park or river catchment. Emerging around the world, such efforts are increasingly targeting and supporting specific natural systems to complement and guide their natural adaptation processes and improve their outcomes. Climate change adaptation is now a prominent agenda in natural resource management and nature conservation. 'Climate-ready conservation' includes interventions to increase valued assets' robustness and resilience to climatic pressures and redoubling efforts to reduce existing vulnerabilities by ameliorating known non-climatic stressors such as human water diversion and extraction from water-dependent ecosystems.[358, 359, 360] There is a long-standing focus on adapting national reserve systems to climate change, including analysing the extent to which they will retain prioritised features, whether existing species will move elsewhere, whether new ones will move in and the cost-effectiveness of and

354. Barros TL, Bracewell SA, Mayer-Pinto M, Dafforn K A, Simpson SL, Farrell M, Johnston EL 2022, 'Wildfires cause rapid changes to estuarine benthic habitat' *Environmental Pollution*, 308, p. 119571, https://doi.org/https://doi.org/10.1016/j.envpol.2022.119571 Accessed 5 July 2023.
355. Shiraishi T, Hirata R 2021, 'Estimation of carbon dioxide emissions from the megafires of Australia in 2019–2020', *Scientific Reports*, 11(1), pp. 1-10.
356. Asseng S, Martre P, Maiorano A, Rötter RP, O'Leary GJ, Fitzgerald GJ, Girousse C, Motzo R, Giunta F, Babar MA, Reynolds MP, Kheir AMS, Thorburn PJ, Waha K, Ruane AC, Aggarwal PK, Ahmed M, Balkovič J, Basso B, Ewert F 2019, 'Climate change impact and adaptation for wheat protein', *Global Change Biology*, 25(1), p.p 155-173, https://doi.org/10.1111/gcb.14481 Accessed 5 July 2023.
357. Roach TN, Dilworth J, Jones AD, Quinn RA, Drury C 2021, 'Metabolomic signatures of coral bleaching history', *Nature Ecology and Evolution*, 5(4), pp. 495-503.
358. Dunlop M, Parris H, Ryan P 2013, 'Climate-ready conservation objectives: A scoping study' National Climate Change Adaptation Research Facility, Southport, Queensland.
359. John A, Horne A, Nathan R, Fowler K, Webb JA, Stewardson M 2021, 'Robust climate change adaptation for environmental flows in the Goulburn River, Australia [Original Research]', *Frontiers in Environmental Science*, 9. https://doi.org/10.3389/fenvs.2021.789206 Accessed 5 July 2023.
360. Prober S M, Doerr VA, Broadhurst LM, Williams KJ, Dickson F 2019, 'Shifting the conservation paradigm: a synthesis of options for renovating nature under climate change', *Ecological Monographs*, 89(1), e01333.

pathways to expanding the network.[361, 362, 363, 364, 365] Associated with this is an examination of the degree to which existing reserve systems include existing and predicted climate refugia based on analysis of both physical features and/or select species' needs under different climate scenarios.[366] Because climate change is progressive and ongoing, a series of connected alternative habitats is needed for mobile species, and the associated 'climate linkage' areas are a priority for protection.[367] More broadly, there are efforts to scale up conservation to landscape scales and beyond.[368] At the global scale, generating climate change and biodiversity benefits from natural systems will require a huge expansion of protected areas and enrolling private land holders in conservation efforts, even in cities where vegetation on private property is essential to the urban canopy and biodiversity.[369, 370, 371]

While conservation methods focused on facilitating species' own adaptation still dominate, more interventionist approaches are also emerging.[372, 373] The use of assisted migration and translocation for critically endangered populations is increasingly discussed, including debate about the uncertainties and implications for host areas.[374] In many cases, difficult decisions about triaging existing ecosystems are being considered.[375] In other cases, the accuracy, relevance and legitimacy of natural baselines and historical reference states are being reassessed in light of the new, non-stationary climate. This is challenging conservation goals and values and promoting a switch in focus from the composition of ecosystems to their functional attributes and the creation and management of novel ecosystems.[376, 377, 378]

Moves to challenge the naturalness of physical environments reinforce longer-standing efforts to recognise landscapes as dynamic and long-shaped by humans, and thus — in the Australian context — recognise Traditional Owners' connection and claims to Country. This, in turn, brings to the fore the human-heritage value of certain places and the need in heritage work to similarly move beyond efforts to preserve and protect. For example, calling for a more adaptive approach to heritage — one that treats sites as living heritage, employs innovative governance, embraces transparency and accountability, invests in monitoring and evaluation, and manages adaptively.[379]

Whatever the goal, it is clear that at least some natural systems require targeted adaptation support, underlining the importance of indicator 'CCA:03 Adaptation of natural systems'. This component of the framework also relies on broader adaptation efforts, especially careful monitoring and evaluation (CCA:05), research and learning (CCA:06) and building adaptive capacity (CCA:09), including among natural resource management (NRM) staff. For example, climate change adaptation of environmental

361. Heller NE, Zavaleta ES 2009, 'Biodiversity management in the face of climate change: a review of 22 years of recommendations', *Biological Conservation*, 142(1), pp. 14-32.
362. Araújo MB, Cabeza M, Thuiller W, Hannah L, Williams PH 2004, 'Would climate change drive species out of reserves? An assessment of existing reserve-selection methods' *Global Change Biology*, 10(9), pp. 1618-1626.
363. Barr SL, Larson BM, Beechey TJ, Scott DJ 2021, 'Assessing climate change adaptation progress in Canada's protected areas', *The Canadian Geographer*, 65(2), pp. 152-165.
364. Arafeh-Dalmau N, Brito-Morales I, Schoeman, DS, Possingham, H. P, Klein C J, Richardson, AJ 2021, 'Incorporating climate velocity into the design of climate-smart networks of marine protected areas', *Methods in Ecology and Evolution*, 12(10), pp. 1969-1983.
365. Lawler JJ, Rinnan DS, Michalak JL, Withey JC, Randels CR, Possingham HP 2020, 'Planning for climate change through additions to a national protected area network: implications for cost and configuration', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 375(1794), 20190117. https://doi.org/doi:10.1098/rstb.2019.0117 Accessed 5 July 2023.
366. Michalak JL, Stralberg D, Cartwright JM, Lawler JJ 2020, 'Combining physical and species-based approaches improves refugia identification', *Frontiers in Ecology and the Environment*, 18(5), pp. 254-260, https://doi.org/https://doi.org/10.1002/fee.2207 Accessed 5 July 2023.
367. Schloss CA, Cameron DR, McRae BH, Theobald DM, Jones A 2022, '"No-regrets" pathways for navigating climate change: planning for connectivity with land use, topography, and climate', *Ecological Applications*, 32(1), e02468, https://doi.org/https://doi.org/10.1002/eap.2468 Accessed 5 July 2023.
368. Galan J, Galiana, F, Kotze DJ, Lynch K, Torreggiani D, Pedroli B 2023, 'Landscape adaptation to climate change: Local networks, social learning and co-creation processes for adaptive planning', *Global Environmental Change*, 78, p. 102627, https://doi.org/https://doi.org/10.1016/j.gloenvcha.2022.102627 Accessed 5 July 2023.
369. Roberts CM, O'Leary BC, Hawkins JP 2020, 'Climate change mitigation and nature conservation both require higher protected area targets', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 375(1794), 20190121, https://doi.org/doi:10.1098/rstb.2019.0121 Accessed 5 July 2023.
370. Seddon N, Chausson A, Berry P, Girardin CA J, Smith A, Turner B 2020, 'Understanding the value and limits of nature-based solutions to climate change and other global challenges', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 375(1794), 20190120, https://doi.org/doi:10.1098/rstb.2019.0120 Accessed 5 July 2023.
371. Kirk H, Garrard GE, Croeser T, Backstrom A, Berthon K, Furlong C, Hurley J, Thomas F, Webb A, Bekessy SA 2021, 'Building biodiversity into the urban fabric: A case study in applying Biodiversity Sensitive Urban Design (BSUD)', *Urban Forestry and Urban Greening*, 62, 127176, https://doi.org/https://doi.org/10.1016/j.ufug.2021.127176 Accessed 5 July 2023
372. Barr SL, Lemieux CJ, Larson BM, Parker SR 2023, 'Open to change but stuck in the mud: Stakeholder perceptions of adaptation options at the frontlines of climate change and protected areas management', *Parks Stewardship Forum*, 39(1).
373. Prober SM, Doerr VA, Broadhurst LM, Williams KJ, Dickson F 2019, 'Shifting the conservation paradigm: a synthesis of options for renovating nature under climate change', *Ecological Monographs*, 89(1), e01333.
374. Butt N, Chauvenet AL, Adams VM, Beger M, Gallagher RV, Shanahan DF, Ward M, Watson JE, Possingham HP 2021, 'Importance of species translocations under rapid climate change', *Conservation Biology*, 35(3), pp. 775-783.
375. Schweizer V, Colloff M J, Pittock J 2022, 'The Dammed and the saved: A conservation triage framework for wetlands under climate change in the Murray–Darling Basin, Australia', *Environmental Management*, 70(4), pp. 549-564, https://doi.org/10.1007/s00267-022-01692-x Accessed 5 July 2023
376. Thomas CD 2020, 'The development of Anthropocene biotas', Philosophical Transactions of the Royal Society B: Biological Sciences, 375(1794), 20190113. https://doi.org/doi:10.1098/rstb.2019.0113 Accessed 5 July 2023.
377. Gawne B, Thompson R 2023, 'Adaptive water management in response to climate change: the case of the southern Murray darling Basin', *Australasian Journal of Water Resources*, pp. 1-18. https://doi.org/10.1080/13241583.2023.2181844 Accessed 5 July 2023.
378. Clement S, Standish RJ 2018, 'Novel ecosystems: Governance and conservation in the age of the Anthropocene'. *Journal of Environmental Management*, 208, pp. 36-45.
379. Perry J, Gordon IJ 2021, 'Adaptive heritage: Is this creative thinking or abandoning our values?', *Climate*, 9(8), pp. 128.

flows requires that flow managers adopt new scenario-based decision-making frameworks that better accommodate the shifting and uncertain character of the water cycle under climate change.[380] At the same time, adapting environmental flows to help riverine ecosystems adapt requires addressing institutional barriers such as the outdated flow assessment methods recommended by government and the need for new legislative and policy guidance, as well as redressing fundamental problems with existing water entitlements and allocations, federal state capacity, and legal risk management standards, underlining the importance of adapting governance, policies and laws (CCA:07).[381, 382, 383, 384]

Natural environment as threatened by adaptation initiatives

Even when climate change adaptation efforts do not intentionally consider natural systems, like any human action they can strongly affect them anyway — including negatively.[385, 386] Although the environmental impacts of adaptation interventions are generally neglected, recent advice from the Science and Technical Advisory Panel of the Global Environmental Facility notes:

'Nearly all adaptation projects will have implications for the achievement of climate mitigation or other GEBs [Global Environmental Benefits]. These implications may be indirect and systemic and therefore not obvious at first sight' [387]

Worsening climate change means that more and more groups are adapting, at least in an automatic, unconscious manner, to facilitate short-term coping. There is a risk that the resultant changes do not adequately anticipate side-effects, worsening conditions for others, including non-humans.

Natural systems are especially at risk when they are framed as part of the problem that climate responses needs to address. For example, efforts to reduce bushfire hazards to human settlements frame vegetation as fuel and can lead to prescribed burning regimes that severely disadvantage some species, especially those with long reproductive cycles or those that are dependent on leaf litter.[388] The Upper Beaconsfield Bushfire and Biodiversity Tool is designed to explore such tensions between fire-risk reduction and biodiversity objectives. Similarly, large infrastructural adaptations, such as sea walls or flood protections, can alter water flows and negatively affect related ecosystems.[389]

Potential environmental impacts also include increased competition for resources, as illustrated by efforts to secure water for human consumption and tensions between different human and non-human water users in the Murray Darling Basin.[390, 391] Resources include space, and land-use change decisions driven partially by climate change adaptation objectives threaten to impact some natural systems. For example, as the suitability of land for different enterprises shifts under a drying climate and some farmers in southern Victoria switch from grazing to cropping, and/or from dryland to irrigated agriculture, biodiversity in southern Victoria could be negatively affected.[392] Combined with the potential for climate change-induced economic stress to intensify some farmers' sense of nature conservation being in conflict with agricultural production, this could undermine existing efforts to protect already critically endangered grassland communities, paddock

380. Judd M, Horne AC, Bond N 2023, 'Perhaps, perhaps, perhaps: Navigating uncertainty in environmental flow management [Original Research]', *Frontiers in Environmental Science*, 11, https://doi.org/10.3389/fenvs.2023.1074896 Accessed 5 July 2023.
381. Judd M, Boese M, Horne AC, Bond N R 2023, 'Perceptions of climate change adaptation barriers in environmental water management', *Ecology and Society*, 28(1), Article 21, https://doi.org/10.5751/ES-13883-280121 Accessed 5 July 2023.
382. Gawne B, Thompson R 2023, 'Adaptive water management in response to climate change: the case of the southern Murray darling Basin', *Australasian Journal of Water Resources*, pp. 1-18. https://doi.org/10.1080/13241583.2023.2181844 Accessed 5 July 2023.
383. Bell S 2022, 'The limits of federal state capacity in managing Australia's Murray-Darling River Basin', *Water Alternatives*, 15(1), pp. 129-149.
384. Chipperfield K, Alexandra J 2022, 'Water governance, the rule of law and regulating risks to the Murray–Darling Basin', *Australasian Journal of Water Resources*, pp. 1-14. https://doi.org/10.1080/13241583.2022.2161143 Accessed 5 July 2023.
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386. Yang Y, Liu, B, Wang P, Chen WQ, Smith TM 2020, 'Toward sustainable climate change adaptation', *Journal of Industrial Ecology*, 24(2), pp, 318-330, https://doi.org/https://doi.org/10.1111/jiec.12984 Accessed 5 July 2023.
387. Carr, ER 2022, 'A decision tree for adaptation rationale', A STAP advisory document, Washington, DC, United States, Scientific and Technical Advisory Panel (STAP) to the Global Environmental Facility, United Nations Environmental Programme.
388. Bradshaw S, Dixon K, Lambers H, Cross A, Bailey J, Hopper S 2018, 'Understanding the long-term impact of prescribed burning in mediterranean-climate biodiversity hotspots, with a focus on south-western Australia' *International Journal of Wildland Fire*, 27(10), pp. 643-657.
389. Piggott-McKellar AE, Nunn PD, McNamara KE, Sekinini S T 2020, 'Dam (n) seawalls: A case of climate change maladaptation in Fiji', *Managing Climate Change Adaptation in the Pacific Region*, pp. 69-84.
390. Alexandra J 2018, 'Evolving governance and contested water reforms in Australia's Murray Darling Basin', *Water*, 10(2), pp. 113.
391. Gawne, B, Thompson R 2023, 'Adaptive water management in response to climate change: the case of the southern Murray darling Basin', *Australasian Journal of Water Resources*, pp. 1-18, https://doi.org/10.1080/13241583.2023.2181844 Accessed 5 July 2023.
392. Maron M, Fitzsimons JA 2007, 'Agricultural intensification and loss of matrix habitat over 23 years in the West Wimmera, south-eastern Australia', *Biological Conservation*, 135(4), pp. 587-593.

trees and other remnant habitat in these and other agricultural landscapes.[393, 394, 395]

Without care, adaptation initiatives might also impact the environment through the production of waste and pollutants. For example, the incremental adaptation of increasing air-conditioning to cope with heat generates significant local pollution as well as greenhouse gas emissions. Kouis et al. (2021) suggest that the local air pollution caused by air conditioners is so significant it can counteract the health benefits of the cooling they provide.[396]

The potential for adaptation initiatives to negatively affect the environment, and thus undermine ecological services and so worsen climate vulnerability, is self-defeating at a collective level. Yet it may, nevertheless, be perpetuated by a narrow scoping of adaptation success or concerns. To help redress this risk, it is important to embed environmental sustainability criteria into adaptation (CCA:04) both via legal requirements for EIAs of large, proposed adaptation projects and definitions of adaptation success that build in the avoidance of negative impacts on the wider environment and associated human communities. To facilitate the latter, governance, policies and laws need to adapt (CCA:07). Monitoring, evaluation and research into the environmental effects of adaptation actions (CCA:05 and CCA:06) is also vital, as is the need to build capacity for environmental analysis and systems thinking as part of efforts to educate groups about climate change (CCA:08 and CCA:09).

Challenges for Adaptation

To progress adaptation of, for and with natural systems, it is important to appreciate the complexities of climate change impacts. The IPCC's latest report on Impacts, Adaptation and Vulnerability makes clear that climatic shifts and extremes are combining and compounding, leading to non-linear changes, more unpredictable conditions and poor outcomes from single-hazard human responses.[397] It also makes clear that climate change risk stems from interactions between climate-related phenomenon and existing systems. Both drivers of risk can be reduced through adaptation actions in order to bring actual impacts below what could otherwise manifest.

Exposure and sensitivity to climate-related hazards

The first component of climate change risk are the many weather and climatic changes, their interactions and immediate flow-on effects that are accelerating under climate change. This cannot be underestimated; the global climate is reacting more strongly to greenhouse gases than first anticipated, with average global temperatures rising, the water cycle accelerating, and local weather veering away from historical patterns.[398] All climatic factors are changing concurrently at different paces and in different ways. Associated multidimensional effects on ecosystems include the emergence of new disturbance regimes.

Most adaptation is focused on managing the risk of direct climatic or biophysical impacts on tangible physical assets or locations (climate risk management). How shifting conditions affect specific systems over different scales requires detailed understanding of current spatial exposure patterns and the different climatic sensitivities of various natural elements. Understanding resultant

393. Schaal T, Jacobs A, Leventon J, Scheele BC, Lindenmayer D, Hanspach J 2022, ''You can't be green if you're in the red': Local discourses on the production-biodiversity intersection in a mixed farming area in south-eastern Australia', *Land Use Policy*, 121, 106306.
394. Farmilo BJ, Moxham C 2019, 'Decadal plant composition changes in grazed native grassland' *Ecological Management and Restoration*, 20(3), pp. 231-238, https://doi.org/https://doi.org/10.1111/emr.12383 Accessed 5 July 2023.
395. Manning AD, Lindenmayer DB 2009, 'Paddock trees, parrots and agricultural production: An urgent need for large-scale, long-term restoration in south-eastern Australia.', *Ecological Management and Restoration*, 10(2), pp. 126-135, https://doi.org/https://doi.org/10.1111/j.1442-8903.2009.00473.x Accessed 5 July 2023.
396. Kouis P, Psistaki K, Giallouros G, Michanikou A, Kakkoura MG, Stylianou KS, Papatheodorou SI, Paschalidou, AK2021, 'Heat-related mortality under climate change and the impact of adaptation through air conditioning: A case study from Thessaloniki, Greece', *Environmental Research*, 199, 111285, https://doi.org/https://doi.org/10.1016/j.envres.2021.111285 Accessed 5 July 2023.
397. Intergovernmental Panel on Climate Change (IPCC) 2022, 'Climate Change 2022: Impacts, adaptation, and vulnerability', Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [HO Pörtner, DC Roberts, M Tignor, ES Poloczanska, K Mintenbeck, A Alegría, M Craig, S Langsdorf, S Löschke, V Möller, A Okem, B Rama (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, United States.
398. Intergovernmental Panel on Climate Change (IPCC) 2022, 'Climate Change 2022: Impacts, adaptation, and vulnerability', Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [HO Pörtner, DC Roberts, M Tignor, ES Poloczanska, K Mintenbeck, A Alegría, M Craig, S Langsdorf, S Löschke, V Möller, A Okem, B Rama (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, United States.

changes also requires understanding the complex causal mechanisms involved (e.g. effects on physiology, food supply, predation) plus high-quality data, monitoring and modelling — underlining the importance of indicators CCA:05 and CCA:06.

Climatic stresses and episodic disruptions can trigger a wide range of flow-on effects in natural systems (e.g. altered pest, weed and disease burdens, altered hydrology, effects on NRM) that can be more detrimental to ecological communities than the direct impacts of climatic change.
An increasing challenge — reflected in indicator CCA:03 on incorporating changes to natural systems — is to 'manage repeatedly damaged and potentially collapsed ecosystems'.[399]

In addition, climatic disruptions are being felt through the impacts to shared infrastructure networks, essential services and supply chains, including the people and natural (infrastructural) systems (CCA:02) that form the 'lifelines' that sustain everyday life.[400] When functioning well, such systems can help moderate local climatic impacts, but dependence on them also greatly increases an entity's spatial exposure, pointing to the need for adaptation efforts to consider climatic conditions far afield and to scale out adaptation over large areas (CCA:08).

Non-climatic, existing vulnerabilities

Powerfully driving climate change impacts are not only climate-related stressors, but what they interact with — the existing challenges that an individual or system is dealing with at a point in time. For example, a plant population dealing with habitat fragmentation and associated in-breeding will be worse affected by a given climatic disturbance than a more diverse population. Vulnerabilities are themselves changing over time. Some are worsening due to the lingering effects of past climatic stressors. That is, as climate change unfolds, inadequate adaptation and incomplete recovery from disasters is leaving systems more at risk of subsequent stresses and disruptions, increasing the likelihood of serious impacts. The urgent task of adaptation is to outpace the repetition and proliferation of impacts to escape a negative spiral of declining capacity.

For natural systems, underlying vulnerabilities reflect societal structures which is why the adaptation of governance, policies and laws (CCA:07) is so important. Natural systems' vulnerability, or conversely its adaptive capacity, reflects the intensity and success of human efforts to protect them (e.g. volunteer nature conservation work). This highlights the importance of building the adaptive capacity of communities and agencies, adapting environmental sustainability work and organisations to climate change, and building environmentally sustainable criteria into all climate adaptation work (CCA:01, CCA:04 and CCA:09). 'Transformational adaptation' aims to redress the 'systems, structures and actions that are driving climate change, risk and disasters' and — more than only negating negatives — to generate new positives.[401] As Galan et al. (2023) note, adaptation 'is increasingly considered an opportunity for change rather than a disconnected problem that needs to be fixed to keep the current status quo'.[402] Associated with transformational adaptation are efforts to scale it, including scaling it out across wider social and spatial scales (as mentioned above) (CCA:08), scaling it up into institutions and social systems (CCA:07), and scaling deep into mindsets and paradigms, including the cultivation of ecological literacy (CCA:09).

399. Lindenmayer DB, Taylor C 2020, 'New spatial analyses of Australian wildfires highlight the need for new fire, resource, and conservation policies', *Proceedings of the National Academy of Sciences*, 117(22), pp. 12481-12485, https://doi.org/doi:10.1073/pnas.2002269117 Accessed 5 July 2023.
400. Singh EA 2021 'Compounding Impacts of Lifeline Infrastructure Failure During Natural Hazard Events', *The Demography of Disasters*, pp. 189-210.
401. Wamsler C, Mulligan J, Bukachi V, Mumbi C 2022, 'Activating transformation: integrating interior dimensions of climate change in adaptation planning', *Climate and Development*, pp. 1-13, https://doi.org/10.1080/17565529.2022.2089089 Accessed 5 July 2023.
402. Galan J, Galiana, F, Kotze DJ, Lynch K, Torreggiani D, Pedroli B 2023, 'Landscape adaptation to climate change: Local networks, social learning and co-creation processes for adaptive planning', *Global Environmental Change*, 78, p. 102627, https://doi.org/https://doi.org/10.1016/j.gloenvcha.2022.102627 Accessed 5 July 2023.
403. Kemter M, Fischer M, Luna LV, Schönfeldt, E, Vogel J, Banerjee A, Korup O, Thonicke K 2021, 'Cascading Hazards in the Aftermath of Australia's 2019/2020 Black Summer Wildfires', *Earth's Future*, 9(3), e2020EF001884, https://doi.org/https://doi.org/10.1029/2020EF001884 Accessed 5 July 2023.

Climate change adaptation indicators

Table CCA10: New and modified climate change adaptation indicators.

New CCA indicators	CCA:01 Adaptation of environmental sustainability work
	CCA:02 Active adaptation of natural systems
	CCA:03 Use of Ecosystem Based Adaptation
	CCA:04 Embedding of sustainability criteria into climate adaptation
	CCA:05 Comprehensive Monitoring and Evaluation
	CCA:06 Adaptation scaled up into governance, policies and law
	CCA:07 Adaptation scaled out across communities and regions
	CCA:08 Investment in adaptive capacity and capabilities
	CCA:09 Investment in research and learning
Modified SoE 2018 indicators (a sample)	2018 CC:14 Community awareness of climate risks and associated responsibilities
	2018 CC:15 Councils (or other organisations) using ecosystem-based adaptation such as urban greening
	2018 CC:16 Considering climate change risks to stakeholders (including natural systems) in land use planning (including in the coastal zone)
	2018 CC:17 Percentage of agri-businesses planning using long-term weather and climate change projections and environmental monitoring

This section describes the nine new climate change adaptation indicators, their relationship to the framework and their intersections. These implementation or process indicators complement the existing indicators in the SoE Report that, together, implicitly provide a comprehensive picture of natural environment outcomes in the context of climate change and human adaptation.

These new indicators highlight the need for specific areas of adaptation, the use of quality criteria to guide human adaptation, efforts to scale adaptation out and up, and deliberate investment in enabling more adaptation (Figure CCA35). Some of the indicators are specific to the natural environment, and some are more generic.

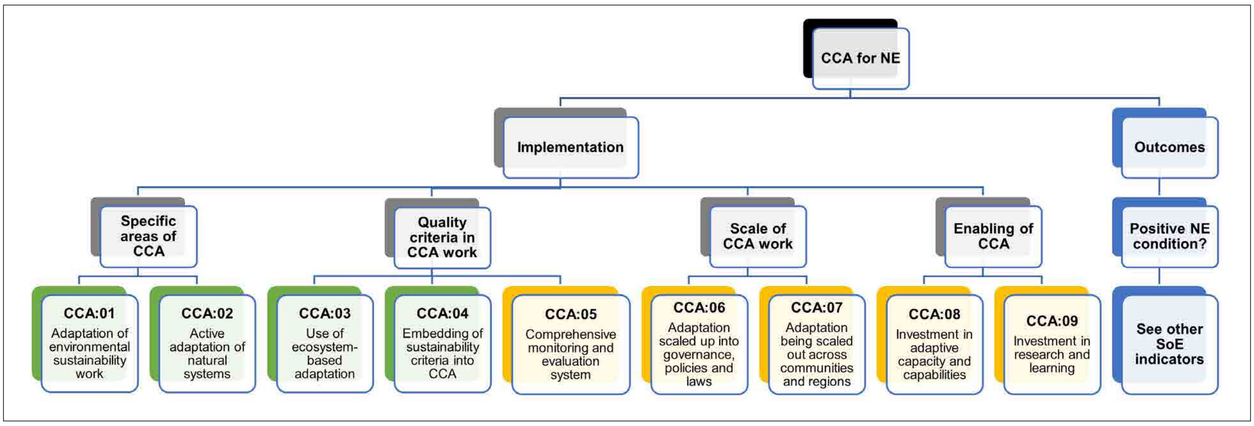


Figure CCA35: An overview of the nine new indicators (bottom level) that help track progress towards the overarching goal of climate change adaptation (CCA) for the natural environment (NE). The third level identifies the aspect of adaptation the indicators are relevant to. Some indicators are specific to the natural environment (green) and some are about generic adaptation practice (yellow).

Climate change — Adaptation

CCA:01 Adaptation of environmental sustainability work

Healthy environments reduce vulnerability to climate change, contribute to our collective adaptive capacity and wellbeing, and thereby help enable positive adaptation outcomes. Efforts to improve environmental health, therefore, need to be part of the portfolio of adaptation actions. Helping drive such efforts is 'environmental sustainability work'. Some of this is paid work (e.g. Sustainability Officers in business, roles in sustainability organisations), but a lot of it is voluntary (e.g. participation in local environmental groups or networks such as Landcare). As environmental sustainability is increasingly prioritised across workplaces and homes, efforts to improve sustainability also intersect with everybody's work and domestic activities (which is one reason that people across Victoria need to be engaged in climate change adaptation, as indicator CCA:08 encourages). All of this work needs to be adapted to reduce the risk of it being disrupted or undermined by climate change.

Whether office- or field-based, sustainability work can already be challenging, involving complex problems, management of different demands, the need to monitor and respond to diverse information and sometimes physical labour. It is also highly climate sensitive in the sense that the general object of concern — 'the environment' — is highly responsive to the climate and is changing in multiple ways under climate change and its innumerable flow-on effects are becoming, in some cases, a threat to humans interacting with it. To the extent that those involved in environmental sustainability work are directly exposed to weather conditions (i.e. outdoor work) or rely on activities (e.g. public fundraising events) and infrastructure and systems (e.g. electricity, roads) that are exposed, then such work is also climate sensitive. Recent climate change-related disasters, such as the Black Summer Fires, have demonstrated how impacts can cascade through infrastructural systems, interacting with and compounding more local challenges such as extreme heat for organisations and communities.[403]

Research points to diverse and pervasive impacts of climate change stressors and disruptions on workers of many sorts, adding to the complexities of organisational adaptation to climate change (Denham and Rickards 2022).[404]

Practical environmental management work, including nature conservation, is only one kind of environmental sustainability work; but it is a vital one as it reduces the direct pressures on natural systems (e.g. pest plants, pollution), enhances local areas (e.g. biodiversity plantings) and enables people to safely use natural areas (e.g. track maintenance). Such work now needs to also involve helping natural systems adapt to climate change. Some of this adaptation takes the form of climate risk management, such as fire management plans for fire-sensitive, threatened species or captive breeding of threatened alpine species facing adaptation limits in their places of origin. It also includes vulnerability reduction approaches to adaptation which work to reduce natural systems' climate change risk by alleviating non-climatic stressors. Given the overlap with normal environmental management work, most climate change adaptation to date within the nature conservation sector focuses on these non-climate-specific, 'low regrets' options.[405, 406] Significantly, however, these structural and circumstantial pressures upon natural systems are themselves continually changing, including as an indirect effect of climate change-related pressures.

A key mechanism by which such feedbacks are propagated is the effects of climate change on environmental management work, disrupting environmental managers' efforts to care for natural systems and undermining their capacity to manage the additional work of helping protect and adapt natural systems to climate change. Increasingly, the likelihood of such effects is the fact that environmental management work is often exposed and sensitive to a wide range of direct and indirect climate change impacts on infrastructure, buildings, equipment and data collection, as well as staff health and morale, work schedules and planning, legal requirements and insurance costs, and

404. Denham T, Rickards L 2022, 'Climate impacts at work: Supporting a climate ready workforce', Climate Resilience Living Lab, RMIT University, Melbourne, Victoria, https://cur.org.au/cms/wp-content/uploads/2022/09/220926-web-climate-impacts-at-work-pages.pdf Accessed 8 July 2023.
405. Javeline D, Chau S N 2019, 'Adaptation of ecosystems in the Anthropocene', In *Research Handbook on Climate Change Adaptation Policy*. Edward Elgar Publishing.
406. Prober SM, Doerr VA, Broadhurst LM, Williams KJ, Dickson F 2019, 'Shifting the conservation paradigm: a synthesis of options for renovating nature under climate change', *Ecological Monographs*, 89(1), e01333.

volunteer availability. As NRM-Regions-Queensland notes about their area of work: 'every dimension of natural resource management is influenced by changing climatic conditions'.[407] Disruptions to, or loss of, sustainability work allows pressures on natural systems to accumulate, adding to their vulnerabilities and making them more susceptible to the direct effects of climate change. All of this means that environmental sustainability work itself needs to be adapted to climate change in order to help sustain it into the future.

The proposed measures are:

- percent of sustainability-related public agencies (e.g. Parks Victoria) and environment-related non-governmental organisations operating in Victoria (e.g. Bush Heritage Australia) that: (a) have climate change adaptation plans; and more specifically (b) include within those plans practical, organisational adaptation (not only natural system adaptation)
- percent of corporate sustainability plans that acknowledge climate change risks to their sustainability activities.

CCA:02 Active adaptation of natural systems

Natural systems, including but not limited to those already the subject of special protections, need to be strongly supported to adapt to and, thus, survive climate change. This requires acknowledging the dynamism of natural systems under climate change. The various effects of climate change threaten to change natural systems in negative and far-reaching ways. A recent assessment of Interacting Risks in Infrastructure and the Built and Natural Environments for the United Kingdom Government Climate Change Committee found that the risks to the natural environment outnumber those to the built environment and infrastructure, triggering 'many knock-on effects'.[408] Noting that the environment is vital to societal resilience, it calls for research into the role of the natural environment in the generation of 'actual and emerging impacts'.[409] In Australia, the 2019 Pathways to Resilient Infrastructure Discussion Paper by Infrastructure Australia (informed by consultation with approximately 600 stakeholders) includes blue and green infrastructure among the key infrastructure that the nation needs to protect, in keeping with the inclusion of natural assets in the National Critical Infrastructure Resilience Strategy 2015, the National Disaster Risk Reduction Framework and the New South Wales Critical Infrastructure Resilience Strategy 2018.[410] In Victoria, the Government's State Significant Risk Interdepartmental Committee acknowledges that damage to the natural environment due to the physical effects of the changing climate is a risk of state significance.[411]

Specific natural systems are increasingly targeted for adaptation by NRM and nature conservation work by government agencies and not-for-profit organisations. The Victorian Natural Environment Adaptation Action Plan, for example, focusses on the adaptation of natural environment assets, notably protected areas, in the state, while Parks Victoria underlines the need to consider climate change in its most recent Corporate Plan.

More broadly, the framework underlying this chapter indicates that, not only do certain natural systems need to be targeted for adaptation, but the changing character of nature — notably species' autonomous adaptation — needs to be accommodated. As Thomas (2020) states, some recent biological changes:

> '...should be seen as responses to multiple drivers of change, rather than being a problem per se. These changes are the means by which the biosphere is adjusting to and will ultimately survive the Anthropocene. Thus, management and conservation of the biological world, and our place in it, requires a transition from trying to minimize biological change to one in which we facilitate dynamism that accelerates the rates at which species and ecosystems adjust to human-associated drivers of change.' [412]

407. NRM-Regions-Queensland, 2020, NRM Queensland 2020 Research Prospectus, https://www.nrmrq.org.au/wp-content/uploads/2021/01/Queensland-NRM-Research-Prospectus-2020.pdf Accessed 5 July 2023.
408. WSP 2020, 'Interacting Risks in infrastructure and the built and natural environments', *Background Research for the Third UK Climate Risk Assessment.*
409. Ibid.
410. Infrastructure Australia 2021, 'A Pathway to infrastructure resilience. Advisory Paper 1: Opportunities for systemic change. https://www.infrastructureaustralia.gov.au/publications/pathway-infrastructure-resilience-0 Accessed 10 July 2023.
411. Victorian Government 2022, 'Victorian Government: Climate-related risk disclosure statement 2022', Melbourne, Victoria, https://www.dtf.vic.gov.au/funds-programs-and-policies/victorian-government-climate-related-risk-disclosure-statement Accessed 5 July 2023.
412. Thomas CD 2020, 'The development of Anthropocene biotas', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 375(1794), 20190113. https://doi.org/doi:10.1098/rstb.2019.0113 Accessed 5 July 2023.

At the same time, as greater dynamism and uncertainty need to be managed, there is a concomitant need for an anticipatory approach that analyses future climate change risks and the associated likely responses and needs of natural systems, as the 'climate adaptation lens' presented in the Victorian Natural Environment Adaptation Action Plan emphasises. For example, future climatic conditions should be considered in the selection of species for new plantings, as well as the adaptation services that different species could provide.[413, 414] There is also a need to ensure that human adaptations are not stymying nature's potential adaptation pathways (e.g. preventing a species from tracking temperature changes by not providing habitat connectivity).[415, 416]

Combined, these challenges suggest that dominant social ways of imagining, engaging with and managing 'the environment' need to substantially change.[417] In particular, climate change focuses attention on the complex abiotic conditions human wellbeing relies on and the spatial extent of natural systems and ecological services far beyond the bounds of designated 'green areas'. As a result, natural systems need to be prioritised and supported in adaptation policies of all sorts, not just those explicitly about natural environment. This includes adaptation initiatives centred on urban areas or private land. To reduce non-climatic vulnerabilities of natural systems, more space needs to be devoted to non-human species. For example, while urban densification can help reduce urban sprawl and habitat loss on city boundaries, it needs to be done in a way that helps increase urban tree canopy. This is a matter not just for environmental managers, but all involved in land-use and land-management decisions.

The proposed measures are:

- percent of Victorian AAPs and RASs that recognise ecological services and incorporate climate change impacts on and adaptation of natural systems
- percent of Victorian local government adaptation plans that recognise ecological services and incorporate climate change impacts on, and adaptation of, natural systems.

CCA:03 Use of ecosystem-based adaptation

EBA initiatives use natural systems as an adaptation tool. They make the most of the way natural systems can reduce the risk of climatic hazards and their biophysical flow-on effects, including compound hazards.[418] Because many climate change-related hazards are not only the result of climatic phenomenon but also biophysical conditions in an area, the risk of such hazards can be reduced by altering the biophysical situation. For example, relative to areas dominated by built infrastructure (concrete and asphalt), areas dominated by vegetation suffer less extreme heat, drought and flooding because of the physical properties and dynamics of the plants and soil, including shading and protecting ground but remaining permeable. In addition to providing cooling and for storing, draining and filtering water, natural vegetation provides adaptation services for coasts by reducing wave velocities, flooding and erosion during storms, helping manage the effects of sea level rise.

The natural systems used for EBA also provide more general ecological services to humans, such as the provision of resources, pollination and pest management and recreation opportunities, thereby indirectly benefiting human adaptation outcomes. In addition, they can provide biodiversity benefits, such as improved habitat connectivity for valued species. EBA can also enable early adaptation action because such options are often not as sensitive to climate change projections or as expensive as grey infrastructure interventions, such as sea walls or waterway modification. EBA initiatives can have a long lead time, however, in that new plantings take time to become established, underlining the need to begin them early.

413. Klaus VH, Kiehl K 2021, 'A conceptual framework for urban ecological restoration and rehabilitation', *Basic and Applied Ecology*, 52, pp. 82-94.
414. Simonson W D, Miller E, Jones A, García-Rangel S, Thornton H, McOwen C 2021, 'Enhancing climate change resilience of ecological restoration—A framework for action', *Perspectives in Ecology and Conservation*, 19(3), pp. 300-310.
415. Bergstrom RD, Johnson LB, Sterner RW, Bullerjahn GS, Fergen JT, Lenters JD, Norris PE, Steinman AD, 2022, 'Building a research network to better understand climate governance in the Great Lakes', *Journal of Great Lakes Research*, 48(6), pp. 1329-1336.
416. Buma B, Schultz C 2020, 'Disturbances as opportunities: Learning from disturbance-response parallels in social and ecological systems to better adapt to climate change', *Journal of Applied Ecology*, 57(6), pp. 1113-1123.
417. Bergstrom RD, Johnson LB, Sterner RW, Bullerjahn GS, Fergen JT, Lenters JD, Norris PE, Steinman AD, 2022, 'Building a research network to better understand climate governance in the Great Lakes', *Journal of Great Lakes Research*, 48(6), pp. 1329-1336.
418. AghaKouchak A, Chiang F, Huning LS, Love CA, Mallakpour I, Mazdiyasni O, Moftakhari H, Papalexiou S M, Ragno E, Sadegh M 2020, 'Climate Extremes and Compound Hazards in a Warming World' *Annual Review of Earth and Planetary Sciences*, 48.

Adoption of EBA is a sign of good climate change adaptation. Although EBA is already being used in some local areas — notably tree cover to provide shading and cooling (e.g. Melbourne's Urban Forest Strategy) — investment in them needs to be greatly scaled up. Larger scale and strategic adoption of EBA, guided by tools such as landscape design, would increase EBA's system-wide benefits by significantly enhancing the adaptation services generated and producing indirect benefits such as the enhanced destination appeal and economy of associated regions.

The proposed measures are:

- percent of Victorian Government AAPs and RASs that prioritise the implementation of EBA
- percent of Victorian local government adaptation plans that prioritise the implementation of EBA.

CCA:04 Embedding of sustainability criteria into climate adaptation

It is increasingly recognised that adaptation needs to be evaluated qualitatively as well as quantitatively; for example, that climate change requires that we focus on how well we adapt, not only how much we adapt. Assessment for the success, or not, of a given adaptation effort or direction depends not only on its effectiveness in immediately reducing climate risk or vulnerability, but on whether it inadvertently or irresponsibly creates 'maladaptation'. Forms of maladaptation include adaptation efforts that:

- 'Rebound vulnerability' by ultimately generating 'conditions that actually worsen the situation' for those directly involved.[419, 420] Drivers of this include an overly strong focus on a single threat or tactic, heavy opportunity or transaction costs, and/or the complexities and uncertainties of socio-environmental systems as Macintosh (2013) discusses in the Victorian context.[421] For example, an organisation may expend precious time and resources implementing a complicated adaptation initiative that leaves them unable to respond adequately to other needs as they arise (e.g. disasters).
- 'Shift vulnerability' by displacing costs and risks onto others, including neighbours (e.g. via a flood or sea wall that directs water onto others) or those operating at a different scale of organisation (e.g. individual animals obscured by an ecosystem focus).[422, 423] Those species that carry the cost will almost always include non-humans.
- 'Erode sustainable development' by undermining wider social and environmental conditions that indirectly worsen vulnerability. For example, resource-, emissions-, and pollution-intensive adaptations (e.g. many mechanical cooling systems or desalination plants) can worsen climate change, local environments and resource scarcity and, thus, others' climate vulnerability.[424, 425] Similarly, human adaptation efforts to secure water and/or to reduce flood risk by cutting water flows to the environment worsen conditions for water-dependent ecosystems.[426]

An often-overlooked criteria of successful adaptation (or maladaptation) is the effects of an intervention on environmental sustainability (part of 'eroding sustainable development', discussed above). To avoid generating negative environmental outcomes, climate change adaptation interventions need to be carefully prioritised, designed and implemented. To assist with this, new adaptation initiatives should be assessed to help avoid unjust and environmentally unsustainable outcomes. Existing EIA processes could assist here if the levels of acceptable risk are adjusted to incorporate natural systems' new climate change vulnerabilities and enhanced importance (CCA:02). Non-maladaptive climate change adaptation requires that we do not worsen, but

419. Juhola S, Glaas E, Linnér BO, Neset TS 2016, 'Redefining maladaptation', *Environmental Science and Policy*, 55, Part 1, pp. 135-140, https://doi.org/http://dx.doi.org/10.1016/j.envsci.2015.09.014 Accessed 5 July 2023.
420. Schipper ELF 2020, 'Maladaptation: When Adaptation to Climate Change Goes Very Wrong', *One Earth*, 3(4), pp. 409-414, https://doi.org/https://doi.org/10.1016/j.oneear.2020.09.014 Accessed 5 July 2023.
421. Macintosh A 2013, 'Coastal climate hazards and urban planning: how planning responses can lead to maladaptation' *Mitigation and Adaptation Strategies for Global Change*, 18, pp. 1035-1055.
422. Juhola S, Glaas E, Linnér BO, Neset TS 2016, 'Redefining maladaptation', *Environmental Science and Policy*, 55, Part 1, pp. 135-140, https://doi.org/http://dx.doi.org/10.1016/j.envsci.2015.09.014 Accessed 5 July 2023.
423. Adger WN, Arnell NW, Tompkins E L 2005, 'Successful adaptation to climate change across scales' Global Environmental Change, 15, pp. 77-86.
424. Barnett J, O'Neill S 2010, 'Maladaptation', *Global Environmental Change-Human and Policy Dimensions*, 20(2), pp. 211-213, https://doi.org/10.1016/j.gloenvcha.2009.11.004 Accessed 5 July 2023.
425. Juhola S, Glaas E, Linnér BO, Neset TS 2016, 'Redefining maladaptation', *Environmental Science and Policy*, 55, Part 1, pp. 135-140, https://doi.org/http://dx.doi.org/10.1016/j.envsci.2015.09.014 Accessed 5 July 2023.
426. McIntyre S, McGinness H M, Gaydon D, Arthur A D 2011, 'Introducing irrigation efficiencies: prospects for flood-dependent biodiversity in a rice agro-ecosystem', *Environmental Conservation*, 38(3), pp. 353-365, https://doi.org/10.1017/S0376892911000130 Accessed 5 July 2023.

also actively improve, environmental conditions, so assessment needs to also help identify opportunities for environmental benefits.

Embedding sustainability principles (e.g. avoiding habitat loss, pollution and unnecessary consumption) into climate change adaptation will help manage the aggregate and systemic effects of autonomous (individual, household or organisational level) adaptation decisions and reduce the risk of negative outcomes. For example, land-use change due to adaptation (as well as direct climate change) could harm natural systems. The use of tools, such as landscape design and spatial planning, can help tilt the balance towards positive outcomes and work towards the 30% increase in native vegetation cover that research on Victoria and New South Wales suggests is needed to help achieve landscape resilience under climate change.[427] Incorporating sustainability principles and biodiversity-focused outcomes into adaptation can also help in areas such as water management, helping shift stormwater management towards options such as wetlands and rain gardens.

To assist with embedding sustainability into adaptation, existing 'nature based' frameworks, such as biodiversity-sensitive urban design, can be incorporated into adaptation, while others — such as the use of ecological vegetation classes based on historical baselines — themselves need to be adapted.[428] This points to the importance of adapting policies and standards (CCA:06). Also assisting with the convergence of sustainability and adaptation efforts is the fact that, in many organisations, sustainability officers have been given responsibility for leading organisational climate change responses, including adaptation. As the Victorian Government notes, for example, its Victoria's Future Climate Tool is designed to particularly benefit not only risk practitioners or infrastructure managers, but environmental/sustainability officers.[429]

Sustainability-centred adaptation could also be promoted via public and preventative health, given the growing recognition of the environmental determinants of health and the associated role of the health sector in community development and planning strategies.[430] For example, the Victorian health sector could use its influence in precinct planning to not only promote place-based adaptation (as the Victorian Government Health and Human Services AAP recommends), but to ensure such adaptation is genuinely health-full for locals and others by ensuring it is as 'green' as possible. Similarly, the Victorian Department of Health and the Department of Families, Fairness and Housing could consider natural infrastructure and ecological services as part of the assets and services they manage, leading, for example, to a prioritisation of substantial climate-adapted gardens in the provision of aged-care facilities, hospitals and social housing.

The move to build Australian Aboriginal self-determination into adaptation is a further avenue through which positive environmental outcomes may be generated, given Traditional Owners' deep knowledge and respect for Country.

The proposed measures are:

- percent of climate change adaptation investments by the Victorian Government that utilise climate change-adjusted EIAs
- percent of Victorian Government AAPs that embed environmental sustainability as a core principle.

CCA: 05 Comprehensive monitoring and evaluation

The Victorian Natural Environment Adaptation Action Plan underlines the need to acknowledge uncertainties and take an experimental approach to adaptation. In doing so, it aligns with international best practice that also emphasises that, while climate change trends are highly certain, increased climatic variability and extremes plus complex flow-on effects mean that resultant changes in any one time or place are highly uncertain and may vary rapidly over time and between localities. Monitoring of conditions at various scales is vital to informing decision-making under climate change. This includes efforts to track and evaluate the outcomes of adaptation interventions in order to understand whether such actions are working as intended and whether they are producing unintended outcomes. Adjusting adaptation efforts in response to such

427. Doerr V, Williams K, Drielsma M, Doerr E, Davies M, Love J, Langston A, Choy SL, Manion G, Cawsey EM, McGinness H 2013, 'Designing landscapes for biodiversity under climate change', National Climate Change Adaption Research Facility.
428. Kirk H, Garrard GE, Croeser T, Backstrom A, Berthon K, Furlong C, Hurley J, Thomas F, Webb A, Bekessy SA 2021, 'Building biodiversity into the urban fabric: A case study in applying biodiversity sensitive urban design (BSUD)', *Urban Forestry and Urban Greening*, 62, 127176, https://doi.org/https://doi.org/10.1016/j.ufug.2021.127176 Accessed 5 July 2023.
429. Victorian Government, 'Victoria's future climate tool', https://vicfutureclimatetool.indraweb.io/ Accessed 8 July 2023.
430. Watts N, Amann M, Arnell N, Ayeb-Karlsson S, Beagley J, Belesova K, Boykoff M, Byass P, Cai W, Campbell-Lendrum D 2021, 'The 2020 report of the Lancet countdown on health and climate change: Responding to converging crises', *The Lancet*, 397(10269), pp. 129-170.

information makes adaptation work itself adaptable and is a critical new way of working in a time of climate change. This is recognised in the Health and Human Services Adaptation Action Plan that includes strategic action 'H2: Improve the evidence base and monitoring of climate related health impacts and in the future.'

Not only is more monitoring and evaluation needed under climate change, but existing frameworks and practices themselves need to be adapted to function more effectively. For example, the existing Parks Victoria Signs of Healthy Parks monitoring framework could more explicitly accommodate climate change-related changes and be made more responsive by making a component of the monitoring more frequent than every five years. This would require changes to the reporting frameworks, highlighting again the need to adapt policies and regulations (CCA: 06).

Reporting frameworks for financial management are increasing the focus of corporations and institutions on climate change, including climate risks. Internationally, the G20 Financial Stability Board's Taskforce on Climate-related Financial Disclosures (TCFD) is pushing for the monitoring and reporting of climate change-related risks to be incorporated into corporate management. The Victorian Government is the first Australian government entity to take up the challenge. Its Victorian Government Climate-related Risk Disclosure Statement 2022 outlines 'how the Government is managing climate-related risks to the state of Victoria, and to the Government's delivery of services to the community'.[431] The Victorian water sector is leading in the adoption of international standards for climate change risk monitoring, assessment and disclosure. As part of the Pilot Water Sector Adaptation Action Plan 2018-2020, DELWP developed the Managing Climate Change Risk Guidance for Board Members and Executives of Water Corporations and Catchment Management Authorities, in line with the TCFD approach. The New Zealand Government has mandated that each of its agencies comply with TCFD reporting requirements.

A related push for entities to publicly disclose their 'nature-related risks' (risks to nature, e.g. biodiversity loss, water pollution) has emerged through the Taskforce on Nature-related Financial Disclosures. While voluntary, public and shareholder expectations now mean that organisations and institutions need to engage with these initiatives or face considerable reputational and even legal risks.

The proposed measures are:

- percent of Victorian AAPs with an explicit monitoring and evaluation framework
- percent of Victorian institutions and corporations that report on their management of climate risks through the TCFD
- percent of Victorian institutions and corporations that report on their management of climate risks through the Taskforce on Nature-related Financial Disclosures.

CCA:06 Adaptation scaled up into governance, policies and laws

Like sustainability, adaptation is not going to be effective if it operates as a silo or issue separate to other activities and agendas. As with greenhouse gas mitigation, climate change adaptation needs to be a central concern in all organisations and institutions. To date, many organisations are approaching climate change, including adaptation, by allocating it to their sustainability teams. There is a need to mainstream adaptation into all decision-making, treating it more akin to the digital revolution that affects all areas of work rather than a side issue relevant to only a few.

Integrating adaptation into existing processes and structures involves applying what the Natural Environment Adaptation Action Plan calls an 'adaptation lens' on all new initiatives, including strategy renewals and updates. It also involves applying an adaptation lens across every existing area of activity to determine fit for purpose. In particular, research on barriers to climate change adaptation repeatedly points to the need to redress institutional barriers to adaptation. Waters et al. (2014), for example, found that most submissions to the 2014 Australian Productivity Commission Inquiry into Barriers to Climate Change Adaptation ranked 'institutional' challenges as the most problematic.[432]

431. Victorian Government 2022, 'Victorian Government: Climate-related risk disclosure statement 2022', Melbourne, Victoria, https://www.dtf.vic.gov.au/funds-programs-and-policies/victorian-government-climate-related-risk-disclosure-statement Accessed 5 July 2023.
432. Waters E, Barnett J, Puleston A 2014 'Contrasting perspectives on barriers to adaptation in Australian climate change policy', *Climatic Change*, 124(4), pp. 691-702.

Issues include the ways that perverse incentives, in-commensurabilities and rigidities in governance, policies, laws and regulations inhibit understanding and prioritisation of climate change impacts and risks and inhibit the transformational and coordinated action that is needed.

Of special concern is the need to update land-use planning systems to consistently and responsibly incorporate climate change risks to prevent the ongoing expansion of new developments into high-risk areas and to enable the converse: the socially-just, managed retreat of certain existing settlements out of high-risk zones such as floodplains or mountainous areas facing excessive bushfire risk.[433, 434, 435] Constraining and redressing settlement patterns in this way offers sustainability co-benefits, notably for land conservation. In turn, areas set aside as too high of a risk for human habitation, but suitable for green open space or conservation, can offer adaptation benefits to humans, doubling their risk-reduction effect (e.g. the restoration of coastal vegetation in areas at risk of ocean inundation not only fills in the space left by settlement retreat but actively reduces coastal erosion). Recognition of the value of natural spaces — including but not limited to their adaptation services — could help prosecute the case for climate adapted land-use decisions.

A further synergy between climate change adaptation and environmental sustainability is the way both tend to be marginalised within mainstream policies and structures. There is an opportunity to 'piggyback' sustainability onto adaptation so that, as the latter is scaled up into institutions and systems, it helps improve sustainability outcomes along the way, thereby contributing to greater general resilience.

The proposed measures are:

- percent of Victorian AAPs that identify opportunities to alter governance arrangements, policies or laws
- percent of Victorian Government policy renewal processes that build in climate change adaptation and sustainability.

CCA: 07 Adaptation scaled out across communities and regions

Because climate change is impacting all areas and demographics, adaptation is relevant to everyone. Without adaptation, climate change impacts will quickly become devastating, including to local environments. Adaptation needs to be scaled out across social and spatial boundaries to not only involve more people, but to enable higher level coordination and tracking of action (Indicator CCA:05). This is especially vital if maladaptive outcomes — such as the displacement of risk onto natural systems — are to be avoided.

Victoria's RASs are indicative of the strong interest and commitment some groups already have towards understanding climate change and combating its possible and observed effects. The Victoria's RASs were developed in a bottom-up approach across six regions, involving a large number and diverse range of stakeholders. Each strategy is different in focus and form. There is potential to facilitate sharing and learning across strategies and to more actively integrate them with the cross-cutting systems-based AAPs in order to identify important tensions and synergies between the planned approaches. It is possible that some RASs align more easily with some AAPs than others. Of particular importance to natural systems is ensuring that the adaptation lens promoted by the Natural Environment Adaptation Action Plan is adopted across all regions to improve environmental outcomes.

Strategising and planning are crucial to climate change adaptation, but a recent global stocktake indicates that, to date, the growth in adaptation plans has not been followed by equally vigorous adaptation action.[436] Action is vital not only because of the urgency of adaptation, but because it is only through action that adaptation know-how will develop given the experimental character of responses to the climate change problem.[437] It is also through action that more people will be engaged on the issue, relative to the more constrained number of

433. Abel N, Gorddard R, Harman B, Leitch, A, Langridge J, Ryan A, Heyenga S 2011, 'Sea level rise, coastal development and planned retreat: analytical framework, governance principles and an Australian case study' Environmental Science and Policy, 14 (3), pp. 279-288, https://doi.org/http://dx.doi.org/10.1016/j.envsci.2010.12.002 Accessed 5 July 2023.
434. Alexandra, J (2020), 'Burning Bush and Disaster Justice in Victoria, Australia: Can Regional Planning Prevent Bushfires Becoming Disasters? In A. Lukasiewicz and C. Baldwin (Eds.)', Natural Hazards and Disaster Justice: Challenges for Australia and Its Neighbours, pp. 73-92, Springer Singapore, https://doi.org/10.1007/978-981-15-0466-2_4 Accessed 5 July 2023.
435. McNicol I 2021, 'Increasing the adaptation pathways capacity of land use planning – Insights from New South Wales, Australia', Urban Policy and Research, 39(2), pp. 143-156, https://doi.org/10.1080/08111146.2020.1788530 Accessed 5 July 2023.
436. Berrang-Ford L, Siders A, Lesnikowski A, Fischer AP, Callaghan MW, Haddaway NR, Mach KJ, Araos M, Shah M AR, Wannewitz M 2021, 'A systematic global stocktake of evidence on human adaptation to climate change', *Nature Climate Change*, 11(11), pp. 989-1000.
437. Collins K, Ison R 2009, 'Jumping off Arnstein's ladder: social learning as a new policy paradigm for climate change adaptation', *Environmental Policy and Governance*, 19(6), pp. 358-373, https://doi.org/10.1002/eet.523 Accessed 5 July 2023.

people who are involved in planning processes. The intentional scaling out of adaptation initiatives across communities and regions, therefore, promises to have a positive feedback effect as more people learn about climate change impacts and risks and realise the importance of embarking on adaptation (with others).

The proposed measures are:

- percent of Victorian regions (a) implementing their RASs and (b) using the Natural Environment Adaptation Action Plan adaptation lens
- percent of Victorian local councils (a) implementing practical adaptation actions and (b) using the Natural Environment Adaptation Action Plan adaptation lens.

CCA:08 Investment in adaptive capacity and capabilities

Adaptation is a new challenge and requires new ways of thinking, knowledge, skills, relationships and resources. It also requires substantial capacity including resources — capacity that is at risk of being eroded as climate change impacts accumulate.

Without deliberate investment and effort, society is not going to develop the adaptive capabilities and capacities it needs quickly enough. While learning by doing is vital (CCA:07), such learning needs to be maximised and accelerated through specifically designed processes. There are also many other forms of knowledge and action needed. Research on adaptive capacity indicates that, at the organisational level for example, valuable steps include seeking diverse perspectives and knowledges to improve situational awareness and better imagine possibilities, giving individuals more power in decision making to improve their engagement and responsiveness, and establishing networks and other ways of linking across silos to improve understanding and coordination and, thus, reduce the risk of unintended consequences and increase the chances of identifying synergies.

Climate change knowledge is an important aspect of the adaptive capabilities required. This includes knowledge of, or literacy in, climate science, including the basic need for probabilistic thinking to understand climate change projections. Climate change adaptation is also its own area of science, requiring a strong grasp of social science and systems thinking, as the overview of climate change challenges above indicates. Climate change adaptation is also assisted by skills in specific planning tools, such as adaptation pathways.[438] Perhaps most importantly, a nature-centred approach to adaptation requires ecological literacy to appreciate the fundamental importance of natural systems to human life and adaptation outcomes.

The proposed measures are:

- number of enrolments in climate change adaptation professional development
- percent of Victorian Government adaptation spending going to adaptive capacity building.

CCA:09 Investment in research and learning

A key contributor to adaptive capabilities is new knowledge. Significant research and learning to support the evolution, roll out and assessment of climate change adaptation (supporting indicators CCA:05, CCA:06 and CCA:07) is required. In addition to research on adaptation, a host of broader research needs to be harnessed for adaptation.[439] This is about corralling, interpreting and applying research to inform understanding of climate change threats and impacts to every sort of system and place, and to then develop with diverse stakeholders a shared understanding of adaptation needs, options and best next steps. For nature-centred adaptation, research on natural systems and their complex relationships with social systems is especially important to inform understanding of existing circumstances, ecological services, biodiversity values and current pressures. As indicated throughout this report, at present, our understanding of the status, mechanisms and drivers of change in many natural systems is severely limited, and so too then is our ability to predict or act on the implications of climate change.

Appreciating the implications of future climate change requires, among other things, up-to-date climate science. Updating observations of how climate change is unfolding in different parts of the state and projections of future climate change is vital, given how rapidly physical conditions, data and models are changing. The planned update of the 2019 Victorian Climate Science Report will be an important resource for adaptation planning across the state.

438. Bosomworth K, Harwood A, Leith P, Wallis P 2015, 'Adaptation Pathways: A playbook for developing options for climate change adaptation in natural resource management. In: *Southern Slopes Climate Change Adaptation Research Partnership (SCARP)*, RMIT University, University of Tasmania, and Monash University.
439. Preston BL, Rickards L, Fünfgeld H, Keenan RJ 2015, 'Toward reflexive climate adaptation research', *Current Opinion in Environmental Sustainability*, 14, pp. 127-135.

Climate change — Adaptation

Because climate change adaptation is essentially experimental, more research is needed on it than can be done by professional researchers. In keeping with the need for systematic and systemic monitoring and evaluation (CCA:05), one of the capabilities that adaptation requires, therefore, is in research. Democratising research through processes such as citizen science and citizen social science could importantly help accelerate new knowledge, learning and adaptation action.

Other learning opportunities also need to be fostered to increase access to adaptation expertise and information. A combination of specialised place-based or profession-based opportunities, and boundary-crossing networks and forums, is needed to encourage the depth and breadth of adaptation knowledge people need. This can help ensure that the adaptation that is undertaken adheres to basic standards (e.g. that it involves the use of EBA, embeds sustainability criteria and utilises monitoring and evaluation). At the same time, it helps foster openness to new ideas and innovation, building the bridging social capital across boundaries that research indicates is a good predictor of transformational adaptation (Dowd et al., 2014).

The proposed measures are:

- number of research funders active in Victoria that prioritise research on climate change impacts and adaptation
- participants in climate change adaptation professional development networks.

Modified indicators

The SoE 2018 Report included four climate change adaptation indicators. These would need to be modified to enhance their value to reporting on nature-centred climate change adaptation. Suggested modifications are provided below.

2018 CC:14 Community awareness of climate risks and associated responsibilities

This indicator has utility in helping track the extent to which the wider public is aware of climate change and its implications (aligning with CCA:07 above on scaling adaptation out to community and regions). There is an opportunity to modify it to include climate risks to others and natural systems, helping combat the tendency for self-centred approaches to climate change. There is also a need to update the title to incorporate climate change impacts, given they are already unfolding. The modified title would be 'Community awareness of climate impacts on and risks to oneself and others, and associated responsibilities'.

2018 CC:15 Councils (or other organisations) with urban forestry plans or urban greening or cooling-related strategies

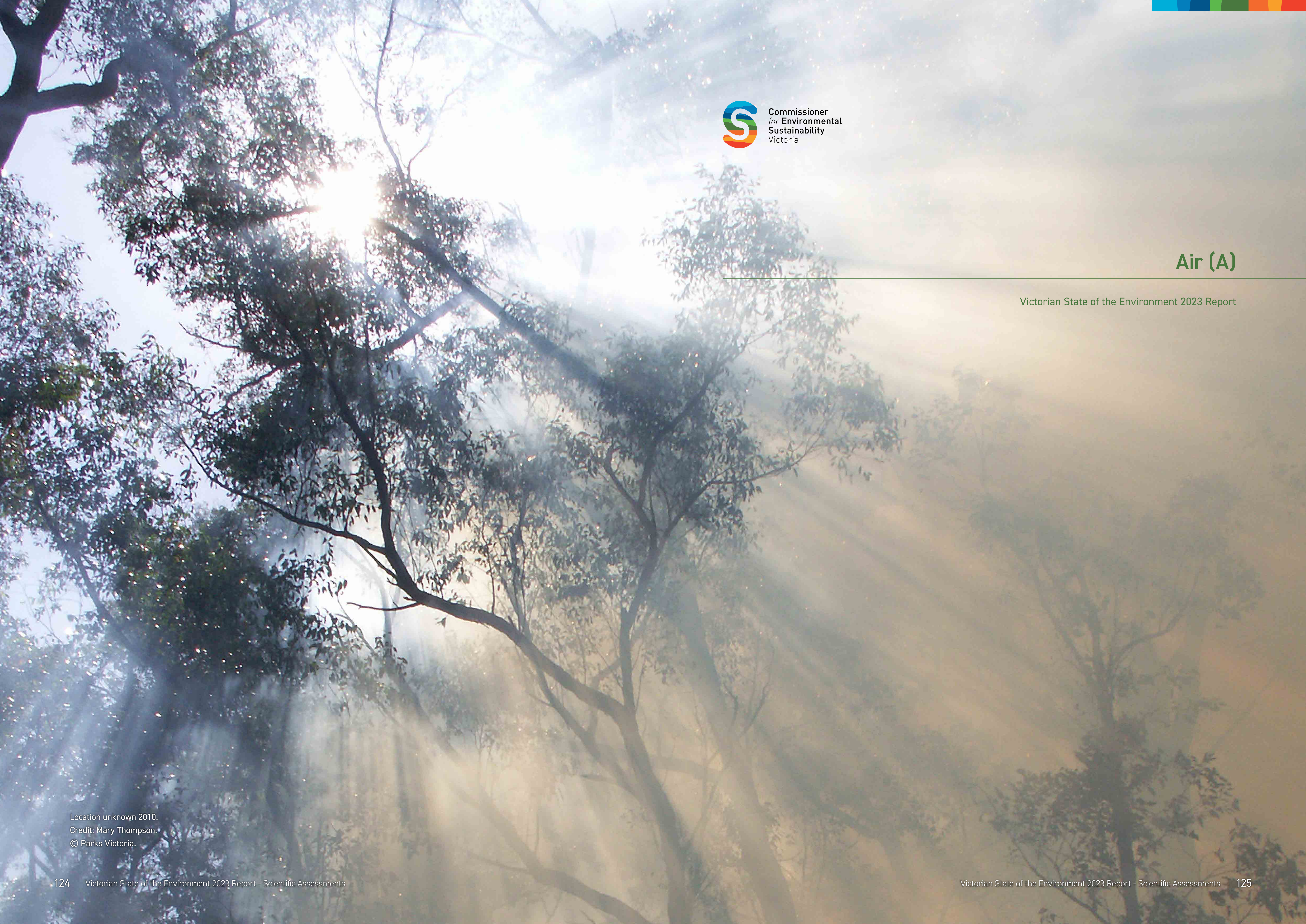
This indicator is also useful, aligning closely with Indicator CCA:03 above on the use of EBA. Given the need to move past planning to action (discussed above), this indicator could shift the emphasis from plans to the implementation of EBA. The new indicator title would be 'Councils (or other organisations) using ecosystem-based adaptation, such as urban greening'.

2018 CC:16 Considering climate change risks in land use planning (including in the coastal zone)

This indicator focuses on the crucial issue of scaling adaptation up into policies and regulations (see CCA:06 above). As discussed, land use planning is a particularly important element of this. To strengthen the indicator, it is modified here to shift from 'considering' risks to 'addressing' risks, and crucially, specifies who and/or what the risks are to in order to increase awareness of risks to natural systems specifically. The modified indicator title would be 'Addressing climate change risks to stakeholders, including natural systems, in land-use planning (including in the coastal zone)'.

2018 CC:17 Percentage of agri-businesses planning using long-term weather and climate change projections

Climate services are proliferating in the agricultural and other sectors in recognition of the value of making decisions in full knowledge of potential shifts in weather and climate. However, the actual conditions that eventuate remain uncertain. To further avoid disasters and attendant environmental degradation, monitoring of environmental conditions is needed (in keeping with CCA:05 above). Thus, this indicator title is modified to 'Percentage of agri-businesses planning using long-term weather and climate change projections, and environmental monitoring, to adapt and adjust practices'.



Commissioner *for* Environmental Sustainability Victoria

Air (A)

Victorian State of the Environment 2023 Report

Location unknown 2010.
Credit: Mary Thompson.

Key findings

Victoria's air quality is considered good relative to international standards, although poor air quality is still measured occasionally in some circumstances, including during major incidents (e.g. bushfires, industrial fires and dust storms), near major industrial facilities, from the domestic use of wood heaters, and during periods of planned burns (Table A1). [440]

Air quality, particularly particle pollution, was generally worse in this reporting period (2018–21) compared to the previous period (2013–17) due to bushfire smoke impacts. [441] However, air quality was generally better in 2020 and 2021 in Melbourne's suburbs and across areas of regional Victoria; this was likely due to increased rainfall during 2021 and less motor vehicle pollution associated with travel restrictions that formed part of the Victorian Government's response to the COVID-19 pandemic.

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

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

This report captures the important work recently undertaken to quantify population exposure to air pollution (A:06) and its health impacts in Victoria (A:11). These were previously identified as knowledge gaps. There is a significant variance from year to year in the proportion of the Victorian population exposed to annual $PM_{2.5}$ concentrations exceeding the air-quality standard. Data provided by EPA Victoria show that 79% of the Victorian population were exposed to annual $PM_{2.5}$ concentrations exceeding the air-quality standard in a year with significant bushfire smoke impacts (2020), compared with 18% in a year without significant bushfire smoke impacts (2021). In terms of health impacts, the average annual mortality burden for Victoria from exposure to anthropogenic $PM^{2.5}$, based on data from 2006 to 2016, was estimated to be more than 600 premature deaths. [442]

Following on from the recommendation in the State of the Environment (SoE) 2018 Report to establish a contemporary pollen-monitoring network, this report is the first time that pollen has been captured within SoE indicator assessments (A:07). Victoria has the second highest rate (23%) of hay fever in Australia.[443] Across the eight sites monitoring pollen in Victoria, there has been a generally increasing trend since 2017 in the number of days of extreme or high grass pollen during grass pollen seasons. Data provided by the University of Melbourne shows that Bendigo recorded 59 days of extreme or high grass pollen in the most recently completed grass pollen season (October to December 2021). This means that grass pollen was likely impacting human health on nearly two out of every three days during the grass pollen season in Bendigo during 2021. Most recently, a multi-year La Niña state has led to increased rainfall and grass pollen levels. However, from 2017 to 2019 (prior to the La Niña state), there was still an average of 20 to 40 days of extreme or high grass pollen per season across Victoria. The narratives for the two pollen indicators (A:07 and A:14) highlight limitations with existing pollen-monitoring arrangements and present future opportunities for monitoring, for example, developing an automated pollen-monitoring network and expanding analysis to include other pollens in addition to grass pollen.

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

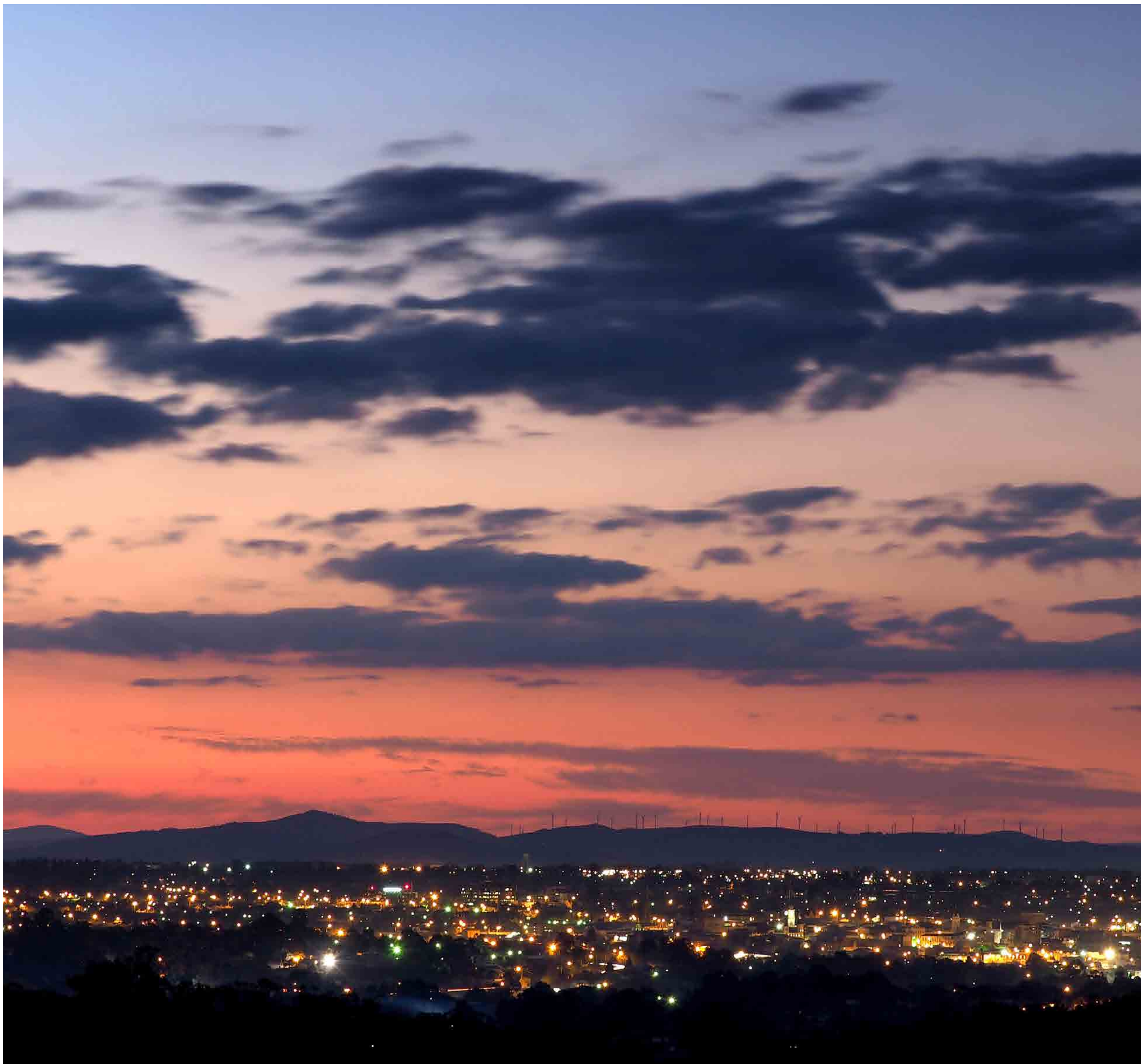
440. World Health Organization, 'WHO Air Quality Database 2022', Geneva, Switzerland, https://www.who.int/publications/m/item/who-air-quality-database-2022 Accessed 17 April 2023.
441. For this indicator, the SoE 2023 reporting period represents the years when data have been available since the SoE 2018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

Air

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

As reported in 2018, there remains no systematic measurements and analysis of light pollution conducted in Victoria (A:10). Remote sensing has been used to identify and analyse light pollution, and this has been complemented by summaries of research investigating how light pollution threatens reproduction and migratory habits of insects, amphibians, fish, birds, bats and other animals.

In contrast to the gradual increases in night-time light emissions observed across Melbourne's urban extent, new analyses completed for this report highlight dramatic light pollution increases in Melbourne's growth areas. For example, night-time light emissions in growth areas of Melbourne's outer western suburbs have nearly tripled from 2014 to 2021.



Night sky over Woowookarung Regional Park near Ballarat.
Credit: Peter Kervarec.

Table A1: Air indicators assessed in this chapter with comparisons to SoE 2018 assessments.

Air							
2023 Indicator	**2023 status**	**2023 trend**	**2023 confidence**	**2018 Indicator**	**2018 status**	**2018 trend**	**2018 data quality**
Air pollution and population exposure							
A:01 Particle pollution ($PM_{2.5}$ and PM_{10})	🟡 (Geelong) 🔴 (Latrobe Valley and Melbourne) ⚪ (elsewhere)	→	🟢 (Geelong, Latrobe Valley and Melbourne) 🔴 (elsewhere)	A:03 Particle pollution ($PM_{2.5}$ and PM_{10})	🟡 (Geelong, Latrobe Valley and Melbourne) 🔴 (Brooklyn) ⚪ (elsewhere)	→	🟡
A:02 Ambient ozone levels	🟢 (Latrobe Valley) 🟡 (Geelong and Melbourne)	→	🟢	A:01 Ambient ozone levels (summer smog)	🟢	→	🟢
A:03 Carbon monoxide	🟢	→	🟢	A:02 Carbon monoxide and nitrogen dioxide	🟢	↗	🟢
A:04 Nitrogen dioxide	🟢	↗ (Melbourne) → (Geelong and Latrobe Valley)	🟢	A:02 Carbon monoxide and nitrogen dioxide	🟢	↗	🟢
A:05 Sulfur dioxide	🟢	→	🟢	A:04 Sulfur dioxide	🟢	→	🟢
A:06 Population exposure to air pollution	🔴 (years with significant bushfires) 🟡 (other years)	?	🟢	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator

Air

2023 Indicator	2023 status	2023 trend	2023 confidence	2018 Indicator	2018 status	2018 trend	2018 data quality
Amenity and wellbeing							
A:07 Pollen	🔴	↙	🟡	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator
A:08 Odour	🟡	→	🟡	A:06 Odour and noise	⚪	↙	🟡
A:09 Noise	🟡	↙	🟡	A:06 Odour and noise	⚪	↙	🟡
A:10 Light pollution	⚪	↙	🟡	A:07 Light pollution	⚪	?	🔴
Health							
A:11 Health impacts of air pollution	🔴	?	🟢	A:09 Health impacts of air pollution	🟡	?	🔴
A:12 Health impacts of noise pollution	🟡 (Melbourne) ⚪ (rest of Victoria)	?	🔴	A:10 Health impacts of noise pollution	🟡 (Melbourne) ⚪ (rest of Victoria)	?	🔴
A:13 Indoor air quality	🟡 (schools and aged care facilities) 🔴 (residential buildings during periods of bushfire smoke) ⚪ (all other scenarios)	?	🟡 (schools and aged care facilities) 🔴 (residential buildings during periods of bushfire smoke and all other scenarios)	A:11 Indoor air quality	⚪	?	🔴
A:14 Health impacts from pollen	🟡	?	🟡	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator

Victorian Government progress on State of the Environment 2018 Report recommendations

The SoE 2018 Report included recommendations to the Victorian Government to improve environmental sustainability outcomes. Presented below are the recommendations specific to this theme as well as:

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

Recommendation 3 of the SoE 2018 Report recommended:

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.

Government response in 2020:
SUPPORT IN PRINCIPLE

Air quality:

'In relation to air quality, EPA [Victoria] are undertaking a number of projects to increase the coverage of its air network with new air monitoring sites in Campbellfield and Bendigo, along with citizen science and source apportionment projects to enhance knowledge of inner-city air pollution issues and sources.'[444]

Ultrafine particles:

'EPA [Victoria] will work to enhance scientific understanding of the characteristics of Australian urban ambient ultrafine particles, their main sources, their potential health effects and provide recommendations for legislative approaches to this emerging airborne pollutant. This will be delivered via an approved Australian Research Council Linkage project with Queensland University of Technology, which commenced in 2019 and is due for completion in 2020.'[445]

Indoor air quality:

'The Government acknowledges a knowledge gap on exposure data for indoor air quality in Australia (sic) homes. However, the priority for indoor air quality and public health in Victoria is addressing known risks to human health and life. Priority activities include:

- Managing carbon monoxide risks through the safe installation, operation and maintenance of gas heating.
- A study run by the EPA [Victoria] with funding from the Department of Health and Human Services (DHHS), to better understand the impacts of regional smoke events on indoor air quality and the role filtration systems can play in reducing exposure to fine particles.
- Information and advice from DHHS to the community on how to protect health, safety and wellbeing from factors in the home, including indoor air quality and comfort (i.e. temperature). Examples of advice include managing mould in the home and guidance on thermal comfort during hot and cold weather conditions.' [446]

444. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Victorian Government response to the state of the environment 2018 report', Melbourne, Victoria.
445. Ibid.
446. Ibid.

Progress made since 2018

EPA Victoria has expanded its air-quality monitoring network since 2018. Most new monitoring is done in regional Victoria and is available online in real-time on EPA Victoria's AirWatch website. However, most of the monitoring is being undertaken with lower quality sensors and the results are deemed indicative and not available for analysis and inclusion in this SoE 2023 Report. This is reflective of EPA Victoria's primary purpose of expanding the sensor monitoring to provide immediate information to the community so that vulnerable members can take timely actions to protect their health.

In 2021, EPA Victoria published a report on an air pollution inventory that it had completed for a base year of 2016. The air pollution inventory has been used as an input for air modelling studies, including estimating population exposure to air pollution.

In relation to enhancing the scientific understanding of the characteristics of Australian urban ambient ultrafine particles, EPA Victoria has collaborated with the Australian Catholic University (ACU), Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Queensland University of Technology (QUT) to develop high-resolution models of black carbon and ultrafine particles in the Melbourne metropolitan area.

There is still no central responsibility for indoor air quality. Policy development is limited to design standards for buildings. However, the overall risk of indoor air quality is still largely unclear and limited to disparate research projects that are detailed in indicator 'A:13 Indoor air quality'. Since the SoE 2018 Report, the Victorian Government's contribution to indoor air-quality management has been targeted at better understanding the impacts of regional smoke events on indoor air quality and the role filtration systems can play in reducing exposure to fine particles. This research has informed advice to the community about how to limit smoke from outdoors getting inside the home.

Recommendation 4 of the SoE 2018 Report recommended:

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

Government response in 2020:
DO NOT SUPPORT

> 'The Victorian Government acknowledges the role of pollen monitoring in assisting people with hay fever to take preventive action during the grass pollen season, and the intent of the recommendation to improve hay fever management. The intent of this recommendation is considered to have been met through the pollen monitoring and community awareness program established after the epidemic thunderstorm asthma event in November 2016. The Government's decisive action following this event resulted in the expansion in the number of pollen traps across Victoria, and the provision of comprehensive public information around protective actions people can take during the grass pollen season.' [447]

Progress made since 2018

This recommendation from the SoE 2018 Report was not supported by the Victorian Government. Despite the absence of government support, the need for a contemporary pollen-monitoring network has been recognised by the University of Melbourne, with researchers purchasing and installing Australia's first automated pollen counter in 2021. Initially operating as a trial and funded by subscribers to

447. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Victorian Government response to the state of the environment 2018 report', Melbourne, Victoria.

the 'Melbourne Pollen' app, the automated monitor is now a permanent fixture that is operated by the University of Melbourne and is complementary to the existing pollen network of eight pollen monitoring sites, overseen by the University of Melbourne and funded by the Victorian Government.

Initial results from the automated pollen counter — provided in 'A:07 Pollen' — show a distinct diurnal profile for grass pollen in Parkville, with the worst part of the high or extreme grass pollen days often being the period from late morning to early evening.

The University of Melbourne's installation of an automated pollen counter reflects a trend in the international pollen research community. In 2021, Switzerland's Federal Office of Meteorology and Climatology installed a network of 10 automated pollen counters and began publishing the data online.[448]

The prospect of this type of real-time monitoring information being publicly accessible in several places within Victoria, combined with pollen forecasts for different parts of the day (rather than daily forecasts), provides potential for Victorians with hay fever or asthma to better manage their daily activities to minimise exposure to the worst pollen concentrations.

The Parliament of Victoria's Environment and Planning Committee report on the Inquiry into the Health Impacts of Air Pollution in Victoria was published in November 2021. The Committee made 35 recommendations aimed at improving the monitoring of air pollution and the mitigation of its impacts on the community. Recommendation 31 was 'that the Victorian Government reconsider its response to Recommendation 4 of the Victorian SoE 2018 report and implement a contemporary pollen monitoring network.' [449]

448. Federal Office of Meteorology and Climatology, 'Automatic pollen measurement network', Zürich, Switzerland, https://www.meteoswiss.admin.ch/home/measurement-and-forecasting-systems/land-based-stations/automatic-pollen-measurement-network.html Accessed 3 June 2022.
449. Legislative Council Environment and Planning Committee Parliament of Victoria 2021, 'Inquiry into the health impacts of air pollution in Victoria', Melbourne, Victoria, https://www.parliament.vic.gov.au/images/stories/committees/SCEP/Air_Pollution/Report/LCEPC_59-04_Health_impacts_air_pollution_Vic_Report.pdf Accessed 2 March 2022.
450. Ibid.
451. Emmerson KM, Keywood MD 2021, 'Australia state of the environment 2021: Air quality', Independent report to the Australian Government Minister for the Environment, Commonwealth of Australia, Canberra, Australian Capital Territory.
452. Environment Protection Authority (EPA) Victoria 2021, 'Annual report for 2020-21, Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/2027 Accessed 14 July 2022.

Background

Good air quality is essential for human health.

The links between air pollution, population exposure to air pollution and adverse health effects are now well established. [450] There is a strong evidence base that air pollution is associated with adverse health effects, even at concentrations below the current air-quality standards. This is discussed in further detail within the indicator narratives of this chapter.

As Victoria's population increases, and the average age increases, the health impacts of poor air quality will increase due to the increasing population numbers and vulnerability, 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. [451]

EPA Victoria has increased the number of standard air-monitoring stations since the publication of the SoE 2018 Report when it operated 19 standard air-monitoring stations across Victoria. As at February 2023, EPA Victoria monitored air quality at 29 standard sites across Victoria — 16 in metropolitan Melbourne, 7 in the Latrobe Valley and 6 elsewhere in regional Victoria (Bendigo, Bright, Geelong, Mildura, Swan Hill and Wangaratta) — noting that the number of monitoring sites can change seasonally and due to operational priorities. During 2021, EPA Victoria expanded its monitoring network to include several sensor monitoring sites. As at February 2023, there were 67 sensor sites located in regional Victoria providing indicative but extensive, real-time coverage of air quality across the state — these sensor sites are new since the SoE 2018 Report was published. During significant smoke events, such as the bushfires during the summer of 2019-20, EPA Victoria also coordinates short-term, incident-related, air-quality monitoring at requisite sites as part of its emergency management function.

Odour and noise can also impact health and wellbeing. They are the most frequent types of pollution report received by EPA Victoria, each prompting more than 5,000 pollution reports to EPA Victoria during 2020-21. [452]

Pollen and light pollution indicators are also included in this chapter. Grass pollen is a focus in Victoria because it is a major outdoor allergen and its impact on the community affects health services. Pollen from grasses, weeds or trees can trigger symptoms of allergic rhinitis (hay fever), and asthma. Light pollution is a global issue, impacting at national and regional scales, and increasing in prevalence as the world becomes more populated and industrialised. [453]

Policy and legislative settings

Since the SoE 2018 Report was published, three significant activities that are highly relevant to better managing Victoria's air quality have occurred or are underway. These activities include:

- In July 2021, EPA Victoria's amended *Environment Protection Act 2017* (EP Act) took effect. The Environment Reference Standard (ERS) is subordinate legislation supporting the new EP Act. The ERS contains values, indicators, and objectives for ambient air environments. The ERS replaces the State Environment Protection Policy (Ambient Air Quality) and generally adopts the objectives that were in the State Environment Protection Policy (Ambient Air Quality). [454]
- In November 2021, the Parliament of Victoria's Environment and Planning Committee published their report on the Inquiry into the Health impacts of Air Pollution in Victoria.[455] The Committee made 35 recommendations aimed at improving the monitoring of air pollution and mitigation of its impacts on the community, with an additional 16 findings aimed at highlighting gaps in air pollution management and encouraging government to continue to improve mitigation strategies.[456] The Victorian Government was required to respond to the Environment and Planning Committee's report within six months of it being tabled. As of February 2023, the Victorian Government is yet to respond.[457]
- The Victorian Air Quality Strategy was released in October 2022. The strategy includes the following four strategic objectives:
    - Targeting the main causes of air pollution in Victoria today — reduce air pollution caused by industry, motor vehicles, wood heaters and planned burns.
    - Helping vulnerable Victorians and supporting the broader community — reduce the impact of air pollution on vulnerable communities and empower individuals to choose cleaner sources of energy and support.
    - Raising the bar on air-quality information — strengthen our understanding of where and when air pollution occurs, and its impact on human health and the environment.
    - Ensuring a clean air future — reduce air pollution by reducing fossil fuel use.[458]

Generally, Victoria's air-quality objectives that are legislated in the ERS are consistent with national air-quality standards and goals in the National Environment Protection (Ambient Air Quality) Measure (NEPM AAQ),[459, 460, 461] with the following important exceptions:

- The Victorian annual average particles as PM_{10} objective of 20 µg/m^3 is more stringent that the national standard of 25 µg/m^3.

453. Coogan AN, Cleary-Gaffney M, Finnegan M, McMillan G, González A, Espey B 2020, 'Perceptions of light pollution and its impacts: Results of an Irish citizen science survey', *International Journal Environmental Research and Public Health, 17(15), pp. 5628.*
454. State of Victoria 2021, 'Victoria Government Gazette, No. S 245, 26 May 2021, Environment Reference Standard', http://www.gazette.vic.gov.au/gazette/Gazettes2021/GG2021S245.pdf Accessed 25 February 2022.
455. Legislative Council Environment and Planning Committee Parliament of Victoria 2021, 'Inquiry into the health impacts of air pollution in Victoria', Melbourne, Victoria, https://www.parliament.vic.gov.au/images/stories/committees/SCEP/Air_Pollution/Report/LCEPC_59-04_Health_impacts_air_pollution_Vic_Report.pdf Accessed 2 March 2022.
456. Ibid.
457. Parliament of Victoria Legislative Council Environment and Planning Committee 2021, 'Inquiry into the health impacts of air pollution in Victoria', Melbourne, Victoria,, https://new.parliament.vic.gov.au/get-involved/inquiries/inquiry-into-the-health-impacts-of-air-pollution-in-victoria/ Accessed 6 February 2023.
458. Department of Energy, Environment and Climate Action (DEECA), 'Victorian air quality strategy', Melbourne, Victoria, https://www.environment.vic.gov.au/sustainability/clean-air-for-all-victorians Accessed 6 February 2023.
459. The ambient air environment objectives are the maximum concentrations for air pollutants included in the Environment Reference Standard. Each air pollutant has an objective (that is, a maximum concentration) and a time period(s) for the air pollutant concentration to be averaged across.
460. Environment Protection Authority (EPA) Victoria 2022, 'Environment Protection Act 2017, Environment Reference Standard, No. S245 Gazette 26 May 2021, as amended by Environment Reference Standard No. S158 Gazette 29 March 2022', Carlton, Victoria, https://www.epa.vic.gov.au/-/media/epa/files/about-epa/laws/consolidated-ers-prepared-by-epa-29-mar-2022.pdf?la=en&hash=D3030F2A5865C6B2394B12B7B53DF540 Accessed 8 December 2022.
461. Commonwealth of Australia 2021, 'National Environment Protection (Ambient Air Quality) Measure', https://www.legislation.gov.au/Details/F2021C00475 Accessed 2 March 2022.

- The Victorian eight-hour average ozone objective of 0.06 ppm is more stringent than the national standard of 0.065 ppm.
- The Victorian one-hour average sulfur dioxide objective of 0.075 ppm is more stringent than the national standard of 0.1 ppm (note that the national standard will be strengthened to 0.075 ppm in 2025).
- There is a Victorian objective for visibility reducing particles, which is not included in the NEPM AAQ. The minimum visual distance indicator is one way the community can assess air quality for themselves without measurement. The objective for visibility (that is, a minimum visual distance of 20 km) represents a typical distance over which the community expects to be able to see. [462]

Air pollution management and regulation in Victoria

As part of the amended EP Act, emitters of air pollution are required to eliminate risks of harm to human health and the environment so far as reasonably practicable.[463] In response to this requirement, EPA Victoria developed a new regulatory framework and management of air pollution emissions. This was released through the Guideline for Assessing and Minimising Air Pollution in Victoria.[464] The guideline provides a framework to assess and control risks associated with air pollution. It is a technical guideline to assist air pollution practitioners and specialists with their role managing pollution discharges to air. The guideline outlines a risk management approach that involves a repeating cycle of four steps:

- identifying hazards
- assessing risks
- implementing controls
- checking controls.

Air pollution assessment criteria (APACs) for air pollutants not listed in the ERS are provided in the guideline to establish a benchmark to understand potential risks. They are risk-based concentrations that help identify when or if an activity is likely to pose an unacceptable risk to human health and the environment. APACs are not concentrations one can 'pollute up to'. They are also not concentrations below which no action is required. EPA Victoria advises that future reviews of the efficacy of this framework will include an evaluation of the successful implementation and application of controls and management practices to prevent and minimise air emissions.

462. Environment Protection Authority (EPA) Victoria 2021, 'Publication 1992 - Guide to the Environment Reference Standard ', Carlton, Victoria, https://www.epa.vic.gov.au/-/media/epa/files/publications/1992.pdf Accessed 2 March 2022.
463. Office of the Chief Parliamentary Counsel Victoria, '*Environment Protection Act 2017*', no. 51 of 2017, authorised version incorporating amendments as at 1 October 2022.
464. Environment Protection Authority (EPA) Victoria 2022, '1961: Guideline for assessing and minimising air pollution', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/1961 Accessed 9 December 2022.

Indicator assessments

Refer to 'Guide to the indicator assessments' at the start of Part 3 for the accompanying definitions and legends related to the indicator assessment summary tables.

SoE indicator suite adjustments

State of the environment indicators are the foundational tools for evaluating and communicating the impact our activities have on the environment. The assessments of SoE 2018 indicators provided a scientific baseline of the state of Victoria's environment from which future SoE reports build upon.

However, as new pressures, challenges and data sources emerge, the SoE indicator suite must also evolve to ensure their collective assessments provide a comprehensive account of the condition of Victoria's natural values. The SoE 2023 indicator suite has been adjusted, with some new indicators being introduced and some existing indicators either being disaggregated to improve the focus of assessments, merged to enable inter-connected indicators to be evaluated as a whole, superseded, or modified in terms of the scope, breadth of measures or to align with policy targets. Refer to Appendix C of the Summary Report for a complete account of the changes that have been made to the SoE 2018 indicator suite in this report.

Changes to the indicator suite for this chapter are outlined below.

- 'A:06 Population exposure to air pollution', 'A:07 Pollen' and 'A:14 Health impacts from pollen' are new SoE 2023 indicators.
- The SoE 2018 indicator 'A:02 Carbon monoxide and nitrogen dioxide' has been disaggregated to form the modified SoE 2023 indicators 'A:03 Carbon monoxide' and 'A:04 Nitrogen dioxide'.
- The SoE 2018 indicator 'A:06 Odour and noise' has been disaggregated to form the modified SoE 2023 indicators 'A:08 Odour' and 'A:09 Noise'.

Air pollution and population exposure

There are some overarching qualifications and/or limitations to the assessments specific to indicators A:01 to A:05. These are outlined below:

- The data have been sourced from EPA Victoria's air-monitoring database.
- The data included in these indicators do not contain all of EPA Victoria's air-monitoring stations. Stations have been selected for inclusion in this report based on their length of operation (to provide a trend), proximity to populated areas and frequency of peak results.
- Data for Geelong come from two sites (Geelong #1 from 1991 to 1996 and Geelong South from 1998 to 2017).
- Data for Melbourne City come from four sites: Science Museum from 1981 to 1986, Parliament of Victoria from 1992 to 1995, Royal Melbourne Institute of Technology (RMIT) from 1996 to 2006, and Richmond from 2007 to 2014.
- The data included in these indicators are only taken from monitoring equipment that meets current or historical reference criteria for assessment against the legislated air-quality standards in Australia and Victoria (e.g. $PM_{2.5}$ data include only data measured by a Partisol or Beta Attenuation Monitor).
- Air-quality standards used in the assessment of these indicators come from the ERS.

Assessment approach for this sub-theme

Status assessments for the air pollutant indicators (A:01 to A:05) in this report are based on the frequency of exceedances of ambient air-quality indicators and objectives in the ERS. It is important that these status assessments are read in conjunction with the trend assessments because adverse health effects occur below the current air-quality objectives. Indeed, the ERS states that it is not a compliance standard, and its primary function is to provide an environmental assessment and reporting benchmark. Therefore, the trend assessments are very important to provide an understanding on general trends in air pollution as a marker for whether air pollution is getting better or worse, bearing in mind that adverse impacts can still occur even when the status of an air pollutant has been rated as good. To complement the air pollutant indicators, and provide a holistic approach to air pollution assessment, indicator 'A:06 Population exposure to air pollution' has been included in this theme, while commentary and data on the sources of air pollution emissions is presented for each pollutant in indicators A:01 to A:05.

Differences in assessment approach compared with the Australian State of the Environment 2021 Report

Basing the status assessments on the frequency of air-quality exceedances, as has been done in this report, differs from the approach used in the 'Air quality' chapter of the Australian State of the Environment 2021 Report where the air pollutant indicator assessments were based on the percentage of days in each category of an Air Quality Index.[465] Based on that assessment criteria, up to 20% of days each year (up to 73 days each year) could exceed the air-quality standard and still be categorised as having a Good status in the Australian State of the Environment 2021 Report. Given that approach, every air pollutant status assessment for every air-monitoring location across Australia was rated as Good or Very Good in the Australian State of the Environment 2021 Report.

The links between air pollution and adverse health impacts are detailed in indicator 'A:06 Population exposure to air pollution' of this theme, as well as indicator 'A:11 Health impacts of air pollution' in the health sub-theme. The material presented in these health-based indicators highlights that:

- Adverse health effects occur below the current air-quality standards.
- Thousands of Victorians are suffering significant adverse health impacts due to current levels of air pollution.
- A small number of days of poor air quality can have dramatic impacts on human health.

Therefore, the air pollutant status assessments in this report are focussed on the frequency of any exceedances of air-quality standards, which includes breaches of annual air-quality standards, not just daily or hourly standards.

Emission sources

Air pollution emission inventories can be used to help identify, inform and guide how air pollution emissions and impacts can be better managed. They provide an understanding of where and how much air pollution is emitted, and the data can be incorporated in modelling to determine how and where emissions are transported and dispersed. Modelling can complement air monitoring to fill data gaps where monitoring data are not available, helping to better estimate regional air pollution levels and human health exposure. Thus, modelling can be extended to other applications to enable:

- forecast air pollution
- inform human health impact assessment
- evaluate the efficacy of air pollution management strategies and emission reduction initiatives.

During 2021, EPA Victoria published a Victorian Air Pollution Emission Inventory that provided a comprehensive assessment of the major air pollution sources in the calendar year of 2016.[466]

465. Emmerson KM, Keywood MD 2021, 'Australia state of the environment 2021: Air quality', Independent report to the Australian Government Minister for the Environment, Commonwealth of Australia, Canberra, Australian Capital Territory.
466. Environment Protection Authority (EPA) Victoria 2021, '2016 emissions inventory report', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/2028 Accessed 17 June 2022.

Air

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

A:01 Particle pollution ($PM_{2.5}$ and PM_{10})						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	(Geelong) (Latrobe Valley and Melbourne) (elsewhere)	→	(Geelong, Latrobe Valley and Melbourne) (elsewhere)	(Geelong, Latrobe Valley and Melbourne) (Brooklyn) (elsewhere)	→	
Data source(s):	EPA Victoria					
Measure(s):	Annual performance against indicators and objectives for PM_{10} and $PM_{2.5}$ specified in the Victorian ERS					

Why this indicator?

Greater concentrations of $PM_{2.5}$ and PM_{10} particles in the air can cause wheezing, chest tightness and difficulty breathing in people with existing heart or lung conditions (including asthma).

NB: This SoE 2023 indicator was 'A:03 Particle pollution ($PM_{2.5}$ and PM_{10})' in the SoE 2018 Report.

Why this assessment in 2023?

Smoke from large bushfires has resulted in the most widespread particle pollution impacts across Victoria, with smoke from large fires capable of travelling across large parts of Victoria.

All monitoring stations in Melbourne and Latrobe Valley have recorded exceedances of the daily $PM_{2.5}$ air-quality standard in each of the past five years (2017–2021), except for Footscray in 2021. Each monitoring location has averaged more than four days exceeding the $PM_{2.5}$ standard, which is why Melbourne and Latrobe Valley have been assessed as having a poor status. Geelong is rated as fair because, in most years of monitoring, no days or only one day has exceeded the $PM_{2.5}$ standard.

PM_{10} pollution remains an issue in Brooklyn in Melbourne's inner west and is associated with dust emissions generated by industry and vehicles.

Summary of State of the Environment 2018 Report assessment

- 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.
- PM10 pollution remains an issue in Brooklyn in Melbourne's inner west and is associated with dust emissions generated by industry and vehicles.

Critical data used for the 2023 assessment

- EPA Victoria air monitoring data
- EPA Victoria 2016 Emissions Inventory Report

2023 assessment

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 that measures $PM_{2.5}$ has not been available for as long as the instruments that measure PM_{10}, so the $PM_{2.5}$ dataset is shorter and, until 2014, quite limited in spatial coverage.

Greater concentrations of $PM_{2.5}$ and particles in the air can cause wheezing, chest tightness and difficulty breathing in people with existing heart or lung conditions (including asthma).[467, 468]

467. Environment Protection Authority (EPA) Victoria, 'PM10 particles in the air', Carlton, Victoria, https://www.epa.vic.gov.au/for-community/environmental-information/air-quality/PM10-particles-in-the-air Accessed 14 July 2022.
468. Environment Protection Authority (EPA) Victoria, 'PM2.5 particles in the air', Carlton, Victoria, https://www.epa.vic.gov.au/for-community/environmental-information/air-quality/pm25-particles-in-the-air Accessed 14 July 2022.

$PM_{2.5}$ particles are smaller than PM_{10} and can be inhaled deeper into the lungs. Those who are recognised as being more sensitive to the effects of breathing in smaller particles include people with existing chronic diseases (e.g. heart or lung conditions, including asthma, and diabetes), people over 65, pregnant women, infants, and young children.[469]

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.[470]

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.

The ERS specifies the daily and annual $PM_{2.5}$ and PM_{10} objectives for Victoria.[471] These objectives are presented in Table A2.

Table A2: Victorian ambient air environment objectives for $PM_{2.5}$ and PM_{10}.[472]

Indicator	Objective	Averaging period
Particles as $PM_{2.5}$	25 µg/m³	1 day
	8 µg/m³	1 year
Particles as PM_{10}	50 µg/m³	1 day
	20 µg/m³	1 year

$PM_{2.5}$

$PM_{2.5}$ trend data in Victoria is only available from 2003, of which data up to 2013 is confined to Alphington and Footscray in Melbourne, except 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 since the 2014 Hazelwood mine fire, particularly in Melbourne and the Latrobe Valley.

The frequency of days exceeding the $PM_{2.5}$ air-quality standard had been relatively stable from 2003 to 2016 when fewer than four days typically exceeded the standard each year (Figure A1). Years with major fires were exceptions - for example, the summer of 2006 to 2007 (Alpine fires) and 2014 (the Hazelwood mine fire and a large East Gippsland fire). Since 2017, monitoring locations in Melbourne and the Latrobe Valley have detected at least five days exceeding the $PM_{2.5}$ standard in most years. There were significant bushfires across eastern Victoria during the summer of 2019-20 and these fires contributed to many air-monitoring stations measuring a record number of days exceeding the daily $PM_{2.5}$ standard during 2020.

Poor air quality has also been recorded during cool, calm and stable atmospheric conditions when particles from a wide variety of sources (e.g. smoke from planned burns and wood heaters) accumulate overpopulated areas. Notably, a station-record number of days exceeded the $PM_{2.5}$ air-quality standard at Alphington in 2017 and 2018 during these conditions.

469. Environmental Health Standing Committee 2021, 'enHealth guidance for public health agencies Managing prolonged smoke events from landscape fires', https://www.health.gov.au/sites/default/files/documents/2022/07/enhealth-guidance-guidance-for-public-health-agencies-managing-prolonged-smoke-events-from-landscape-fires.pdf Accessed 10 January 2023.
470. World Health Organization, 'WHO global urban ambient air pollution database (update 2016)', Geneva, Switzerland https://cdn.who.int/media/docs/default-source/air-quality-database/aqd-2016/aap_database_summary_results_2016_v02.pdf?sfvrsn=384beb23_3 Accessed 3 December 2018.
471. State of Victoria 2021, 'Victoria Government Gazette, No. S 245, 26 May 2021, Environment Reference Standard', http://www.gazette.vic.gov.au/gazette/Gazettes2021/GG2021S245.pdf Accessed 25 February 2022.
472. Ibid.

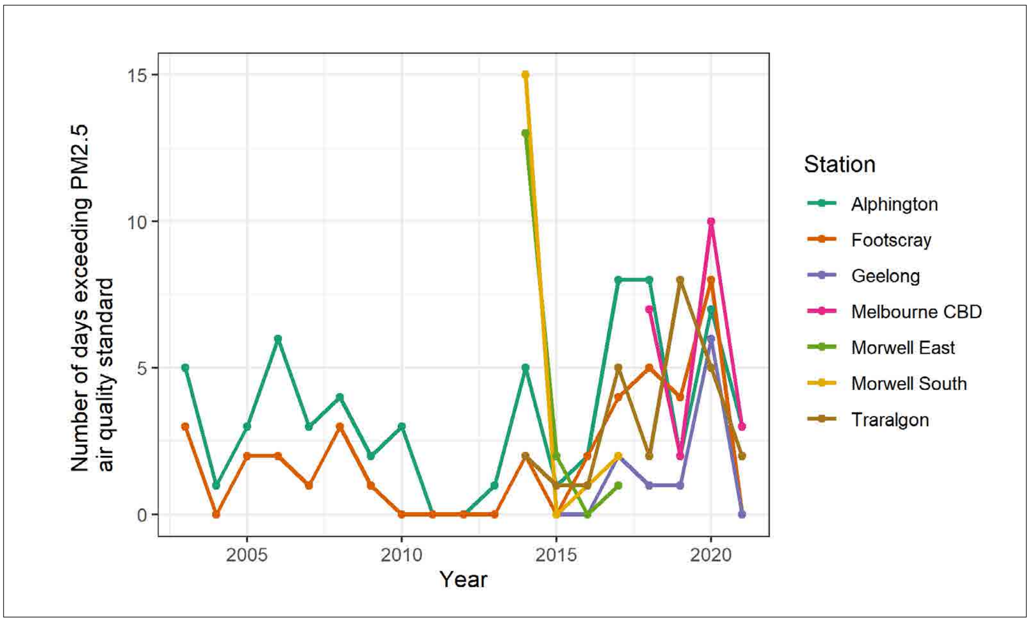


Figure A1: Number of days exceeding the $PM_{2.5}$ (daily average) standard in Victoria from 2003 to 2021.[473]

The magnitude of the $PM_{2.5}$ 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. In Traralgon, during the 2019-20 bushfire season, peak $PM_{2.5}$ levels were recorded at nearly 10 times the air-quality standard (Figure A2).

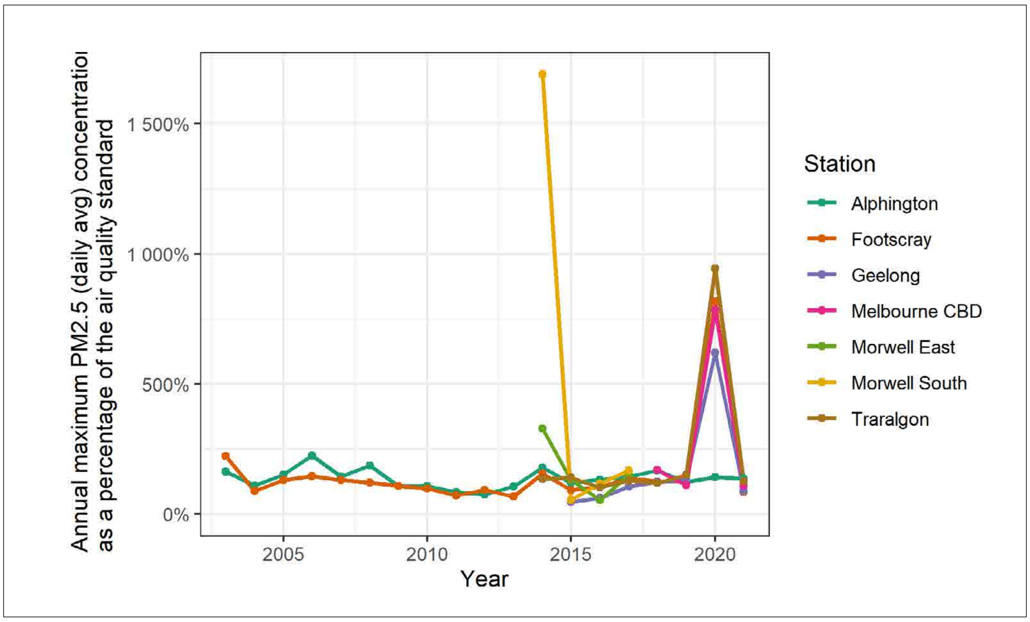


Figure A2: Annual maximum $PM_{2.5}$ (daily average) concentrations in Victoria from 2003 to 2021.[474] Concentrations are shown as a percentage of the air-quality standard.

473. Environment Protection Authority (EPA) Victoria, 'Unpublished data', Carlton, Victoria, Accessed 2022.
474. Ibid.

The annual average $PM_{2.5}$ air-quality standard is 8 μg/m³. This standard has been met for every year of monitoring in Footscray (except for 2020) but has been exceeded nearly half the time at Alphington (Figure A3). It is likely that Alphington records slightly greater levels of $PM_{2.5}$ pollution than Footscray due to greater urban emissions (e.g. smoke from wood heaters) in Alphington and surrounding suburbs. The annual standard has been exceeded in half the years of monitoring at Traralgon since 2014, however, there is limited interannual variability and the $PM_{2.5}$ annual average concentration has remained between 90% and 112% of the standard for each of the eight monitored years.

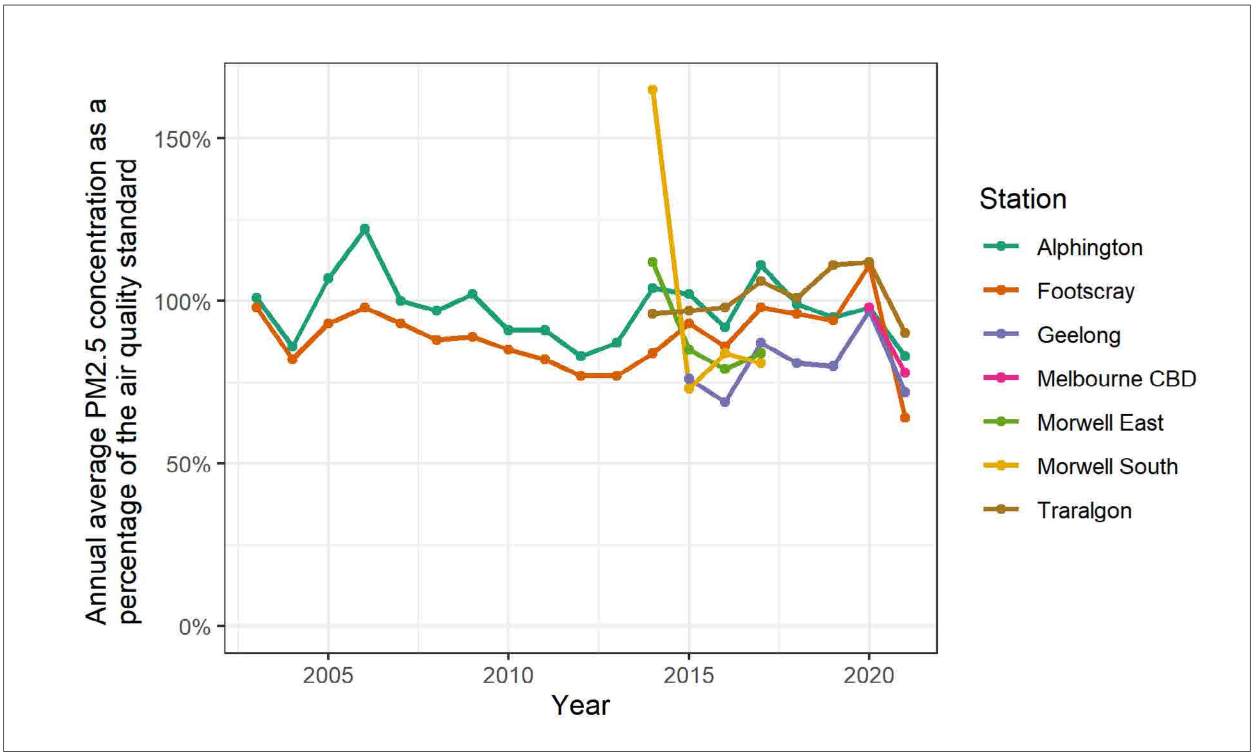


Figure A3: Annual average $PM_{2.5}$ concentrations in Victoria from 2003 to 2021.[475] Concentrations are shown as a percentage of the air-quality standard.

It is likely that the areas of regional Victoria that most frequently use wood heaters, and are impacted by smoke from planned burns, have greater $PM_{2.5}$ concentrations than suburban Melbourne. The monitoring network has expanded during recent years, with more equipment placed in regional Victoria, including the deployment of a sensor network. Data from this expanded network will help improve the understanding of regional $PM_{2.5}$ and inform future regional air-quality management strategies.

Shipping emissions are known to affect communities in coastal locations, especially near harbours. In recent years, residents in apartments at Beacon Cove, Port Melbourne, have been concerned about exposure to air pollution from ships. This residential area is near Station Pier. To investigate the spatial and temporal variability of emissions reaching the shore, the Victorian Ports Corporation (Melbourne) monitored $PM_{2.5}$ concentrations next to Station Pier for a 26-month period between 2016 and 2018. The results of the monitoring showed that annual average $PM_{2.5}$ concentrations exceeded the $PM_{2.5}$ standard in two successive years.[476]

As shipping emission plumes are intermittent and fluctuate spatially, there are limitations with using a single fixed air-quality monitor to detect the

475. Environment Protection Authority (EPA) Victoria, 'Unpublished data', Carlton, Victoria, Accessed 2022.
476. Jayaratne R, Kuhn T, Christensen B, Liu X, Zing I, Lamont R, Dunbabin M, Maddox J, Fisher G, Morawska L 2020, 'Using a network of low-cost particle sensors to assess the impact of ship emissions on a residential community', *Aerosol and Air Quality Research*, 20(12), pp. 2754-2764.

pollution. As part of a collaborative research project led by QUT, seven low-cost sensors monitored air quality in residential areas near Station Pier from December 2018 to March 2019. Four of the sensors monitored air quality at ground level and three were located on the upper balconies of two high-rise apartment blocks. Both the daily average $PM_{2.5}$ concentrations and the number of short-term spikes in $PM_{2.5}$ concentrations over five-minute periods were generally greater at the elevated monitoring sites, highlighting the impact of altitude on potential exposure to the shipping pollution.[477]

On average, the spikes observed at the seven monitoring locations were approximately four to five times above the normal background value. Because of their very short duration, these spikes did not significantly raise the daily $PM_{2.5}$ averages at any of the locations. However, some incremental contributions to the daily averages did increase the number of days when $PM_{2.5}$ concentrations exceeded the $PM_{2.5}$ air-quality standard in the Measure. More days were measured to exceed the $PM_{2.5}$ air-quality standard near Station Pier than the nearest air-quality station in EPA Victoria's ambient air-quality monitoring network.[478]

The research concluded that if maritime traffic increases, ports will not comply with future pollution standards unless measures to reduce ship emissions are implemented.[479] Although the long-term health effects of elevated PM concentrations are known (refer to indicator A:11 Health impacts of air pollution), few studies have been conducted on the risks of short-term exposures to extreme spikes — a topic that merits additional research.

Black carbon

Black carbon is the soot-like by-product of wildfires and fossil fuel consumption.[480] In 2021, international researchers linked long-term exposure to black carbon with increased mortality risk, reinforcing the emerging evidence that black carbon is a harmful component of $PM_{2.5}$.[481]

Black carbon is an emerging pollutant of interest and EPA Victoria has been leading work to understand its impact in Victoria. Modelling completed as part of a collaborative project between EPA Victoria and ACU indicates that black carbon exposure across Melbourne may be greatest during time spent on major arterial roads and motorways. The modelling was completed by combining results from a short-term mobile particle monitoring campaign in the field and a wide range of geographic information system (GIS) and satellite-derived predictors - this combination led to a high-resolution (100 m grid cells) map of annual average black carbon concentrations across Melbourne (Figure A4). The map shows a very high spatial variability of black carbon concentrations. Given there is a limited understanding of black carbon diffusion and transport from sources (e.g. tailpipes), it is recommended that estimates of population exposures are considered with caution. Notwithstanding, the modelling represents increasing insights and knowledge about the presence of black carbon across Melbourne.

477. Jayaratne R, Kuhn T, Christensen B, Liu X, Zing I, Lamont R, Dunbabin M, Maddox J, Fisher G, Morawska L 2020, 'Using a network of low-cost particle sensors to assess the impact of ship emissions on a residential community', *Aerosol and Air Quality Research*, 20(12), pp. 2754-2764.
478. Ibid.
479. Ibid.
480. Elias S 2021, ' Threats to the Arctic ', Elsevier, ISBN 9780128215555, https://doi.org/10.1016/B978-0-12-821555-5.02001-5 Accessed 13 December 2022.
481. Yang J, Zare Sakhvidi MJ, de Hoogh K, Vienneau D, Siemiatyck J, Zins M, Goldberg M, Chen J, Lequy E, Jacquemin B 2021, 'Long-term exposure to black carbon and mortality: A 28-year follow-up of the GAZEL cohort', *Environment International*, Volume 157, 2021, 106805, ISSN 0160-4120, https://doi.org/10.1016/j.envint.2021.106805 Accessed 13 December 2022.

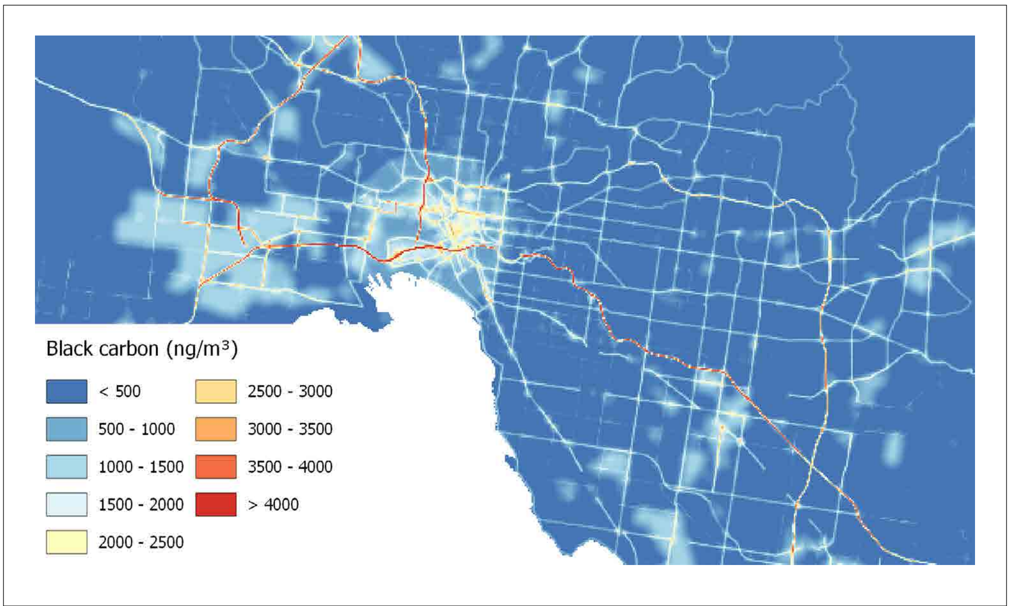


Figure A4: Modelled black carbon concentrations (ng/m³) across Melbourne.[482]

PM_{10}

The pattern of days exceeding the PM_{10} standard has traditionally aligned with that for $PM_{2.5}$ although more days generally exceeded the PM_{10} standard. This pattern has been changing since the mid-2010s, notably 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 A5). Peak PM_{10} readings are associated with major fires (e.g. 2003 and 2020) or windblown dust events (e.g. in Geelong during 2015) (Figure A6).

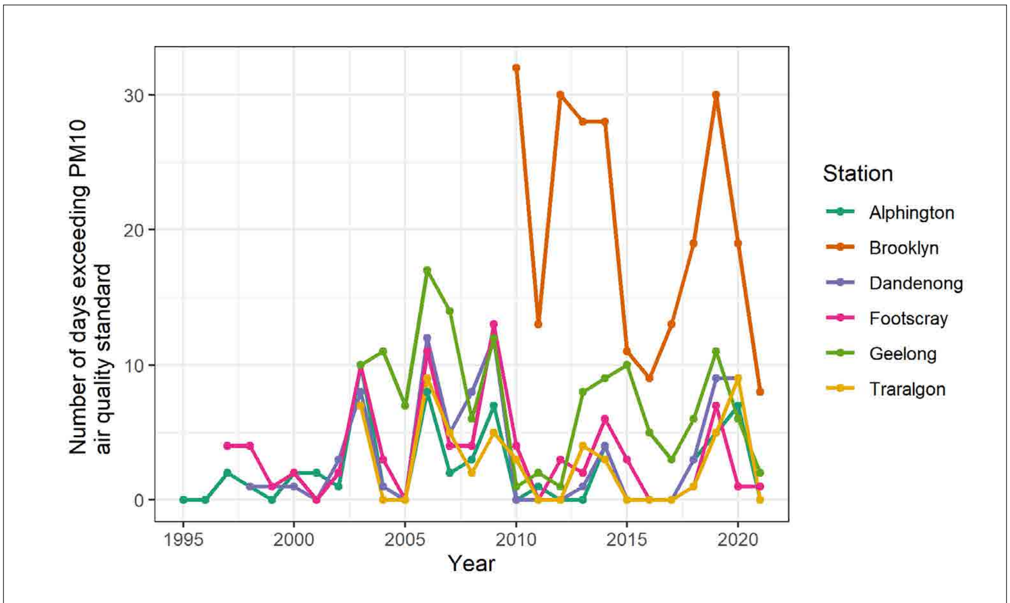


Figure A5: Number of days exceeding the PM_{10} (daily average) standard in Victoria from 1995 to 2021.[483]

482. Black carbon concentrations (ng/m³) were measured at 200 sites in metropolitan Melbourne and were modelled across the region using satellite observations and land-use predictors. The data and geospatial models used in Figure A4 were provided by EPA Victoria and developed by Dr David Donaire-Gonzalez and Dr Amanda Wheeler under an EPA Victoria contract with the ACU.

483. Environment Protection Authority (EPA) Victoria, 'Unpublished data', Carlton, Victoria, Accessed 2022.

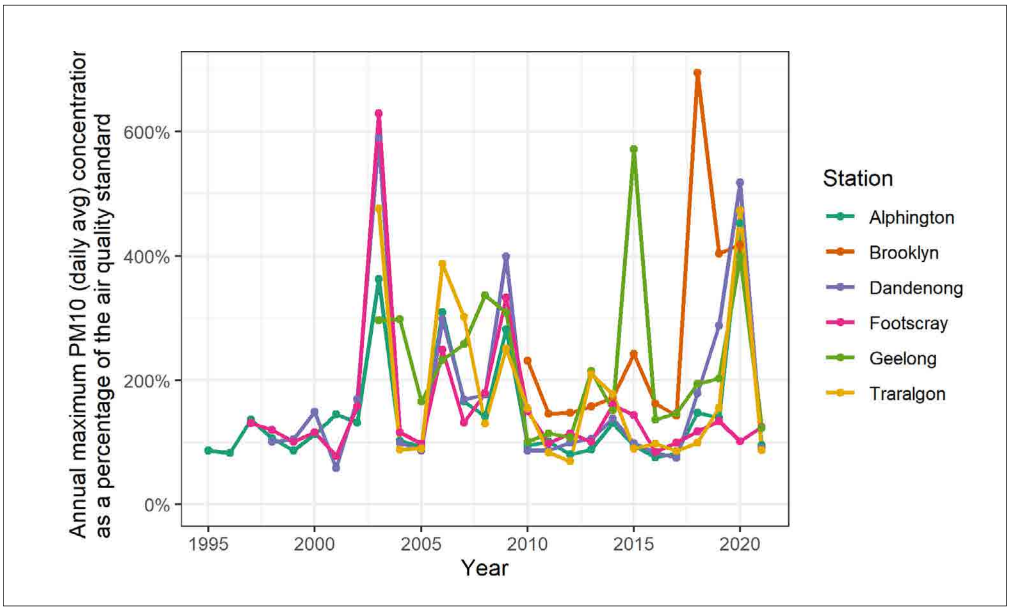


Figure A6: Annual maximum PM_{10} (daily average) concentrations in Victoria from 1995 to 2022. Concentrations are shown as a percentage of the air-quality standard.[484]

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. Previously unsealed roads frequently used by heavy vehicles were sealed during 2015 resulting in a significant improvement in local air quality that persisted until 2018, when the local air quality worsened and reached 30 days exceeding the PM_{10} standard during 2019. It is possible that deteriorating management of local air quality, rather than changes in weather, is the cause of Brooklyn's poorer air quality during 2018 and 2019, with 2015 (when there were 11 exceedances of the PM_{10} standard) and 2019 (when there were 30 exceedances of the PM_{10} standard) having almost identical rainfall totals. Increased rainfall during 2020 and 2021, which were the wettest years in the region since 2011, has led to improved air quality in the region. Furthermore, several industrial facilities have had their sites sealed and asphalted during 2020 and 2021, which has also helped drive improving local air quality. However, more improvements are required to bring the suburb's air quality in-line with neighbouring suburbs such as Footscray.

Annual average PM_{10} concentrations across Victorian had been consistently meeting the air-quality standard since 2010, with the exception of Brooklyn (all years), Geelong (2014 and 2021), Dandenong (2020), Footscray (2014) and Traralgon (2020) (Figure A7). Significant smoke impacts from bushfires occurred during 2014 and 2020. The higher historical annual average PM_{10} readings from 2000 to 2009 are likely to be due to drier conditions associated with the millennium drought.

484. Environment Protection Authority (EPA) Victoria, 'Unpublished data', Carlton, Victoria, Accessed 2022.

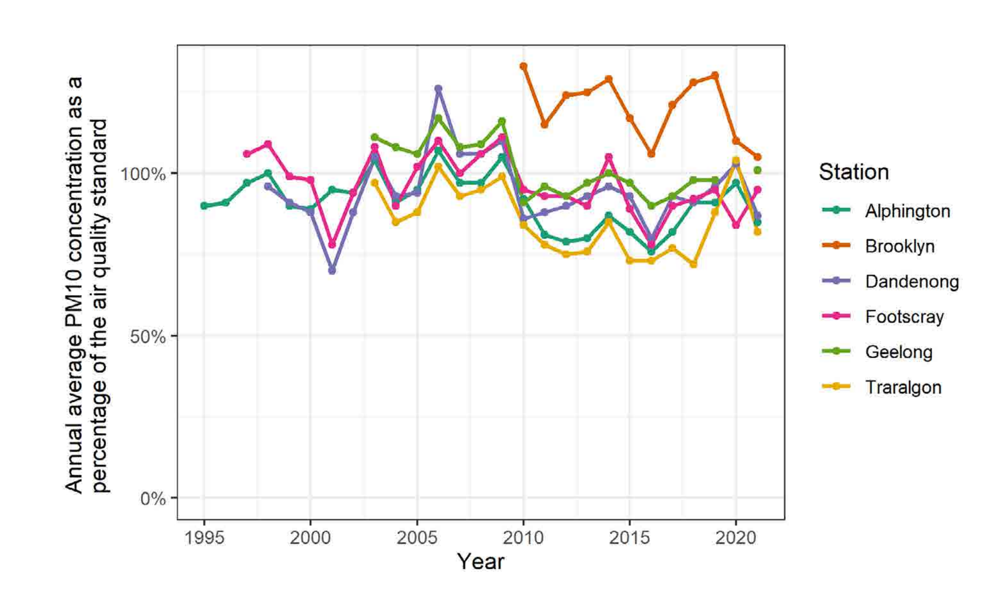


Figure A7: Annual average PM_{10} concentrations in Victoria from 1995 to 2021. Concentrations are shown as a percentage of the air-quality standard.[485]

Emission sources

Across Victoria, sources of emissions comprise a mixture of natural and anthropogenic sources. The landscape in regional Victoria is characterised by natural vegetation and low population. In these locations, natural emission sources from bushfires, dust and vegetation result in elevated releases of $PM_{2.5}$ and PM_{10}.[486]

Figure A8 shows that $PM_{2.5}$ and PM_{10} anthropogenic sources are higher than natural sources in Melbourne, while the opposite is true in regional Victoria where bushfires and dust sources are more prevalent.

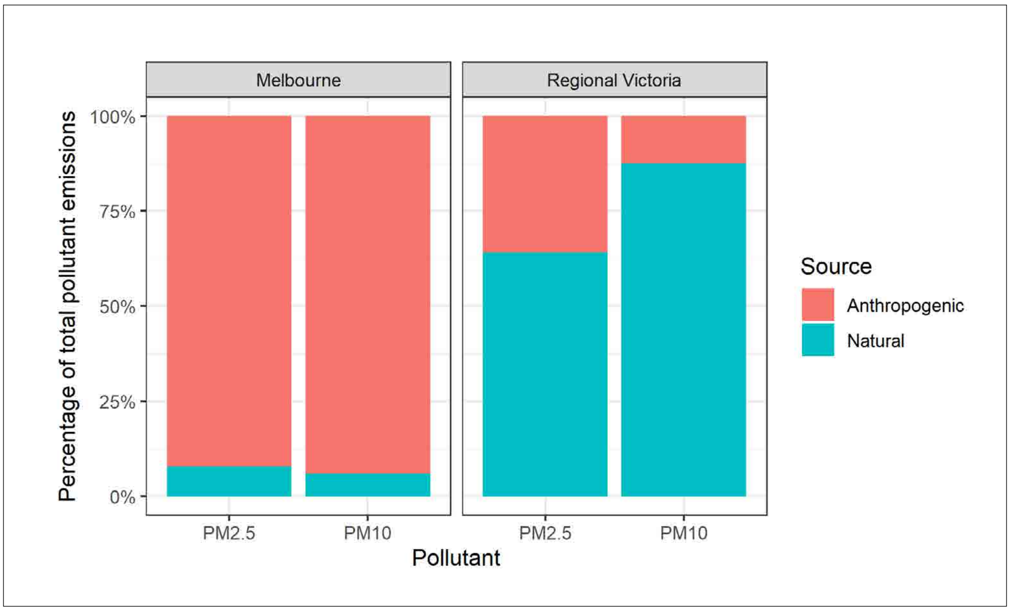


Figure A8: Proportions of natural and anthropogenic emissions for natural and anthropogenic $PM_{2.5}$ and PM_{10} sources across Melbourne and regional Victoria, as estimated for 2016.[487]

485. Environment Protection Authority (EPA) Victoria, 'Unpublished data', Carlton, Victoria, Accessed 2022.
486. Environment Protection Authority (EPA) Victoria 2021, '2016 emissions inventory report', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/2028 Accessed 17 June 2022.
487. Ibid.

In terms of managing $PM_{2.5}$ anthropogenic emission sources, they are greatest from domestic wood heaters in Melbourne, with domestic wood heating estimated to account for 51% of all anthropogenic $PM_{2.5}$ emissions in Melbourne. PM_{10} anthropogenic emission sources are greatest from motor vehicles in Melbourne, which includes dust raised from motor vehicle wheels travelling along dirty or unsealed roads.[488]

In its 2016 Victorian air pollution emissions inventory report that was published in 2021, EPA Victoria recommended reducing wood heater emissions, given that they comprise more than half of all $PM_{2.5}$ emissions in Melbourne and a significant proportion (38%) across Victoria.[489]

Melbourne skyline view from Mount Dandenong, 2023.
Credit: ai_yoshi.

488. Environment Protection Authority (EPA) Victoria 2021, '2016 emissions inventory report', Carlton, Victoria, https://www.epa.vic.gov.au/-/media/epa/files/publications/2028---2016-emissions-inventory-report.pdf Accessed 17 June 2022.
489. Ibid.

Indicator A:02 Ambient ozone levels

A:02 Ambient ozone levels						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	(Latrobe Valley) (Geelong and Melbourne)					
Data source(s):	EPA Victoria					
Measure(s):	Annual performance against indicators and objectives for ozone specified in the Victorian ERS					

Why this indicator?

Ozone can increase respiratory problems. The elderly and those with lung disease are most at risk.

NB: This SoE 2023 indicator was 'A:01 Ambient ozone levels (summer smog)' in the SoE 2018 Report.

Why this assessment in 2023?

With the new 8-hour average ozone standard replacing the previous 4-hour and 1-hour average ozone standards, more days exceed the ozone standard than were reported in the SoE 2018 Report.

The exceedances of ozone standards in recent years have generally been due to smoke from bushfires, as during the 2019–20 summer bushfire season. Exceedances of the ozone standard are slightly more likely to occur in Melbourne and Geelong (averaging between one and two ozone exceedances per year this century) compared with Traralgon (averaging less than one ozone exceedance per year this century).

Summary of State of the Environment 2018 Report assessment

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

Critical data used for the 2023 assessment

- EPA Victoria air monitoring data
- EPA Victoria 2016 Emissions Inventory Report

2023 assessment

Ozone is the primary pollutant in summer smog, which forms around large cities on sunny days with light winds.[490, 491] Ozone is formed when reactions between hydrocarbons and oxides of nitrogen take place during intense sunlight.

The ERS specifies the 8-hour average photochemical oxidants (as ozone) objective for Victoria.[492] This objective is presented in Table A3. The current standard came into effect in March 2022, replacing the previous ozone standards that were based on hourly and 4-hour average data. The current 8-hour average standard has been used in this indicator assessment to compare historical air-quality data.

490. Environment Protection Authority (EPA) Victoria, 'Ozone in the air', Carlton, Victoria, https://www.epa.vic.gov.au/for-community/environmental-information/air-quality/ozone-in-the-air Accessed on 14 July 2022.
491. Environment Protection Authority (EPA) Victoria 2007, 'Summer smog in Victoria', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/1188 Accessed on 14 July 2022.
492. Environment Protection Authority (EPA) Victoria 2022, *'Environment Protection Act 2017*, Environment Reference Standard, No. S245 Gazette 26 May 2021, as amended by Environment Reference Standard No. S158 Gazette 29 March 2022', Carlton, Victoria, https://www.epa.vic.gov.au/-/media/epa/files/about-epa/laws/consolidated-ers-prepared-by-epa-29-mar-2022.pdf?la=en&hash=D3030F2A5865C6B2394B12B7B53DF540 Accessed 8 December 2022.

Table A3: Victorian ambient air environment objectives for photochemical oxidants (as ozone).[493]

Indicator	Objective	Averaging period
Photochemical oxidants (as ozone)	0.06 ppm	8 hours

The frequency and magnitude of high ambient ozone concentrations have reduced in Victoria since the early 1980s. The rate of air-quality improvement has slowed considerably since the turn of the century and, despite the improvement since the 1980s, summer smog days are still being recorded in Melbourne this century (Figure A9). The exceedances of ozone standards in recent years have generally been due to smoke from bushfires, as occurred during the 2006-07, 2013-14 and 2019-20 summer bushfire seasons.[494] Exceedances of the ozone standard are slightly more likely to occur in Melbourne and Geelong (averaging between one and two ozone exceedances per year this century) compared with Traralgon (averaging less than one ozone exceedance per year this century). This is most likely a combination of Melbourne and Geelong having more hydrocarbon and oxides of nitrogen emissions associated with motor vehicle traffic and urban activity, as well as Melbourne and Geelong being situated along Port Phillip Bay. Prevailing offshore winds in the morning can blow the reacting pollutants over the bay to form ozone before blowing the ozone back over land during afternoon sea breezes.

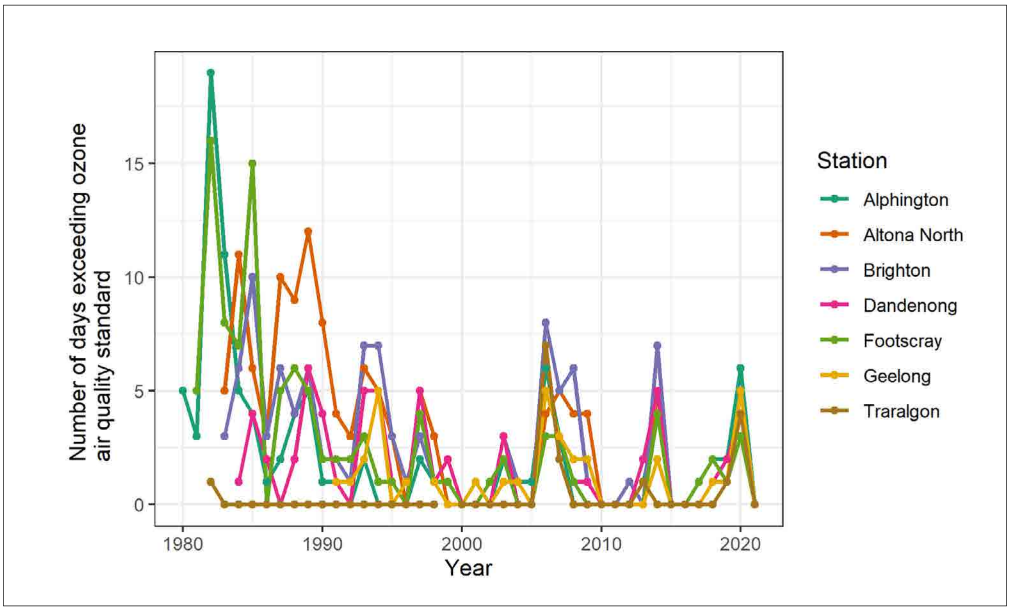


Figure A9: Number of days exceeding the ozone (8-hour average) standard in Victoria from 1980 to 2021.[495]

493. Environment Protection Authority (EPA) Victoria 2022, *'Environment Protection Act 2017*, Environment Reference Standard, No. S245 Gazette 26 May 2021, as amended by Environment Reference Standard No. S158 Gazette 29 March 2022', Carlton, Victoria, https://www.epa.vic.gov.au/-/media/epa/files/about-epa/laws/consolidated-ers-prepared-by-epa-29-mar-2022.pdf?la=en&hash=D3030F2A5865C6B2394B12B7B53DF540 Accessed 8 December 2022.
494. Environment Protection Authority (EPA) Victoria 2018, 'Air monitoring report 2017 – Compliance with the National Environment Protection (Ambient Air Quality) Measure', Carlton Victoria, https://www.epa.vic.gov.au/about-epa/publications/1703 Accessed on 14 July 2022.
495. Environment Protection Authority (EPA) Victoria, 'Unpublished data', Carlton, Victoria, Accessed 2022.

Emission sources

Volatile organic compounds (VOCs) are an important precursor for secondary air pollution such as ozone. VOC emissions can lead to the formation of ozone. There are more VOC emissions from anthropogenic sources (55%) than natural sources in Melbourne (Figure A10). This is reversed in regional Victoria where the natural sources (90%) dominate the contribution to total VOC emissions.

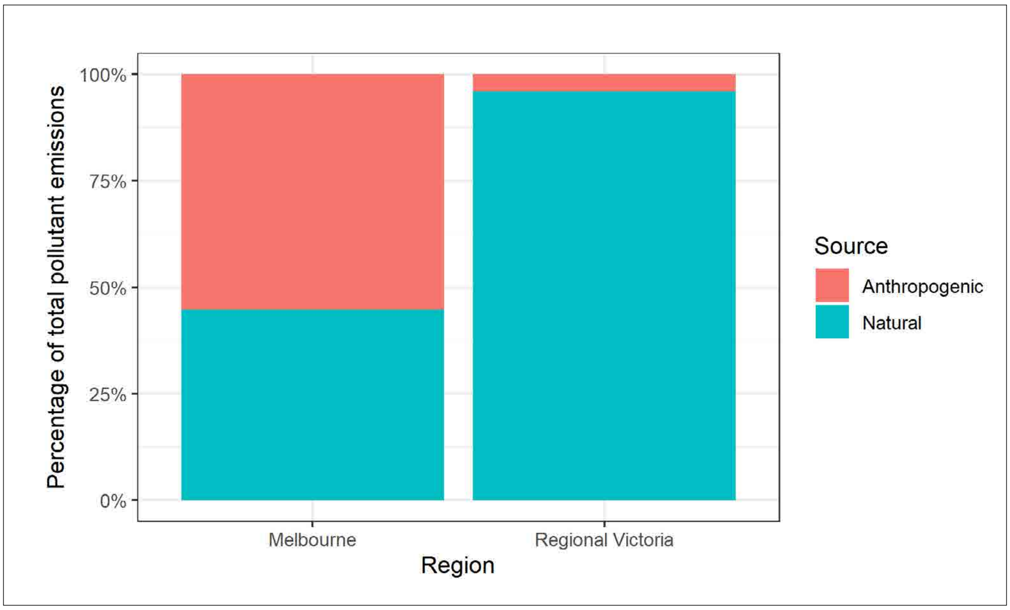


Figure A10: Proportions of natural and anthropogenic emissions for natural and anthropogenic total volatile organic compound sources across Melbourne and regional Victoria, as estimated for 2016.[496]

The main sources of VOC emissions in Victoria are motor vehicle and industrial emissions, as well as domestic activities such as solvent use or the operation of gardening equipment with small engines.[497] 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.[498] 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.[499] A projected increase in the frequency and severity of bushfires is also likely to increase peak ozone levels.

496. Environment Protection Authority (EPA) Victoria 2021, '2016 emissions inventory report', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/2028 Accessed 17 June 2022.
497. Environment Protection Authority (EPA) Victoria, 'Ozone in the air', Carlton, Victoria, https://www.epa.vic.gov.au/for-community/environmental-information/air-quality/ozone-in-the-air Accessed on 14 July 2022.
498. Environment Protection Authority (EPA) Victoria 2013, 'Future air quality in Victoria: Final Report, 2013', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/1535 Accessed 14 July 2022.
499. Ibid.

Indicator A:03 Carbon monoxide

A:03 Carbon monoxide						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	●	→	●	●	↗	●
Data source(s):	EPA Victoria					
Measure(s):	Annual performance against indicators and objectives for carbon monoxide specified in the Victorian ERS					

Why this indicator?

Breathing air with a high concentration of carbon monoxide reduces the amount of oxygen that can be transported in the bloodstream to organs such as the heart and brain. People with cardiovascular disease are particularly at risk.

NB: This is a modified SoE 2023 indicator that was formed by disaggregating the measures of the SoE 2018 indicator 'A:02 Carbon monoxide and nitrogen dioxide'.

Why this assessment in 2023?

Carbon monoxide concentrations rarely exceed the air-quality standard; the only exceedance this century was measured at Morwell South during the fire at the Hazelwood open-cut coal mine.

Summary of State of the Environment 2018 Report assessment

- Carbon monoxide 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.

Critical data used for the 2023 assessment

- EPA Victoria air monitoring data
- EPA Victoria 2016 Emissions Inventory Report

2023 assessment

Carbon monoxide concentrations are closely linked to motor vehicle emissions. The ERS specifies the 8-hour average carbon monoxide objective for Victoria.[500] This objective is presented in Table A4.

Table A4: Victorian ambient air environment objective for carbon monoxide.[501]

Indicator	Objective	Averaging period
Carbon monoxide	9.0 ppm	8 hours

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 2021 (Figure A11). 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 such high levels of carbon monoxide in populated areas was more than 25 years ago, when motor vehicle carbon monoxide emissions were

500. State of Victoria 2021, 'Victoria Government Gazette, No. S 245, 26 May 2021, Environment Reference Standard', http://www.gazette.vic.gov.au/gazette/Gazettes2021/GG2021S245.pdf Accessed 25 February 2022.
501. Ibid.

much higher. Since the SoE 2018 Report was published, there was a spike in carbon monoxide concentrations during 2020 associated with the eastern Victorian bushfires, however, carbon monoxide concentrations were still well within the carbon monoxide standard.

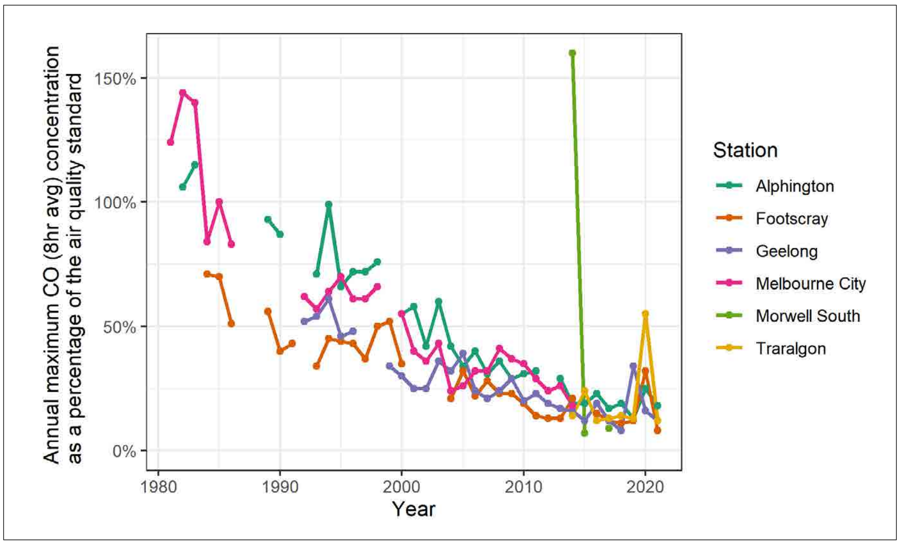


Figure A11: Annual maximum carbon monoxide (8-hour average) concentrations in Victoria from 1981 to 2021. Concentrations are shown as a percentage of the air-quality standard.[502]

Carbon monoxide concentrations are expected to continue gradually reducing 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.

Emission sources

Anthropogenic emissions of carbon monoxide are significantly higher than natural emissions across Victoria, particularly in Melbourne (Figure A12).[503] Carbon monoxide anthropogenic sources are greatest from motor vehicle emissions in Melbourne and most of regional Victoria, although fossil fuel electricity generation is the highest source in the Latrobe Valley.

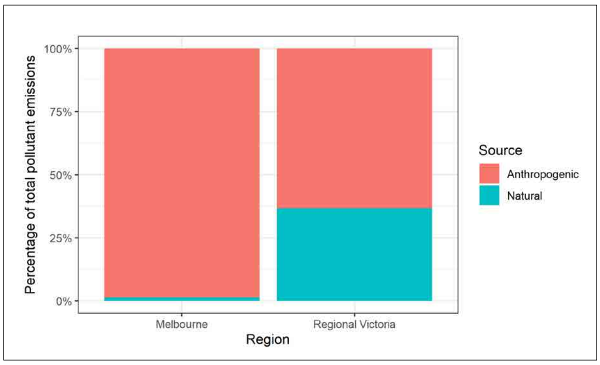


Figure A12: Proportions of natural and anthropogenic emissions for natural and anthropogenic carbon monoxide sources across Melbourne and regional Victoria, as estimated for 2016.[504]

In its 2016 Victorian air pollution emissions inventory report that was published in 2021, EPA Victoria recommended efforts should be directed at reducing motor vehicle emissions as they make up significant anthropogenic sources of carbon monoxide (59%) — as well as oxides of nitrogen (70%), $PM_{2.5}$ (29%) and PM_{10} (72%) — in Melbourne.[505]

502. Environment Protection Authority (EPA) Victoria, 'Unpublished data', Carlton, Victoria, Accessed 2022.
503. Environment Protection Authority (EPA) Victoria 2021, '2016 emissions inventory report', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/2028 Accessed 17 June 2022.
504. Ibid.
505. Ibid.

Air

Indicator A:04 Nitrogen dioxide

A:04 Nitrogen dioxide						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	●	↗ (Melbourne) → (Geelong and Latrobe Valley)	●	●	↗	●
Data source(s):	EPA Victoria					
Measure(s):	Annual performance against indicators and objectives for nitrogen dioxide specified in the Victorian ERS					

Why this indicator?

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

NB: This is a modified SoE 2023 indicator that was formed by disaggregating the measures of the SoE 2018 indicator 'A:02 Carbon monoxide and nitrogen dioxide' to provide a greater focus on nitrogen dioxide concentrations and its sources.

Why this assessment in 2023?

Nitrogen dioxide concentrations have not exceeded air-quality standards in Victoria this century. Annual average concentrations have still reduced during this century, albeit at a slower rate than in the 1980s and 1990s. Reductions in nitrogen dioxide concentrations were observed in Melbourne in 2020 and 2021. It is highly likely that this was due to travel restrictions in Melbourne as part of the Victorian Government's response to limit the spread of COVID-19.

Summary of State of the Environment 2018 Report assessment

- 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.

Critical data used for the 2023 assessment

- EPA Victoria air monitoring data
- EPA Victoria 2016 Emissions Inventory Report

2023 assessment

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 ground-level concentrations significantly in populated areas.

The ERS specifies the hourly and yearly nitrogen dioxide objectives for Victoria.[506] These objectives are presented in Table A5.

Table A5: Victorian ambient air environment objectives for nitrogen dioxide.[507]

Indicator	Objective	Averaging period
Nitrogen dioxide	0.080 ppm	1 hour
	0.015 ppm	1 year

506. State of Victoria 2021, 'Victoria Government Gazette, No. S 245, 26 May 2021, Environment Reference Standard', http://www.gazette.vic.gov.au/gazette/Gazettes2021/GG2021S245.pdf Accessed 25 February 2022.
507. Ibid.

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 current standards were tightened in March 2022 and these stricter standards have been used in this indicator assessment to compare historical air-quality data.

The hourly average standard has not been exceeded in Victoria this century (Figure A13). Previous exceedances during the 1980s and 1990s were typically recorded on days when motor vehicle emissions accumulated during calm weather. Peak nitrogen dioxide concentrations (based on hourly average data) decreased significantly in Melbourne during the late 1980s and early 1990s where, despite there being more vehicles, changes in technology have meant fewer emissions per vehicle. The trend has continued this century, albeit at a much slower rate.

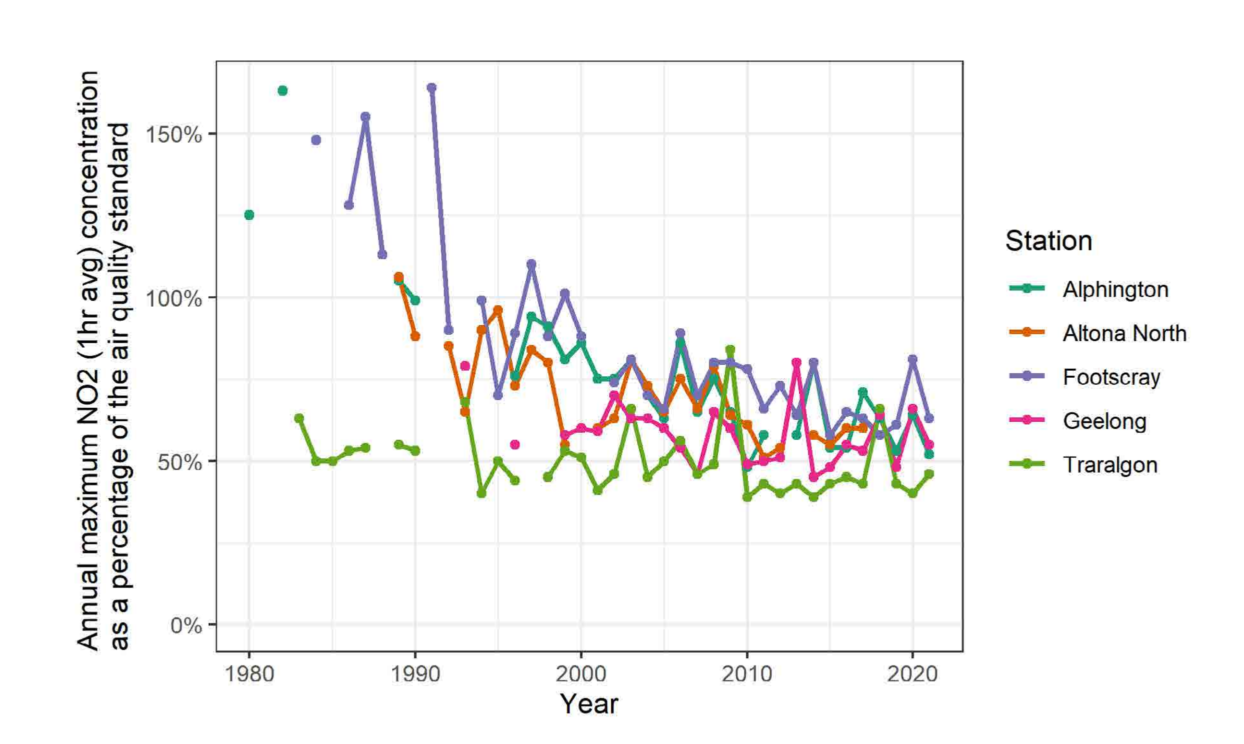


Figure A13: Annual maximum nitrogen dioxide (1-hour average) concentrations in Victoria from 1980 to 2021. Concentrations are shown as a percentage of the air-quality standard.[508]

The annual nitrogen dioxide standard has not been exceeded since 1989 (Figure A14). In general, there has been a reducing trend in annual average concentrations for nitrogen dioxide since monitoring began. The rate of reduction was diminishing during the 2000s. However, there has been a noticeably sharper decrease in annual average nitrogen dioxide concentrations in Melbourne's suburbs during 2020 and 2021, which was likely due to travel restrictions in Melbourne that formed part of the Victorian Government's response to the significant health risks posed by COVID-19.[509]

508. Environment Protection Authority (EPA) Victoria, 'Unpublished data', Carlton, Victoria, Accessed 2022.
509. Choi J, Utembe S, Fisher G, Torre P 2021, 'Air pollution impacts in Melbourne, Victoria associated with COVID-19 measures in 2020', *Air Quality and Climate Change Journal*, Clean Air Society of Australia and New Zealand, 55(1), pp. 16-32.

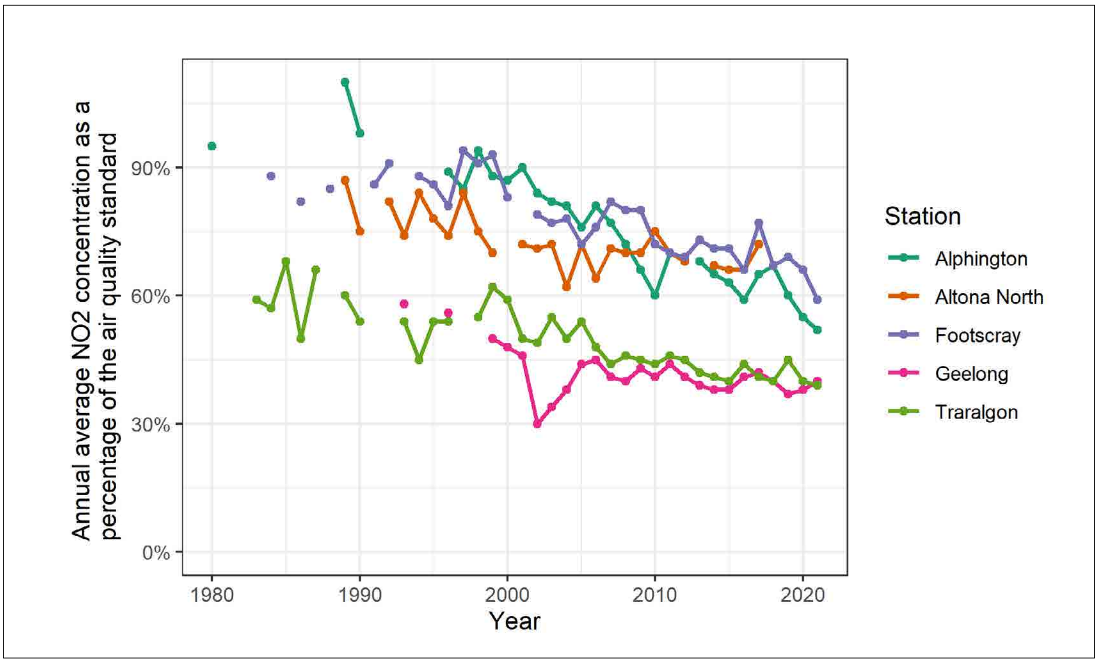


Figure A14: Annual average nitrogen dioxide concentrations in Victoria from 1980 to 2021. Concentrations are shown as a percentage of the air-quality standard.[510]

Nitrogen dioxide concentrations are expected to continue gradually reducing 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.

Emission sources

Anthropogenic emissions of nitrogen dioxide are significantly higher than natural emissions across Victoria (Figure A15).[511] Nitrogen dioxide anthropogenic sources are greatest from motor vehicle emissions in Melbourne and most of regional Victoria, although fossil fuel electricity generation is the highest source in the Latrobe Valley.

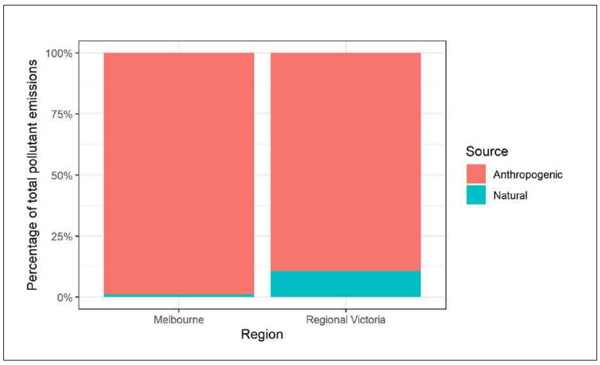


Figure A15: Proportions of natural and anthropogenic emissions for natural and anthropogenic nitrogen dioxide sources across Melbourne and regional Victoria, as estimated for 2016.[512]

In its 2016 Victorian air pollution emissions inventory report that was published in 2021, EPA Victoria recommended efforts should be directed at reducing motor vehicle emissions as they make up significant anthropogenic sources of oxides of nitrogen (70%) — as well as carbon monoxide (59%), $PM_{2.5}$ (29%) and PM_{10} (72%) — in Melbourne.[513]

510. Environment Protection Authority (EPA) Victoria, 'Unpublished data', Carlton, Victoria, Accessed 2022.
511. Environment Protection Authority (EPA) Victoria 2021, '2016 emissions inventory report', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/2028 Accessed 17 June 2022.
512. Ibid.
513. Ibid.

Indicator A:05 Sulfur dioxide

A:05 Sulfur dioxide						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	●	→	●	●	→	●
Data source(s):	EPA Victoria					
Measure(s):	Annual performance against indicators and objectives for sulfur dioxide specified in the Victorian ERS					

Why this indicator?

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

NB: This SoE 2023 indicator was 'A:04 Sulfur dioxide' in the SoE 2018 Report.

Why this assessment in 2023?

Sulfur dioxide concentrations have rarely exceeded air-quality standards in Victoria this century. There have been no significant trends in sulfur dioxide concentrations in Victoria since the 1980s, except for some isolated spikes in Altona North and Traralgon in the 1990s and 2000s.

Summary of State of the Environment 2018 Report assessment

- 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.

Critical data used for the 2023 assessment

- EPA Victoria air monitoring data
- EPA Victoria 2016 Emissions Inventory Report

2023 assessment

Power stations are the main driver of peak sulfur dioxide concentrations in Victoria, while ships that travel near the coast and dock at Victoria's ports are also a significant source. Victoria's peak sulfur dioxide levels are measured near major industrial facilities in Altona North and Traralgon.

The ERS specifies the hourly and daily sulfur dioxide objectives for Victoria.[514] These objectives are presented in Table A6.

Table A6: Victorian ambient air environment objectives for sulfur dioxide.[515]

Indicator	Objective	Averaging period	Maximum exceedances
Sulfur dioxide	0.075 ppm	1 hour	1 day a year
	0.020 ppm	1 day	1 day a year

514. State of Victoria 2021, 'Victoria Government Gazette, No. S 245, 26 May 2021, Environment Reference Standard', http://www.gazette.vic.gov.au/gazette/Gazettes2021/GG2021S245.pdf Accessed 25 February 2022.
515. Ibid.

There are two air-quality standards for sulfur dioxide in Victoria. One standard is based on hourly average data, the other for daily average data. The current standards were tightened in March 2022 and these stricter standards have been used in this indicator assessment to compare historical air-quality data.

There have been no significant trends in sulfur dioxide concentrations in Victoria since the 1980s apart from some isolated spikes in Altona North and Traralgon during the 1990s and 2000s (Figure A16 and Figure A17).

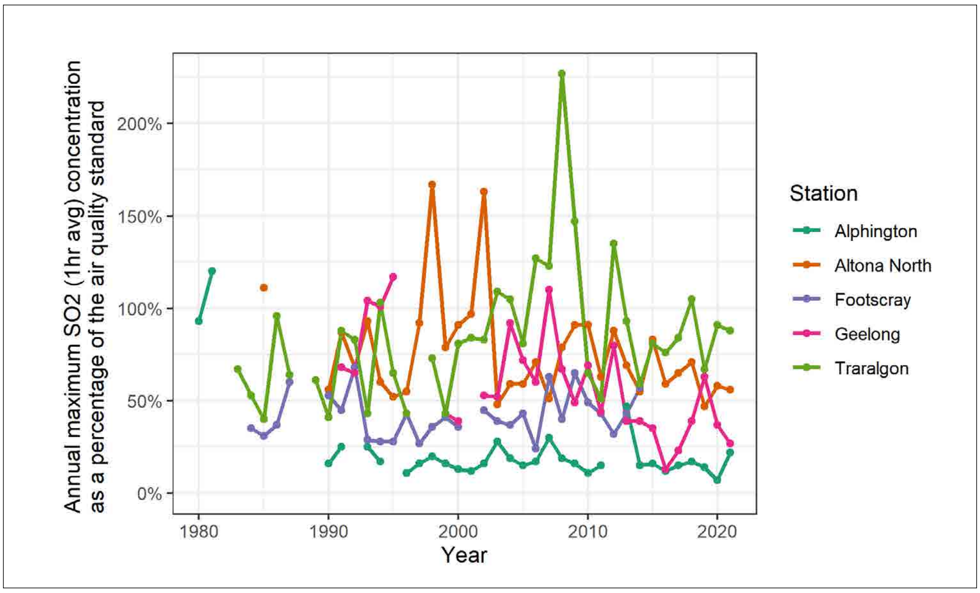


Figure A16: Annual maximum sulfur dioxide (hourly average) concentrations in Victoria from 1980 to 2021. Concentrations are shown as a percentage of the air-quality standard.[516]

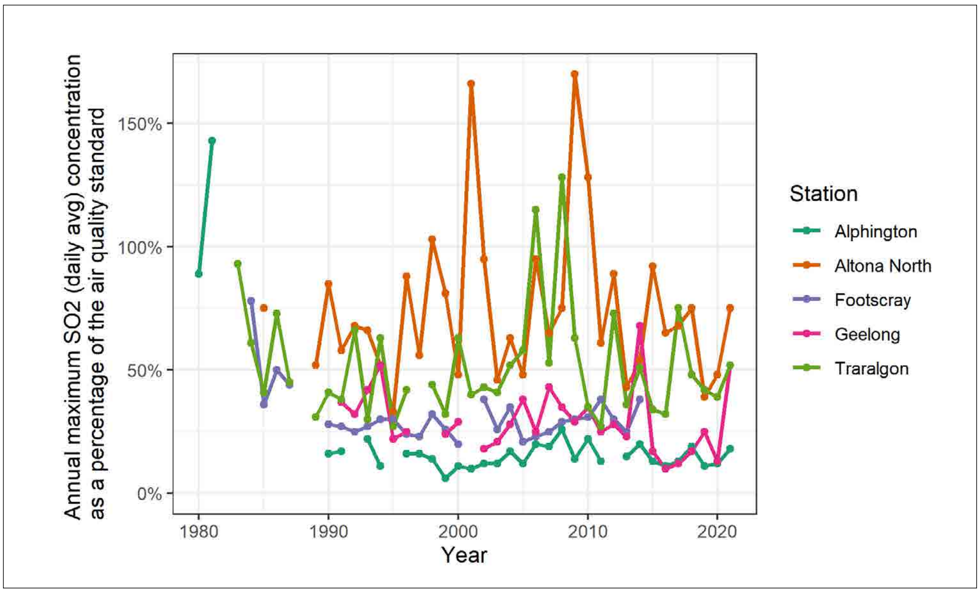


Figure A17: Annual maximum sulfur dioxide (daily average) concentrations in Victoria from 1981 to 2021. Concentrations are shown as a percentage of the air-quality standard.[517]

516. Environment Protection Authority (EPA) Victoria, 'Unpublished data', Carlton, Victoria, Accessed 2022.
517. Ibid.

Emission sources

Sulfur dioxide emissions in Victoria are almost exclusively from anthropogenic sources (Figure A18).[518] Sulfur dioxide anthropogenic sources are greatest from fossil fuel electricity generation, as well as petroleum refining and petroleum fuel manufacturing. The amount of sulfur dioxide emissions in Melbourne and over Port Phillip Bay is likely to reduce in future reporting due to the closure of the oil refinery in Altona in 2021 and the introduction of low sulfur marine fuel for shipping from 2020.[519, 520]

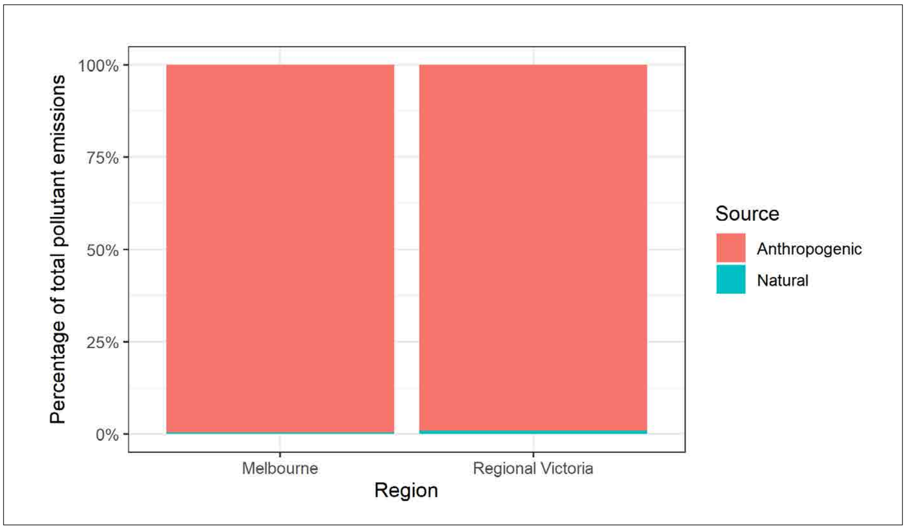


Figure A18: Proportions of natural and anthropogenic emissions for natural and anthropogenic nitrogen dioxide sources across Melbourne and regional Victoria, as estimated for 2016.[521]

In its 2016 Victorian air pollution emissions inventory report that was published in 2021, EPA Victoria recommended emissions reduction programs for sulfur dioxide should focus on the Latrobe Valley as it produces 87% of the sulfur dioxide emissions for Victoria.[522]

518. Environment Protection Authority (EPA) Victoria 2021, '2016 emissions inventory report', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/2028 Accessed 17 June 2022.
519. ExxonMobil, 'Shutting down Altona refinery for the last time', https://www.exxonmobil.com.au/community-engagement/local-outreach/mobil-community-news/2021/altona-shut-down-teams Accessed 9 December 2022.
520. Australian Maritime Safety Authority, 'Compliance with low sulphur 2020', Canberra, Australian Capital Territory, https://www.amsa.gov.au/marine-environment/air-pollution/compliance-low-sulphur-2020 Accessed 9 December 2022.
521. Environment Protection Authority (EPA) Victoria 2021, '2016 emissions inventory report', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/2028 Accessed 17 June 2022.
522. Ibid.

Air

Indicator A:06 Population exposure to air pollution

A:06 Population exposure to air pollutiona						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	(years with significant bushfires) (other years)	?		New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator
Data source(s):	EPA Victoria					
Measure(s):	Percentage of total population exposed to $PM_{2.5}$ air pollution concentrations exceeding Victorian air pollution standards					

Why this indicator?

Health impacts from air pollution is an important environmental health issue. Its magnitude depends on population exposure to air pollution.

NB: This is a new indicator that was not included in the SoE 2018 Report. This indicator has been included to align with Victoria's legislative requirement to report population exposure to air pollution. It replaces 'A:08 Emissions of major air pollutants by sector' from the SoE 2018 Report, with commentary and data on the sources of air pollution emissions now presented for each pollutant in indicators A:01 to A:05.

Why this assessment in 2023?

Of the years when population exposure to $PM_{2.5}$ concentrations have been estimated, there is a large range in the percentage of the Victorian population being exposed to annual $PM_{2.5}$ concentrations exceeding the air-quality standard.
Seventy-nine percent of the Victorian population was exposed to annual $PM_{2.5}$ concentrations exceeding the air-quality standard in a year with significant bushfire smoke impacts (2020) compared with 18% in a year without significant bushfire smoke impacts (2021).

Summary of State of the Environment 2018 Report assessment

- New SoE 2023 indicator

Critical data used for the 2023 assessment

- Estimated percentage of Victorian population exposed to various annual $PM_{2.5}$ concentrations provided by EPA Victoria
- EPA Victoria population-weighted annual $PM_{2.5}$ concentrations data

2023 assessment

Legislative requirement to report population exposure to air pollution

From June 2018, the NEPM AAQ has required the Victorian Government to annually evaluate and report on population exposures to $PM_{2.5}$. From June 2021, the requirement was expanded to also include nitrogen dioxide and ozone.

Estimating population exposure to air pollution

A spatial assessment of air pollution concentrations is required to be able to quantify population exposure to air pollution. In EPA Victoria's 2019 air monitoring report, population weighted PM2.5 concentrations were estimated across a 3 x 3 km grid using the AQFx air-quality forecasting system developed by CSIRO, Bureau of Meteorology (BOM), the Department of Environment, Land, Water and Planning (DELWP) and the university sector.[523, 524] The modelling for 2019 showed that bushfires and controlled burns can have a significant impact

523. Environment Protection Authority (EPA) Victoria 2020, 'Air monitoring report 2019 – Compliance with the National Environment Protection (Ambient Air Quality) Measure', Carlton, Victoria, https://www.epa.vic.gov.au/-/media/epa/files/publications/1875.pdf Accessed 11 March 2022.
524. Commonwealth Scientific and Industrial Research Organisation (CSIRO), 'National AQFx prototype system', Canberra, Australian Capital Territory, https://research.csiro.au/aqfx/ Accessed 11 March 2022.

on annual $PM_{2.5}$ concentrations. To calculate population exposure in Victoria, the modelled $PM_{2.5}$ concentrations are weighted against population data.

Air pollution emission inventories are a critical input to calculate population exposure to air pollution. They provide an understanding of where and how much air pollution is emitted, and the data can be incorporated in modelling to determine how and where emissions are transported and dispersed. During 2021, EPA Victoria published a Victorian Air Pollution Emission Inventory that provided a comprehensive assessment of the major air pollution sources for the calendar year of 2016.[525]

$PM_{2.5}$ population exposure in Victoria

Of the three modelled years (2019-2021), 2020 was the year when the most Victorians were exposed to an estimated annual mean concentration greater than the $PM_{2.5}$ air monitoring standard (greater than 8 μg/m3).[526] Table A7 and Figure A19 show that 79% of Victorians were estimated to be exposed to annual $PM_{2.5}$ concentrations exceeding the air-quality standard during 2020. Conversely, 2021 was a year without significant bushfire smoke and far fewer (18%) Victorians were exposed to $PM_{2.5}$ concentrations exceeding the standard.

Table A7: Estimated percentage of Victorian population exposed to various annual $PM_{2.5}$ concentrations for the 2019-21 period.[527]

Concentration (μg/m3)	Percentage of population exposed		
	2019	2020	2021
5	99.8	99.8	79.0
6	86.0	99.8	54.4
7	68.3	91.9	37.8
8 (air-quality standard)	52.6	79.2	18.1
9	28.2	54.9	3.3
10	4.0	33.2	0.0
15	0.3	0.03	0.0
20	0.1	0.01	0.0

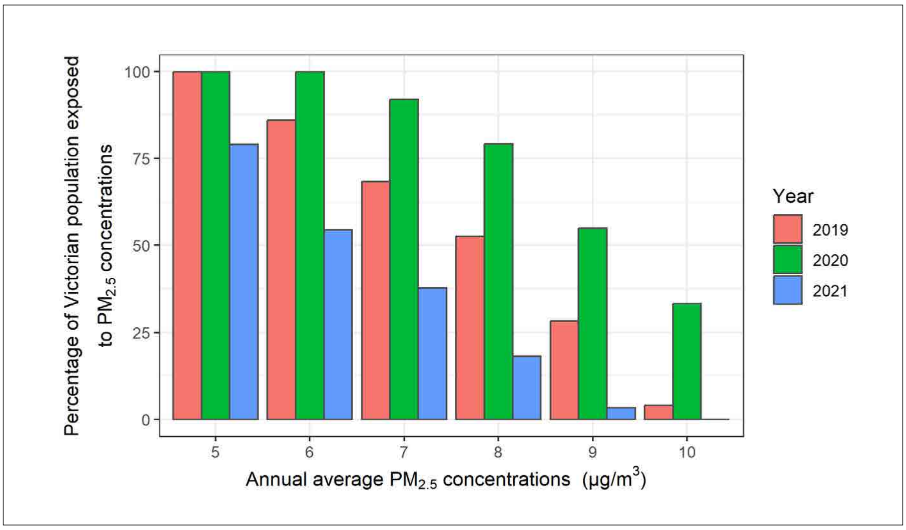


Figure A19: Estimated percentage of Victorian population exposed to various annual $PM_{2.5}$ concentrations for the 2019-21 period.[528]

525. Environment Protection Authority (EPA) Victoria 2021, '2016 emissions inventory report', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/2028 Accessed 17 June 2022.
526. Environment Protection Authority (EPA) Victoria 2020, 'Air monitoring report 2019 – Compliance with the National Environment Protection (Ambient Air Quality) Measure', Carlton, Victoria, https://www.epa.vic.gov.au/-/media/epa/files/publications/1875.pdf Accessed 11 March 2022.
527. Environment Protection Authority (EPA) Victoria, 'Unpublished data', Carlton, Victoria, Accessed 2022.
528. Environment Protection Authority (EPA) Victoria, 'Unpublished data', Carlton, Victoria, Accessed 2022.

Population weighting can provide an overall view of human exposure levels, which can support better quantitative assessments that provide a stronger basis for critical public health evaluation on the extent of damage caused by air pollution.[529] Population-weighted concentrations of $PM_{2.5}$ across Victoria are shown in Figure A20 and Figure A21 for all Statistical Area 2 (SA2) areas of Victoria for two 3-year periods: 2013-15 (Figure A20) and 2019-21 (Figure A21). The maps show a greater exposure to $PM_{2.5}$ across most of Victoria for the 2019-21 period, which is highly likely to be due to a greater exposure to smoke from fires during this 3-year period (relative to the 3-year period of 2013-15), particularly smoke from the extensive bushfires during the 2019-20 summer fire season. The maps also highlight the effect of population, with increased exposure over the relatively densely populated city of Melbourne.

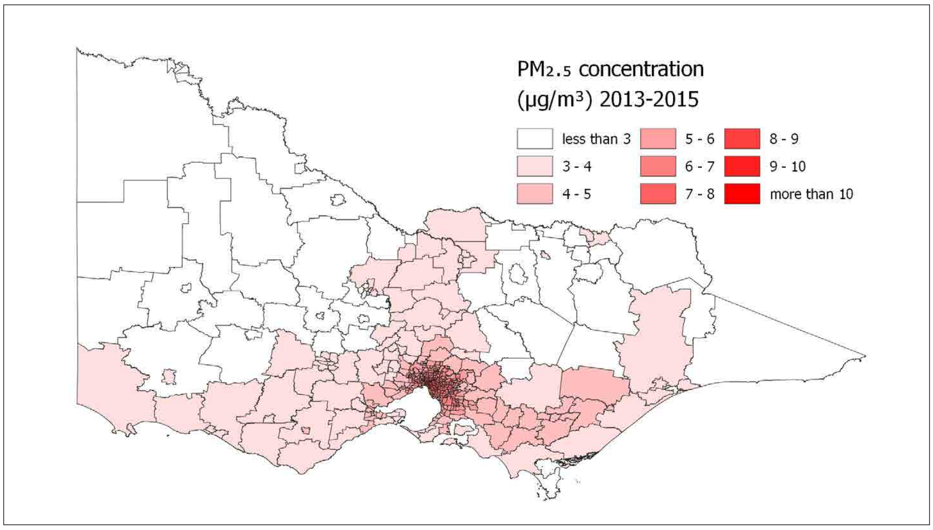


Figure A20: SA2 population-weighted annual $PM_{2.5}$ concentrations, averaged for the 2013-15 period.[530, 531]

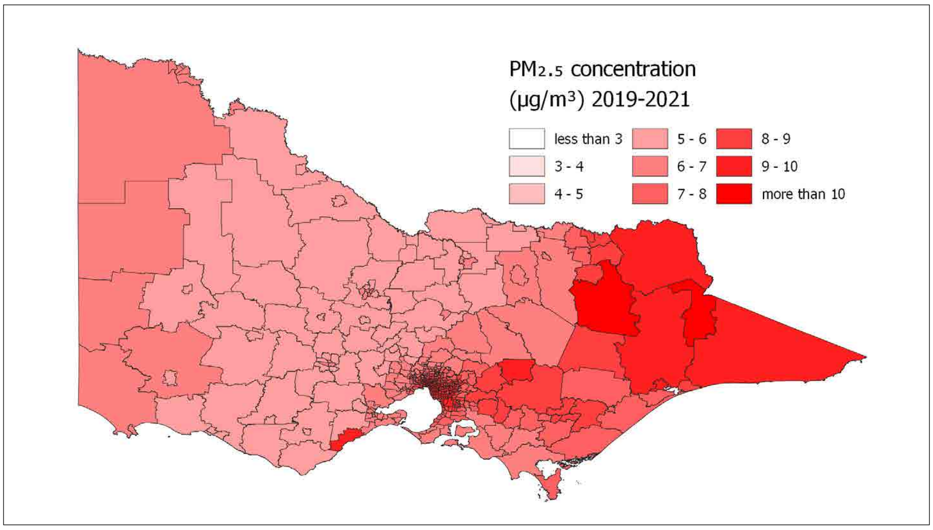


Figure A21: SA2 population-weighted annual $PM_{2.5}$ concentrations, averaged for the 2019-21 period.[532, 533]

Future assessments of population exposure to air pollution should include a focused analysis to determine whether there are any disproportionate exposures to air pollution among communities more vulnerable to the effects of air pollution, such as people with chronic diseases (e.g. heart or lung conditions, including asthma, and diabetes), people over 65, pregnant women, infants and young children.

529. Abdul Shakor AS, Pahrol MA, Mazeli MI 2020, 'Effects of Population Weighting on PM10 Concentration Estimation', *Journal of Environmental and Public Health*, vol. 2020, Article ID 1561823, https://doi.org/10.1155/2020/1561823 Accessed 7 June 2023.
530. Environment Protection Authority (EPA) Victoria, 'Unpublished data', Carlton, Victoria, Accessed 2022.
531. Colours indicate the average concentration of PM2.5 during the 3-year period of 2013-2015.
532. Environment Protection Authority (EPA) Victoria, 'Unpublished data', Carlton, Victoria, Accessed 2022.
533. Colours indicate the average concentration of PM2.5 during the 3-year period of 2019-21.

Amenity and wellbeing

Indicator A:07 Pollen

A:07 Pollen						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide				New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator
Data source(s):	University of Melbourne					
Measure(s):	Grass pollen counts Other pollen counts					

Why this indicator?

Grass pollen is a focus in Victoria because it is a major outdoor allergen and impacts the health services.

NB: This is a new SoE 2023 indicator that was not included in the SoE 2018 Report. This indicator has been included to address a gap on pollen in previous SoE Reports.

Why this assessment in 2023?

Across the eight sites that monitor pollen in Victoria, there has been a generally increasing trend in the number of days of extreme or high grass pollen in Victoria during grass pollen seasons since 2017. Demonstrating the effect of increasing grass pollen, Bendigo recorded 59 days of extreme or high grass pollen levels in the most recently completed grass pollen season (October to December 2021).

Most recently, the increasing grass pollen has been influenced by a multi-year La Niña state that has been leading to increased rainfall and grass pollen. This is the basis for the trend assessment of deteriorating. However, from 2017 to 2019 (prior to the La Niña state), there was still an average of 20 to 40 days of extreme or high grass pollen per season across Victoria.

Summary of State of the Environment 2018 Report assessment

- New SoE 2023 indicator

Critical data used for the 2023 assessment

- University of Melbourne pollen monitoring data

2023 assessment

Victoria's pollen monitoring network

Victoria's pollen monitoring network is funded by the Victorian government and operates for three months of the year (October to December) because it is targeted at grass pollen and thunderstorm asthma forecasting.

The network comprises eight monitoring sites located in Bendigo, Burwood, Churchill, Creswick, Dookie, Geelong, Hamilton and Parkville, with each site reporting once every 24 hours during the operating months. As of June 2022, the underlying information technology infrastructure that records, transmits and maintains the data and produces the forecasts is operated by the University of Melbourne.

Grass pollen

Grass pollen is a focus of the pollen monitoring in Victoria because it is a major outdoor allergen that impacts the community's health and wellbeing, and hence health service demand, including through thunderstorm asthma. More information on the impacts of pollen is provided in indicator 'A:14 Health impacts from pollen'.

534. Schäppi GF, Taylor PE, Kenrick J, Staff IA, Suphioglu C 1998, 'Predicting the grass pollen count from meteorological data with regard to estimating the severity of hayfever symptoms in Melbourne (Australia)', *Aerobiologia* 14, 29.

Figure A22 shows the number of days of extreme or high grass pollen in Victoria during the 92-day grass pollen season (October to December) each year from 2017 to 2021. Extreme or high grass pollen days are the bad days for people allergic to grass pollen.[534] Across the eight monitored sites there has been a generally increasing trend in the number of days of extreme or high grass pollen in Victoria during grass pollen seasons since 2017 — this is reflected in a trend assessment of deteriorating for this indicator. Most recently the increasing grass pollen has been influenced by a multi-year La Niña state that has been leading to increased rainfall and grass pollen.

However, from 2017 to 2019 (prior to the La Niña state) there was still an average of between 20 to 40 days of extreme or high grass pollen per season across Victoria.

Demonstrating the effect of increasing grass pollen, Bendigo recorded 59 days of extreme or high grass pollen in the most recently completed grass pollen season (October to December in 2021). This means there was high or extreme grass pollen for 64% of the season. In other words, during 2021, nearly two out of every three days during the grass pollen season in Bendigo were bad grass pollen days.

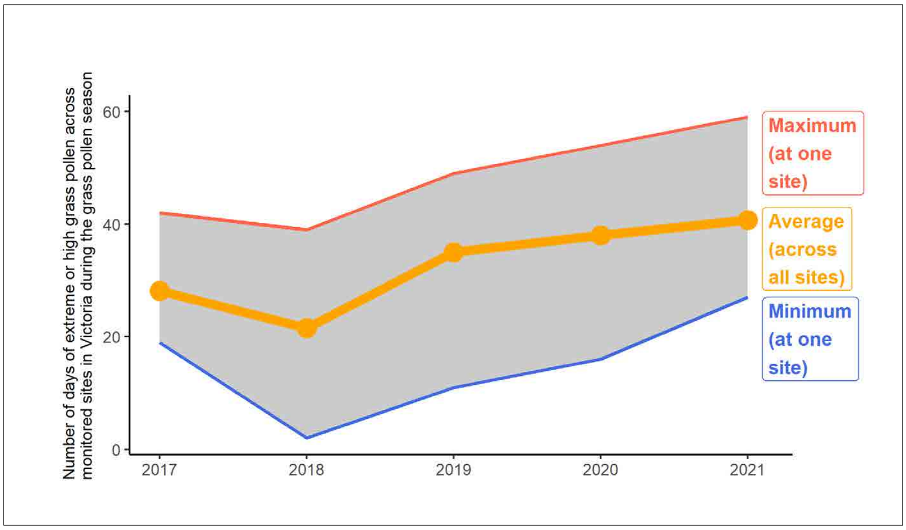


Figure A22: Number of days of extreme or high grass pollen across monitored sites in Victoria during the grass pollen season (October-December) from 2017 to 2021.[535]

Grass pollen abundance is closely linked to rainfall. For example, a wet spring can increase grass growth and result in more abundant flowering and a heavier pollen season. The size of the grass pollen season can be estimated, for example, using satellite data measuring the greenness of Victoria's grasslands; however, the ability to produce these estimates is currently limited by the paucity of available data.[536]

535. The University of Melbourne, 'Unpublished data', Parkville, Victoria, Accessed 2022.
536. University of Melbourne 2021, 'Severity of Melbourne's pollen season hanging on rain', Parkville, Victoria, https://pursuit.unimelb.edu.au/articles/severity-of-melbourne-s-grass-pollen-season-hanging-on-rain Accessed 3 June 2022.

Other types of pollen

As well as grass pollen, University of Melbourne researchers have also been counting the total loads of pollen in the air, which is the sum of grass and all the 'other' pollen types. The 'other' pollen load can be significant. For instance, in Melbourne during September (and likely earlier) there is around five times more pollen in the air than at any other time, and it is mostly 'other' pollen. Even during November, when grass pollen levels are often at their highest, there is often just as much, if not more, 'other' pollen in the air (Figure A23).[537] There is uncertainty around the health impacts from 'other' pollen, which is highlighted as a knowledge gap in indicator 'A:14 Health impacts from pollen'.

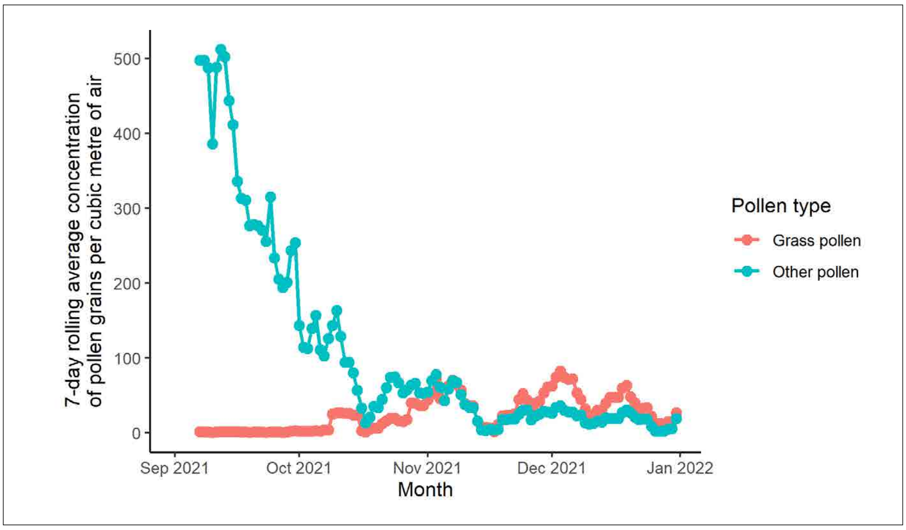


Figure A23: Pollen concentrations during the 2021 pollen season. Grass pollen concentration indicated in blue and 'other' pollen in orange.[538, 539]

Automated pollen counting

The current pollen monitoring process is labour-intensive and uses technology that is more than 50 years old. Australia's first automated pollen counter — which is expected to significantly improve the way airborne pollen is recorded and help people with hay fever (allergic rhinitis) or asthma better manage their allergies — was installed by researchers at the University of Melbourne's Parkville campus during 2021 as part of a trial.[540] Automated monitoring has the potential to include more pollen types, as well as extending coverage to more of the state, providing continual pollen counts 24 hours a day, 365 days a year. This would enable a greater understanding of pollen and its health implications, including rare, but potentially deadly, thunderstorm asthma.

Initial results from the automated pollen counter in Parkville show a distinct diurnal profile for grass pollen, with the worst part of the high or extreme grass pollen days often being the period from late morning to early evening (Figure A24).

537. University of Melbourne 2022, 'Melbourne's pollen riddle', Parkville, Victoria, https://pursuit.unimelb.edu.au/articles/melbourne-s-pollen-riddle Accessed 3 June 2022.
538. The University of Melbourne, 'Unpublished data', Parkville, Victoria, Accessed 2022.
539. University of Melbourne 2022, 'Melbourne's pollen riddle', Parkville, Victoria, https://pursuit.unimelb.edu.au/articles/melbourne-s-pollen-riddle Accessed 19 August 2022.
540. University of Melbourne 2022, ' Automated pollen counter to revolutionise hay fever management', Parkville, Victoria, https://www.unimelb.edu.au/newsroom/news/2022/january/Automated-pollen-counter-to-revolutionise-hay-fever-management Accessed 3 June 2022.

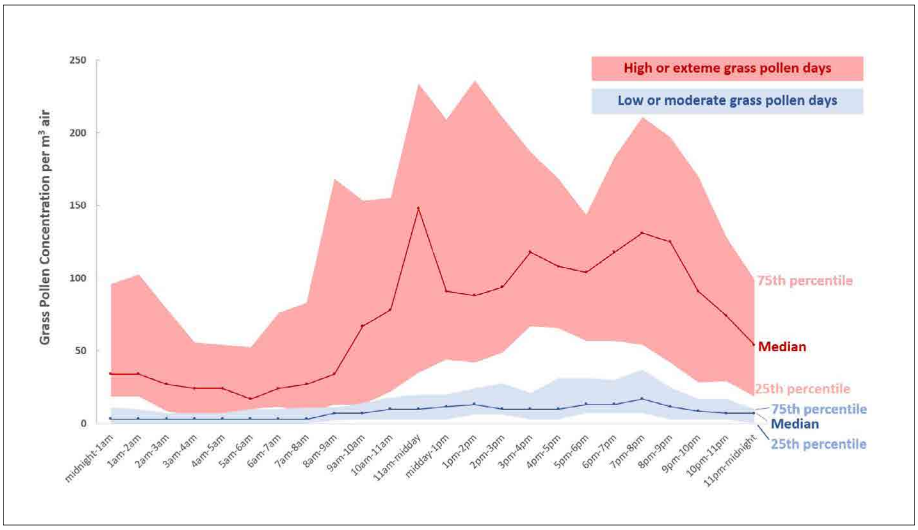
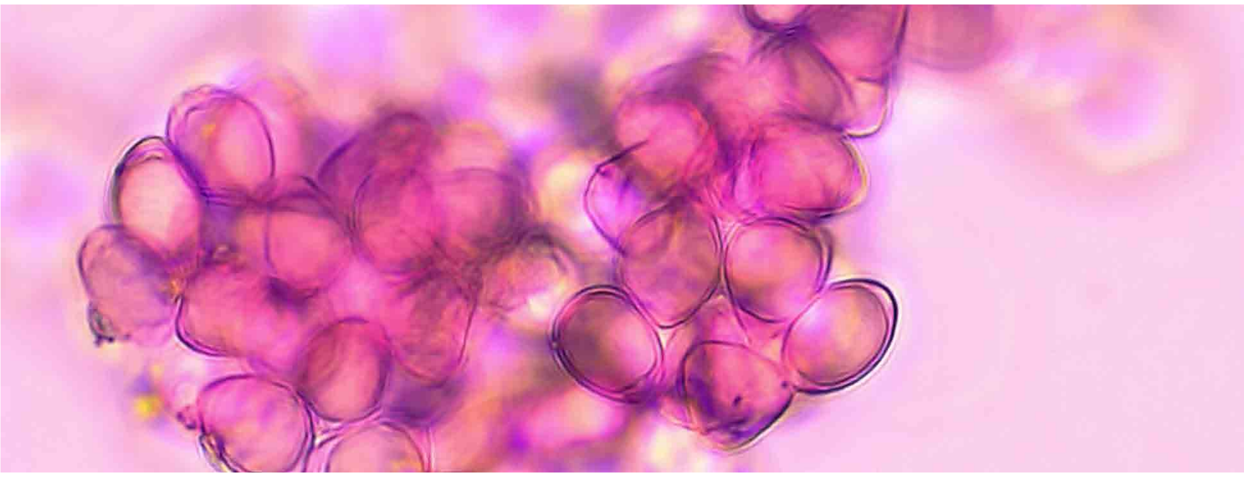


Figure A24: Hourly grass pollen concentrations at Parkville for various percentile ranges, displayed on days with high or extreme grass pollen (in pink) and days with low or moderate grass pollen (in blue).[541]

The use of an automated pollen counter in Victoria is occurring as the international pollen research community embarks on a shift to automated pollen counters. In 2021, Switzerland's Federal Office of Meteorology and Climatology installed a network of 10 automated pollen counters and began publishing the data online.[542] The automated pollen counters are being used to significantly improve the pollen forecasts and the quality of information available to people with allergies, medical practitioners, and for research.

The prospect of this type of real-time monitoring information being publicly accessible in several places within Victoria, combined with pollen forecasts for different parts of the day (rather than daily forecasts), provides potential for Victorians with hay fever or asthma to better manage their daily activities to minimise their exposure to the worst pollen concentrations.



Pollen under the microscope – pollen counting technology is revolutionising the way airborne pollen is recorded to help hay fever sufferers. © The University of Melbourne.

541. The University of Melbourne, 'Unpublished data', Parkville, Victoria, Accessed 2022.
542. Federal Office of Meteorology and Climatology, 'Automatic pollen measurement network', Zürich, Switzerland, https://www.meteoswiss.admin.ch/home/measurement-and-forecasting-systems/land-based-stations/automatic-pollen-measurement-network.html Accessed 3 June 2022.

Indicator A:08 Odour

A:08 Odour						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide						
Data source(s):	EPA Victoria					
Measure(s):	Number of odour pollution reports					

Why this indicator?

Impacts from odour are a significant issue in Victoria, both in terms of amenity and complaints to regulators. Excessive exposure to odour can have serious impacts on liveability. Short-term exposure to offensive odour can cause health effects such as irritation of the eyes, nose and throat, coughing, nausea and headaches. It can also affect sleep and the ability to exercise.

NB: This is a modified SoE 2023 indicator that was formed by disaggregating the measures of the SoE 2018 indicator 'A:06 Odour and noise'.

Why this assessment in 2023?

Odour is generally the type of pollution most frequently reported to EPA Victoria, with the regulator receiving more than 3,000 odour reports in each of the past nine years. This highlights a significant number of odour impacts occurring in Victoria. A fair status has been assessed to reflect this impact while also being cognisant of EPA Victoria's achievements in supporting and regulating industry to improve odour-management practices that reduce odour impacts on communities over time.

Summary of State of the Environment 2018 Report assessment

- Odour is the type of pollution most frequently reported to EPA.
- Apart from a spike in 2014, odour reports have generally increased from 2013 to 2017.

Critical data used for the 2023 assessment

- EPA Victoria Pollution Report data.

2023 assessment

Odour is generally the type of pollution most frequently reported to EPA Victoria. The regulator received more than twice as many complaints about odour from 2012-13 to 2019-20 (Figure A25) than about noise, the next most-frequent source of complaints in that period.[543] Offensive odour can cause a variety of health and amenity impacts in human beings, and can result in harm to human health and to the environment.[544]

In 2020-21, the shift to remote working due to COVID-19 restrictions was attributed with increasing numbers of noise reports, therefore, even though the number of odour pollution reports increased in 2020-21, it dropped to being the second most reported type of environmental pollution.

543. Environment Protection Authority (EPA) Victoria, 'Unpublished data', Carlton, Victoria, Accessed 2022.
544. Senior Odour Engineer, Environment Protection Authority (EPA) Victoria, personal communication, 13 May 2022.

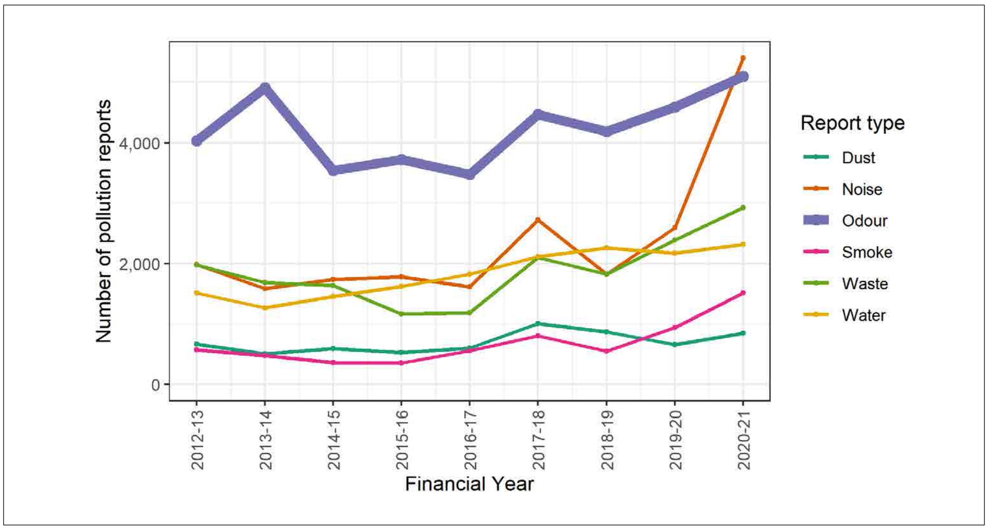


Figure A25: Number of pollution reports received by EPA Victoria each financial year from 2012-13 to 2020-21.[545]

Although the number of odour pollution reports received by EPA Victoria has increased in three of the past four years, it is not necessarily reflective of increasing odour impacts because some of the increase in pollution reporting is likely to be attributable to improved community awareness and accessibility to reporting pollution to EPA Victoria.

Sources of odour

Landfills and meat renderers have historically dominated the list of the 10 most frequently alleged sources of odour pollution.[546] Due to historical planning decisions, residential areas are located near these types of industrial facilities in some locations where there is an ongoing likelihood of odour impacts. However, during recent years, there has been a reduction in odour from some landfills and meat renderers, and other odour sources are emerging as major odour sources. Manufacturers, including wood product and paper manufacturers, as well as paper-recycling mills were significant odour contributors in Victoria during 2020-21.[547] A recent example from May 2022 shows that coffee roasting has become an important activity for odour management, with EPA Victoria issuing a second remedial notice over offensive odour and smoke from a coffee roasting facility in Preston.[548]

Locations of odour hot spots

The location of pollution reports is heavily weighted towards populated areas and industrial precincts: areas with more people and more pollution sources are, on balance, more likely to have more pollution reports. Because of this, pollution reports are presented in Table A8 as the total number of reports for each local government area (LGA) and the per capita reports for each LGA. Table A8 shows the seven LGAs that rank in the top five for odour pollution reports, either for total number of reports or per capita. As it was for the previous SoE Report (2013-17 data), Hobsons Bay ranks in the top five for both total odour pollution reports and reports per capita. Brimbank now also ranks in the top five for both metrics, while Kingston has dropped from being the LGA with the most odour pollution reports (for 2013-2017) to the fourth most in this period. The results for Hobsons Bay and Brimbank represent an increasing number of odour pollution reports in those LGAs, while the number of odour pollution reports in Kingston has been decreasing.

545. Environment Protection Authority (EPA) Victoria, 'Unpublished data', Carlton, Victoria, Accessed 2022.
546. Commissioner for Environmental Sustainability (CES) 2019, 'State of the Environment 2018 Report', Melbourne, Victoria.
547. Environment Protection Authority (EPA) Victoria, 'Unpublished data', Carlton, Victoria, Accessed 2022.
548. Environment Protection Authority (EPA) Victoria 2022, 'Trouble brewing for popular coffee maker', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/news-media-and-updates/media-releases-and-news/trouble-brewing-for-popular-coffee-maker Accessed 14 July 2022.

Table A8: Top five LGAs for odour pollution reports (by total number of reports and by reports per capita) received by EPA Victoria from 2016-17 to 2020-21.[549]

LGA	Average number of odour reports per year	Rank (total number of reports)	Rank (per capita)
Hobsons Bay	552	1	1
Brimbank	509	2	3
Casey	437	3	11
Kingston	250	4	6
Ballarat	245	5	4
Maribyrnong	167	6	5
Hepburn	47	14	2

There are some associations between per capita pollution reporting hotspots and socio-economic disadvantage. Victorians living in less affluent areas are reporting disproportionately more impacts from odour.

The location of odour hot spots in the Melbourne metropolitan area is represented by the red dots in the heat map in Figure A26, which shows Melbourne's west and south-east are the most affected by odour issues.

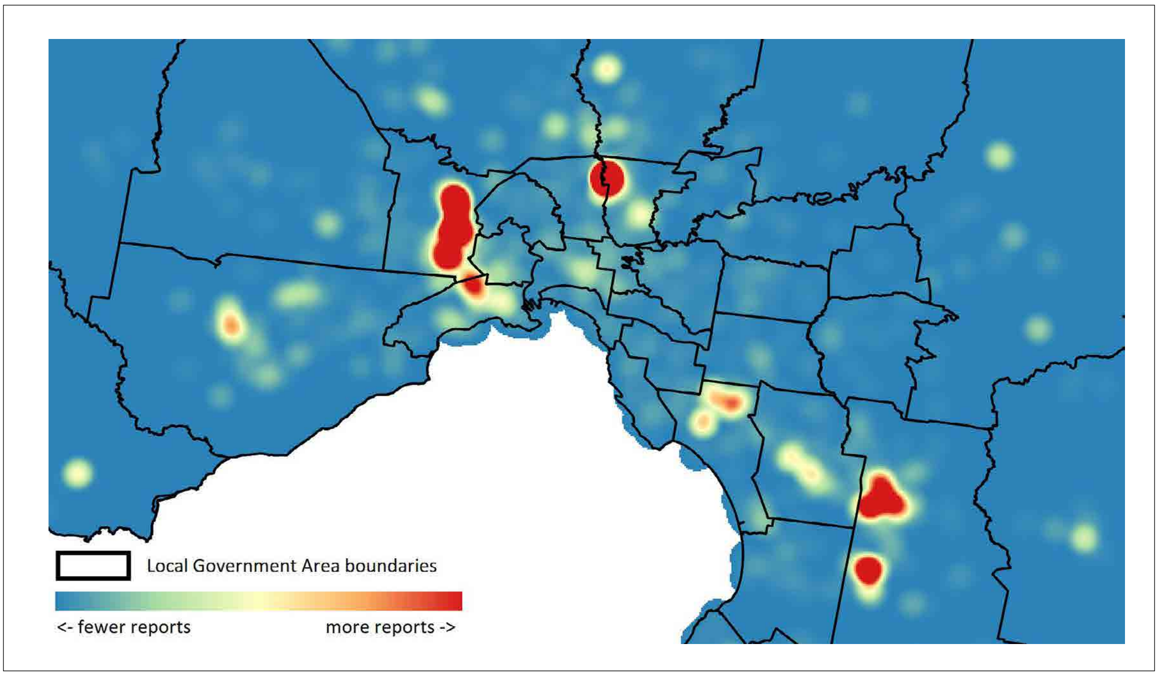


Figure A26: Odour pollution reporting hotspots in Melbourne during 2021-22.[550]

549. Environment Protection Authority (EPA) Victoria, 'Unpublished data', Carlton, Victoria, Accessed 2022.
550. Ibid.

Odour management and regulation in Victoria

An independent Inquiry into EPA Victoria was completed in 2016 and included a recommendation for EPA Victoria to develop, as a priority, strengthened land-use planning mechanisms that establish and maintain buffers to separate conflicting land uses, avoid encroachment problems, help manage health, safety and amenity impacts, and ensure integration with EPA Victoria regulatory requirements. As part of its response to this recommendation, and the EP Act that came into force in 2021, EPA Victoria has revised the odour assessment framework in Victoria, focusing on the need to minimise harm to human health and the environment, rather than the previous concept that was compliance with a set level (that is, polluting up to a limit).

As part of the new regulatory and odour management paradigm, EPA Victoria has:

- Developed improved processes for odour reporting from the community, including tools to help community reporters better describe the odour, which helps EPA Victoria pinpoint the odour source.
- Developed and published formal guidance on conducting odour assessments to support land use and industrial development applications.[551]
- Developed contemporary guidance materials for industries to apply best available techniques and technologies in odour control. Fact sheets have been developed for: biofilters (biofilter design and maintenance is also covered by a specific publication), odour capture, stacks, containment, scrubbers, photo-ionisation, site planning and management, covers, metal sintered filters, bio-trickling filters and bio-scrubbers, carbon filters, metal mesh filters, effective microbes and thermal oxidisers.[552] Anecdotally, the guidance from these fact sheets is being incorporated into remedial notices.
- Established stronger powers via the EP Act that changed Victoria's focus for environment protection and human health to a prevention-based approach. Since 2021, EPA Victoria has enhanced powers and tools to prevent and minimise the risks of harm to human health and the environment from pollution and waste. It also provides EPA Victoria with the ability to pursue stronger sanctions and penalties to hold environmental polluters to account.[553]
- Published guidance on odour surveillance to boost its capability to evaluate the extent, source and frequency of odour emissions.[554]

551. Environment Protection Authority (EPA) Victoria 2022, 'Guidance for assessing odour - 1883', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/1883Accessed 9 December 2022.
552. Environment Protection Authority (EPA) Victoria 2022, '1880: Biofilter design and maintenance', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/1880 Accessed 9 December 2022.
553. Environment Protection Authority (EPA) Victoria, 'Laws and regulations', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/laws Accessed 14 July 2022.
554. Environment Protection Authority (EPA) Victoria 2021, '1881: Guidance for field odour surveillance', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/1881 Accessed 14 July 2022.

Indicator A:09 Noise

A:09 Noise						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide						

Data source(s):	EPA Victoria
Measure(s):	Noise pollution reports Modelled noise level exposures

Why this indicator?

Impacts from noise are a significant issue in Victoria, both in terms of amenity and complaints to regulators. Excessive exposure to noise can have serious impacts on liveability and human health.

NB: This is a modified SoE 2023 indicator that was formed by disaggregating the measures of the SoE 2018 indicator 'A:06 Odour and noise'.

Why this assessment in 2023?

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

Summary of State of the Environment 2018 Report assessment

- Noise is the type of pollution second most frequently reported to EPA Victoria (after odour).
- Noise reports were generally stable from 2013 to 2016 until a spike of reports in 2017.

Critical data used for the 2023 assessment

- EPA Victoria Pollution Report data

2023 assessment

Environmental noise is defined as unwanted or harmful outdoor sound created by human activity, such as noise emitted by means of transport, road traffic, rail traffic, air traffic and industrial activity.[555]

Noise pollution reports

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 the custodian. However, EPA Victoria's noise pollution report data provides limited insight to some major issues, such as residential and traffic noise. As was noted in the SoE 2018 Report, future noise reporting needs to include assessments of noise monitoring and pollution reports from local councils and Victoria Police.[556]

The recent history (2012-13 to 2020-21) of noise pollution reporting in Victoria (Figure A27) demonstrates a:

- Stable frequency of noise pollution reporting from 2012-13 to 2016-17, with between 1,587 and 1,987 reports received each year by EPA Victoria.[557, 558, 559]

555. Murphy E, King E 2014, 'Environmental Noise Pollution: Noise Mapping, Public Health, and Policy', Elsevier, ISBN 9780124115958, https://doi.org/10.1016/B978-0-12-411595-8.00001-X Accessed 12 May 2023.
556. Commissioner for Environmental Sustainability (CES) 2019, 'State of the Environment 2018 Report', Melbourne, Victoria.
557. Environment Protection Authority (EPA) Victoria 2015, 'Annual report for 2014-15', Carlton, Victoria.
558. Environment Protection Authority (EPA) Victoria 2016, 'Annual report for 2015-16, Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/1635 Accessed 14 July 2022.
559. Environment Protection Authority (EPA) Victoria 2017, 'Annual report for 2016-17, Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/1665 Accessed 14 July 2022.

- Significant spike in noise reports to EPA Victoria in 2017-18, when 2,726 reports were 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.[560]
- Reduction to below 2,000 for the number of noise pollution reports received by EPA Victoria during 2018-19.[561]

The sharp increase from March 2020 coincides with the shift to remote working due to COVID-19.[562, 563] It is likely that this distinct increase was because more people were working from home during this period and were hearing more residential and industrial noise than when they would previously have been at their place of work.[564] This has likely been compounded by measures adopted to facilitate the operation of essential business, such as noise exemptions.[565, 566] Similarly, an increase in reports for noise from entertainment venues was observed from November 2020, which has been linked with 'outdoor activation' measures initiated at that time, where bars and restaurants were allowed to establish or expand outdoor areas to enable the reopening of hospitality and entertainment venues while mitigating transmission of COVID-19 in indoor environments.[567, 568]

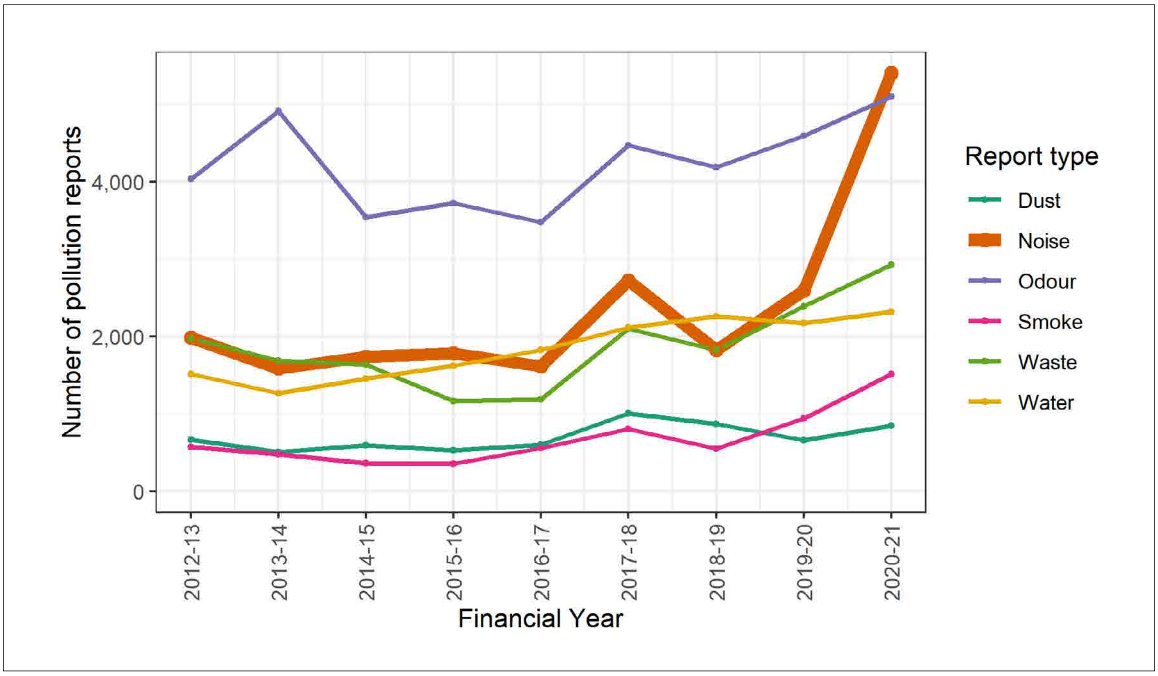


Figure A27: Number of pollution reports received by EPA Victoria each financial year from 2012-13 to 2020-21.[569]

560. Commissioner for Environmental Sustainability (CES) 2019, 'State of the environment 2018 report', Melbourne, Victoria.
561. Environment Protection Authority (EPA) Victoria 2020, 'Annual report for 2019-20, Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/1899 Accessed 14 July 2022.
562. Environment Protection Authority (EPA) Victoria 2021, 'Annual report for 2020-21, Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/2027 Accessed 14 July 2022.
563. Buret M, Just E 2021, 'Evolution of noise pollution reports during COVID-19', *Proceedings of Meetings on Acoustics 2021*, Wollongong, New South Wales, 21-23 February 2022, https://acoustics.asn.au/conference_proceedings/AAS2021/papers/p89.pdf Accessed 27 September 2022.
564. Environment Protection Authority (EPA) Victoria 2022, 'Noise pollution reports on the increase', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/news-media-and-updates/media-releases-and-news/noise-pollution-reports-on-the-increase Accessed 7 June 2022.
565. Buret M, Just E 2021, 'Evolution of noise pollution reports during COVID-19', *Proceedings of Meetings on Acoustics 2021*, Wollongong, New South Wales, 21-23 February 2022, https://acoustics.asn.au/conference_proceedings/AAS2021/papers/p89.pdf Accessed 27 September 2022.
566. Environment Protection Authority (EPA) Victoria 2020, 'Annual report for 2019-20, Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/1899 Accessed 14 July 2022.
567. Buret M, Just E 2021, 'Evolution of noise pollution reports during COVID-19', *Proceedings of Meetings on Acoustics 2021*, Wollongong, New South Wales, 21-23 February 2022, https://acoustics.asn.au/conference_proceedings/AAS2021/papers/p89.pdf Accessed 27 September 2022.
568. Environment Protection Authority (EPA) Victoria, 'New guidance for outdoor music noise during coronavirus (COVID-19)', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/news-media-and-updates/coronavirus/noise-during-coronavirus/how-to-manage-outdoor-music-noise-during-coronavirus Accessed 9 December 2022.
569. Environment Protection Authority (EPA) Victoria, 'Unpublished data', Carlton, Victoria, Accessed 2022.

Given the likelihood of many people continuing to work from home full-time or part-time in the post-pandemic working environment, it is anticipated that the doubling of noise pollution reports received by EPA Victoria in 2020-21 is likely to be representative of a 'new normal' of noise experienced by the community.

Modelling environmental noise

EPA Victoria reported in its 2020-21 Annual Report that its environmental public health function and the ACU have collaborated to address a knowledge gap relating to spatial analysis of environmental noise in Melbourne.[570] EPA Victoria has provided preliminary analysis from this work highlighting initial modelling estimates for noise exposures at the building level — this is shown in Figure A28 and can be used by the regulator and researchers to quantify the population exposure to noise pollution.

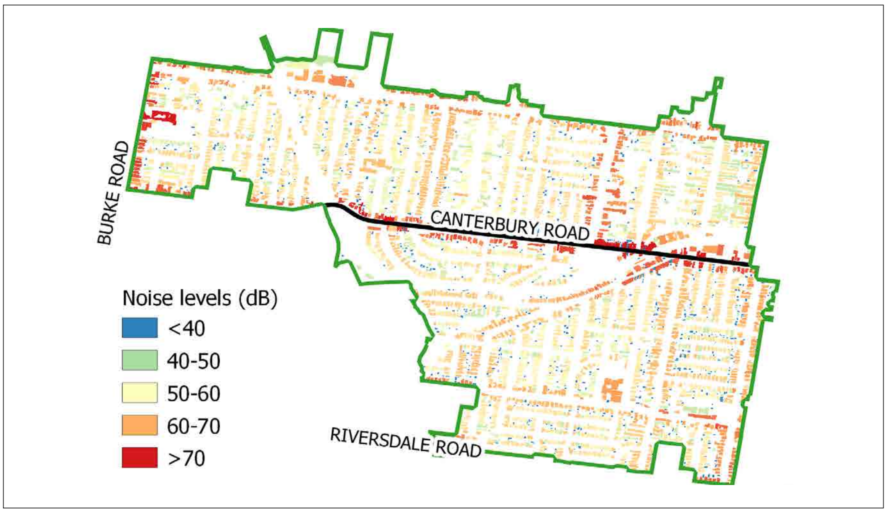


Figure A28: Modelled road noise exposures at the building level across Canterbury, Melbourne.[571, 572]

Managing and regulating environmental noise

In preparation for the EP Act that came into force in 2021, EPA Victoria published guidance material for a range of noise-related topics including: noise technical guidance, residential equipment assessment, low frequency noise, and measuring and analysing industry noise and music noise.[573]

EPA Victoria also developed a toolkit to support local government officers working in residential noise compliance and enforcement in Victoria.[574] Fact sheets have also been developed for: site planning and management, acoustic louvres, barriers and enclosures, duct attenuators/silencers, mufflers/exhaust silencers, pipe lagging, vibration isolation and managing noise from trucks and reverse beepers.[575, 576, 577, 578, 579, 580, 581, 582, 583]

570. Environment Protection Authority (EPA) Victoria 2021, 'Annual report for 2020-21, Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/2027 Accessed 14 July 2022.
571. Environment Protection Authority (EPA) Victoria, 'Unpublished data', Carlton, Victoria, Accessed 2022.
572. The data used in the map were produced by Dr Rachel Tham, Dr David Donaire-Gonzalez, Dr Miguel Alvarado-Molina and Dr Amanda Wheeler under an EPA Victoria Science Division Project Contract with the ACU.
573. Environment Protection Authority (EPA) Victoria 2021, 'Annual report for 2020-21, Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/2027 Accessed 14 July 2022.
574. Environment Protection Authority (EPA) Victoria 2021, 'Regulating residential noise: local government toolkit', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/1969 Accessed 9 December 2022.
575. Environment Protection Authority (EPA) Victoria 2021, '1884: Site planning and management', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/1884 Accessed 9 December 2022.
576. Environment Protection Authority (EPA) Victoria 2021, '1885: Noise: Acoustic louvres', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/1885 Accessed 9 December 2022.
577. Environment Protection Authority (EPA) Victoria 2021, '1886: Noise: Barriers and enclosures', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/1886 Accessed 9 December 2022.
578. Environment Protection Authority (EPA) Victoria 2021, '1887: Noise: Duct attenuators or silencers', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/1887 Accessed 9 December 2022.
579. Environment Protection Authority (EPA) Victoria 2021, '1888: Noise: Mufflers or exhaust silencers', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/1888 Accessed 9 December 2022.
580. Environment Protection Authority (EPA) Victoria 2021, '1889: Using pipe lagging to eliminate or reduce the risk of harm from noise', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/1889 Accessed 9 December 2022.
581. Environment Protection Authority (EPA) Victoria 2021, '1890: Managing noise from reversing alarms', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/1890 Accessed 9 December 2022.
582. Environment Protection Authority (EPA) Victoria 2021, '1891: Managing truck noise', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/1891 Accessed 9 December 2022.
583. Environment Protection Authority (EPA) Victoria 2021, '1892: Noise: Vibration isolation', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/1892 Accessed 9 December 2022.

Indicator A:10 Light pollution

A:10 Light pollution						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide		↙			?	
Data source(s):	Academic researchers					
Measure(s):	Artificial sky brightness as a ratio to the natural sky brightness					

Why this indicator?

Light pollution is excessive or obtrusive artificial light that has an adverse impact on biodiversity and human health. It is a global issue, impacting at both national and regional scales, and increasing in prevalence as the world becomes more populated and industrialised. In addition to the negative biodiversity and health effects, poorly designed outdoor lighting can be inefficient and drain energy resources while carrying a significant financial burden.

NB: This SoE 2023 indicator was 'A:07 Light pollution' in the SoE 2018 Report.

Why this assessment in 2023?

In contrast to the gradual increases in night-time light emissions observed across Melbourne's urban extent, dramatic increases in light pollution have been observed in Melbourne's growth areas. For example, the night-time light emissions in growth areas of Melbourne's outer western suburbs have nearly tripled from 2014 to 2021.

Summary of State of the Environment 2018 Report assessment

- Artificial lighting has reduced bat activity and species richness in Victoria as well as affecting bird survival patterns on Phillip Island.

Critical data used for the 2023 assessment

- Visible infrared imaging radiometer suite (VIIRS) data measured by the United States National Oceanic and Atmospheric Administration (NOAA) Earth observation group and published by Jurij Stare

2023 assessment

Impacts to wildlife from light pollution

Animals perceive light differently from humans and artificial light can disrupt critical behaviour in wildlife as well as cause physiological changes.[584] Light pollution threatens reproduction and migratory habits of insects, amphibians, fish, birds, bats and other animals, while a distortion of the natural day:night cycle can affect a wide variety of organisms, including most plants and animals.[585] Examples of these impacts in Victoria are:

- Fledgling seabirds may not take their first flight if their nesting habitat never becomes dark.[586] The State of the Marine and Coastal Environment 2021 Report contains further detail on the management interventions to mitigate the impacts of light pollution on short-tailed shearwaters (*Ardenna tenuirostris*) at Phillip Island.[587]
- Clownfish eggs incubated under constant light do not hatch.[588]

584. Russart K, Nelson R 2018, 'Artificial light at night alters behavior in laboratory and wild animals', *JEZ-A Ecological and Integrative Physiology*, 329(8-9), pp. 401-408.
585. Hölker F, Wolter C, Perkin E, Tockner K 2010, 'Light pollution as a biodiversity threat', *Trends in Ecology and Evolution*, 25, pp. 681–682.
586. Rodríguez A, Holmes N, Ryan PG, Wilson K-J, Faulquier L, Murillo Y, Raine AF, Penniman J, Neves V, Rodríguez B, Negro JJ, Chiaradia A, Dann P, Anderson T, Metzger B, Shirai M, Deppe L, Wheeler J, Hodum P, Gouveia C, Carmo V, Carreira GP, Delgado-Alburqueque L, Guerra-Correa C, Couzi FX, Travers M, Le Corre M 2017, 'A global review of seabird mortality caused by land-based artificial lights', *Conservation Biology*, 31, pp. 986-1001.
587. Commissioner for Environmental Sustainability (CES) 2021, 'State of the marine and coastal environment 2021 report - Part 3 scientific assessments', Melbourne, Victoria.
588. Fobert E, Burke da Silva K, Swearer SE 2019, 'Artificial light at night causes reproductive failure in clownfish', *Biology Letters*, 15, pp. e20190272.

- Streetlights attract invertebrates away from dark spaces, as observed in the City of Moreland, and were much worse under higher colour temperature (blue-rich) lighting. These effects can impact abundance and composition as well as behavioural responses, including disorientation and attraction/repulsion or increased mortality through exhaustion, predation, heat or collision.[589]
- Streetlight levels of artificial light disrupt sleep of pigeons and Australian magpies; for magpies these effects were worse under higher colour temperature lighting.[590]
- Artificial light reduces the size, development time and number of eggs produced, and increases juvenile mortality among orb-web spiders.[591]

Socio-economic impacts from light pollution

The artificial lighting of the night-time environment has brought many benefits to humankind. It has also given rise to substantial costs. In addition to the impacts on wildlife and ecosystems, artificial lighting impacts on human health and wellbeing, vehicle accidents, crime, aesthetics, energy consumption and carbon emissions.[592]

There are no published analyses on the socio-economic impacts of light pollution in Australia. Only sporadic international studies have been completed, with research published during 2010 finding that light pollution costs $7 billion annually in the United States.[593]

Policy and Management

The National Light Pollution Guidelines for Wildlife (Guidelines) was published by the Australian Government in January 2020.[594] In the introduction of these Guidelines, natural darkness was described as providing a conservation value in the same way that clean water, air, and soil has intrinsic value. The Guidelines outline the process to be followed where there is the potential for artificial lighting to affect wildlife. The Guidelines apply to new projects, lighting upgrades (retrofitting) and where there is evidence of wildlife being affected by existing artificial light.[595] However, it is unclear if these Guidelines have:

Raised awareness of the potential impacts of artificial light on susceptible wildlife.

Contributed to improved impact assessment and management for susceptible wildlife.

Measurement and trends

Even though there are no systematic measurements and analysis of light pollution conducted in Victoria, remote sensing can be used to identify and analyse light pollution.[596]

Global light pollution data have been collected from two satellite sensors covering time periods of 1992-2013 and 2012-present. The satellite sensors have important differences that means it is not possible to have a single record running from 1992 to today. Therefore, data collection commencing in 2012 from the currently operating instrument — Visible Infrared Imaging Radiometer Suite (VIIRS) — has been used to inform the assessment for this light pollution indicator. Using the VIIRS data, artificial light at night was estimated to be increasing globally by about 2% per year.[597]

VIIRS data are publicly available through online web applications and shows Victoria's artificial light at night is most pronounced over Melbourne (Figure A29).[598]

589. Lockett MT, Jones TM, Elgar MA, Gaston KJ, Visser ME, Hopkins GR 2021, 'Urban street lighting differentially affects community attributes of airborne and ground-dwelling invertebrate assemblages', *Journal of Applied Ecology*, 58, 2329– 2339.
590. Aulsebrook, AE, Connelly F, Johnsson RD, Jones TM, Mulder RA, Hall ML, Vyssotski AL, Lesku JA 2020, 'White and amber light at night disrupt sleep physiology in birds', *Current Biology*, 30(18), pp. 3657-3663, e5.
591. Willmott NJ, Henneken J, Selleck CJ, Jones TM 2018, 'Artificial light at night alters life history in a nocturnal orb-web spider', *PeerJ*, vol. 6 e5599.
592. Gaston KJ, Gaston S, Bennie J, Hopkins J 2014, 'Benefits and costs of artificial nighttime lighting of the environment', *Environmental Reviews, 23(1), pp. 14-23.*
593. Gallaway T, Olsen R, Mitchell D 2010, 'The economics of global light pollution', *Ecological Economics*, 69, pp. 658-665.
594. Commonwealth of Australia 2020, 'National light pollution guidelines for wildlife including marine turtles, seabirds and migratory shorebirds'.
595. Ibid.
596. Nurbandi W, Yusuf FR, Prasetya R, Afrizal MD 2016, 'Using Visible Infrared Imaging Radiometer Suite (VIIRS) Imagery to identify and analyze light pollution', *IOP Conference Series: Earth and Environmental Science*, 47.
597. Kyba C, Kuester T, Sánchez de Miguel A, Baugh K, Jechow A, Hölker F, Bennie J, Elvidge C, Gaston K, Guanter L 2017, 'Artificially lit surface of Earth at night increasing in radiance and extent', *Science Advances*, 3(11), e1701528.
598. Jurij Stare 'Light pollution map' https://www.lightpollutionmap.info/help.html

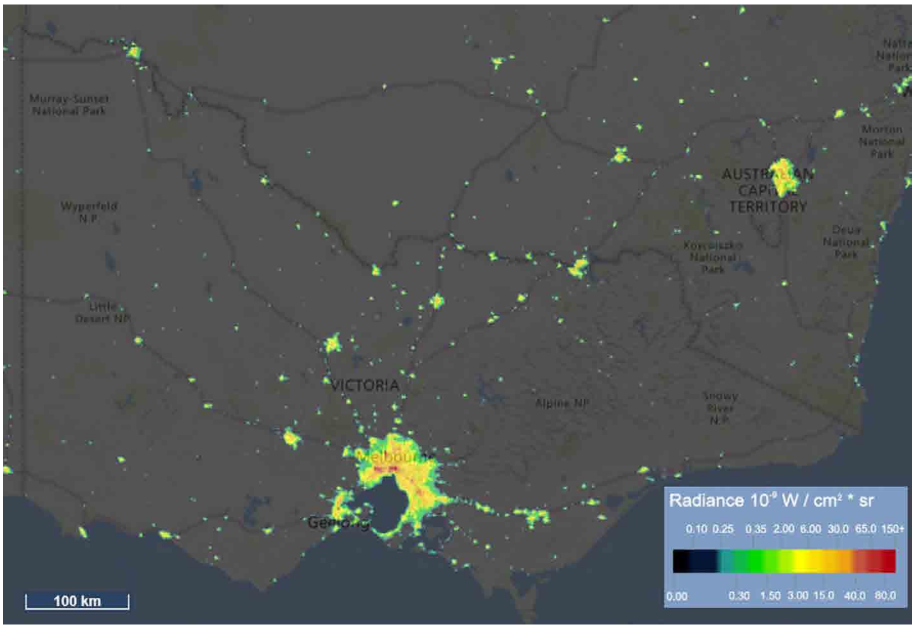


Figure A29: Image of artificial light at night across Victoria using VIIRS data for 2021.[599, 600, 601]

Using the web applications, it is possible to calculate changes in night-time light emissions for areas less than 10,000 km^2. For this report, polygon shapefiles covering the urban extent of Melbourne and growth areas of Melbourne's outer western suburbs have been used to assess night-time light emission trends.

Based on a polygon shapefile covering the urban extent of Melbourne (Figure A30), there has been a 5% total increase in night-time light emissions across Melbourne from 2014 to 2021.

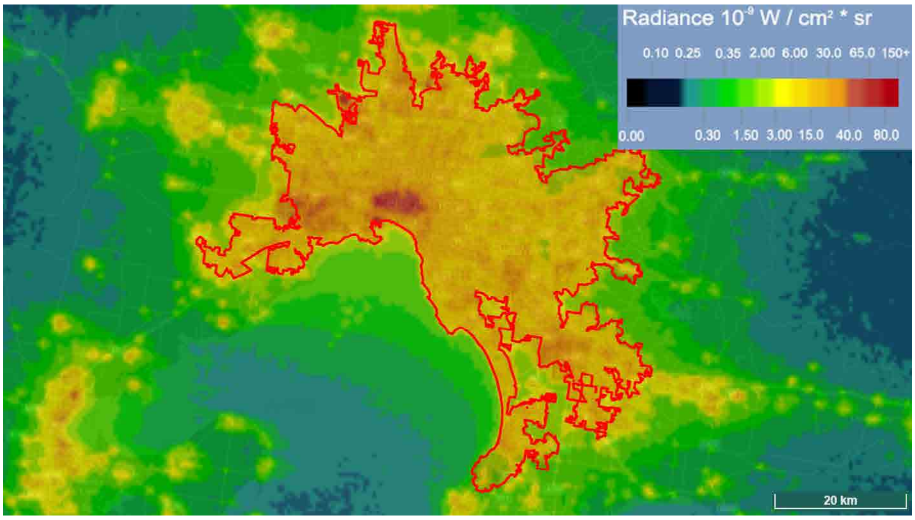


Figure A30: Image of artificial light at night across Melbourne for 2021. The red polygon represents the urban extent of Melbourne.[602, 603, 604]

599. National Oceanic and Atmospheric Administration (NOAA) Earth observation group, 'Visible infrared imaging radiometer suite (VIIRS)' National Geophysical Data Center, Washington, D.C., United States of America, https://ngdc.noaa.gov/eog/viirs/index.html Accessed 13 May 2022.
600. Jurij Stare, 'Light pollution map' https://lighttrends.lightpollutionmap.info/ Accessed 13 May 2022.
601. The unit of radiance is W/cm^2 * sr, which is a SI radiometry unit for radiance. Radiance is radiant flux emitted, reflected, transmitted or received by a surface, per unit solid angle per unit projected area.
602. National Oceanic and Atmospheric Administration (NOAA) Earth observation group, 'Visible infrared imaging radiometer suite (VIIRS)' National Geophysical Data Center, Washington, D.C., United States of America, https://ngdc.noaa.gov/eog/viirs/index.html Accessed 13 May 2022.
603. Jurij Stare, 'Light pollution map' https://lighttrends.lightpollutionmap.info/ Accessed 13 May 2022.
604. Department of Environment, Land, Water and Planning (DELWP) 2016, 'Plan Melbourne spatial data ESRI shape file format', Melbourne, Victoria, https://www.planmelbourne.vic.gov.au/__data/assets/file/0005/381254/Plan-Melbourne-Shape-Files.zip Accessed 13 May 2022.

Air

In contrast to the gradual increases in night-time light emissions across Melbourne's urban extent, there have been dramatic increases in Melbourne's growth areas. For example, the night-time light emissions in growth areas of Melbourne's outer western suburbs have nearly tripled (an increase of 171%) since 2014 (Figure A31 and Figure A32). The growth areas were derived from the Victorian Planning Authority's Precinct Structure Plan data.

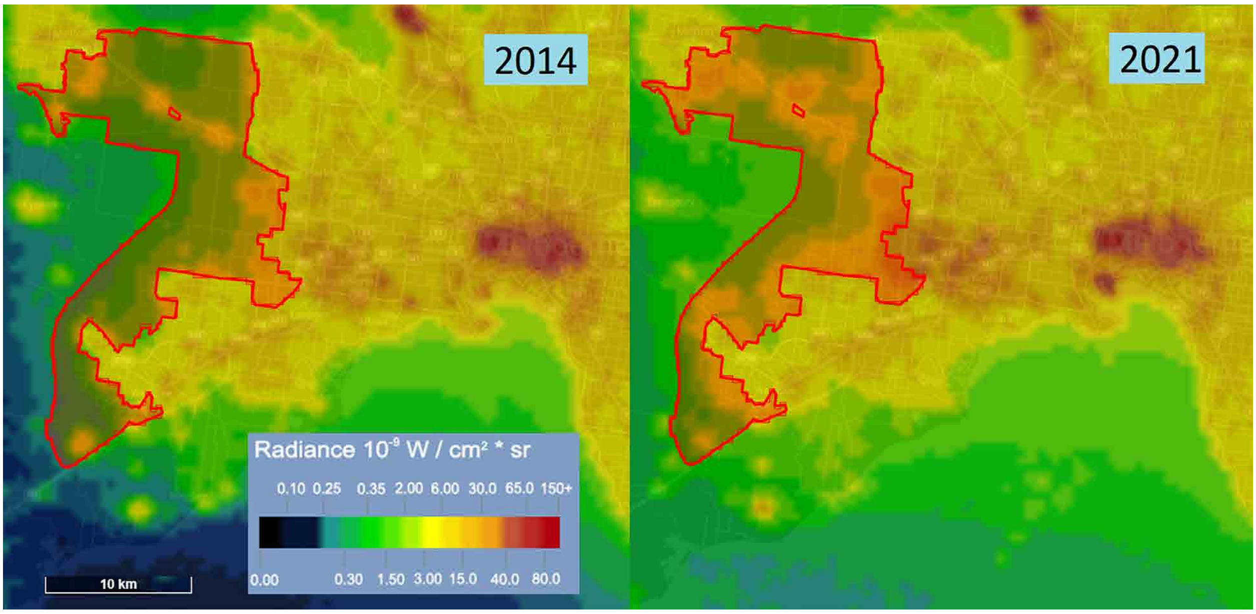


Figure A31: Image of artificial light at night across Melbourne for 2014 (left) and 2021 (right). The red polygon represents growth areas of Melbourne's outer western suburbs.[605, 606, 607]

Figure A32 shows an underlying trend of increasing night-time light emissions, noting that the apparent decrease in emissions around 2016 likely reflects a change in light wavelength due to the rollout of light emitting diode (LED) streetlights at this time, rather than a genuine decrease in light emissions.[608]

605. National Oceanic and Atmospheric Administration (NOAA) Earth observation group, 'Visible infrared imaging radiometer suite (VIIRS)' National Geophysical Data Center, Washington, D.C., United States of America, https://ngdc.noaa.gov/eog/viirs/index.html Accessed 13 May 2022.
606. Jurij Stare, 'Light pollution map' https://lighttrends.lightpollutionmap.info/ Accessed 13 May 2022.
607. Department of Environment, Land, Water and Planning (DELWP) 2016, 'Plan Melbourne Spatial Data ESRI Shape file format', Melbourne, Victoria, https://www.planmelbourne.vic.gov.au/__data/assets/file/0005/381254/Plan-Melbourne-Shape-Files.zip Accessed 13 May 2022.
608. From around 2016 many local government areas and network operators replaced existing lighting with 4000K light emitting diodes (LEDs). The 4000K LEDs contain a higher proportion of short wavelength (blue and violet) light, and a lower proportion of long wavelength (amber) light than older technologies (e.g. sodium lights). The VIIRS satellite sensor doesn't detect short wavelength light. Accordingly, the change in lighting technology and shift in spectrum appears as a reduction in overall light emitted in around 2016, even though this is unlikely to be the case. In addition, the increasing preponderance of LED lighting since 2016 means that VIIRS no longer captures the full scope of lighting increases.

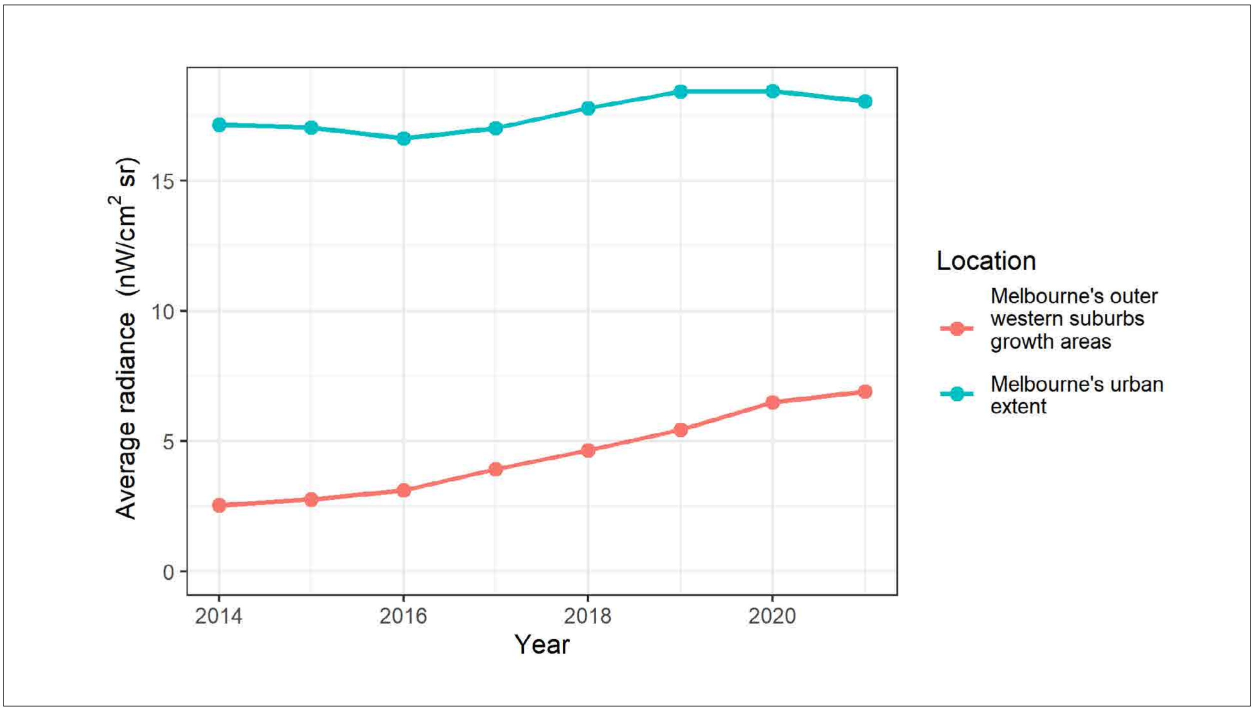


Figure A32: Annual night-time light emissions (nW/cm² * sr) across Melbourne's urban extent and outer western suburbs growth areas between 2014 and 2021.[609, 610, 611]

These data, albeit indicative due to imperfections associated with some wavelengths not able to be captured, highlight the significant risk and potential for impact of artificial light at night on susceptible wildlife and ecosystems in Melbourne's outer suburban growth areas.

The brief analysis presented above is important given the growth in Melbourne's outer western suburbs is occurring adjacent to sections of the Port Phillip (Western Shoreline) and Bellarine Peninsula Ramsar Site, including the Werribee-Avalon section that contains the Western Treatment Plant, which provides a haven to tens of thousands of birds, including seabirds and migratory shorebirds. The known adverse effects of artificial light at night on migratory shorebirds mean the increase in artificial light at night near the Werribee-Avalon section of the Port Phillip (Western Shoreline) and Bellarine Peninsula Ramsar Site is a risk to the birds using that habitat.[612]

609. The unit of radiance is W/cm² * sr, which is a SI radiometry unit for radiance. Radiance is radiant flux emitted, reflected, transmitted or received by a surface, per unit solid angle per unit projected area.
610. National Oceanic and Atmospheric Administration (NOAA) Earth observation group, 'Visible infrared imaging radiometer suite (VIIRS)' National Geophysical Data Center, Washington, D.C., United States of America, https://ngdc.noaa.gov/eog/viirs/index.html Accessed 13 May 2022.
611. Jurij Stare, 'Light pollution map' https://lighttrends.lightpollutionmap.info/ Accessed 13 May 2022.
612. Commonwealth of Australia 2020, 'National light pollution guidelines for wildlife including marine turtles, seabirds and migratory shorebirds'.

Health

Indicator A:11 Health impacts of air pollution

A:11 Health impacts of air pollution						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide		?			?	
Data source(s):	Academic researchers, EPA Victoria					
Measure(s):	Measures of health impacts due to anthropogenic air pollution include: • change in life expectancy from birth • Years of life lost (YLL) • economic cost associated with years of life lost.					

Why this indicator?

Poor air quality can harm people's health and quality of life, and has been linked to respiratory and cardiovascular health effects, and premature mortality. This indicator tracks progress in reducing the health burden associated with air pollution.

NB: This SoE 2023 indicator was 'A:09 Health impacts of air pollution' in the SoE 2018 Report.

Why this assessment in 2023?

Since the SoE 2018 assessments, researchers have been able to quantify the impact of long-term exposures to $PM_{2.5}$ on mortality. The average annual mortality burden for Victoria from exposure to anthropogenic $PM_{2.5}$, based on data from 2006 to 2016, was estimated to be more than 600 premature deaths. Researchers have determined that this is higher than community standards should allow, and reductions in emissions are recommended to avoid attributable mortality.

Summary of State of the Environment 2018 Report assessment

- Associations between adverse health effects and exposure to $PM_{2.5}$ have been found in Victoria.

Critical data used for the 2023 assessment

- EPA Victoria data on years of life lost (YLL) due to $PM_{2.5}$ in Statistical Area 4 areas of Victoria

2023 assessment

This indicator looks at major air pollution and health impact studies published since the SoE 2018 Report. The indicator is focused on Victorian studies, but relevant research from other states has also been included.

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. 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.[613]

613. Environment Protection Authority (EPA) Victoria 2018, 'Air pollution in Victoria – A summary of the state of knowledge', Publication 1709, Carlton, Victoria.

Indeed, research focussed on Sydney concluded that low-level air pollution exposure was associated with increased risk of mortality in adults aged 45 years and over, even at the relatively low concentrations seen in Sydney.[614] Because of this, the concept of continuous improvement is important for air-quality management. Gradually tightening air-quality standards and reducing pollutant concentrations and emissions are important markers for progress in reducing the health burden associated with air pollution. Several pollutants now have tighter air-quality standards than was the case when SoE 2018 Report was published; these are positive changes and are detailed within the indicator narratives of indicators A:01 to A:05 in this report.

Ambient $PM_{2.5}$ air pollution increases premature mortality globally. And while some $PM_{2.5}$ is natural, anthropogenic $PM_{2.5}$ is comparatively avoidable. A collaborative Australian research study from 2020 determined the impact of long-term exposures to the anthropogenic component of $PM_{2.5}$ on mortality in Australia based on data from 2006 to 2016. The average annual mortality burden for Victoria was estimated to be more than 600 premature deaths and nearly 10,000 YLL per year. Annually and nationally, anthropogenic $PM_{2.5}$ pollution was estimated to be associated with:

- 2,616 deaths (within a 95% confidence interval of 1,712 to 3,455)
- A 0.2-year reduction in life expectancy for children aged 0 to 4 years (within a 95% confidence interval of 0.14 to 0.28)
- 38,962 YLL (within a 95% confidence interval of 25,391 to 51,669)
- An average annual economic burden of $6.2 billion (within a 95% confidence interval of $4.0 billion to $8.1 billion).[615]

The researchers concluded that the anthropogenic $PM_{2.5}$ -related costs of mortality in Australia are higher than community standards should allow, and reductions in emissions are recommended to avoid $PM_{2.5}$ -attributable mortality.[616] 'Clean air for all Victorians' — Victoria's air-quality strategy — was released in 2022 and included a strategic objective to target the main causes of air pollution in Victoria, which should stimulate programs and projects that reduce anthropogenic $PM_{2.5}$-related costs of mortality.[617]

A preliminary evaluation of the health burden of the extensive bushfires that occurred in Victoria during the summer of 2019-20 estimated that bushfire smoke was associated with 120 excess deaths, 331 hospitalisations for cardiovascular problems, 585 hospitalisations for respiratory problems and 401 emergency department presentations for asthma.[618]

EPA Victoria and the University of New South Wales have been working together to calculate health impacts from $PM_{2.5}$ for Victoria. YLL due to $PM_{2.5}$ in Statistical Area 4 (SA4) areas of Victoria have been estimated for two 3-year periods (2013-15 and 2019-21). Preliminary results have been supplied and are shown in Figure A33 (2013-15) and Figure A34 (2019-21). The results show significantly worse health impacts in 2019-2021, with considerably more YLL during that 3-year period (an estimated 21,720 YLL within a 95% confidence interval of 14,136 to 28,843 YLL) compared to the 2013-15 period (an estimated 9,618 YLL within a 95% confidence interval of 6,267 to 12,757 YLL). The higher YLL in the 2019-2021 period is most likely due to the significant bushfires in eastern Victoria during the 2019-20 summer and drought conditions in north-western Victoria.

The 2013-15 period estimate agrees closely with estimates from the national study cited above and equates to an average $PM_{2.5}$ attributable loss of life expectancy from birth of 72 days (within a 95% confidence interval of 47 to 95 days).[619]

614. Hanigan IC, Rolfe MI, Knibbs LD, Salimi F, Cowie CT, Heyworth J, Marks GB, Guo Y, Cope M, Bauman A, Bin Jalaludin B, Morgan GG 2015, 'All-cause mortality and long-term exposure to low level air pollution in the '45 and up study' cohort, Sydney, Australia, 2006–2015, *Environment International*, 126.
615. Hanigan IC, Broome RA, Chaston TB, Cope M, Dennekamp M, Heyworth JS, Heathcote K, Horsley JA, Jalaludin B, Jegasothy E, Johnston FH, Knibbs LD, Pereira G, Vardoulakis S, Vander Hoorn S, Morgan GG 2020, 'Avoidable mortality attributable to anthropogenic fine particulate matter ($PM_{2.5}$) in Australia', *International Journal of Environmental Research and Public Health*, 18, 254.
616. Ibid.
617. Department of Environment, Land, Water and Planning (DELWP) 2022, 'Clean air for all Victorians', Melbourne, Victoria, https://www.environment.vic.gov.au/__data/assets/pdf_file/0032/603977/Victorias-air-quality-strategy.pdf Accessed 10 January 2023.
618. Borchers-Arriagada N, Palmer AJ, Bowman DM, Morgan GG, Jalaludin BB, Johnston FH 2020, 'Unprecedented smoke-related health burden associated with the 2019–20 bushfires in eastern Australia', *Medical Journal of Australia*.
619. Hanigan IC, Broome RA, Chaston TB, Cope M, Dennekamp M, Heyworth JS, Heathcote K, Horsley JA, Jalaludin B, Jegasothy E, Johnston FH, Knibbs LD, Pereira G, Vardoulakis S, Vander Hoorn S, Morgan GG 2020, 'Avoidable Mortality Attributable to Anthropogenic Fine Particulate Matter (PM2.5) in Australia', *International Journal of Environmental Research and Public Health*, 18, 254.

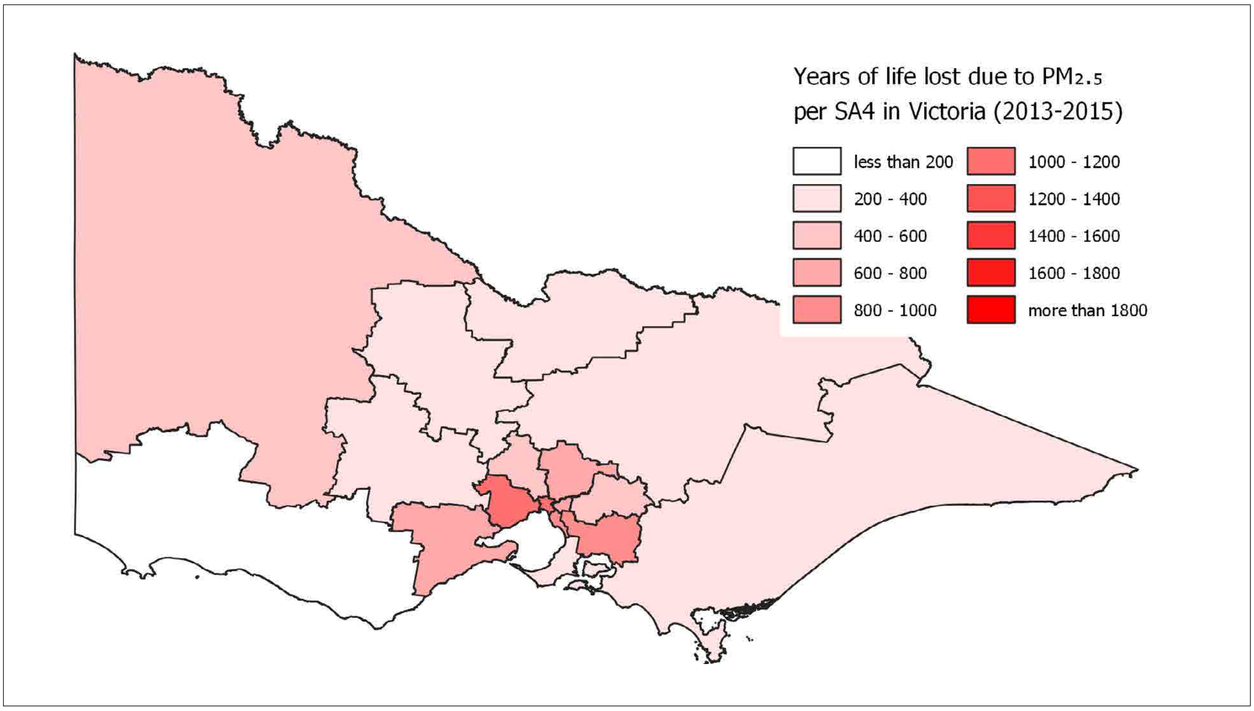


Figure A33: YLL due to $PM_{2.5}$ in SA4 areas of Victoria during the 3-year period of 2013-15. Colours indicate the annual YLL burden of $PM_{2.5}$.[620]

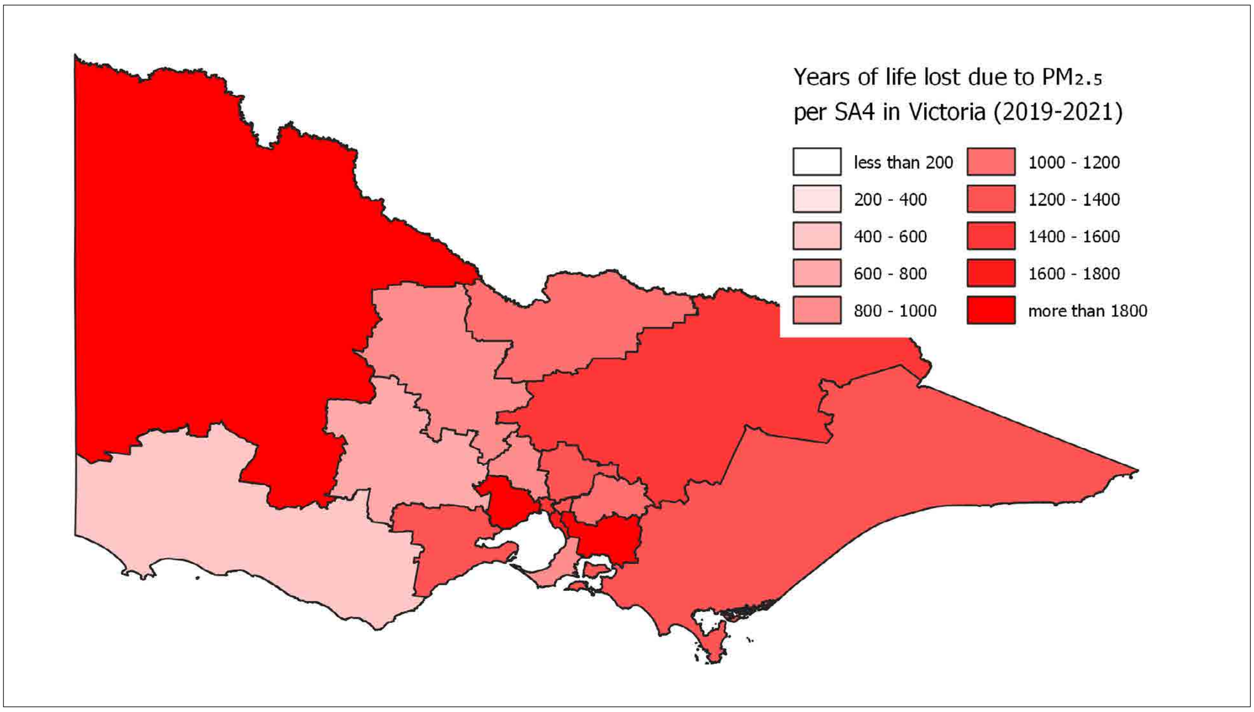


Figure A34: YLL due to $PM_{2.5}$ in SA4 areas of Victoria during the 3-year period of 2019-21. Colours indicate the annual YLL burden of $PM_{2.5}$.[621]

620. Environment Protection Authority (EPA) Victoria, 'Unpublished data', Carlton, Victoria, Accessed 2022.
621. Ibid.

Indicator A:12 Health impacts of noise pollution

A:12 Health impacts of noise pollution						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	(Melbourne) (rest of Victoria)	?		(Melbourne) (rest of Victoria)	?	
Data source(s):	Academic researchers					
Measure(s):	The proportion of the population exposed to high levels of road traffic noise in Melbourne					

Why this indicator?

Long-term exposure to noise can cause a variety of health effects, including annoyance, sleep disturbance, negative effects on the cardiovascular and metabolic systems, and cognitive impairment in children.

NB: This SoE 2023 indicator was 'A:10 Health impacts of noise pollution' in the SoE 2018 Report.

Why this assessment in 2023?

Approximately 5% of the population in Melbourne was exposed to traffic noise above the risk threshold of 55 dB, based on research published in 2019. However, these estimates were based on road traffic data from 2011 and low-resolution health data. Accordingly, there is low confidence in the status assessment of fair for Melbourne that has been based on these data and research.

Summary of State of the Environment 2018 Report assessment

- Melbourne has a lower percentage of its population exposed to excessive night-time noise than many of Europe's major cities.

Critical data used for the 2023 assessment

- Data and analysis from academic research published in 2019

2023 assessment

Noise pollution is an important problem, impacting human health. There are more premature deaths associated with air pollution than for noise, however the European Environment Agency report that noise seems to have a larger impact on indicators related to quality of life and mental health.[622]

Noise caused by transport is considered the second most significant environmental cause of ill health in western Europe, behind $PM_{2.5}$ air pollution.[623, 624, 625]

Road traffic noise increases the risk of mortality from ischemic heart disease (IHD).[626] Understanding local exposures and health outcomes, for example by developing high-resolution maps, are critical to design urban planning interventions that are informed by health risks because noise is highly localised.

During 2019, researchers generated environmental health risk maps for traffic noise in Melbourne at the mesh block level (~90 people). Noise levels of 80 dB were recorded in some mesh blocks and approximately 5% of the population in Melbourne was exposed to traffic noise above the risk threshold of 55 dB. Attributable rates of IHD deaths due to noise were generally very low.[627] This information is the basis of a fair status assessment for Melbourne, with environmental noise deemed to be exerting a moderate pressure on human health.

622. European Environment Agency 2020, 'Noise pollution is a major problem, both for human health and the environment', Copenhagen, Denmark, https://www.eea.europa.eu/articles/noise-pollution-is-a-major Accessed 12 July 2022.
623. European Environment Agency 2020, 'Environmental noise in Europe — 2020', EEA Report No 22/2019, Copenhagen, Denmark.
624. World Health Organization and Joint Research Centre, 2011, 'Burden of disease from environmental noise — quantification of healthy life years lost in Europe'.
625. Hänninen O, Knol AB, Jantunen M, Lim TA, Conrad A, Rappolder M, Carrer P, Fanetti AC, Kim R, Buekers J, Torfs R, Iavarone I, Classen T, Hornberg C, Mekel OC 2014, 'Environmental burden of disease in Europe: assessing nine risk factors in six countries', *Environmental Health Perspectives*, 122(5), pp. 439-446.
626. van Kempen E, Casas M, Pershagen G, Foraster M 2018, 'WHO environmental noise guidelines for the European region: a systematic review on environmental noise and cardiovascular and metabolic effects: a summary', *International Journal of Environmental Research and Public Health*, 15(2) pp. 379.
627. Hanigan IC, Chaston TB, Hinze B, Dennekamp M, Jalaludin B, Kinfu Y, Morgan GG 2019, 'A statistical downscaling approach for generating high spatial resolution health risk maps: a case study of road noise and ischemic heart disease mortality in Melbourne, Australia', *International Journal of Health Geographics*, 18, 20.

However, the research described above was based on road traffic data from 2011 and low-resolution health data. Therefore, there is low confidence in the status assessment that was based on this research. As detailed in indicator 'A:09 Noise', EPA Victoria has developed spatial noise maps at the building level, and these can be utilised in the future to assess population exposure and health impacts of road traffic noise.

Indicator A:13 Indoor air quality

A:13 Indoor air quality

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	(schools and aged care facilities) (residential buildings during periods of bushfire smoke) (all other scenarios)	?	(schools and aged care facilities) (residential buildings during periods of bushfire smoke and all other scenarios)		?	

Data source(s):	Academic researchers
Measure(s):	Measured indoor air-quality concentrations of $PM_{2.5}$ and PM_{10}

Why this indicator?

Good indoor air quality is critical for health and wellbeing, given that our modern lifestyles are increasing the amount of time we spend indoors.

NB: This SoE 2023 indicator was 'A:11 Indoor air quality' in the SoE 2018 Report.

Why this assessment in 2023?

$PM_{2.5}$ and PM_{10} concentrations measured in classrooms and aged care facilities were within the World Health Organization guidelines.

An evaluation of existing analyses of indoor air quality during bushfire smoke events found bushfire smoke can substantially increase the levels of pollutants within residential buildings.

Summary of State of the Environment 2018 Report assessment

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

Critical data used for the 2023 assessment

- Synthesis of academic research.

2023 assessment

The SoE 2018 Report highlighted that, despite humans spending an overwhelming majority of time indoors, relatively little research has been done to investigate the quality of air in our homes, schools, recreational buildings, restaurants, public buildings, offices, or inside cars. This significant knowledge gap was captured in Recommendation 3 of the SoE 2018 Report, which included a component that future Victorian air-quality monitoring and assessments should be expanded to include indoor air quality. The Victorian Government's response to this recommendation acknowledged a knowledge gap on exposure data for indoor air quality in Australia homes.

Air

Two significant Victorian research projects on indoor air quality have been completed by RMIT researchers since the SoE 2018 Report and are summarised below.

A report published in 2020, as part of a project funded by DELWP, detailed investigations of indoor air quality in schools and aged care facilities — these are places with particularly vulnerable groups of people to poor indoor air quality.[628] Indoor air quality was monitored in schools and aged care homes for one year. Fresh filtered air ventilation systems were found to be effective at reducing indoor carbon dioxide concentrations but not $PM_{2.5}$ (particles less than 2.5 micrometres in diameter) or PM_{10} (particles less than 10 micrometres in diameter). The $PM_{2.5}$ and PM_{10} concentrations in classrooms were found to be influenced heavily by local activities, such as the movement of people inside and outside the room and opening windows. Key findings of the study included:

- $PM_{2.5}$ and PM_{10} concentrations were within the guidelines stipulated by the World Health Organization.
- School classroom ventilation rates met the minimum ventilation requirement of Australian Standard 1668.2 in only two out of ten classrooms measured.[629]

Residential buildings are important places of refuge from bushfire smoke, however, the air quality within these locations can become heavily polluted by smoke infiltration. In 2021, RMIT researchers evaluated existing analyses of indoor air quality during bushfire smoke events and found bushfire smoke can substantially increase the levels of pollutants within residential buildings.[630] Notably, indoor $PM_{2.5}$ concentrations of approximately 500 µg/m^3 have been observed during bushfire smoke events.[631] Because many Australian homes are very leaky compared to those in countries such as the USA, appropriate design, selection and operation of household ventilation systems that include particle filtration will be critical to reduce indoor exposures during prolonged smoke events in Victoria.

Since the SoE 2018 Report, the Victorian Government's contribution to indoor air-quality management has been targeted at better understanding the impacts of regional smoke events on indoor air quality and the role filtration systems can play in reducing exposure to fine particles.[632] This research has informed advice to the community about how to limit smoke from outdoors getting inside the home.[633]

As part of the Parliament of Victoria Legislative Council Environment and Planning Committee Inquiry into the health impacts of air pollution in Victoria, the Centre for Urban Research provided a submission and advocated for the introduction of a low-cost sensor network for real-time air pollution measuring to improve public communications during events such as bushfires.[634] Critically, the suggestion included an indoor monitoring component:

> 'That low-cost sensors networks [should] be deployed to provide real-time measurements of air pollutants. These could be based on similar networks in other cities that provide data to inform decision makers and help communities reduce exposure to air pollutants. Ideally, sensor networks should be used to monitor both outdoor and indoor levels of pollutants.' [635]

Southern Cross Railway Station in Melbourne, which is semi-enclosed under a roof, represents a potentially higher-risk indoor air-quality environment due to the: diesel emissions from the regional trains that arrive or terminate at the station, large number of people using the facility each day, and significant number of workers that have extended exposure to any air pollution at the station. Publicly available air monitoring at the station would confirm the indoor air-quality risk at the station and determine if any actions are required to manage the air quality.

628. Rajagopalan R, Andamon MM, Woo J 2020, 'Enhanced indoor air quality for improving the well-being of vulnerable population in victoria', Final Report prepared for the Victorian Department of the Environment, Land, Water and Planning (DELWP). Virtual Centre for Climate Change Innovation (VCCCI) by the Sustainable Building Innovation Laboratory (SBi Lab), School of Property, Construction and Project Management, RMIT University, Melbourne, Australia.
629. Ibid.
630. Rajagopalan R, Goodman N 2021, 'Improving the indoor air quality of residential buildings during bushfire smoke events', *Climate*, 2021, 9, 32.
631. Yu P, Xu R, Abramson MJ, Li S, Guo Y 2020, 'Bushfires in Australia: A serious health emergency under climate change', *Lancet Planetary Health, 4, pp. e7–e8.*
632. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Victorian Government response to the state of the environment 2018 report', Melbourne, Victoria.
633. Environment Protection Authority (EPA) Victoria 2020, '1743.1: Smoke and your health', Carlton, Victoria, https://www.epa.vic.gov.au/about-epa/publications/1743-1 Accessed 14 July 2022.
634. Parliament of Victoria Legislative Council Environment and Planning Committee 2021, 'Inquiry into the health impacts of air pollution in Victoria' Melbourne, Victoira.
635. Ibid.

Indicator A:14 Health impacts from pollen

A:14 Health impacts from pollen						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	(yellow)	?	(yellow)	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator
Data source(s):	ABS, Academic researchers					
Measure(s):	Prevalence of allergic rhinitis					

Why this indicator?

Pollen from grasses, weeds or trees can trigger symptoms of allergic rhinitis (hay fever) and asthma.

NB: This is a new indicator that was not included in the SoE 2018 Report. This indicator has been included to address a gap on pollen in previous SoE Reports.

Why this assessment in 2023?

Victoria has the second-highest rate (23%) of hay fever in Australia.

Victorian studies on exposure to grass pollen have found that:

- Short-term exposure to grass pollen is associated with reduced lung function and with airway inflammation.
- Persistent pollen exposure during infancy is associated with increased risk of subsequent childhood asthma and hay fever.
- Grass pollen exposure is associated with higher re-admission rates for paediatric asthma.
- Exposure to grass pollen increases the risk of complications and adverse outcomes among patients undergoing coronary artery stenting to treat their coronary artery disease.

Grass pollen is only one of the types of pollen found in Victoria's air. Other types are often more prevalent and potentially also affect health, although these health impacts have rarely been quantified in Australia because of a lack of data, which is a significant knowledge gap.

Summary of State of the Environment 2018 Report assessment

- New SoE 2023 indicator

Critical data used for the 2023 assessment

- Australian Institute of Health and Welfare data on the prevalence of allergic rhinitis by location, sex and age groups
- Australian Bureau of Statistics (ABS) reports

2023 assessment

Health impacts

Pollen from grasses, weeds or trees can trigger symptoms of allergic rhinitis (hay fever), and asthma.[636] In 2017-18, an estimated 19% of Australians had hay fever, with children less likely to have hay fever (10%) compared with all other age groups (Figure A35).[637, 638]

636. Australasian Society of Clinical Immunology and Allergy, 'Pollen Allergy', https://www.allergy.org.au/patients/allergic-rhinitis-hay-fever-and-sinusitis/pollen-allergy Accessed 6 May 2022.
637. Australian Institute of Health and Welfare 2020, 'Allergic rhinitis ('hay fever')', Canberra, Australian Capital Territory, https://www.aihw.gov.au/reports/chronic-respiratory-conditions/allergic-rhinitis-hay-fever/contents/allergic-rhinitis Accessed 6 May 2022.
638. Note that seasonal allergic rhinitis associated with pollen would be a subset of these percentages.

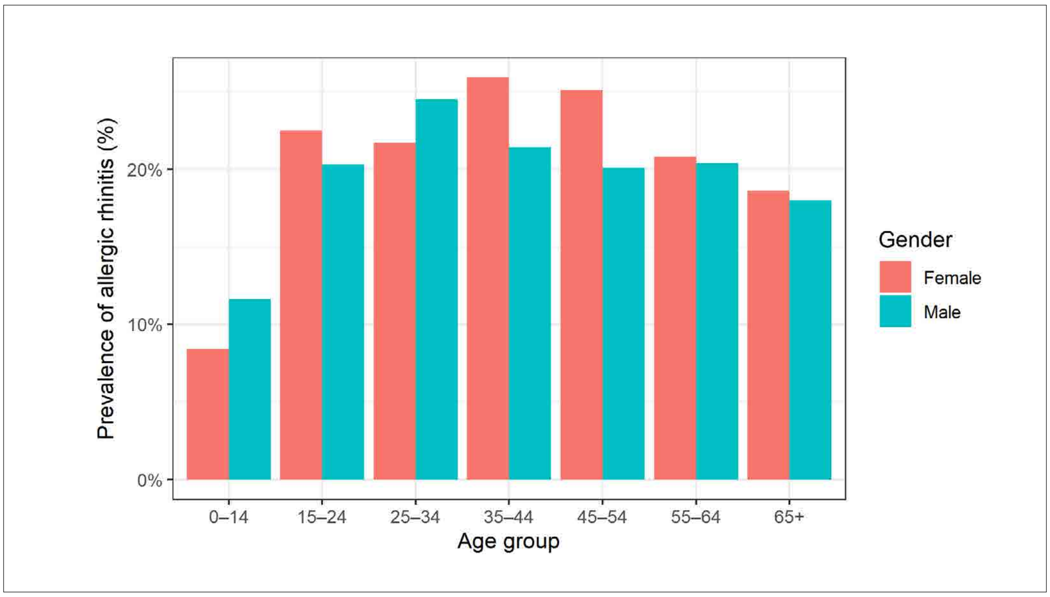


Figure A35: Prevalence of allergic rhinitis, by sex and age group during 2017-18.[639, 640]

Victoria had the second highest rate of hay fever in Australia (23%) in 2017-18 compared with all other states and territories (Figure A36).

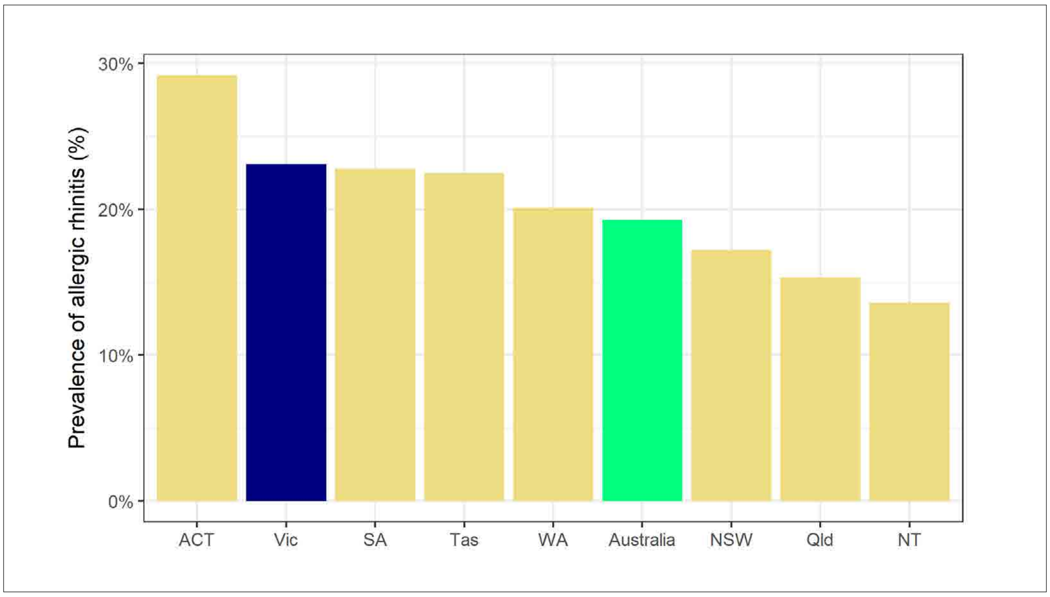


Figure A36: Prevalence of allergic rhinitis by state and territory, and nationally, during 2017-18.[641, 642]

639. Australian Institute of Health and Welfare 2020, 'Allergic rhinitis ('hay fever')', Canberra, Australian Capital Territory, https://www.aihw.gov.au/reports/chronic-respiratory-conditions/allergic-rhinitis-hay-fever/contents/allergic-rhinitis Accessed 6 May 2022.
640. Australian Bureau of Statistics 2018, 'National Health Survey: First results', Canberra, Australian Capital Territory, https://www.abs.gov.au/statistics/health/health-conditions-and-risks/national-health-survey-first-results/latest-release Accessed 6 May 2022.
641. Australian Institute of Health and Welfare 2020, 'Allergic rhinitis ('hay fever')', Canberra, Australian Capital Territory, https://www.aihw.gov.au/reports/chronic-respiratory-conditions/allergic-rhinitis-hay-fever/contents/allergic-rhinitis Accessed 6 May 2022.
642. Australian Bureau of Statistics 2018, 'National Health Survey: First results', Canberra, Australian Capital Territory, https://www.abs.gov.au/statistics/health/health-conditions-and-risks/national-health-survey-first-results/latest-release Accessed 6 May 2022.

Pollen seasons can last for several months and exposure is difficult to avoid. Hay fever symptoms are caused by the body's immune response to inhaled pollen, resulting in chronic inflammation of the eyes and nasal passages. Hay fever symptoms include:

- runny, itchy, congested nose
- irritable, itchy, watery and red eyes
- itchy ears, throat and palate.[643]

Quantifying Victorian health impacts associated with pollen exposure is complex because hay fever can occur throughout the year from exposure to other allergens (e.g. pet dander and dust mites), not just pollen.

Asthma can be exacerbated by pollen and around 80% of people with asthma have hay fever. Because pollen is one of many triggers for asthma (others include exercise, poor air quality, cigarette smoke, weather, and cold and flu viruses), tracking asthma is unlikely to provide a clear picture of the asthma health burden associated with pollen. Asthma presentations to hospitals and other health services would include asthma triggered by the extensive list of other factors additional to pollen.

Victorian studies on exposure to grass pollen have found:

- Short-term exposure to grass pollen is adversely associated with lung function and airway inflammation in the community.[644]
- Persistent pollen exposure during infancy is associated with increased risk of subsequent childhood asthma and hay fever.[645]
- Grass pollen exposure is associated with higher readmission rates for paediatric asthma.[646]
- Exposure to grass pollen increases the risk of complications and adverse outcomes among patients undergoing coronary artery stenting to treat their coronary artery disease.[647]

Grass pollen is only one of the types of pollen found in Victoria's air. Other types are often more abundant, as discussed in indicator 'A:07 Pollen' and potentially also affect health, although these health impacts have rarely been quantified in Australia because of a lack of data, which is a significant knowledge gap. Furthermore, pollen count and self-reported respiratory symptom data from Tasmania was analysed in 2021, with researchers finding associations between respiratory symptoms and *Dodonaea* (hop bush) and Myrtaceae (eucalypt family), highlighting the need to further investigate the role of Australian native pollen types in allergic respiratory disease.[648] Research published in 2022 has highlighted the link of total pollen (that is, not just grass pollen) with acute coronary syndrome and adverse health outcomes, as well as detecting that notable increases in pollen-related associations with cardiopulmonary outcomes were not restricted to any one season.[649, 650]

Mitigating the adverse health impacts associated with pollen

For both asthma and seasonal hay fever, the most effective means of preventing and minimising symptoms from exposure to pollen in the grass pollen season is ensuring:

- Appropriate preventive treatments are taken as prescribed, or as indicated, with good technique to ensure medication is delivered effectively.
- Those with asthma have an up-to-date asthma action plan and/or hay fever treatment plan for those with hay fever, know how to manage an asthma exacerbation (e.g. guided by instructions in a person's asthma action plan or by using asthma first aid) and minimise exposure to triggers.

643. Australasian Society of Clinical Immunology and Allergy, 'Pollen Allergy', https://www.allergy.org.au/patients/allergic-rhinitis-hay-fever-and-sinusitis/pollen-allergy Accessed 6 May 2022.
644. Idrose NS, Tham RCA, Lodge CJ, Lowe AJ, Bui D, Perret JL, Vicendese D, Newbigin EJ, Tang MLK, Aldakheel FM, Waidyatillake NT, Douglass JA, Abramson MJ, Walters EH, Erbas B, Dharmage SC 2021, 'Is short-term exposure to grass pollen adversely associated with lung function and airway inflammation in the community?', *Allergy*, 2021 Apr;76(4), pp. 1136-1146.
645. Erbas B, Lowe AJ, Lodge CJ, Matheson MC, Hosking CS, Hill DJ, Vicendese D, Allen KJ, Abramson MJ, Dharmage SC 2013, 'Persistent pollen exposure during infancy is associated with increased risk of subsequent childhood asthma and hayfever', *Clinical and Experimental Allergy*, 43(3), p 337–343.
646. Batra M, Newbigin E, Dharmage S, Abramson M, Erbas B, Vicendese D 2021, 'Grass pollen exposure and children's asthma repeat admissions in Victoria, Australia', *International Journal of Epidemiology*, 50.
647. Al-Mukhtar O, Vogrin S, Lampugnani ER, Noaman S, Dinh DT, Brennan AL, Reid C, Lefkovits J, Cox N, Stub D, Chan W 2022, 'Temporal Changes in Pollen Concentration Predict Short-Term Clinical Outcomes in Acute Coronary Syndromes', *Journal of the American Heart Association*, 11, pp. e023036.
648. Jones PJ, Koolhof IS, Wheeler AJ, Williamson GJ, Lucani C, Campbell SL, Bowman D, Cooling N, Gasparrini A, Johnston FH 2021, 'Characterising non-linear associations between airborne pollen counts and respiratory symptoms from the AirRater smartphone app in Tasmania, Australia: a case time series approach', *Environmental Research*, Article 111484.
649. Al-Mukhtar O, Vogrin S, Lampugnani ER, Noaman S, Dinh DT, Brennan AL, Reid C, Lefkovits J, Cox N, Stub D, Chan W 2022, 'Temporal Changes in Pollen Concentration Predict Short-Term Clinical Outcomes in Acute Coronary Syndromes', *Journal of the American Heart Association*, 11, pp. e023036.
650. Nitschke M, Simon D, Dear K, Venugopal K, Jersmann H, Lyne K 2022, 'Pollen Exposure and Cardiopulmonary Health Impacts in Adelaide, South Australia', *International Journal of Environmental and Public Health*, 19(15), pp. 9093.

Public education and communication programs are critical components of the health response to mitigate the adverse impacts of exposure to pollen. Daily pollen forecasts are primarily provided to create behaviour changes in people, such as people choosing to postpone activities if they know pollen counts are going to be high; this type of information provision and behaviour change likely represents a direct saving in health and economic costs because people are less likely to experience symptoms and, in the worst of cases, potentially have an asthma attack.

Pollen forecasting can also provide secondary benefits beyond the provision of daily forecast information. For example, forecasting is part of the marketing and engagement that keeps pollen in the mind of many community members, which can then mean they are more likely to take the medication that can reduce their adverse health effects. Forecasts are also useful for minimising the effect of potential epidemic thunderstorm asthma events, with the epidemic thunderstorm asthma risk forecasts used by emergency services, such as Ambulance Victoria, to roster more staff to work during times with a greater likelihood of a thunderstorm asthma event.

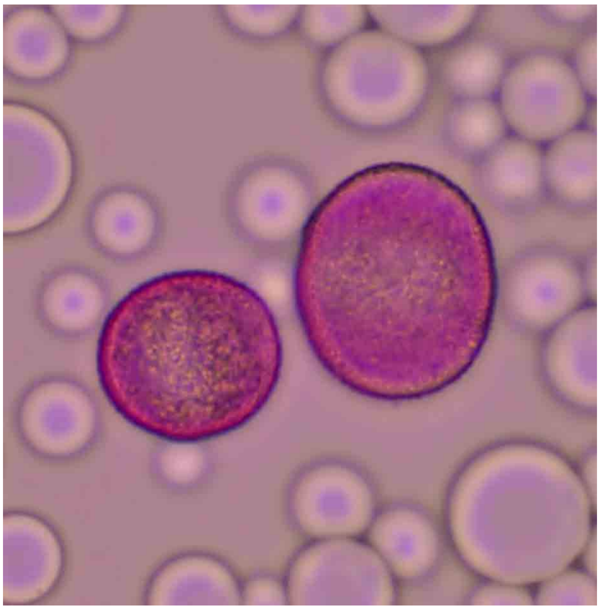
Melbourne Pollen is a service that uses information about airborne pollen levels (pollen counts) to deliver grass pollen forecasts to Victorians. Victorians with respiratory allergies, such as hay fever and asthma, find this information useful because it helps them to plan their week and take the steps needed to reduce their exposure to airborne allergy triggers. Traffic to the Melbourne Pollen website and app has been growing at 30% year-on-year, showing the level of public interest in this information.

Economic and social impacts

Globally, few studies describe the burden of the totality of allergic rhinitis and asthma, with only a handful of studies providing a comprehensive overview of the socio-economic impact of these diseases.[651] A Danish study from 2016 concluded the economic burden of allergic rhinitis is considerable, with indirect costs due to absenteeism and presenteeism (lower productivity while at work) making up most of the cost.[652]

As part of a report into the economic impact of allergic disease in Australia prepared by Access Economics for the Australasian Society of Clinical Immunology and Allergy in 2007, the financial cost of allergies was estimated to be $7.8 billion, with more than half of this cost estimated to be due to presenteeism. It is unclear how much of this cost was associated with allergic rhinitis and exposure to pollen, however allergic rhinitis is the most prevalent allergy-related condition in Australia.[653]

More recently, a Tasmanian study quantified the direct and indirect costs of asthma and hay fever for 2018 in Tasmania. Total costs ranged between $126.5 million and $436.7 million for asthma and between $65.3 million and $259.7 million for hay fever.[654]



Pollen under the microscope – pollen counting technology is revolutionising the way airborne pollen is recorded to help hay fever sufferers. © The University of Melbourne.

651. Dierick BJH, van der Molen T, Flokstra-de Blok BMJ, Muraro A, Postma MJ, Kocks JWH, van Boven JFM 2020, 'Burden and socioeconomics of asthma, allergic rhinitis, atopic dermatitis and food allergy', *Expert Review of Pharmacoeconomics and Outcomes Research*, 20:5, p 437-453.
652. Linneberg A, Dam Petersen K, Hahn-Pedersen J, Hammerby E, Serup-Hansen N, Boxall N 2016, 'Burden of allergic respiratory disease: a systematic review', *Clinical and Molecular Allergy*, 14, 12.
653. Report by Access Economics Pty Limited for the Australasian Society of Clinical Immunology and Allergy 2007, 'The economic impact of allergic disease in Australia: not to be sneezed at'.
654. Borchers-Arriagada N, Jones PJ, Palmer AJ, Bereznicki B, Cooling N, Davies JM, Johnston FH 2021, 'What are the health and socioeconomic impacts of allergic respiratory disease in Tasmania?', *Australian Health Review*, 45, pp. 281-289.

Commissioner
for Environmental
Sustainability
Victoria

Biodiversity (B)

Victorian State of the Environment 2023 Report

Platypus, Lake Elizabeth.
Credit: David Paul.

Key findings

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

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

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

There has been little change in the status, trend and data confidence for the indicators assessed in the State of the Environment (SoE) 2018 and 2023 reports (Table B1). The status of many indicators remains poor, deteriorating trends continue, and data confidence in the assessments is generally low. This is also the case for the new SoE 2023 'Threatened species' indicators. Assessment of the 'Ecosystem health' indicators had mixed results, with status ranging from poor for grasslands, wetlands, rivers and riparian vegetation to fair for mallee, heathlands and alpine ecosystems.

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

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

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

Ecosystem health

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

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

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

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

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

Threatened species

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

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

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

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

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

Safe havens on islands and within fenced areas that exclude feral predators and herbivores are being used to conserve critically endangered species such as bandicoots, possums and wallabies across Australia. Their establishment in various parts of Australia has prevented the extinction of 13 mammal species and conserved many more.[655] Several safe havens already exist in Victoria, with more planned at Wilsons Promontory National Park and at Haining Farm. Together with improved and broad-scale management of invasive species and other threats, and the expansion of conservation reserves, they can make a significant contribution to the conservation of threatened species.

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

Threats and responses

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

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

655. Trust for Nature, 'Statewide conservation plan for private land in Victoria', https://trustfornature.org.au/wp-content/uploads/2020/11/Trust-for-Nature-Statewide-Conservation-Plan.pdf Accessed 3 August 2023.

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

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

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

Conservation and community engagement

Indicators B:36 to B:40 assess conservation and community engagement. Almost 90% of the EVCs that are poorly represented in parks and reserves are found on private land. About 62% of Victoria's land is privately owned, yet only 1% to 2% of private agricultural land is managed for conservation, for example, native vegetation protection, revegetation and livestock exclusion.[656, 657]

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

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

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

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

656. The proportion of Victorian land that is private was reported as 57.6% in the SoE 2018 Report. Trust for Nature, which focusses on the conservation of biodiversity on private land, now reports it as being 62%. This should not be interpreted as an increase; it is a recalculation of the spatial extent of private land.
657. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Victorian Government response to the state of the environment 2018 report', Melbourne, Victoria.

Table B1: Biodiversity indicators assessed in this chapter with comparisons to SoE 2018 assessments.

Biodiversity							
2023 Indicator	**2023 status**	**2023 trend**	**2023 confidence**	**2018 Indicator**	**2018 status**	**2018 trend**	**2018 data quality**
Ecosystem health							
B:01 Changes in land cover	Red	?	Green	B:19 Landscape-scale change	Red	↙	Yellow
B:02 Wetlands	Red	↙	Yellow	B:16 Wetlands extent and condition	Grey	?	Red
B:03 Health and status of Victorian inland Ramsar wetlands	Yellow	↗	Green	B:17 Health and status of Ramsar wetlands in Victoria	Grey	?	Red
B:04 Groundwater -dependent ecosystems	Grey	?	Grey	WR:10 Groundwater ecosystems	Grey	?	Red
B:05 Rivers	Red	→	Yellow	B:09 River health	Red	→	Green
B:06: Riparian vegetation	Red	→ (statewide) ↗ (CMA and local reaches level)	Yellow	B:10 Riparian vegetation habitat extent	Red	?	Red
B:07 Floodplains	Red	→	Yellow	B:11 Area of functional floodplain	Grey	?	Red
B:08 Grasslands	Red	↙	Green	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator
B:09 Alpine	Yellow	↙	Yellow	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator

Biodiversity

2023 Indicator	2023 status	2023 trend	2023 confidence	2018 Indicator	2018 status	2018 trend	2018 data quality
Ecosystem health							
B:10 Mallee	🟡	→	🟡	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator
B:11 Heathlands	🟡	→	🟡	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator
Threatened species							
B:12 Threatened terrestrial and freshwater mammals	🔴	↙	🟢	B:06B: Vertebrates	🔴	↙	NC*
B:13 Threatened wetland-dependent species	🔴	↙	🟡	B:05 Threatened species that are wetland dependent	⚪	?	🔴
B:14 Threatened terrestrial bird species	🔴	↙	🟢	B:06B: Vertebrates	🔴	↙	NC
B:15 Waterbird species in the Murray–Darling Basin	🔴	↙	🟢	B:14 Distribution and abundance of waterbirds in the Murray–Darling Basin	🔴	↙	🟡
B:16 Threatened terrestrial and wetland reptile species	🔴	↙	🟡	B:06B: Vertebrates	🔴	↙	NC
B:17 Threatened large-bodied freshwater fish species	🔴	↙	🟡	B:13 Distribution and abundance of fish	🔴	↙	NC
B:18 Threatened small-bodied freshwater fish species	🔴	↙	🟡	B:13 Distribution and abundance of fish	🔴	↙	NC
B:19 Threatened frog species	🔴	↙	🟡	B:12 Distribution and abundance of frogs	🔴	↙	🟢
B:20 Threatened freshwater invertebrate species	🔴	↙	🔴	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator
B:21 Threatened terrestrial invertebrate species	🔴	↙	🔴	B:06C Invertebrates	🔴	↙	🟡

** NC indicates that comparisons between the SoE 2018 and SoE 2023 assessments for the modified SoE 2023 indicator is inappropriate due to the extensive level of variability in the measures and/or data used in the assessment between SoE reports.*

Biodiversity							
2023 Indicator	**2023 status**	**2023 trend**	**2023 confidence**	**2018 Indicator**	**2018 status**	**2018 trend**	**2018 data quality**
Threatened species							
B:22 Threatened terrestrial vascular plant species	🔴	↙	🟡	B:06A Vascular plants	🔴	↙	🟡
B:23 Threatened terrestrial fungi, lichen, moss and liverwort species	🔴	?	🔴	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator
Threats and responses							
B:24 Invasive freshwater plant species	⚪	?	⚪	B:01 Invasive freshwater plants and animals	⚪	?	🔴
B:25 Invasive freshwater animal species	🔴	↙	🟡	B:01 Invasive freshwater plants and animals	⚪	?	🔴
B:26 Trend in carp	🔴	↙	🟢	B:01A Trend in carp (*Cyprinus carpio*) distribution	🔴	↙	🟢
B:27 Invasive terrestrial plant species	🔴	↙	🟡	B:02 Invasive terrestrial plants	🔴	↙	🟢
B:28 Priority weed control	⚪	?	⚪	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator
B:29 Invasive terrestrial herbivore species	🔴	↙	🟡	B:03 Invasive terrestrial animal species	🔴	↙	NC
B:30 Priority pestherbivore control	⚪	?	⚪	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator
B:31 Invasive terrestrial predator species	🔴	↙	🟡	B:03 Invasive terrestrial animal species	🔴	↙	NC
B:32 Priority pest predator control	⚪	?	⚪	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator
B:33 Net gain in extent and condition of native vegetation	🔴	↙	🟢	B:18 Net gain in extent and condition of native vegetation	🔴	↙	🟢

Biodiversity

2023 Indicator	2023 status	2023 trend	2023 confidence	2018 Indicator	2018 status	2018 trend	2018 data quality
Threats and responses							
B:34 Change in suitable habitat for threatened native species		?		B:20 Change in suitable habitat		→	
B:35 Climate-sensitive ecosystems		?		CC13: Extent and condition of key climate-sensitive ecosystems		?	
Conservation and community engagement							
B:36 New, permanently protected areas on private land		?		New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator
B:37 The conservation of Victorian ecosystems on public land		→		B:08 Conservation of Victorian ecosystems		→	
B:38 Priority revegetation		?		New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator
B:39 Victorians value nature	(Target 1: All Victorians are connected to nature) (Target 2: More than five million Victorians acting for nature)	→		B:22 Victorians value nature		?	
B:40 Number of Victorian Government organisations that manage environmental assets that contribute to DELWP Standard Output Data		?		B:23 Number of Victorian Government organisations that manage environmental assets that contribute to DELWP Standard Output Data		?	

Victorian Government progress on State of the Environment 2018 Report recommendations

The SoE 2018 Report included recommendations to the Victorian Government to improve environmental sustainability outcomes. Presented below are the recommendations specific to this theme as well as:

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

Recommendation 5 of the SoE 2018 Report recommended:

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

Government response in 2020:

SUPPORT IN PART

Science and data capability

'As an evidence-driven organisation, DELWP invests strategically across its portfolio to ensure that decisions are made based on the best available science. DELWP recognises the need for continual improvement in the way data and knowledge are used across its portfolio areas. The Department has recently commenced several initiatives to progress the coordination and impact of biodiversity science, research, data collection/use and analysis. Key initiatives include the review of all DELWP Science Programs by the DELWP Science Leadership Group, initiation of a new project to develop a unifying small set of biodiversity indicators to be used across DELWP and the establishment of the DELWP Scientific Reference Panel. In combination this work is seen as an essential enabler to resolving the broader issues covered by this recommendation, including more efficient, transparent and more fit-for-purpose evidence-based decision making and reporting, to maximise desired biodiversity outcomes. It is considered that this will deal with the fundamental problem that is the lack of alignment across DELWP and its portfolio agencies in dealing with biodiversity data and science.' [658]

Chief Biodiversity Scientist

'DELWP has implemented a range of activities since the State of the Environment 2018 report was prepared, that respond to the requirement to establish a Chief Biodiversity Scientist.' [659]

'The opportunity for the Victorian Government of achieving the intent of the Chief Biodiversity Scientist recommendation is through the recent establishment of a new mix of key entities, including the newly formed DELWP Science Reference Panel, the recently formed DELWP Science Leadership Group, the VicEnvironments Forum (VEF) and supporting VEF Science Committee, as well as more targeted use of the existing Flora and Fauna Guarantee Act Scientific Advisory Committee and DELWP's biodiversity research centre of excellence, the Arthur Rylah Institute (ARI).' [660]

658. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Victorian Government response to the state of the environment 2018 report', Melbourne, Victoria.
659. Ibid.
660. Ibid.

> 'Improved oversight of this coordinated effort can be realised by using these entities in a more cohesive, interdependent and collaborative manner than was previously possible. These arrangements are now in place and this will 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. Implementation of this approach and its effectiveness in meeting the intent of the recommendation will be reviewed and evaluated within 12 months of establishment of the Science Reference Panel to inform future implementation.' [661]

Progress made since 2018

Victoria's first Chief Biodiversity Officer was appointed in July 2022. The Chief Biodiversity Officer:

- provides leadership for biodiversity science and information within DEECA and across the portfolio
- provides technical leadership and oversight of research and information systems within DEECA
- liaises with key portfolio partners and community groups to ensure evidence-based decision making within the sector.

In June 2022, the Biodiversity Stewardship Committee, a sub-Group of DEECA's Board was established, recognising the important role that all groups across DEECA and PV play in delivering improved biodiversity outcomes across Victoria. The Committee is chaired by DELWP's Secretary and comprises representatives from DEECA's Environment and Climate Change, Water and Catchments, Forest Fire and Regions, Energy, Land Services and First Peoples, Planning and Corporate Services groups and Parks Victoria (PV).

The creation of the Biodiversity Stewardship Committee provides an opportunity to assess and review the work program currently contributing to biodiversity outcomes in Victoria and streamline governance and co-ordination of biodiversity across the department.

Endorsement of the Biodiversity Stewardship Committee has oversight of the development of five-year Biodiversity 2037 business plan to improve accountability and monitoring of progress against key milestones, deliverables and outcomes of Biodiversity 2037. The operation of the Biodiversity Stewardship Committee will be supported by a newly established Biodiversity Portfolio Management Office.

Further actions by DEECA building on the Government's in-principle response to Recommendation 6 include the continued development and refinement of the Strategic Management Prospects (SMP) decision-support tool that enables biodiversity managers to identify and prioritise management options in a transparent, objective and repeatable way. Since 2018, SMP has expanded from including data on almost 2,000 native species to more than 4,000 native species. SMP currently includes comprehensive information on the benefit and cost-effectiveness of landscape scale actions, such as weed and fox control, to help protect Victoria's native plants and animals. The data on the unique combinations of management actions, species and locations analysed has increased from approximately 120,000 to over 200,000 over that time. Work is underway to include aquatic species in the next update to SMP. This will include approximately 20 fish species and activities such as revegetation of riverbanks and restoration of wetlands.

In addition, DEECA is currently responding to recommendations from the Victorian Auditor-General's Office (VAGO) Protecting Biodiversity Audit to prioritise threatened species for assessment and action and to provide advice on funding required to recover threatened species. This work will build upon the landscape actions in SMP to include more actions specific to threatened species, such as nest boxes and captive breeding. The outcomes of DEECA's improved decision-support tools with respect to pest control are evident in the increased alignment of activity with the most cost-effective actions since 2018.

661. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Victorian Government response to the state of the environment 2018 report', Melbourne, Victoria.

Biodiversity

At the biodiversity-response planning and whole-of-ecosystem-and-landscape scale, the Natural Environment Climate Change Adaptation Action Plan 2022-2026 provides direction to environmental managers about how to approach climate change adaptation across Victoria. The Plan reflects leading-edge approaches to adaptation promoted by the Commonwealth Scientific and Research Organisation (CSIRO) and the international Transformative Adaptation Research Alliance, particularly decision frameworks that support flexible, adaptive and robust decision making in conditions of high uncertainty.

DEECA is also responding to recommendations that the Biodiversity 2037 monitoring, evaluation, reporting and improvement framework (MERF) be revised and expanded to improve monitoring and reporting.

DEECA is developing an indicator framework for the Biodiversity 2037 MERF, which will improve monitoring and reporting on biodiversity status and trends and assess the effectiveness of management interventions. The indicator framework builds on a core set of existing policy indicators enabling the framework to be delivered quickly and to readily identify gaps that will be addressed by new indicator development. DEECA views the indicator framework and the development of a Biodiversity Index for Victoria as first key steps in addressing these recommendations and ensuring a more comprehensive and holistic monitoring and reporting of Victoria's biodiversity.

The Knowledge Framework supports the Biodiversity 2037 MERF and has been developed to identify key knowledge gaps to better support investment in research, monitoring and data collecting, and improve outcomes for biodiversity in Victoria. Specifically, the Biodiversity Knowledge Framework uses modelling to describe the relationship between biodiversity values and management actions in different scenarios. DEECA is currently developing a communications and engagement strategy to promote use of the Knowledge Framework as a decision support and biodiversity investment tool with key stakeholders. In addition, DEECA is currently updating the Knowledge Framework's interactive portal, the Knowledge Portal, to include over 60 new casual models that stakeholders can use to identify knowledge and data gaps.

In addition, there is a Marine and Coastal Knowledge Framework (MACKF) developed in 2020 that provides the standards for information management, data collection and analysis to inform decision making and reporting for marine and coastal environments. The MACKF is supported by a knowledge management system and has 3 core themes:

- Drivers: the legal and policy setting, incorporating international scientific and management principles
- Outputs: information management, research and monitoring programs, data standards, classification and modelling
- Applications: the components that apply the outputs to support management, planning and evaluation, such as coastal hazard assessments, marine spatial planning and State of the Marine and Coastal Environment reporting.

DEECA has included improved scientific expert input into the Threatened Species and Communities Risk Assessment (TSCRA). Over 60 experts contributed technical and operational knowledge to assessing the risk posed by forestry operations to 140 forest-dependent threatened species and communities. The TSCRA also commissioned new science to address key knowledge gaps. A multidisciplinary research project was commissioned into the most appropriate mitigations for the impacts of sedimentation from forestry operations on freshwater crayfish and fish. The outcomes of this research are incorporated in new protections for these species. The package of protections in the TSCRA reports are the biggest improvements to protections for threatened forest-dependent species in 20 years.

As noted, the 2019-20 Victorian bushfires were exceptional in size and impact, with approximately 1,500,000 hectares burnt across Victoria. The bushfires impacted more than 4,400 species, with 244 species of plants and animals with at least 50% of their likely statewide habitat burnt, 215 of which are rare or threatened species. The Bushfire Biodiversity Response and Recovery program has supported the relief and early recovery of species and various habitats impacted by the 2019-20 bushfires. This includes threatened warm temperate rainforest and sensitive alpine bogs, and wetlands that are habitat for numerous threatened plants and animals. Information is available in the Biodiversity Bushfire Response: Supplementary report on bushfire impacts on species in Victoria.

Some highlights/outcomes from the Bushfire Biodiversity Response and Recovery program include:

- The return of all 14 extracted threatened species to their unique habitats in Victoria. Eastern bristlebirds were carefully trapped and evacuated to a Zoos Victoria facility in a highly coordinated joint retrieval operation as the fire front threatened their far east Gippsland home. This was the first time in Australia that a retrieval operation of this nature, to extract a rare and threatened species as the fire front approached their habitat, had ever been undertaken.
- Threatened freshwater species including fish, crustaceans and molluscs that were retrieved from remote streams impacted by bushfire have now also been returned. These species were housed in temporary captive management at the ARI for Environmental Research aquaria since early 2020.
- The collection of seeds and cuttings from rare plants has led to increased resilience for recovery of threatened flora, with representation of listed threatened species in the gardens collection increasing from 45% to 50%.
- 565,000 hectares of introduced herbivore control, and 130,000 hectares of predator control.
- Collaborative work with Traditional Owners across bushfire affected areas to apply a cultural landscape lens to species' renewal and resilience – using cultural knowledge and practices.
- Development of a new dataset called 'Biodiversity Risk' deployed into the Department's Bushfire Emergency Management eMap mapping tool, reducing risk of impacts to biodiversity values during bushfire preparedness and response activities.

Recommendation 6 of the SoE 2018 Report recommended:

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

<u>Government response in 2020:</u>

SUPPORT IN PRINCIPLE

> 'The Victorian Government supports improving biodiversity outcomes on private land. Biodiversity 2037 acknowledges the need to address the ongoing decline in the extent and quality of native vegetation on private land and includes a target to permanently protect 200,000 hectares of private land by 2037. The primary mechanism for this is through the establishment of conservation covenants registered on the title of private landholdings by Trust for Nature via the *Victorian Conservation Trust Act 1972*.' [662]
>
> 'The Government recognises the shift in conservation management towards considering whole ecosystems and landscapes, rather than focussing on a single threatened species. The Department of Environment, Land, Water and Planning (DELWP) supports this approach by taking a collaborative, landscape level approach to biodiversity response planning that provides a mechanism for all stakeholders within a landscape to work together to identify priority outcomes for biodiversity – including actions on private land. Additionally, DELWP's Strategic Prospects Management Tool identifies priority biodiversity values on private land for management and protection.' [663]

662. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Victorian Government response to the state of the environment 2018 report', Melbourne, Victoria.
663. Ibid.

'In Victoria, the Invasive Plants and Animals Policy Framework (IPAPF), under the *Catchment and Land Protection Act 1994* (CaLP Act), sets out the Government's approach to the management of existing and potentially invasive species. The IPAPF 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 and take an asset-based approach to managing widespread invasive species.' [664]

'The effective management of invasive plants and animals on private land in Victoria relies on a partnership approach that involves all three levels of government, community and the private sector. DELWP currently invests in a number of strategic programs to build capability of local government to respond to the threats of invasive species. Programs include:

- The Roadside Weeds and Pests Program: assistance to regional councils to respond to weeds and pests' threats on roadsides and prevent spread to private land.
- The Peri-urban Weed Management Partnership Program: to help manage weed threats in peri-urban Melbourne.
- The Good Neighbour Program: helping public land managers reduce the spread of weeds and pests to private land.
- The Land for Wildlife and Landcare programs which encourage voluntary conservation efforts on both private and public land.' [665]

'The Government, primarily through the Department of Jobs, Skills, Industry and Regions, invests in the enforcement and compliance of the noxious weeds and pest animals' provisions of the CaLP Act. Local Government Areas also have local laws to penalise landholders who do not comply with the Act.' [666]

'Illegal clearing contributes to the decline of biodiversity on private land. Compliance with the Guidelines for the Removal, Destruction or Lopping of Native Vegetation is a requirement of all planning schemes in Victoria. The government acknowledges that enforcement by local governments varies for a range of reasons and DELWP has established a cross-departmental working group to develop an action plan to deliver more effective administration of Victoria's native vegetation regulations, in order to reduce the impacts of unauthorised vegetation removal.' [667]

Progress made since 2018

Work has occurred in the first five years of implementation of Biodiversity 2037 (2017-2022). The Victorian Government has allocated more than $400 million to biodiversity conservation and the natural environment since the publication of Biodiversity 2037 in 2017.

This has funded on-ground management to control pest plants and animals, targeted management of threatened species including application of techniques such as gene mixing and translocation, programs to mitigate harm to the environment, works on Country in partnership with Traditional Owners, foundational work in monitoring, research and reporting to underpin decisions and programs to increase the involvement of the community in caring for nature, including the Victorian Government's $120 million investment across a range of programs to support community action, Landcare and environmental volunteering.

The 2021–22 State Budget provided $4 million over four years and $1 million per annum ongoing to Trust for Nature to provide longer-term investment certainty that will deliver improved biodiversity outcomes and conservation on private land.

The Government is investing in new approaches to increase the area of private land protected. For example, the BushBank program is seeking to restore and protect 20,000 hectares of habitat on private land across targeted areas of Victoria.

Funding is also being made available through the $10 million Nature Fund to support high-impact projects that deliver on the goals of Biodiversity 2037. This funding could also support projects that increase private land protection.

664. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Victorian Government response to the state of the environment 2018 report', Melbourne, Victoria.
665. Ibid.
666. Ibid.
667. Ibid.

In terms of the native vegetation regulations, a 2021 VAGO audit into offsetting native vegetation on private land made five recommendations to DELWP (one joint with audited councils). These related to improving its reporting on the no-net-loss objective, the currency and completeness of its datasets and its management of the credit register, its monitoring of clearing across the state, including using spatial imagery analysis, its management of offset sites and its support to councils in implementing the regulations.

DELWP has formally responded to the audit findings and has either accepted or accepted in principle all of the recommendations. DELWP also submitted a Management Action Plan to describe how it will work to address the recommended improvements. Many of the associated actions are already being examined or DELWP has committed to investigating options to develop tools and approaches that can effectively respond to VAGO's recommendations.

Rainbow lorikeet and ringtail possum.
Credit: Paul Hitch. © Parks Victoria.

Background

> 'Biodiversity encompasses all components of the living world: the number and variety of plants, animals and other living things, including fungi and micro-organisms, across our land, rivers, coast and ocean. It includes the diversity of their genetic information, the habitats and ecosystems within which they live, and their connections with other life forms and the natural world.' [668]
>
> 'Despite understanding the importance of our natural environment, not enough has been done to protect it from harm. Victoria's biodiversity is in decline. More than half of the state's native vegetation has been cleared since European settlement, and many native plant and animal species are at risk from a range of pressures, including the impacts of climate change.' [669]

In its 2020 submission to the Victorian Legislative Council Environment and Planning Committee Inquiry into ecosystem decline in Victoria, the DELWP reported that one quarter to one third of 'Victoria's terrestrial plants, birds, reptiles, amphibians and mammals, along with numerous invertebrates and ecological communities, are considered threatened with extinction', a fate that has already occurred for 18 mammal, two bird, one snake, three freshwater fish, six invertebrate and 51 plant species since European settlement.[670, 671, 672]

According to the DELWP submission:

> 'the longer-term outlook for many threatened species and habitats that rely on Victoria's approximately 8 million hectare public land estate for their conservation is poor.' [673] DELWP added that protecting the state's biodiversity, habitats and public lands estate 'will require biodiversity conservation being given greater consideration in decisions involving competing public land uses as well as increased, better targeted and coordinated investment to manage key threats within a tenure-blind ecosystem-based framework.' [674]

The main drivers of biodiversity's decline have been urban development, mining, timber harvesting, bushfires, invasive species, river regulation, clearing for agriculture and now climate change. The results of these pressures include highly fragmented native vegetation, habitat loss and degradation, reduced connectivity, loss of ecological processes and functions, and an increasing threat to Victoria's biodiversity.

The region of the Glenelg Hopkins CMA encompasses several bioregions. It has lost 81% of its native vegetation cover since European colonisation, although that varies from bioregion to bioregion. For example, the Greater Grampians bioregion has 89% of its native vegetation largely intact, whereas the Victorian Volcanic Plain has just 7%.[675] Figure B1 shows that habitat loss in the CMA's region has continued. Between 1985 and 2019, native vegetation cover in seasonal and perennial wetlands declined by 27% and 41%, respectively, 47% of grassland has been lost since 2010, and native paddock trees have reduced by 11% since 1990.[676] The Glenelg Hopkins CMA also reported that in parts of the region red gum paddock trees declined by 35% between 2003 and 2013. The only category to increase between 1985 and 2019 was native tree cover, mainly along watercourses due to riparian protection and restoration works.[677]

668. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Protecting Victoria's biodiversity 2037', Melbourne, Victoria.
669. Ibid.
670. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Submission to the Legislative Council Environment and Planning Committee Inquiry into ecosystem decline in Victoria', Parliament of Victoria, Melbourne, Victoria.
671. The monitoring of invertebrate biodiversity is limited. It is likely that many more than six species of invertebrates have become extinct.
672. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Submission to the Legislative Council Environment and Planning Committee Inquiry into ecosystem decline in Victoria', Parliament of Victoria, Melbourne, Victoria.
673. Ibid.
674. Ibid.
675. Glenelg Hopkins Catchment Management Authority (CMA) 2021, 'Annual Report 2020-21', Hamilton, Victoria.
676. Ibid.
677. Ibid.

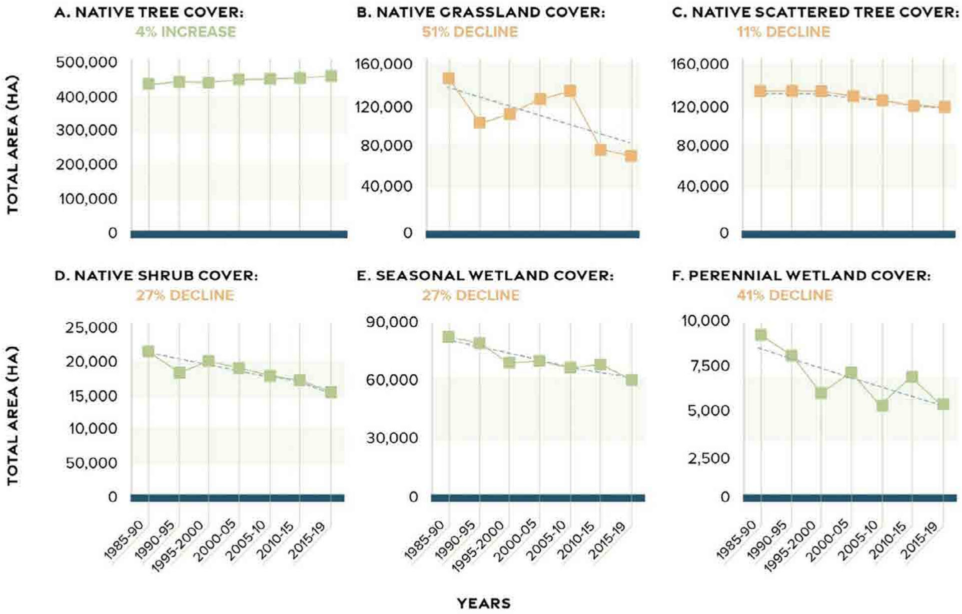


Figure B1: Change in dominant native vegetation cover in the Glenelg Hopkins Region from 1985 to 2019.[678]

Although the decline of Victoria's biodiversity continues, there is recognition of the need for, and an increasing commitment to, action. Released in April 2017, Biodiversity 2037 is the Victorian Government's policy response to addressing the decline in the state's biodiversity. It presents a long-term vision for Victoria's biodiversity supported by two goals: 'Victorians value nature', and 'Victoria's natural environment is healthy.' [679] Biodiversity 2037 sets statewide targets and contributing targets for both goals. Progress on achieving the plan's targets is reported annually and is assessed in the 'Threats and responses' and 'Conservation and community engagement' sub-themes of this chapter [680].

The Victorian Government's commitment to the implementation of Biodiversity 2037 includes funding for landscape-scale projects, iconic species projects and grants for community and volunteer action groups. Government agencies, including CMAs, Traditional Owners, community organisations and landholders are working together across the state to improve the health of Victoria's environment through projects that include the control of invasive species and the restoration of local areas and broader landscapes.

Along with funding limitations, the implementation of Biodiversity 2037 has been impacted by two major events since the SoE 2018 Report. The first being the 2019-20 bushfires, followed immediately by the COVID-19 pandemic. The impact on biodiversity of a third major event, the floods of 2022, is yet to be determined.

678. Glenelg Hopkins Catchment Management Authority (CMA) 2021, 'Annual Report 2020-21', Hamilton, Victoria.
679. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Protecting Victoria's environment: Biodiversity 2037', Melbourne, Victoria.
680. Department of Environment, Land, Water and Planning (DELWP), 'Implementing biodiversity 2037' https://www.environment.vic.gov.au/biodiversity/Implementing-Biodiversity-2037 Accessed 1 November 2022.

Policy and legislative settings

There are national and state policies and legislative settings that apply to the protection, conservation, management and use of Victoria's natural environment, and the threats facing it.

The key piece of national environmental legislation is the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Actions that will lead to changes in land use or land management in Victoria (or other states and territories) may be subject to provisions in the EPBC Act. There are nine Matters of National Environmental Significance that are protected under the EPBC Act and they include listed threatened species and communities, listed migratory species and Ramsar wetlands of international importance.

The Australian Government's 2022-2032 Threatened Species Action Plan: Towards Zero Extinctions sets a pathway for threatened species conservation and recovery over the next 10 years.[681] The plan has four objectives:

- The risk of extinction is reduced for all priority species.
- The condition is improved for all priority places.
- New extinctions of plants and animals are prevented.
- At least 30% of Australia's land mass is protected and conserved.[682]

As part of the plan's release, the Australian Government committed $225 million to the implementation of its Saving Native Species program. The plan identifies 110 priority species (25 in Victoria) and 20 priority places (five in Victoria, four of which are shared with other jurisdictions).

The Australian Government's commitment to 30% protection by 2030 does not make any reference to ecosystem types or their representation across bioregions, nor is there clarity on what approach or measures may contribute to the target's achievement. In addition, the Victorian Government has not made any announcement about any commitment to meeting the 2030 target for 30% protection.

In December 2022, the Australian Government released the Nature Positive Plan: Better for the Environment, Better for Business, its response to the 2020 Samuel review of the EPBC Act.[683] The reforms will include National Environmental Standards, regional planning and the establishment of an independent Environment Protection Agency and a nature repair market, which will issue biodiversity certificates for investment in the planting or protection of native vegetation on private land.

Under Victoria's *Wildlife Act 1975* it is an offence to kill, poison, take, control or harm wildlife without authorisation. Wildlife is defined to include both native and specified non-native species, for example, game species of deer, pheasants and partridges. The Wildlife Act also provides for wildlife reserves.

The *Flora and Fauna Guarantee Act 1988* (FFG Act) is Victoria's key statute for the conservation of threatened species and communities and the management of potentially threatening processes. More than 2,000 species, communities and potentially threatening process are currently on the FFG Act Threatened List and the FFG Potentially Threatening Processes List. The FFG Act has tools that can be used to protect threatened species, including action statements, flora and fauna management plans, habitat conservation orders, critical habitat determinations and public authority management agreements.

The *Crown Land (Reserves) Act 1978* provides for the reservation of Crown land and its management for public purposes. The reserves can be managed by the Department of Energy, Environment and Climate Action (DEECA), PV, the Great Ocean Road Coast and Parks Authority or by a committee of management.

The *Environment Protection Act 2017* (EPA Act) aims to prevent air, land and water pollution and environmental damage by setting environmental quality objectives. The EPA Act is administered by the Environment Protection Authority (EPA Victoria).

681. Department of Climate Change, Energy, the Environment and Water (DCCEEW) 2022, '2022-2032 Threatened species action plan: Towards zero extinctions', Canberra, Australian Capital Territory.
682. In December 2022, the Convention of the Parties (COP 15) of the UN Convention on Biodiversity Conservation agreed on the same goal of 30% protection of lands and seas.
683. Department of Climate Change, Energy, the Environment and Water (DCCEEW) 2022, 'Nature positive plan: better for the environment, better for business', Department of Climate Change, Energy, the Environment and Water, Canberra, December. CC BY 4.0.

Biodiversity

The *Planning and Environment Act 1987* (P&E Act) establishes the framework for land-use planning, development and protection in Victoria. Provisions of the P&E Act refer to the removal, destruction or lopping of trees or the removal of vegetation or topsoil as a result of noxious weed and pest animal control works. Land-use zoning and overlays are also conservation tools under the Act.

The *National Parks Act 1975* includes provisions to establish national parks, state parks, marine national parks and marine sanctuaries, wilderness parks, other parks and landscape conservation areas. PV is the agency responsible for the management of most of the state's conservation estate and its operations are guided by the relevant legislation applying to the land and the *Parks Victoria Act 2018.*

The *Heritage Rivers Act 1992* identifies and provides protection to heritage rivers (currently 18 in the state) that have recreation, nature conservation, scenic and aesthetic values. The Heritage Rivers Act prohibits certain activities, such as land clearing, the construction of artificial barriers and water diversions.

The purposes of the *Catchment and Land Protection Act 1994* (CaLP Act) include establishing a framework for the integrated management and protection of catchments and the encouragement of community participation in land and water resource management. It can be used to declare plant and vertebrate species as noxious weeds and pest animals (fish and invertebrates are excluded) that threaten primary production, Crown land, the environment and community health. Under the CaLP Act, each CMA and Melbourne Water must prepare and implement a regional catchment strategy that seeks to achieve sustainable land, water and biodiversity management though partnerships with government, landholders and the community.

The object of the *Conservation, Forests and Lands Act 1987* is 'to be an effective conserver of the State's lands, waters, flora and fauna; and to make provision for the productive, educational and recreational use of the State's lands, waters, flora and fauna in ways which are environmentally sound, socially just and economically efficient.' [684]

The *Forests Act 1958* is used to support the management and use of Victoria's state forests and includes provisions for firewood collection, fire management, forest park establishment and licensing of various uses such as grazing (see the 'Forests' chapter for more details).

The *Fisheries Act 1995* provides the framework for the regulation, management, and conservation of Victorian commercial and recreational fisheries, including aquatic habitats. An aquatic species can be declared as noxious under the Fisheries Act.

The *Victorian Conservation Trust Act 1972* established the Trust for Nature which seeks to expand the conservation of significant habitat and species on private land. To increase the incentives for landholders to conserve native vegetation on their land, those who have an existing Trust for Nature conservation covenant or who establish one will be exempt from land tax from 1 January 2024.[685]

The *Traditional Owner Settlement Act 2010* provides for settlements that may include joint management of public land and rights for the use of natural resources.

The *Aboriginal Cultural Heritage Act 2006* established the Victorian Aboriginal Heritage Council, Registered Aboriginal Parties, the Victorian Aboriginal Heritage Register and cultural heritage management plans and permits.

The *Water Act 1989* provides the legal framework for managing Victoria's water resources. Water for Victoria: Water Plan is a strategic plan for the sustainable management of Victoria's water resources and was released in 2016.[686] It contains actions for improved integration and more efficient use of water resources as well as improved infrastructure and environmental flow management. The plan is due for review in 2023.

The Victorian Waterway Management Strategy was released in 2013. It provides the framework for government, in partnership with the community, to maintain or improve the condition of rivers, estuaries and wetlands so that they can continue to provide environmental, social, cultural and economic values for all Victorians. Regional waterway strategies,

684. Government of Victoria, '*Conservation, Forests and Lands Act 1987*', Melbourne, Victoria.
685. State Revenue Office (SRO) 2023, 'State Budget 2023-24 announcement', Melbourne, Victoria.
686. Department of Environment Land, Water and Planning (DELWP) 2016, 'Water for Victoria: Water plan', Melbourne, Victoria.

which are a requirement of the Water Act, drive implementation of the management approach outlined in the Victorian Waterway Management Strategy. Under the Water Act, regional waterway strategies are developed by catchment management authorities and Melbourne Water in partnership with other regional agencies, authorities and boards involved in natural resource management (NRM), along with Traditional Owners, regional communities and other key stakeholders.

The Invasive Plants and Animals Policy Framework, released in 2010, 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.[687]

The Victorian Government is currently in the process of reforming the state's biosecurity legislation which govern the management and control of pests, weeds and diseases. The reform will consolidate legislation that currently exists across multiple acts into a new Biosecurity Act. The reform is occurring due to an increasing biosecurity threat from:

- greater movement of people, goods and ships creating more pathways for pests, weeds and diseases to enter Victoria
- changes in climate and land uses which result in the alteration of the environment and the distribution of biosecurity risks
- illicit trade in plants and animals.[688]

The Victorian Deer Control Strategy was released in 2020 with a vision to create a future where 'deer are no longer significantly impacting on priority environmental, agricultural and Aboriginal cultural heritage values and public safety in Victoria.' [689] Two of its objectives are to 'prevent the establishment of new deer species and populations in Victoria' and 'facilitate development of a commercial deer harvest industry.'

The Protection of the Alpine National Park Feral Horse Action Plan 2021 aims to reduce horse damage to alpine habitats, improve knowledge, protect Aboriginal cultural heritage, prevent new horse populations from establishing and remove isolated horse populations.[690] The Strategic Action Plan: Protection of Floodplain Marshes in Barmah National Park and Barmah Forest Ramsar Site (2020–23) is also focussed on the major threats posed by feral horses, along with invasive weeds.[691]

Victoria's *Climate Change Act 2017* established a long-term emissions reduction target of net zero by 2050, with interim emissions reduction targets set for 5-year periods from 2021. It also required the Victorian Government to develop a climate change strategy (released in May 2021), along with five-yearly adaptation action plans for seven key systems that include the natural environment and the water cycle.

The Victorian Natural Environment Climate Change Adaptation Action Plan 2022-2026 is a 5-year plan that aims to help improve how Victoria manages its natural environment in response to climate change impacts.[692] It will embed climate change adaptation into natural environment management by guiding planning in regional and place-based plans that manage specific areas, species and ecosystems. The actions in the plan focus on providing decision makers with tools to support flexible, adaptive and robust decision making in conditions of high uncertainty.

In December 2022, leading experts from 11 universities joined with philanthropists in establishing the Biodiversity Council to advocate for biodiversity. The Council aims to 'foster public, policy and industry recognition of the biodiversity crisis, the importance of biodiversity for wellbeing and prosperity, and positive opportunities and solutions to address these challenges.'[693]

687. Department of Primary Industries (DPI) 2010, 'Invasive plants and animals policy framework', Melbourne, Victoria.
688. Department of Jobs, Precincts and Regions (DJPR) 2022, 'Reforming Victoria's biosecurity legislation: discussion paper August 2022', Melbourne, Victoria.
689. Department of Environment Land, Water and Planning (DELWP) 2020, 'Victorian deer control strategy 2020', Melbourne, Victoria.
690. Parks Victoria (PV) 2021, 'Protection of the Alpine National Park feral horse action plan 2021', Melbourne, Victoria.
691. Parks Victoria (PV) 2020, 'Strategic Action Plan: Protection of floodplain marshes in Barmah National Park and Barmah Forest Ramsar Site 2020–2023', Melbourne, Victoria.
692. Department of Environment Land, Water and Planning (DELWP) 2022, 'Natural environment climate change adaptation and action plan', Melbourne, Victoria.
693. Biodiversity Council 2022, 'Council launching to spearhead solutions for our biodiversity crisis', Carlton, Victoria.

In the same month, the Royal Society of Victoria released its position paper 'Towards Conservation and Recovery of Victoria's Biodiversity' and which included six recommended actions:

- Action 1: Recognise First Nations' leadership in ecological management
- Action 2: Resource local ownership and leadership of restoration ecology projects
- Action 3: Appoint an independent regulator to govern biodiversity values in Victoria
- Action 4: Establish funding diversity for an intersectoral nature fund
- Action 5: Provide effective investment instruments for the business sector
- Action 6: Create an independent intersectoral taskforce for biodiversity recovery and conservation in Victoria.[694]

Native bee on daisy Davies Hut, Alpine National Park. 2016.
Credit: David Paul. © Museum Victoria.

694. Royal Society of Victoria 2022, ''Towards conservation and recovery of Victoria's biodiversity', Melbourne, Victoria.

Indicator assessments

Refer to 'Guide to the indicator assessments' at the start of Part 3 for the accompanying definitions and legends related to the indicator assessment summary tables.

SoE indicator suite adjustments

State of the environment indicators are the foundational tools for evaluating and communicating the impact our activities have on the environment. The assessments of SoE 2018 indicators provided a scientific baseline of the state of Victoria's environment from which future SoE reports build upon.

However, as new pressures, challenges and data sources emerge, the SoE indicator suite must also evolve to ensure their collective assessments provide a comprehensive account of the condition of Victoria's natural values. The SoE 2023 indicator suite has been adjusted, with some new indicators being introduced and some existing indicators either being disaggregated to improve the focus of assessments, merged to enable inter-connected indicators to be evaluated as a whole, superseded, or modified in terms of the scope, breadth of measures or to align with policy targets. Refer to Appendix C of the Summary Report for a complete account of the changes that have been made to the SoE 2018 indicator suite in this report.

Changes to the indicator suite for this chapter are outlined below.

- The modified SoE 2023 indicator 'B:03 Health and status of Victorian inland Ramsar wetlands' was formed by narrowing the measure of the SoE 2018 indicator 'B:17 Health and status of Ramsar wetlands in Victoria'.
- The modified SoE 2023 indicator 'B:07 Floodplains' was formed by broadening the measure of the SoE 2018 indicator 'B:11 Area of functional floodplain'.
- The modified SoE 2023 indicators 'B:12 Threatened terrestrial and freshwater mammals', 'B:14 Threatened terrestrial bird species' and 'B:16 Threatened terrestrial and wetland reptile species'. were formed by merging the SoE 2018 indicators 'B:06 Trends in populations and distributions of threatened terrestrial species' and 'B:06B Vertebrates'.
- The modified SoE 2023 indicator 'B:17 Threatened large-bodied freshwater fish species' was formed by merging the SoE 2018 indicators 'B:04A Trend in population number and distribution of trout cod *(Maccullochella maquariensis)*'' 'B:04B Trend in population number and distribution of Macquarie perch *(Macquaria australasica)'* and 'B:13 Distribution and abundance of fish'.
- The modified SoE 2023 indicator 'B:18 Threatened small-bodied freshwater fish species'.
- The modified SoE 2023 indicator 'B:19 Threatened frog species' was formed by merging the SoE 2018 indicators 'B:04D Trend in population number and distribution of spotted tree frog *(Litoria spenceri),* 'B:04E Trend in population number and distribution of Booroolong tree frog *(Litoria booroolongensis)*', 'B:04F Trend in population number and distribution of Baw Baw frog *(Philoria frosti)'* and 'B:12 Distribution and abundance of frogs'.
- The modified SoE 2023 indicators 'B:24 Invasive freshwater plant species' and 'B:25 Invasive freshwater animal species' were formed by disaggregating the measures of the SoE 2018 indicator 'B:01 Invasive freshwater plants and animals'.
- The modified SoE 2023 indicator 'B:29 Invasive terrestrial herbivore species' was formed by merging the SoE 2018 indicators 'B:03 Invasive terrestrial animal species', 'B:03A Trend in deer populations and their distributions' and 'B:03B Trend in horse populations and their distributions'.
- The modified SoE 2023 indicator 'B:31 Invasive terrestrial predator species' was formed by narrowing the measure of the SoE 2018 indicator 'B:03 Invasive terrestrial animal species'.
- The new SoE 2023 indicators 'B:08 Grasslands', 'B:09 Alpine', 'B:10 Mallee', 'B:11 Heathlands' 'B:23 Threatened terrestrial fungi, lichen, moss and liverwort species' were not represented by an indicator in previous SoE reports.
- The new SoE 2023 indicator 'B:20 Threatened freshwater invertebrate species' was formed by expanding the measure of the SoE 2018 indicator 'B:15 Distribution and abundance of macroinvertebrates'.

- The new SoE 2023 indicators 'B:28 Priority wee control', 'B:30 Priority pest herbivore control', 'B:32 Priority pest predator control', and 'B:38 Priority revegetation' were formed by disaggregating the SoE 2018 indicator 'B:21 Area of management in priority locations'.
- The new SoE 2023 indicator 'B:36 New, permanently protected areas on private land' was formed by merging the SoE 2018 indicators 'B:07 Private land conservation', 'L:10 Land management activities' and disaggregating 'B:21 Area of management in priority locations' into five separate indicators.

Ecosystem health

The Legislative Council's Environment and Planning Committee Inquiry into ecosystem decline in Victoria released its final report in November 2021 which stated that:

> 'Victoria's precious ecosystems are at incredible risk. The cumulative effects of a rapidly changing climate and bushfires that are increasing in size and intensity, habitat loss and fragmentation through continuing land clearing, and invasive plants and animals, threaten our native plants and animals, ecosystems and the crucial services they provide. Biological diversity helps to maintain a functioning biosphere that supports human life, such as through clean water and productive agriculture. Without urgent action, its ongoing decline will have critical consequences.' [695]

Biodiversity is directly linked to the functioning of natural ecosystems, the health of which is also critical for human prosperity. Researchers found that a reduction in the diversity of plant species had an equal or greater impact on ecosystem function and health than other factors, such as fire, drought and elevated carbon dioxide levels.[696, 697] While another study argued that as a consequence, the 'preservation, conservation, and restoration of biodiversity should be a high global priority.' [698]

Such actions that ensure the diversity of species and the functioning of ecosystems provide many ecological benefits, as the following examples illustrate.

- Many ecosystems, such as those associated with forests, provide essential ecosystem services, including the amelioration of climate, the sequestering of carbon in the soil, and the maintenance of humidity.[699]
- Small digging mammals are key species in Australian forests because they serve to increase the absorption of water and nutrients into the ground and disperse the fungi — processes which serve to sustain trees.[700]
- Pollination is essential for the survival of many plant species and, as a result, the integrity of the ecosystems in which they live. Pollination depends on the diversity of organisms, including bees, moths, butterflies, beetles, wasps, birds and mammals[701]

Aquatic and terrestrial ecosystems also provide many environmental, cultural, social and economic values that include:

- spiritual and cultural significance for Aboriginal communities
- popular locations for recreation, education and tourism
- ecosystem services contribute more than $15 billion annually and thousands of jobs to the Victorian economy.[702, 703, 704]

695. Legislative Council Environment and Planning Committee 2021, 'Inquiry into ecosystem decline in Victoria', Parliament of Victoria, Melbourne, Victoria.
696. Tilman D, Reich PB, Isbell F 2012, 'Biodiversity impacts ecosystem productivity as much as resources, disturbance, or herbivory', Proceedings of the National. Academy Sciences, 109, pp. 10394–10397.
697. Hooper D, Adair E, Cardinale B, Byrnes J, Hungate B, Matulich KL, Gonzalez A, Duffy JE, Gamfeldt L, O'Connor MI 2012, 'A global synthesis reveals biodiversity loss as a major driver of ecosystem change', *Nature*, 486, pp 105–108.
698. Tilman D, Isbell F, Cowles J 2014, 'Biodiversity and ecosystem functioning', *Annual Review of Ecology, Evolution, and Systematics*, 45, pp. 471–493.
699. Schmitz O 2018, 'The new ecology: rethinking a science for the Anthropocene', Princeton University Press.
700. Fleming P, Anderson H, Prendergast A, Bretz M, Valentine L, Hardy G 2013, 'Is the loss of Australian digging mammals contributing to a deterioration in ecosystem function?', *Mammal Review*.
701. Ollertin J 2017, 'Pollinator diversity: distribution, ecological function, and conservation', *Annual Review of Ecology, Evolution, and Systematics*, 48, pp. 353–376.
702. McCormick F, Showers C 2019, 'Ecosystem services from forests in Victoria: assessment of regional forest agreement regions', Department of Environment Land, Water and Planning (DELWP), Melbourne, Victoria.
703. Eigenraam M, McCormick F, Contreras Z 2016, 'Marine and coastal ecosystem accounting: Port Philip Bay', report to the Commissioner for Environmental Sustainability (CES), Department of Environment Land, Water and Planning (DELWP), Melbourne, Victoria.
704. Abernethy K, Barclay K, McIlgorm A, Gilmour P, McClean N, Davey J 2020, 'Victoria's fisheries and aquaculture: economic and social contributions', FRDC 2017-092, University of Technology Sydney, Sydney, New South Wales.

Ecosystem health can be threatened by the loss, decline or fragmentation of vegetation, invasive species, climate change, inappropriate fire regimes, timber harvesting, urban and agricultural development, and altered river flows. For example, climate impacts can occur suddenly and cause large environmental shifts, including the collapse of ecosystems.

PV has mapped the distribution of nine major ecosystems across Victoria (Figure B2).[705] Indicators in this 'Ecosystem health' sub-theme cover wetlands, grasslands, mallee, heathlands and alpine. The remaining four are covered elsewhere in this or other Commissioner for Environmental Sustainability reports.

Six of the 10 'Ecosystem health' indicators consider riparian vegetation, floodplains, grasslands, alpine areas, the Mallee and heathlands, and the assessments review the bioregional conservation status of EVCs, their pre-1750s and current extents, and their level of protection in the formal protected area network.[706] The protection level for each EVC is assessed against both the Commonwealth Government's commitment to the protection of 30% of lands and seas by 2030, and the JANIS Criteria that requires 15% of the pre-1750s extent to be included in protected areas.[707] Although developed to assess protection of forests, in this report it is also used as a benchmark for protection levels in floodplains, grasslands, alpine areas, mallee and heathlands.

The bioregional conservation status refers to the depletion in extent and/or quality of an EVC in a particular bioregion when compared to its pre-1750s extent and condition.[708] The status of an EVC within a bioregion is either presumed extinct, endangered, vulnerable, rare, depleted or of least concern. This categorisation is a little different to that for threatened species, which is comprised of extinct, critically endangered, endangered and vulnerable categories. Figure B3 shows the locations of each bioregion. The purpose of the analysis is to indicate the status of EVCs in particular bioregions, which provides insight on the level of loss and fragmentation of native vegetation. Further, it is used to identify opportunities for increased protection of those EVCs that have remnants on other public land or private land. Specific gaps in the reserve system have been reported by VEAC, most recently in its Statewide Assessment of Public Land.[709]

705. On the basis of a classification of nine main ecosystems in Victoria's 1998 Biodiversity Strategy and by amalgamating broadly similar ecological vegetation classes (EVCs).
706. The data used for the assessments is from Victorian Environment Assessment Council (VEAC) 2017, 'Bioregional conservation status of EVCs in 28 bioregions and change in EVC extent between 1750 and 2015', Melbourne, Victoria. This accompanied VEAC's 2017 'Statewide Assessment of Public Land'.
707. The JANIS criteria, which were agreed to be Commonwealth and state jurisdictions in 1997 as part of the regional forest agreements process, require at least 15% of pre-1750s extent of each forest ecosystem be included in protected areas.
708. Department of Environment, Land, Water and Planning (DELWP), 'Bioregions and EVC benchmarks', https://www.environment.vic.gov.au/biodiversity/bioregions-and-evc-benchmarks Accessed 20 August 2022.
709. Victorian Environmental Assessment Council (VEAC) 2017, 'Statewide assessment of public land', Melbourne, Victoria.

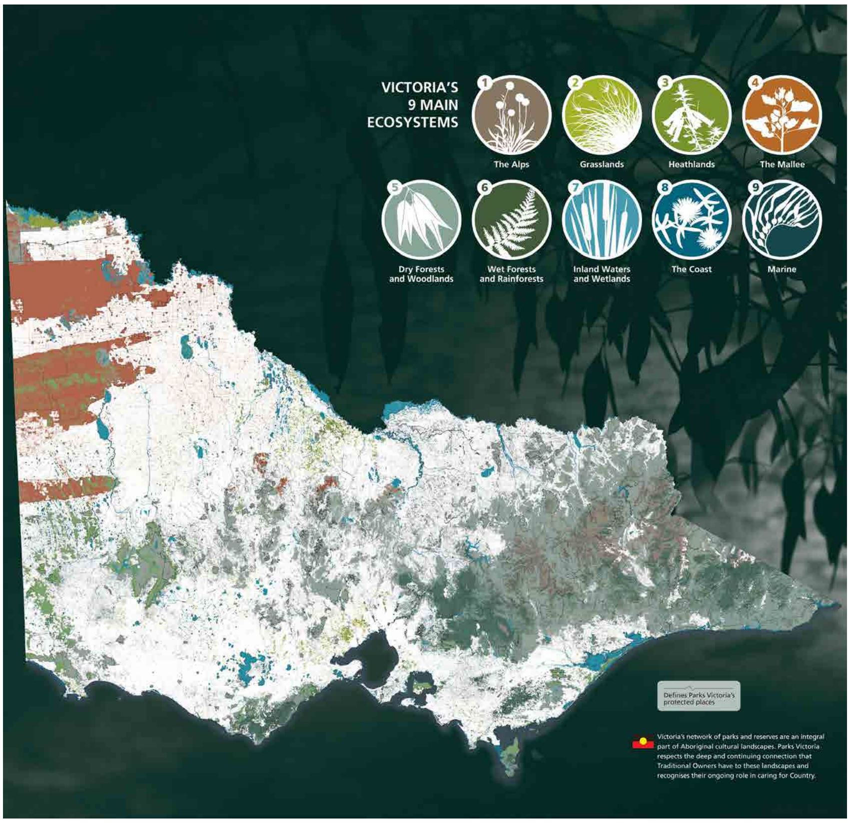


Figure B2: Victoria's nine primary ecosystems as mapped by Parks Victoria.[710]

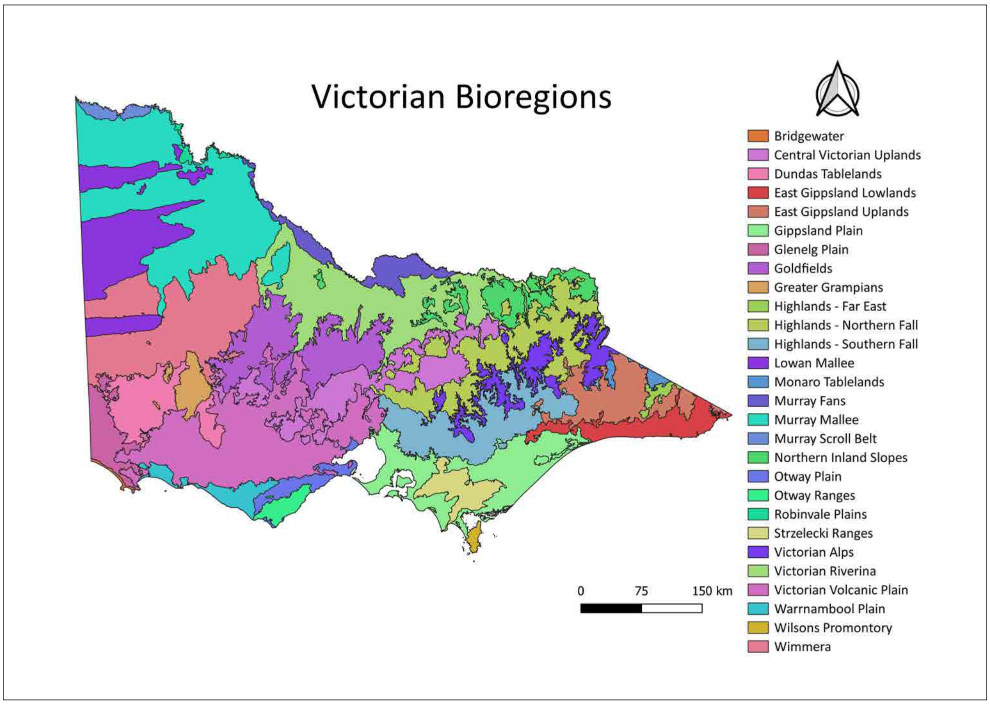


Figure B3: Victoria's 28 terrestrial bioregions.[711]

710. Parks Victoria (PV), 'Our amazing diversity', Melbourne, Victoria, https://www.parks.vic.gov.au/get-into-nature/conservation-and-science/our-amazing-diversity Accessed 18 April 2023
711. Department of Energy, Environment and Climate Change (DEECA), 'Bioregions and EVC benchmarks' https://www.environment.vic.gov.au/biodiversity/bioregions-and-evc-benchmarks Accessed 10 January 2023.

Indicator B:01 Changes in land cover

B:01 Changes in land cover						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?			↙	
Data source(s):	DELWP					
Measure(s):	Changes in land-cover classes from 1985 to 2019					

Why this indicator?

Monitoring change in land cover can provide a statewide view of the loss of natural areas and threats to biodiversity, and guide policy and on-ground action.

NB: This SoE 2023 indicator was 'B:19 Landscape-scale change' in the SoE 2018 Report.

Why this assessment in 2023?

Analysis of DELWP's Land Cover Time Series across Victoria shows an increased area of land-cover classes that are development-based and an overall decrease in those that are nature-based. The long-term trend has been evident across the seven epochs since 1985 and has placed more pressure on Victoria's biodiversity. However, it is not possible to determine a 2023 trend until data on the eighth epoch are released.

Summary of State of the Environment 2018 Report assessment

- Urban expansion had resulted in a loss of native grasslands and increased pressures on surrounding native vegetation in terms of asset protection from fire.
- Hardwood plantations, irrigated horticulture and exotic woodlands increased between 1990 and 2015.
- Native grasslands, native scattered trees, native shrubs and intermittent seasonal wetlands declined over the same period.

Critical data used for the 2023 assessment

- 2020 DELWP data for the 2015-19 epoch

2023 assessment

DELWP has developed a time series that provides data on land-cover classes and native vegetation changes across seven five-yearly time epochs from 1985 to 2019. Figure B4 maps the distribution of each land-cover class in the 2015 to 2019 epoch and shows that dryland cropping dominates north-western Victoria, exotic pasture/grassland dominates south-western and north-eastern Victoria as well as South and West Gippsland, while treed native vegetation covers much of eastern Victoria and is scattered in the Grampians, Central Highlands, the Otway Ranges and the far north-west and south-west.

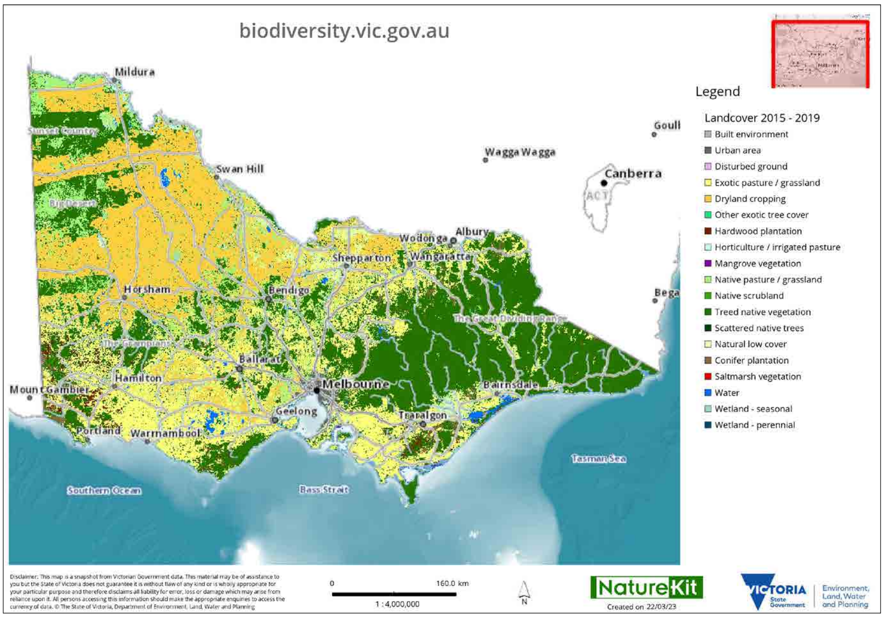


Figure B4: Land cover types in Victoria during the 7th epoch (2015-19).[712]

Figure B5 provides details on percentage increases and decreases in land-cover classes across Victoria over the seven epochs. The next time epoch, the eighth, will be released in 2025 and will cover the years from 2020 to 2024. Land cover classes that increased their spatial extent between 1985 and 2019 were exotic woody (+63%), hardwood plantation (+54%), urban (+54%), built-up (+42%), disturbed ground (+40%), natural low cover (+26), dryland cropping (+20%), pine plantation (+15%), irrigated horticulture (+5%) and native trees (+1%).

Those land-cover classes that experienced a decrease in their spatial extent were native shrub (-48%), wetland perennial (-33%), wetland seasonal (-26%), native scattered trees (-23%), pasture not native (-13%), and native grass herb (-12%). In general, it can be said that land-cover classes associated with human-based activities have continued to increase, while native vegetation cover has declined. A more detailed discussion of changes in land cover can be found within the indicators L:01 and L:02 of the 'Land' chapter of this report.

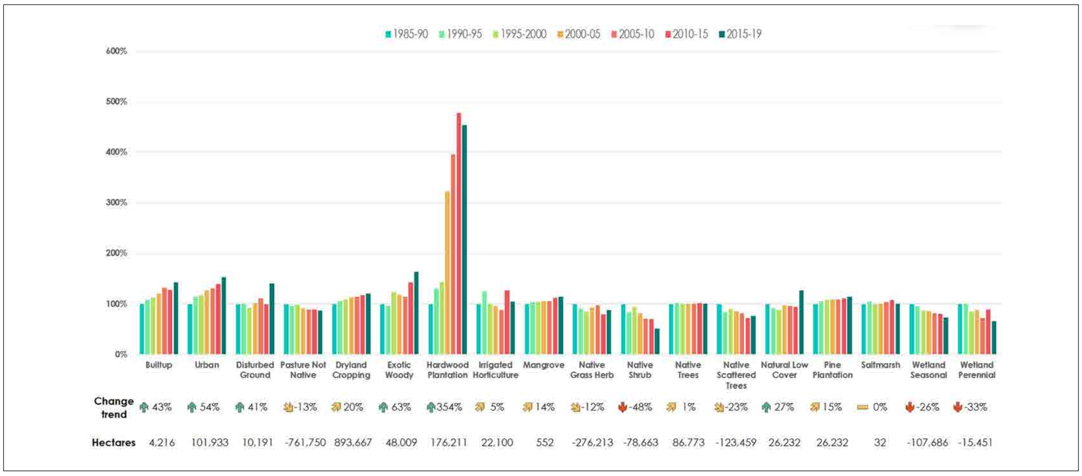


Figure B5: Percentage change in land-cover classes across Victoria between the 1st (1985-90) and 7th (2015-19) epochs.[713]

712. Department of Environment Land, Water and Planning (DELWP), 'NatureKit' https://maps2.biodiversity.vic.gov.au/Html5viewer/index.html?viewer=NatureKit Accessed 17 July 2022.
713. Department of Environment Land, Water and Planning (DELWP), 'Victorian land cover time series' https://www.environment.vic.gov.au/biodiversity/Victorias-Land-Cover-Time-Series Accessed 9 May 2021.

Indicator B:02 Wetlands

B:02 Wetlands						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide		↙			?	
Data source(s):	DELWP					
Measure(s):	Bioregional conservation status Wetland extent and water regime frequency					

Why this indicator?

Wetlands provide important ecosystem services to the environment and communities. Determining the level of threats can guide actions for mitigation.

NB: This SoE 2023 indicator was 'B:16 Wetlands extent and condition' in the SoE 2018 Report.

Why this assessment in 2023?

More than 75% of the wetland ecological vegetation classes (EVCs) across the state's bioregions are either endangered, vulnerable or rare. Drainage, cropping, urbanisation, altered water flows and climate change continue to impact wetland condition. A recent DELWP analysis of wetland water regimes has shown that more than 20% of wetlands show signs of significant stress. Data have improved since the SoE 2018 Report.

Summary of State of the Environment 2018 Report assessment

- Based on a comparison of wetlands between 1788 and 1994, more than a quarter of Victoria's wetlands had been lost since European settlement.
- Of the 149 wetland EVCs, nearly all were threatened in at least one Victorian bioregion. Furthermore, more than 75% of all wetland EVCs across Gippsland Plain, Glenelg Plain, Otway Plain, Victorian Riverina, Victorian Volcanic Plain and Warrnambool Plain were considered endangered or vulnerable.

Critical data used for the 2023 assessment

- New DELWP analysis of wetland regimes
- VEAC bioregional conservation status of wetland EVCs

2023 assessment

Wetlands are a key feature of Victoria's landscape and are valuable for water purification, flood mitigation, and carbon sequestration and as habitat for many threatened species. However, they have been significantly reduced in their spatial extent, as is shown in B:01.

A review of statewide assessments and condition modelling for Victoria's wetlands showed that there were more than 12,800 natural wetlands covering 530,000 hectares and 3,000 artificial wetlands across 201,000 hectares across the state.[714] The report also noted that 3,925 (23%) of natural wetlands covering 201,175 hectares estimated in 2007 had been lost in Victoria since European colonisation.[715] Shallow freshwater wetlands have experienced the greatest losses since European colonisation — 3,532 wetlands covering 95,443 hectares. Deep freshwater wetlands declined by 349 covering 91,055 hectares, while 44 saline wetlands covering 14,675 hectares were lost. Of those wetlands remaining, 72% are found on private land.[716]

714. Papas P, Moloney P 2012, 'Victoria's wetlands 2009–2011: Statewide assessments and condition modelling', Arthur Rylah Institute (ARI) for Environmental Research Technical Report Series No. 229, Heidelberg, Victoria.
715. Department of Sustainability and Environment (DSE) 2007, 'Wetland 1994 spatial dataset', Melbourne, Victoria and Department of Sustainability and Environment (DSE) 2007, 'Corporate geospatial data library. Wetland 1788 spatial dataset', Melbourne, Victoria.
716. Papas P, Moloney P 2012, 'Victoria's wetlands 2009–2011: Statewide assessments and condition modelling', Arthur Rylah Institute (ARI) for Environmental Research Technical Report Series No. 229, Heidelberg, Victoria.

The review also identified the main threats to Victoria's wetlands which were found to be changed water regimes, reduced wetland area, altered wetland form, degraded water quality, soil disturbance, and invasive flora and aquatic and terrestrial fauna.

A report by Frood and Papas (2016) listed 716 wetland EVCs found within the state's bioregions (many are found in multiple bioregions), along with their bioregional conservation status.[717] Those bioregions with the greatest number of endangered and vulnerable wetland EVCs were the Gippsland Plain, Glenelg Plain, Otway Plain, Victorian Riverina, Victorian Volcanic Plain, the Dundas Tablelands, Warrnambool Plain and the Wimmera bioregions, all of which have experienced extensive clearing since European colonisation.[718]

DELWP had consultants analyse 30 years of Landsat imagery to detect inundation at Victorian wetlands, characterise water regimes for all Victorian wetlands and detect any trends in extent and water regime frequency of inundation. In a draft report to DELWP, the water regime has been described for each wetland EVC and includes the phase context (continuous, inundated, or drying), frequency of inundation, duration of waterlogging and inundation, maximum depth of regular or sustained inundation and salinity.[719]

A metric has been developed to indicate the degree to which a wetland's water regime has been impacted over the 30-year period, providing the clearest picture yet of how wetlands are tracking across the state using extent and water regime frequency. This will help identify drivers for any identified hydrological trends and the level of threat, as well as provide statewide knowledge of water regimes.

The distribution of results, highlighting key areas of increased stress for each wetland metric, is shown in Figure B6. The negative values indicate a decrease in metric value relative to long-term variability, whereas a positive result indicates an increase in the metric value relative to long-term variability. When the stress index is less than -1 (orange) or greater than 1 (dark blue), this indicates a wetland that is experiencing a substantially different hydrological regime.

The analysis revealed substantial widespread reductions in some wetland hydrologic metrics, including inundation magnitude (mean), magnitude (max), duration and frequency. More than 20% of the approximately 7,400 wetlands in the dataset showed significant stresses in inundation magnitude (mean) and duration. The causes of this stress have not been identified in the report —although they are consistent with a widespread drying trend.

Inundation timing and rate of change showed no clear trends at a whole-of-state level. However, there were still many individual wetlands that experienced significant increases or decreases.

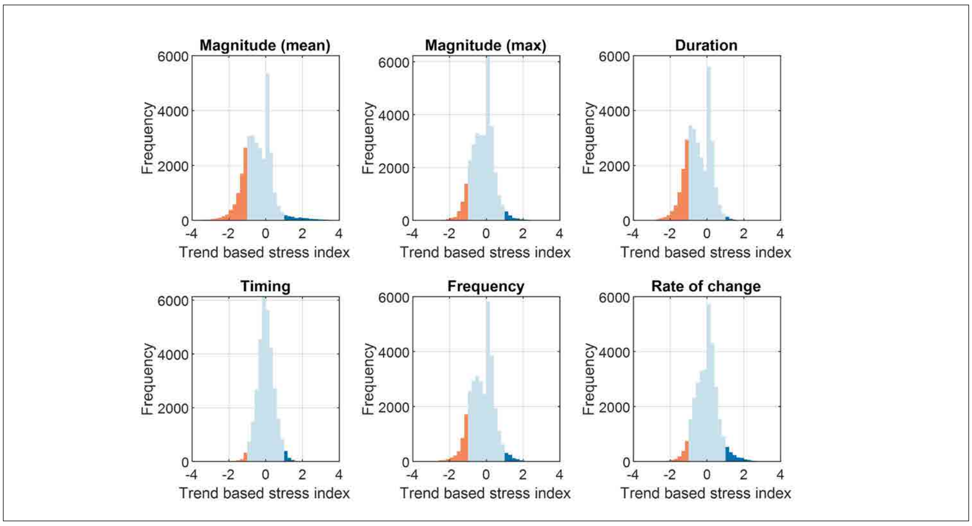


Figure B6: Distribution of calculated stress indices for the six wetland hydrologic metrics from 1988 to 2018.[720]

717. Frood D, Papas P 2016, 'A guide to water regime, salinity ranges, and bioregional conservation status of Victorian wetland ecological vegetation classes', Pathways Bushland and Environment and Arthur Rylah Institute (ARI) for Environmental Research, Melbourne, Victoria.
718. Ibid.
719. John A, Horne A, Nathan R 2022, 'Assessing stressors and risks to Victorian wetlands: Phase A research outcomes', A report for the Department of Environment Land, Water and Planning (DELWP), Melbourne, Victoria.
720. John A, Horne A, Nathan R 2022, 'Assessing stressors and risks to Victorian wetlands: Phase A research outcomes', A report for the Department of Environment Land, Water and Planning (DELWP), Melbourne, Victoria.

The analysis showed that northern and western Victoria, especially in the Wimmera, North Central and Goulburn Broken CMAs, experienced the largest impacts and most significant reductions in hydrologic metrics. This pattern is shown in Figure B7, which maps the stress index for inundation magnitude. A similar pattern was found to exist for inundation duration. There is a clear pattern of stresses following the main reach of the Goulburn River. Larger wetlands were also more likely to show significant stress. The next phase of the project will seek to attribute observed stress to climatic or non-climatic factors.

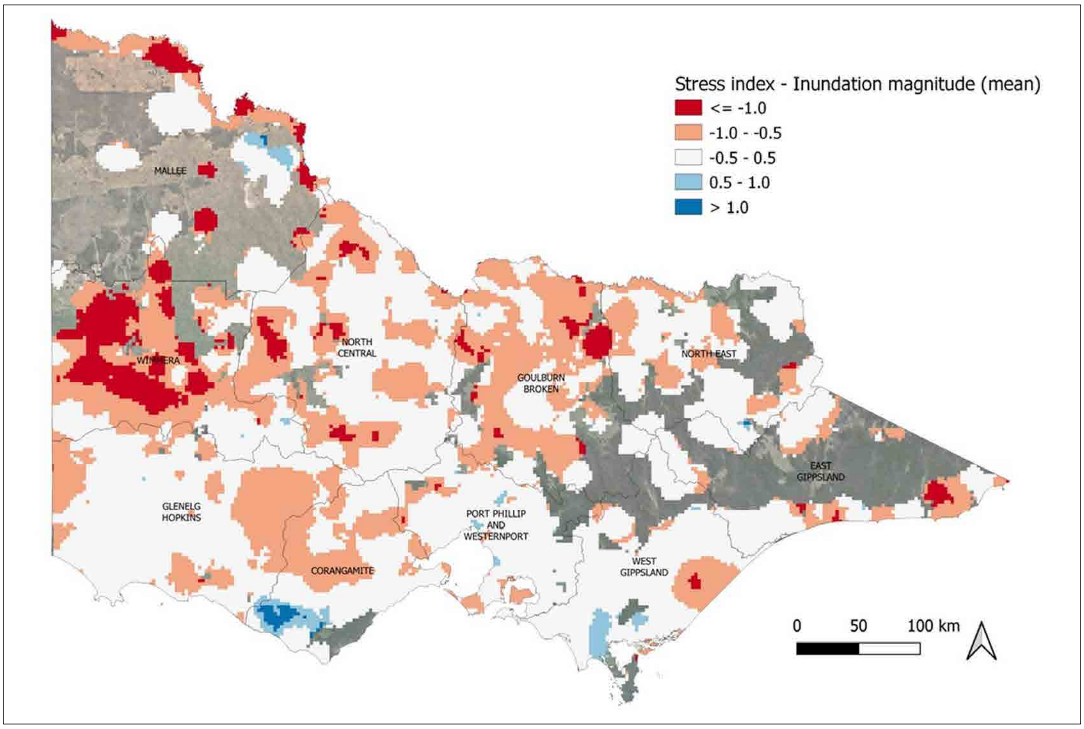


Figure B7: Stress index for the inundation magnitude (mean) metric for Victorian wetlands from 1988 to 2018.[721]

In presenting these data here, DELWP has advised that the following caveats apply:

- The detail of these figures may change as part of completing this work and there may be different results for individual wetlands in the final version of the report. However, it is believed that the statewide trends will remain largely consistent with those identified in the 2022 draft report.
- The likely changes in individual wetland results are due to improvements in the processing of Landsat data, which will provide more nuanced results.
- Regarding the statewide result for wetland inundation timing (no clear signal), only changes greater than one month will be detected due to methodology and data, however, changes in the order of weeks may still be significant for wetland ecology.

721. John A, Horne A, Nathan R 2022, 'Assessing stressors and risks to Victorian wetlands: Phase A research outcomes', A report for the Department of Environment Land, Water and Planning (DELWP), Melbourne, Victoria.

Indicator B:03 Health and status of Victoria's inland Ramsar wetlands

B:03 Health and status of Victoria's inland Ramsar wetlands						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Inland Ramsar sites: •Barmah Forest •Edithvale-Seaford Wetlands •Gunbower Forest •Hattah-Kulkyne Lakes •Kerang Wetlands •Lake Albacutya •Western District Lakes					?	
Data source(s):	DELWP, PV, Melbourne Water					
Measure(s):	Governance, management and monitoring Limits of acceptable change					

Why this indicator?

Signatories to the Ramsar Convention have an obligation to maintain/improve the ecological character of the site.

NB: This is a modified 2023 indicator that provides greater focus on inland Ramsar wetlands and was formed by narrowing the measure of the SoE 2018 indicator 'B:17 Health and status of Ramsar wetlands in Victoria'. The coastal Ramsar wetlands are now assessed within the State of the Marine and Coastal Environment reporting.

Criteria used for status assessment

Good: Limits of acceptable change for 5 to 7 inland Ramsar sites are met
Fair: Limits of acceptable change for 4 or 5 inland Ramsar sites are met
Poor: Limits of acceptable change for <4 inland Ramsar sites are met

Why this assessment in 2023?

Weaknesses in the governance, monitoring and management arrangements for Victoria's Ramsar sites were highlighted in the 2016 Victorian Auditor-General's Office's report. In response, those arrangements have been improved by government agencies responsible for site management. Management plans are largely consistent with national standards and most limits of acceptable change are being met at the seven inland Ramsar sites. Environmental watering programs have been positive for several sites on regulated rivers.

Summary of State of the Environment 2018 Report assessment

- In 2016, VAGO found limited evidence that ecological character for each Ramsar site was being maintained.
- Where information was available, it showed that some Ramsar sites were not being effectively managed and protected from ecological decline. For these sites, the declines were attributed to changed water regimes, water quality, recreational use, agricultural use, invasive species, salinity incursion and climate change.

Critical data used for the 2023 assessment

- Data gathering and reporting on Victoria's Ramsar sites have improved since the SoE 2018 Report.

2023 assessment

The international Ramsar Convention aims to halt the loss of wetlands and conserve those that remain.[722] Victoria has 12 Ramsar sites, with their wetland complexes covering a total of 173,426 hectares.

722. Ramsar Convention, 'Wetlands of international importance' www.ramsar.org Accessed 6 June 2021.

This indicator assessment focusses on the seven inland sites found in Victoria, although reference is also made for all 12 Ramsar sites as a whole.

Victorian management agencies are responsible for maintaining the ecological character of each Ramsar site. In 2016, the VAGO audit of Ramsar wetlands was critical of site management and monitoring and concluded that improvements in governance, coordination and oversight were required.[723] There was also evidence of potential negative change in the ecological condition of some sites. VAGO also found that the ecological character descriptions and Ramsar information sheets were out of date, funding was inadequate, and management plans failed to meet Australian guidelines.

DELWP and other managers accepted the VAGO findings and recommendations and in response have improved the governance arrangements by developing a statewide inter-agency management group and coordinating committees for each site. Managers have also developed frameworks for implementing management plans as well as monitoring, evaluation, reporting and improvement (MERI). The plans for the Port Phillip (Western Shoreline) and Bellarine Peninsula site and the Western Port site have been finalised.

Each of Victoria's 12 Ramsar sites now has a management plan that meets the Australian Ramsar Management Principles under the EPBC Act. Four sites have addenda to their ecological character descriptions published on the DEECA website.[724] The addendum for the Gunbower Forest site is in the late draft stage, with analysis showing no change in ecological character, while the Lake Albacutya site will be assessed when the results of long-term monitoring become available.[725] Seven (of the 12 sites) sites will have their management plans renewed in 2023-24 as part of a 7-year review cycle that is now in place for all site plans. Ramsar information sheets are also being updated. In recent years, six of Victoria's 12 Ramsar sites have received deliveries of environmental water, including the inland sites of Hattah-Kulkyne, Gunbower and Barmah.

A report on the achievement of environmental outcomes in the northern waterways of Victoria included indicator data for four inland Ramsar sites, including Hattah-Kulkyne Lakes, Gunbower Forest, Barmah Forest, and Kerang Wetlands (Hird Swamp, Johnsons Swamp, and Lake Cullen).[726]

The assessment found that, except for tree survival and recruitment in Hird Swamp, all other measures were either improved or maintained. Ecological character was maintained in the water-delivery footprint and health measures were within, or met, the limits of acceptable change (LAC).[727] The exception was moira grass in the Barmah Forest, which had suffered a severe spatial decline.

LAC assessments are undertaken in accordance with Ramsar monitoring priorities. Data on assessing the LAC are sourced from a wide range of datasets, including commissioned reports, the Living Murray Program, EPA Victoria water quality monitoring, Birdlife Australia, citizen scientists, the Australian Living Atlas, CMAs, PV and Melbourne Water.

A recent review of whether LACs have been met for Victoria's inland Ramsar sites has been provided by DELWP. In summary:

- Barmah Forest: of 10 LACs, six met the limits, one likely met the limits, one exceeded the limits, one is under review and one had insufficient data
- Edithvale and Seaford Wetland: of four LACs, three met the limits and one partially met the limits
- Hattah-Kulkyne Lakes: of six LACs, each were met
- Gunbower Forest: of eight LACs, three met the limits, one likely met the limits, one likely exceeded the limits, two are under review and one had insufficient data
- Kerang Wetlands: of 17 LACs, 13 met the limits, one partially met, two under review and one had insufficient data
- Western District Lakes: of six LACs, five met the limits and one partially met the limits.
- Lake Albacutya: of five LACs, one met the limits, one was met in part, two were unable to be assessed and for one there were insufficient data. The lake has been dry for the past three decades.

723. Victorian Auditor-General's Office (VAGO) 2016, 'Meeting obligations to protect Ramsar wetlands', Melbourne, Victoria.
724. Ecological character is defined as the combination of the critical ecosystem components, processes, and benefits and services (CPS) that characterise a Ramsar site.
725. Department of Environment, Land, Water and Planning (DELWP), 'Unpublished data', Melbourne, Victoria, Accessed 2022.
726. Department of Environment Land, Water and Planning (DELWP) 2020, 'Achievement of environmental outcomes in northern Victoria's waterways', report to meet Murray-Darling Basin Plan Schedule 12 Matter 8 obligations, Melbourne, Victoria.
727. The limit of acceptable change (LAC) defines the natural level of variability for each critical CPS and is the variation that is considered acceptable without indicating a possible change in ecological character.

Indicator B:04 Groundwater-dependent ecosystems

B:04 Groundwater-dependent ecosystems						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	Grey	?	Grey	Grey	?	Red
Data source(s):	CSIRO, DELWP, Melbourne Water					
Measure(s):	Health of groundwater-dependent ecosystemsa					

Why this indicator?

Groundwater is important for maintaining the health of wetlands and other groundwater-dependent ecosystems.

NB: This SoE 2023 indicator was 'WR:10 Groundwater ecosystems' in the 'Water resources' chapter of the SoE 2018 Report.

Why this assessment in 2023?

Knowledge about the location, ecology and status of groundwater-dependent ecosystems is limited. However, their inclusion as values to be considered in environmental assessments for major projects will begin to improve the understanding of them, as will their tracking in the CSIRO Groundwater Dependent Ecosystems Atlas.

Summary of State of the Environment 2018 Report assessment

- Salination 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 affect groundwater-dependent ecosystems.

Critical data used for the 2023 assessment

- Investigation of the Gippsland and Otway basins provided limited but new data on stygofauna
- Other studies have identifying known and potential groundwater-dependent ecosystems

2023 assessment

Groundwater-dependent ecosystems (GDEs) rely in part or completely on groundwater for their functioning and survival. They include subterranean waters, caves, wetlands, rivers, creeks and riparian, estuarine and nearshore marine ecosystems.[728] In time of drought, GDEs can act as refuges for animals and plants and support the base flows of rivers and streams.

The main threats to GDEs are largely from groundwater extraction for mining, urban development, agriculture and town and livestock water supplies. However, other threats include increasing levels of salinity and nutrients, and climate change.[729] For example, a study of GDEs in the Bogong High Plains found that snowpack reduction due to climate change could reduce groundwater recharge and the distribution of the moss *Blindia robusta*.[730]

728. Dresel P, Clark R, Cheng X, Reid M., Fawcett J, Cochraine D 2010, 'Mapping terrestrial groundwater dependent ecosystems: method development and example output', Department of Primary Industries (DPI), Melbourne, Victoria.
729. Ibid.
730. McCartney V 2020, 'The vegetation and hydrology of groundwater dependent ecosystems on the Bogong High Plains, Victoria', A thesis of fulfilment of the requirements for the degree of Doctor of Philosophy, School of Life Sciences, La Trobe University, Bundoora, Victoria.

Data on the location of GDEs are limited, with most studies identifying only potential locations. After a comprehensive analysis of Landsat images, researchers concluded that sites with the greatest potential for GDEs were those with shallow water tables.[731] More recently, research has been conducted into the nature of stygofauna in groundwater that might be affected by the development of gas reserves from the Gippsland and Otway basins.[732, 733] In the Otway basin, 149 individual animals from five stygofauna taxa were collected from six groundwater bores, while in the Gippsland Basin, the number was five individual animals from one stygofauna taxon. Figure B8 was derived from CSIRO's Groundwater Dependent Ecosystems Atlas and maps the distribution of known, low, moderate, and high potential aquatic GDEs across Victoria. Very few GDEs are known.

There is increasing awareness of the need to minimise the impacts on GDEs, and in 2015 the Ministerial Guidelines for Groundwater Licensing and the Protection of High Value Groundwater Dependent Ecosystems were released. The potential impact of development on GDEs is now being included in environmental impact analyses.

In the case of Victoria's railway crossings removal project, investigation of the potential impact of tunnelling on the Edithvale-Seaford Wetlands Ramsar site was required. The assessment concluded that the site would not be significantly impacted, and tunnelling proceeded.[734] There are also concerns about the impact that the deep footings of wind turbines could have on GDEs at the site of the proposed Kentbruck Green Power Hub abutting the Discovery Bay Coastal Park. The planning minister's requirement for the project's Environmental Effects Statement identified one of the key environmental risks as 'effects on groundwater that may result in adverse changes to groundwater dependent ecosystems or affect the ecological character of the Glenelg Estuary and Discovery Bay Ramsar site.' [735]

Melbourne Water has a Groundwater Dependent Ecosystem program that identifies high value and high risk GDEs (wetlands and waterways) in the Port Phillip and Westernport region. The program monitors condition using the Index of Wetland Condition which has been adapted for GDEs. The information is being used to inform input to strategic infrastructure projects and groundwater extraction licences.

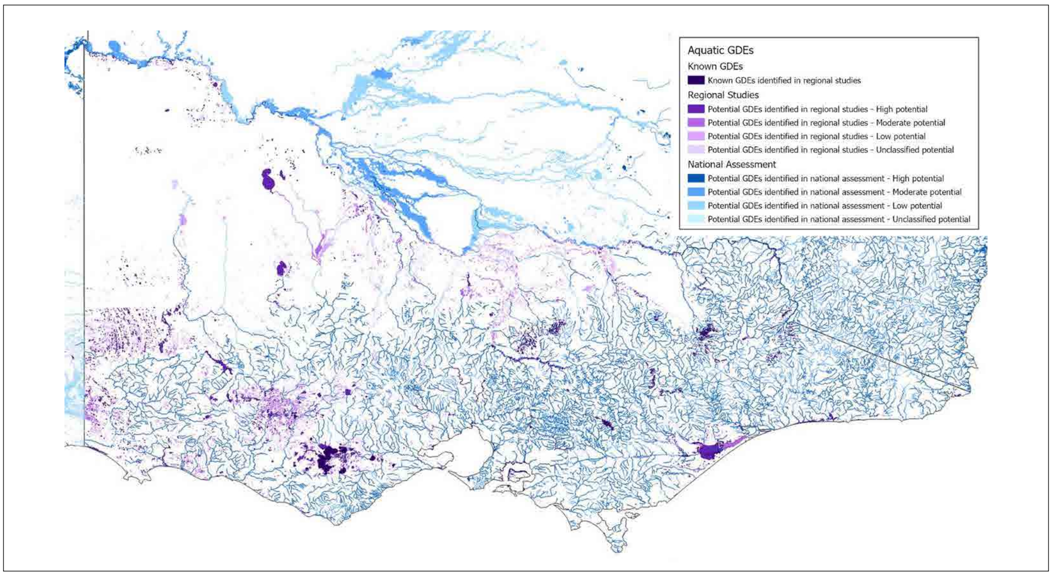


Figure B8: Distribution of known and potential aquatic GDEs in Victoria in 2023.[736]

731. Dresel P, Clark R, Cheng X, Reid M., Fawcett J, Cochraine D 2010, 'Mapping terrestrial groundwater dependent ecosystems: method development and example output', Department of Primary Industries (DPI), Melbourne, Victoria.
732. Bold T, Serov P, Iverach C, Hocking M 2020, 'Regional baseline stygofauna survey, onshore Gippsland Basin', Victorian Gas Program Technical Report 14, Melbourne, Victoria.
733. Bold T, Serov P, Iverach C, Hocking M 2020, 'Regional baseline stygofauna survey, onshore Otway Basin', Victorian Gas Program Technical Report 13, Melbourne, Victoria.
734. AECOM GHD Joint Venture 2018, 'Edithvale and Bonbeach level crossing removal projects environment effects statement technical report B ecological impact assessment: Wetlands and groundwater dependent ecosystems', Melbourne, Victoria.
735. Department of Environment Land, Water and Planning (DELWP) 2019, 'Draft scoping requirements for Kentbruck Green Power Hub Environment Effects Statement: *Environment Effects Act 1978*', Melbourne, Victoria.
736. Commonwealth Scientific and Industrial Research Organisation (CSIRO), 'Groundwater Dependent Ecosystem Atlas' http://www.bom.gov.au/water/groundwater/gde/map.shtml Accessed 4 January 2023.

Biodiversity

Indicator B:05 Rivers

B:05 Rivers						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide						

Data source(s):	CMAs, DELWP
Measure(s):	Number of river basins that have 70% to 100% of their river lengths in good-to-excellent condition Depletion of in-stream woody habitat

Why this indicator?

The health of Victorian rivers is influenced by grazing, clearing, bushfires, invasive species, regulation, water extraction, waste discharges, timber harvesting and urban development. These can cause disturbances in river dynamics, and impact native aquatic species and cultural, social and economic values.

NB: This SoE 2023 indicator was 'B:09 River health' in the SoE 2018 Report.

Criteria used for status assessment

Good: ≥21 river basins have 70% to 100% of their river lengths in good to excellent condition
Fair: 14 to 20 river basins have 70% to 100% of their river lengths in good to excellent condition
Poor: <14 river basins have 70% to 100% of their river lengths in good to excellent condition

Why this assessment in 2023?

Based on data from 2013, river health is poor in western and central Victoria and good in the far east of the state. Only three river basins had 70% to 100% of their river lengths in good to excellent condition. In-stream woody habitat status is poor in the western, southern and north-central parts of the state and good in the north-east and far east. In the longer term, climate change, increasing water demands in urban and rural areas due to population growth, and the intensification of agriculture, could lead to lower flows and declining river health. Some data used in this assessment are now a decade old, hence the moderate confidence.

Summary of State of the Environment 2018 Report assessment

- Victoria's River Monitoring and Assessment Program (RiverMAP) found that Victorian river health was influenced by grazing, land clearing for agriculture, timber production and urban development which has led to increased sedimentation, runoff, nutrient and pollutant loads, removal and/or reductions of riparian vegetation and the loss of in-stream habitat for aquatic biota.

Critical data used for the 2023 assessment

- The Long-Term Water Resource Assessment for Southern Victoria.

2023 assessment

Victoria's rivers and streams flow along an estimated 85,000 km, sustaining floodplains, lakes, wetlands and estuaries that support diverse ecosystems containing more than 100 waterbird species, 50 freshwater fish species, 38 frog species, 40 crayfish species and more than 800 vascular plant species.[737, 738]

737. Department of Environment Land, Water and Planning (DELWP) 2015, 'Regional riparian action plan 2015–2020', Melbourne, Victoria.
738. Victorian National Parks Association 2020, 'Submission to the Legislative Council Environment and Planning Committee inquiry into ecosystem decline in Victoria', Parliament of Victoria, Melbourne, Victoria.

Biodiversity

The impact of land clearing on river health is revealed in Figure B9 which shows that in the western areas of the state, where most land clearing has occurred, rivers are in poor condition. In contrast, the relative lack of clearing in East Gippsland has resulted in rivers that are in good to excellent condition. A similar pattern exists for the heath of in-stream woody habitat.

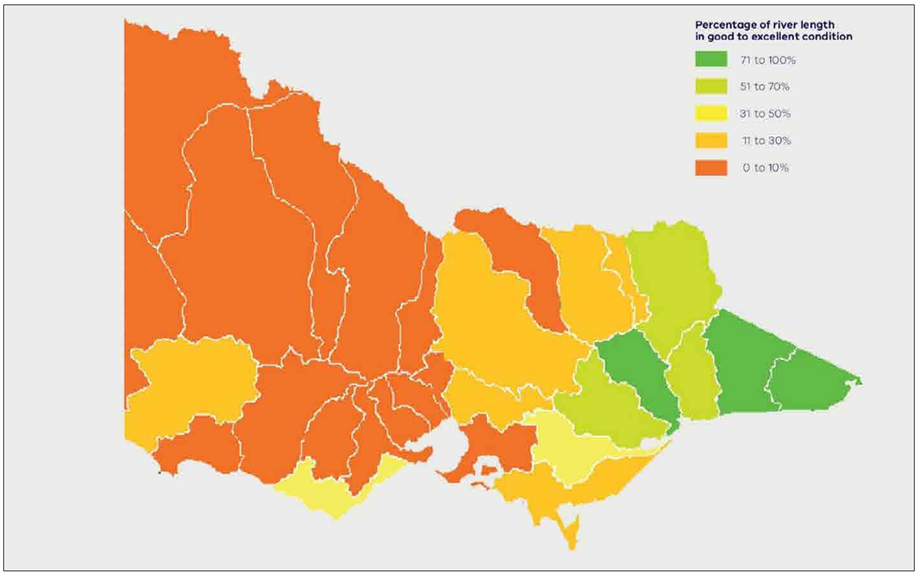


Figure B9: Waterway health in Victoria during 2013.[739]

In response to the declining health of rivers, governments are using the delivery of environmental water to support aquatic life across freshwater environments. In the technical report accompanying Victoria's 2020 Report Card for the Murray-Darling Basin Plan, indicators for fish, vegetation cover, riparian and instream vegetation, and waterbirds were improved or maintained in association with environmental water delivery.[740, 741] This is implemented alongside other longstanding and complementary on-ground management practices such as fencing, revegetation, instream habitat additions and weed control.

Each year, CMAs assess the condition of their catchments and present the results in their annual reports. In their 2020-21 annual reports, four of the 10 CMAs rated waterway condition as concerned, three as neutral and two as positive. Reasons for concern about waterway condition included drought, reduced stream flows, the loss of wetlands to cropping, and the impacts of the 2019–20 bushfires, which included fish kills.

For those that rated waterway condition as neutral or positive, reasons given were environmental watering, removal of stock grazing in riparian vegetation, tree planting, threat mitigation and investment in waterway health.

Instream Woody Habitat

In 2013, the then Department of Environment and Primary Industries (DEPI) mapped instream woody habitat in 38,000 river reaches along 27,700 km of rivers across Victoria. The analysis found 53%, or approximately 17,000 km, had severely or highly depleted densities, while approximately 9,000 km had densities that were more than 80% below natural levels (Figure B10).[742] Instream woody habitat (IWH) was in very poor condition in the South Western Floodplains and the Glenelg and North Central Floodplain river regions, whereas IWH within the Alpine, North East Uplands and East Gippsland Uplands river regions were at natural densities.

739. Department of Environment Land, Water and Planning (DELWP) 2016, 'Water for Victoria: Water plan', Melbourne, Victoria.
740. Department of Environment Land, Water and Planning (DELWP) 2020, 'Victoria's basin plan report card 2020', Melbourne, Victoria.
741. Department of Environment Land, Water and Planning (DELWP) 2020, 'Achievement of environmental outcomes in northern Victoria's waterways', report to meet Murray-Darling Basin Plan Schedule 12 Matter 8 obligations, Melbourne, Victoria.
742. Department of Environment and Primary Industries (DEPI) 2013, 'Instream woody habitat assessment', Melbourne, Victoria.

In another study that included more than 300 sites across eight Victorian waterways, Tonkin et al. (2020) found positive relationships between IWH and the abundance of fish, especially the Murray cod.[743] The modelling used by the authors predicted a fourfold increase in the abundance of Murray cod if the density of IWH was increased from low levels to natural levels. According to the authors, the results were further evidence that the loss of instream woody habitat had had 'major adverse impacts on the health of south-eastern Australian fish populations.' [744] The results also suggested that 'restoring IWH is likely to lead to more pronounced changes in fish abundance in reaches that are more degraded, both in terms of historical IWH removal and the population status of the native fish community.' [745]

Hale et al. (2022) reviewed 15 years of data collected on IWH interventions and their benchmarks along 275 rivers in Victoria.[746] They also analysed fish responses for 25 interventions. The reviewers found that:

> 'Many rivers had lower IWH densities than their benchmarks. The density of IWH had increased by less than 20% in many waterways where IWH had been added. However, at some locations, IWH additions had led to density increases of more than 40%.' [747]

Positive responses from fish were more likely at sites where intervention had occurred more than eight years earlier or where the density of IWH had already been higher before the intervention.

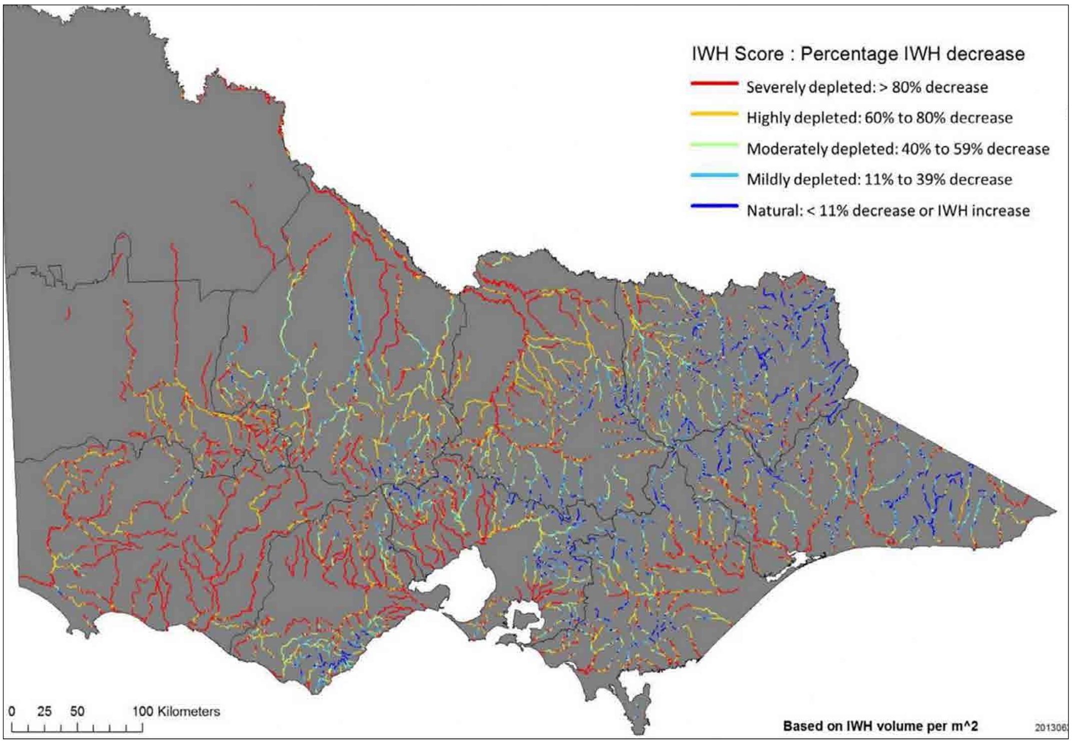


Figure B10: Percent decline of instream woody habitat within Victorian rivers in 2013.[748]

743. Tonkin Z, Kitchingman A, Fanson B, Lyon J, Ayres R, Sharley J, Koster W, O'Mahony J, Hackett G, Reich P, Hale R 2020, 'Quantifying links between instream woody habitat and freshwater fish species in south-eastern Australia to inform waterway restoration', *Aquatic Conservation*, 30(7), pp 1385–1396.
744. Ibid.
745. Ibid.
746. Hale R, Kitchingham A, Sharley J, Reich P, Tonkin Z 2022, 'A synthesis of 15 years of instream woody habitat management: progress towards benchmarks and assessing fish responses', *Freshwater Biology*, 2022, 67(10), pp. 1739-1751.
747. Ibid.
748. Department of Environment and Primary Industries (DEPI) 2013, 'Instream woody habitat assessment', Melbourne, Victoria.

Indicator B:06 Riparian vegetation

B:06 Riparian vegetation						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide		→ (statewide) ↗ (CMA and local reaches level)			?	
Data source(s):	DELWP, VEAC					
Measure(s):	ISC 2010 streamside zone scores DELWP 2022 recapture of LiDAR data for ISC 2010 Bioregional conservation status of riparian EVCs Protection levels of riparian EVCs					

Why this indicator?

The loss of riparian vegetation through clearing, drainage, stock access, channelisation and invasive plants has impacted terrestrial and aquatic plants and animals.

NB: This SoE 2023 indicator was 'B:10 Riparian vegetation habitat extent' in the SoE 2018 Report.

Why this assessment in 2023?

There are no new data to suggest an improvement in statewide status, although local riparian restoration projects have been successful. In regions with significant national parks, such as in the Grampians and East Gippsland, most EVCs are contained within the protected area network. Bioregions where EVCs are endangered or vulnerable with little or none of their current extent protected include the Victorian Volcanic Plain, Gippsland Plain and Central Victorian Uplands, and where most remnants are on private land. The three ISC assessments and DELWP's recent LiDAR-based Stream Change Assessment suggest that the trend is stable on a statewide basis.

Summary of State of the Environment 2018 Report assessment

- Twenty-one of 29 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 channelisation of drainage and agricultural activity alongside rivers.
- The loss of riparian vegetation exposes the water surface to more sunlight, encouraging the growth of algae and potentially of algal blooms.

Critical data used for the 2023 assessment

- DELWP's recapturing of ISC 2010 streamside zone scores
- Bioregional Conservation Status of EVCs in 28 Bioregions and Change in EVC Extent Between 1750 and 2015
- Statewide Assessment of Public Land

2023 assessment

Riparian vegetation adjoins freshwater rivers, streams and wetlands, and is critical habitat for many native plants and animals. However, along many waterways, riparian vegetation has been removed or become degraded by weeds, feral pests, vehicle and stock access, and agricultural runoff.

In the 2010 Index of Stream Condition (ISC), streamside zone scores for the 1167 river reaches surveyed ranged from 3 to 10, with ten being the highest. The higher the number, the better the streamside condition. In the final scores, 18.6% of river reaches were rated as 3 or 4, 32.6% were 5 or 6, and 48.8% scored 7, 8, 9 or 10.[749]

The 2010 ISC made use of LiDAR to measure riparian woody vegetation.[750] In 2022, DELWP recaptured the LiDAR data, enabling an analysis of change from 2010 to 2020. The LiDAR was recaptured at 13%, or 3,424 km, of the 2010 ISC stream reaches for four indicators: fractional canopy cover, canopy height, fragmentation, and vegetation width.[751] The reaches were chosen in consultation with CMAs to assist them to evaluate the effects of their management and to guide future planning.

At the statewide scale, the study found that there was no change in ISC streamside zone scores in 81% of the reaches. However, at the statewide, CMA and ISC-reach scales, fractional canopy cover, canopy height and vegetation width increased along many sections while fragmentation declined. The largest changes were found along shorter sections of streams where there had been sustained riparian management by agencies and the community. East Gippsland and West Gippsland CMA regions were where the largest changes occurred.

Since 2018, under the on-ground works of DELWP's Victorian Waterway Management Program, 47,825 hectares of waterway vegetation works have been undertaken to improve the health and resilience of waterways. This total was calculated by summing the gross land area of sites where waterway vegetation works are undertaken, including fencing to manage stock access, revegetation, and weed and pest animal management and control.

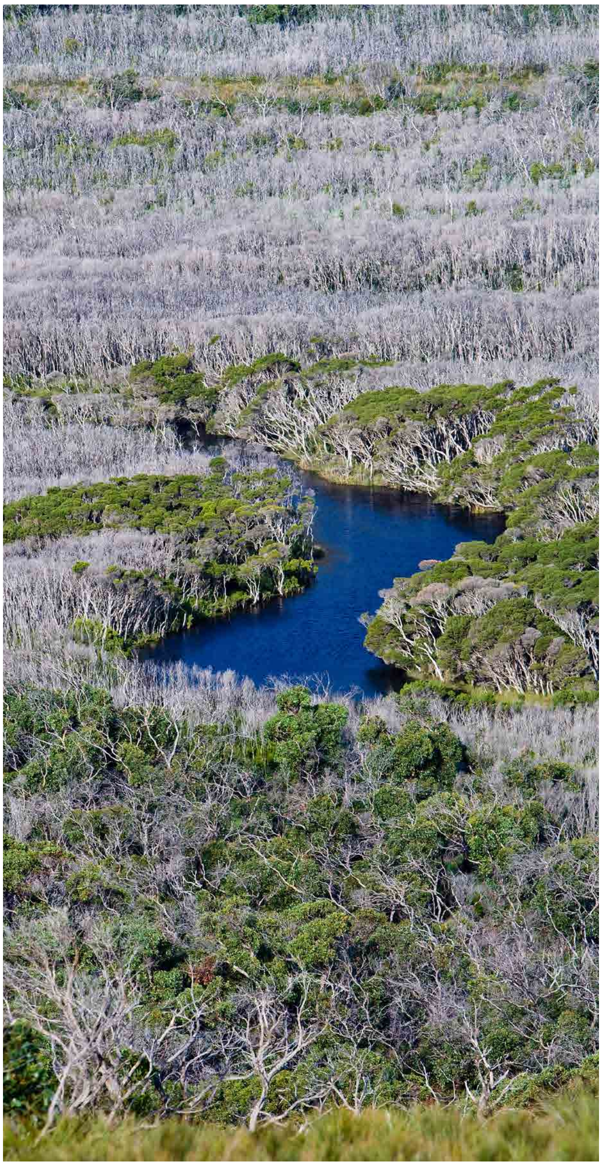
The Regional Riparian Action Plan 2015-2020 achieved the protection and improvement of nearly 3,481 km (and 53,3745 ha) of riparian land. CMAs worked with more than 1,500 landholders and about 600 Traditional Owner, Landcare, angling, school and other community groups over the five years to achieve these outcomes. Instream and riparian habitat have been improved through volunteer efforts of recreational anglers and from CMAs. In the past three years, more than 113 angling clubs have contributed to 31 habitat restoration projects across 24 waterways to restore habitat. The volunteers have planted more than 23,700 native plants over 45 km of streams.[752]

The bioregional conservation status, pre-1750s and current extents, percentages in the protected area network and on other public land and percentages on private land were analysed for 77 riparian EVCs (including complexes and mosaics having multiple EVCs within them) across 25 bioregions. With some of the EVCs found across multiple bioregions (e.g. riparian forest in 18 bioregions and swampy riparian woodland in 13 bioregions), there were in total 208 EVC entries. The analysis found that:

- Sixty-two EVCs were endangered, 50 were vulnerable, six were rare, 27 depleted and 55 were of least concern.
- Seventy-eight had at least 30% of their current extent within protected areas, while 85 had at least 15% of their pre-1750s extent in protected areas.
- The 55 EVCs that were of least concern largely had high percentages of their current extent in national parks, such as in the Grampians Wilsons Promontory and the Alps.
- Endangered and vulnerable EVCs had very little or none of their current extent within the protected area network and much of what remains exists on private land.
- Swampy riparian woodland was endangered in 10 of the 13 bioregions, riparian woodland was endangered in six of the 10 bioregions and floodplain riparian woodland was endangered in 7 of 11 bioregions. Little or none of their current extent occurred in the protected area network.

749. Department of Environment and Primary Industries (DEPI) 2010, 'Index of stream condition: The third benchmark of Victorian river condition', Melbourne, Victoria.
750. Ibid.
751. Department of Environment Land, Water and Planning (DELWP) 2022, 'Stream change assessment: detecting change in riparian woody vegetation using LiDAR derived data, fact sheet', Melbourne, Victoria.
752. Department of Environment, Land, Water and Planning (DELWP), 'Unpublished data', Melbourne, Victoria, Accessed 2022.

- Of the 208 entries, other public land could be used to give 32 EVCs at least 30% coverage in the protected area network, private land could be used to reach at least 30% for 62 entries, and either public or private land could be used for 38 entries. Such changes to the level of protection for those EVCs would be dependent upon their size, location, condition and degree of fragmentation, their current use and whether private landholders were supportive of increasing the legal protection of the remnant EVCs on their land.
- Of the 208 entries, 42 are found in the Greater Grampians bioregion and Grampians National Park. Most are relatively small areas — 36 are below 100 hectares and 22 under 20 hectares. The bioregional conservation status of 35 is of least concern, with 23 having 100% of their current extent in the protected area network. Thirty-seven have greater than 30% of their current extent within protected areas, and 39 have at least 15% of their pre-1750s extent in protected areas.
- If the 42 riparian EVCs found in the Greater Grampians bioregion are removed from the analysis, the status of the remaining 166 EVCs comprises: 60 endangered, 48 vulnerable, six rare, 24 depleted and 20 of least concern (eight were not assigned a status). With regards to the extent of protection, 41 have greater than 30% of their current extent within protected areas, while 46 have greater than 15% of their pre-1750s extent in protected areas.



Wilsons Promontory National Park.
Credit: James Lauritz. © Parks Victoria.

Indicator B:07 Floodplains

B:07 Floodplains						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	🔴	→	🟡	⚪	?	🔴
Data source(s):	DELWP, VEAC					
Measure(s):	Bioregional conservation status of EVCs in river red gum forests along the Murray River and floodwater-dependent EVCs in other bioregions Protection levels for EVCs in terms of 30% of their current extent or 15% of their pre-1750s extent					

Why this indicator?

River red gum forests, and other floodwater-dependent EVCs, provide habitat for native plants and animals and cultural and recreational sites.

NB: This is a modified 2023 indicator that allows greater focus on the protection levels and conservation status of floodplain vegetation than previous SoE reports and was formed by broadening the measure of the SoE 2018 indicator 'B:11 Area of functional floodplain'.

Why this assessment in 2023?

Sixty percent of the river red gum EVCs along the Murray River have 30% or more of their current extent in dedicated reserves. However, there are limited data on their condition. Elsewhere, floodwater-dependent EVCs are mostly endangered or vulnerable and have little of their current or pre-1750s extent in the protected area network. Most floodwater-dependent EVCs are on private land. Environmental water delivery projects are being used to return some floodplain wetlands, including Ramsar sites, to more natural flood cycles.

Summary of State of the Environment 2018 Report assessment

- Projections under climate-change scenarios indicate that floods and droughts will increase in intensity and frequency.
- Floodplains are potential drought refuges as they are cooler, have localised microclimates compared to adjacent areas, and have greater water availability through groundwater and flooding.
- There was a lack of data on functional floodplain areas.

Critical data used for the 2023 assessment

- 2008 VEAC investigation of the river redgum forests along the Murray River
- Bioregional Conservation Status of EVCs in 28 Bioregions and Change in EVC Extent Between 1750 and 2015
- Statewide Assessment of Public Land

2023 assessment

Floodplains serve many functions that include:

- Regulation functions: flood storage and conveyance, groundwater recharge, water filtration, soil formation, soil retention, buffer protection, micro-climate regulation, greenhouse gas regulation and water treatment
- Supporting functions: bird habitat, fish habitat, frog habitat and floodplain vegetation
- Cultural functions: heritage, aesthetic and recreation.[753]

Floodplains have been shown to be drought refuges for native flora and fauna because they are cooler, with localised microclimates and larger volumes of water available when compared with adjoining land. Research by Selwood et al. (2015) found that, during drought, fewer bird species declined in floodplain zones compared to non-floodplain zones.[754]

753. Peters G 2016, 'Identifying and valuing the functions of floodplains', 2016 Floodplain Management Association National Conference, Nowra, Floodplain Management Australia, Sydney, New South Wales.
754. Selwood K, Thomson J, Clarke R, McGeoch M, Mac Nally R 2015, 'Resistance and resilience of terrestrial birds in drying climates: do floodplains provide drought refugia?', *Global Ecology and Biogeography*, 24, 838–848.

Floodplains across Victoria have been transformed by European settlement and land-use changes associated with pastoralism, irrigated agriculture (dams, weirs, levees and channels), mining (excavation, dams), transport (rail and road) and urban growth. River regulation, drought and climate change have caused reductions in flood frequency that have led to declines in the condition of floodplain vegetation, especially river red gum and black box woodlands.[755] The Millennium Drought also saw floodplain ecosystems on the verge of collapse.[756] Such threats have degraded aquatic habitats, increased sedimentation of wetlands, encouraged black-water and cold-water pollution, increased salinity and nutrients, and reduced the volume of water flowing through the system.

The focus of governments when improving floodplain functionality has been the adjustment of water allocations and the introduction of water-saving measures to make water available for environmental flows. These are aimed at helping restore degraded aquatic habitats by restoring more natural watering cycles.

The delivery of environmental water is focussed on the river channel and associated wetlands. Any overbank flows onto the floodplain are largely unintentional. Examples of connecting floodplains are mostly via works or pumps, such as at Mulcra Island, where flows are delivered through an anabranch and with a regulator to back flows up onto the floodplain, a similar approach to weir raising on the Murray River.

In its 2008 River red gum forests investigation, which covered four main bioregions (Murray Scroll Belt, Murray Fans, Victorian Riverina and Robinvale Plains), VEAC found that the lack of regular flooding was threatening floodwater-dependent EVCs (e.g. grassy riverine forest and riverine swampy woodland), floodwater-dependent grasses had been invaded by species better adapted to dry conditions, and grazing had eliminated some sensitive plant species and encouraged weed invasions.[757] VEAC also found that vegetation was in the best condition around Lindsay, Wallpolla and Mulcra Islands, as well as at Kings Billabong and Belsar Island, in moderate condition in Gunbower and Barmah forests, and in poor condition at the Kerang Lakes and on floodplains upstream of Lake Mulwala.

VEAC recommended new areas for inclusion in the dedicated reserve network, and in 2010 the Victorian Government declared the Lower Goulburn, Gunbower, Barmah and Warby Range-Ovens River national parks. VEAC also recommended the creation of the Murray River Park, which was to be a series of small, protected areas between the SA border and Lake Hume to protect wetlands between the river red gum national parks and a habitat corridor along the river. The land, which included state forests, parts of regional parks and water frontages, is now managed by PV. Although the recommendation for the Murray River Park was accepted by the Victorian Government and legislated, it was never gazetted.

The VEAC investigation's discussion paper identified 34 major EVCs in the study area, including complexes that have multiple EVs within them, and analysed their extent.[758, 759] At the time of the investigation, only four of the 34 EVCs had at least 30% of their current extent in the dedicated reserve network; this number has increased to now be 20 EVCs. If Trust for Nature covenanted properties and reserves are included, the number rises to 21 EVCs. Were the Murray River Park established, that number would then increase to 26 EVCs having at least 30% of their current extent in the dedicated reserve network. A further two EVCs could be included if other public land was used to increase their percentage coverage. For the remainder, Trust for Nature covenanting of private land could be an option Such changes to the level of protection for those EVCs would be dependent on their size, location, condition and degree of fragmentation, their current use and whether private landholders were supportive of increasing the legal protection of remnant EVCs on their land.

755. Cunningham S, White M, Griffioen P, Newell G, Mac Nally R 2013, 'Mapping floodplain vegetation types across the Murray-Darling Basin using remote sensing', Murray-Darling Basin Authority, Canberra.
756. Ibid.
757. Victorian Environmental Assessment Council (VEAC) 2008, 'River red gum forests investigation discussion paper', Melbourne, Victoria.
758. Ibid.
759. For EVCs, the analysis calculated their pre-1750s extent, current extent, Trust for Nature and the proposed Murray River Park extent, along with the percent of the current extent in dedicated reserves, the percent of the current extent in dedicated reserves, the percent of the current extent in dedicated reserves plus Trust for Nature land, and the percent of the current extent in dedicated reserves network, Trust for Nature and the Murray River Park if it were established. Dedicated Reserves are national parks, state parks, National Parks Act Schedule 3 parks, nature conservation reserves, bushland areas and streamside areas.

As part of the VEAC river red gum investigation, at least 110 floodwater-dependent EVCs were identified in the investigation area. Within these EVCs, there were at least 124 rare or threatened plant species and 62 threatened vertebrate species (excluding fish) that were dependent on flooding of the Murray, Goulburn, Ovens and King rivers in northern Victoria.[760] For approximately 30 EVCs, a flood every two years was critical.

The list of 110 floodwater-dependent EVCs (including complexes and mosaics, which have multiple EVs within them) has been used to review the bioregional conservation status, current and pre-1750s extent, and the percentage of those extents found in the protected area network across 16 bioregions. The analysis excluded the four bioregions in the river red gum investigation area and any other bioregions that did not have any of the floodwater-dependent EVCs identified by VEAC. There were 88 EVC entries across the bioregions having the following extent and conservation status:

- 26 EVCs had their current extent represented within the protected area network
- 56 EVCs had no representation of their current extent in the protected area network
- 11 EVCs had greater than 15% of their pre-1750s extent in the protected area network
- nine EVCs had 1% to 30% representation of their current extent in the protected area network
- 50 EVCs were assigned a bioregional conservation status of endangered
- 17 EVCs were assigned a bioregional conservation status of vulnerable
- five EVCs were assigned a bioregional conservation status of depleted
- three EVCs were assigned a bioregional conservation status of least concern
- 13 EVCs had no assigned bioregional conservation status.

The most numerous representations within the protected area network were plains grassy woodland (found in 13 bioregions), floodplain riparian woodland (11 bioregions), red gum swamp (nine bioregions), and plains grassy wetland (eight bioregions). For the 79 EVC entries with less than 30% representation of their current extent in the protected area network, nine could achieve the target percentage with the use of other public land, 53 by conserving the vegetation on private land, and 17 on either public or private land.

The illegal removal of old-growth river red gums for sale into the firewood market is on the rise and could further undermine the status of EVCs on floodplains. More than half of 1,600 reported instances of illegal logging in the past three years occurred in northern Victoria, including in the Shepparton Regional Park and the Lower Goulburn National Park.[761] In response, Operation River Red Gum, a joint operation between the Conservation Regulator, Victoria Police and Parks Victoria, is now targeting the illegal removal of trees.[762]

The Victorian Murray Floodplain Restoration Project is being delivered as part of Victoria's obligations under the Murray-Darling Basin Plan and through a partnership between DEECA, PV, Lower Murray Water, Goulburn-Murray Water and the North Central and Mallee CMAs. The project is removing 'blockages that stop water flowing into creeks and implement options to manage water effectively and efficiently on the floodplain' at nine sites (in April 2023 Victoria put on hold the work at four sites and is seeking an extension of time for their completion to 2026).[763, 764] The Living Murray Program, also part of the implementation of the Murray-Darling Basin Plan, is returning water to the environment and using regulators, weirs and fishways to improve the health of four iconic sites in Victoria — Barmah Forest, Gunbower Forest, Hattah Lakes, and Lindsay-Wallpolla Islands.[765]

760. Fitzsimons J, Peake P, Frood D, Mitchell M, Withers N, White M, Webster R 2011, 'Flooding requirements for biodiversity values along the Victorian floodplain of the Murray Valley', *The Victorian Naturalist*, 128, pp. 48–85.
761. Ritchie R 2023, 'Illegal logging operations on the rise in northern Victoria, officials say', *ABC* Shepparton, 13 June 2023.
762. Cunningham S 2022, 'Firewood harvesting threatens forests', The Monthly, December 2022-January 2023.
763. State of Victoria, 'Victorian Murray Floodplain Restoration Project', https://www.vmfrp.com.au/home/ Accessed 2 November 2022.
764. Shing H 2023, Answer by the Victorian Minister for Water, Harriet Shing, to a question from Sarah Mansfield, member for Western Victoria, in Victoria's Legislative Council, 4 May 2023, https://new.parliament.vic.gov.au/parliamentary-activity/hansard/hansard-details/HANSARD-974425065-21437 Accessed 13 June 2023.
765. Government of South Australia, Department for Environment and Water, 'The living Murray program', https://www.environment.sa.gov.au/topics/river-murray/improving-river-health/wetlands-and-floodplains/the-living-murray-program Accessed 3 August 2023.

Indicator B:08 Grasslands

B:08 Grasslands						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Victorian Volcanic Plain, Wimmera Plain, Gippsland Plain and Warrnambool Plain bioregions				New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator
Data source(s):	DELWP, Grassy Plains Network, VEAC					
Measure(s):	Bioregional conservation status Grassland EVCs that have protection coverage above 30% of their current extent or 15% of pre-1750s extent					

Why this indicator?

Very little of Victoria's grasslands remain and they continue to be threatened by environmental weeds, introduced predators and herbivores, urban development, fragmentation, conversion to cropping, inadequate levels of protection and the absence of fire.

Why this assessment in 2023?

Of the 15 grassland EVC entries across the four bioregions analysed, 13 are endangered and two have more than 40% of their pre-1750s extent remaining. Three of the 15 grassland EVC entries have any of their remaining area (7% to 14%) within the protected area network. The condition of grasslands continues to deteriorate.

Summary of State of the Environment 2018 Report assessment

- New SoE 2023 indicator

Critical data used for the 2023 assessment

- Protecting Critically Endangered Grasslands
- Bioregional Conservation Status of EVCs in 28 Bioregions and Change in EVC Extent Between 1750 and 2015
- Statewide Assessment of Public Land

2023 assessment

Natural temperate grasslands have all but disappeared in Victoria, although they once covered between 800,000 and 1,000,000 ha. Due to agricultural and urban development, weed invasions, inappropriate fire regimes and herbicide and fertiliser use, just 2% of that area remains, with half of that in poor condition.[766] It is a similar story for the grassy eucalypt woodlands, of which only 5% remains and all in poor condition.[767]

Natural temperate grasslands and grassy eucalypt woodlands are both listed as critically endangered under the EPBC Act. The listing advice identified plains grassland (EVC 132), creekline tussock grassland (EVC 654) and plains grassland/plains grassy woodland mosaic (EVC 897) in the natural temperate grasslands. The EVCs within grassy eucalypt woodlands were identified as plains grassy woodland (EVC 55), plains swampy woodland (EVC 651), stony knoll shrubland (EVC 649) and plains grassland/plains grassy woodland mosaic (EVC 897).

The EVCs in natural temperate grasslands and grassy eucalypt woodlands (including mosaics, which have multiple EVs within them) on the Victorian Volcanic Plain, Wimmera Plain, Gippsland Plain and Warrnambool Plain were reviewed for this assessment, along with their bioregional conservation status, and the percentage of their current and pre-1750s extent in the protected area network, on other public land or on private land.

766. Victorian Auditor-General's Office (VAGO) 2020, 'Protecting critically endangered grasslands', Melbourne, Victoria.
767. Ibid.

Of the 15 EVC entries (some were found in multiple regions), the bioregional conservation status of 13 is endangered, and only two have more than 40% of their pre-1750s extent remaining. Two others have not been assigned a bioregional conservation status on the Victorian Volcanic Plain. However, their small current areas would suggest they are at high risk. Only three of the 15 bioregional EVCs have any coverage within the protected area network, (these calculations do not include the incomplete 15,000-hectare Western Grasslands Reserve discussed in 'Grassland reserves in Melbourne'), and none have more than 30% of their current extent in that network. For 11 of the 15 bioregional EVCs, at least 75% of their current extent is on private land. One EVC (plains swampy woodland on the Wimmera Plain) could be given 30% protection by using other public or private land. All others would require private land conservation to achieve 30% protection. Lack of management of these remnants, either in protection or unprotected, can lead to a deterioration of the grasslands through weed invasion.

Kern (2022) reports that grassland EVCs on the Victorian Volcanic Plain are 'functionally extinct' and plains grassland remains as 'small scraps' with most remnants less than 10 hectares in area.[768] In the case of the plains grassland EVC, Kern estimates that there could be as little as 0.1% of the pre-1750 extent remaining. Of the 15 EVCs reviewed for this chapter, the percentage of their pre-1750s extent in the protected area network was 1% for two EVCs, 3% for one EVC and the remaining EVCs had no coverage within protected area network.

A critical element in the future protection for grasslands is the purchase of private land (as is occurring under the Melbourne Strategic Assessment program – see box 'Grasslands reserves in Melbourne') or increasing their legal protection on private land. Such changes to the level of protection for those EVCs would be dependent on their size, location, condition and degree of fragmentation, their current use and whether private landholders were supportive of increasing the legal protection of the remnant EVCs on their land.

The Grassy Plains Network has identified 614 indigenous plant species in Victoria's grasslands. Of those, 20 are critically endangered, 35 endangered and five vulnerable, however, only 17 of those 60 threatened species have action statements.[769] In June 2022, the Grassy Plains Network successfully challenged a developer's application in VCAT to overturn the City of Hobson Bay's refusal to issue a permit for the development of warehouses on remnant grassland along Ajax Road in Altona.[770]

According to research conducted by Sinclair et al. (2021), the structure of grasslands on the Victorian Volcanic Plain is changing, with a significant decline in native annual forbs.[771] The authors report that, of 35 annual forbs that were known to occur in the grasslands, 11 are possibly extinct and only five widespread. Possible causes of the decline are competition with exotic plants and suppression by the organic litter they produce as well as fire, soil disturbance, loss of tree cover, trampling and soil compaction by sheep. Melbourne Water has observed a deterioration in grasslands in recent years due to infestations of Chilean needle-grass.[772]

The absence of fire is a major threat to grasslands. A study analysing nine years of occupancy data at 291 sites found that the careful use of fire as a management tool in grasslands was positive for the persistence of the critically endangered striped legless lizard.[773]

The Linear Reserves Project, a collaboration between DELWP and the Glenelg Hopkins and Corangamite CMAs, aims:

> 'to reduce critical threats to, and enhance the condition, connectivity, and resilience of, native grasslands and associated species on linear reserves (i.e. roadside and rail reserves) and grasslands reserves through the implementation of strategic threat reduction activities.' [774]

768. Kern L 2022,' 'Expert witness statement: Victorian Civil and Administrative Tribunal VCAT Reference: PA1841550, pp. 37-45 Ajax Road, Altona'.
769. Grassy Plains Network 2022, 'Victorian grassland species 2022', Melbourne, Victoria.
770. Victorian Civil and Administrative Tribunal (VCAT) 2022, 'VCAT Reference No. P11352/2021 Permit Application No. PA1841550', Melbourne, Victoria/
771. Sinclair, S, Scott-Walker G, Batpurev K, Morgan J, Just K, Cook D 2021, 'The forgotten annual forbs of Victoria's basaltic plains grassland', *Ecological Management and Restoration*, vol. 22 No. 2 May 2021.
772. Department of Environment, Land, Water and Planning (DELWP), 'Unpublished data', Melbourne, Victoria, Accessed 2022.
773. Scroggie M, Peterson G, Rohr D, Nicholson E, Heard G 2019, 'Disturbance has benefits as well as costs for fragmented populations of a cryptic grassland reptile', *Landscape Ecology*, 34(8), pp 1949-1965.
774. Statewide Integrated Flora and Fauna Teams (SWIFFT), 'Linear reserves project' https://www.swifft.net.au/cb_pages/team_linear_reserves_project.php Accessed 29 January 2023.

The project also involves 11 local councils, the Country Fire Authority, VicRoads, VicTrack, the Australian Rail Track Corporation, Federation University and utility providers.[775] It uses ecological burning and weed management along roadside and railway reserves, as well as grassland restoration projects such as along the Penshurst-Dunkeld Road and Woorndoo-Dundonnell Road.[776,777]

Grassland Wilsons Promontory National Park - Kangaroo Grass.
Credit: Steven Wright. © Parks Victoria.

775. Department of Environment Land, Water and Planning (DELWP), 'The linear reserves project on the Victorian Volcanic Plain', Melbourne, Victoria.
776. Department of Environment Land, Water and Planning (DELWP) 2020, 'Linear reserves grassland news No 6 July 2021', Melbourne, Victoria.
777. Department of Environment Land, Water and Planning (DELWP) 2022, 'Linear reserves grassland news No 8 July 2022', Melbourne, Victoria.

Grassland reserves in Melbourne

Under the Melbourne Strategic Assessment program, agreed to with the Commonwealth Government in 2010, the Victorian Government committed to establish a 15,000-hectare Western Grassland Reserve and a 1,200-hectare Grassy Eucalypt Woodlands Protected Area to offset the losses of grassland from urban development elsewhere.[778] In 2020, VAGO reported on the Government's progress in delivering that commitment and found that:

> 'DELWP has not met its commitments to deliver the WGR and GEWR by 2020. DELWP intended these reserves to offset native vegetation loss from urban development within the extended UGB. However, delays in acquiring land, and continuing threats of degradation, pose significant risks to the ecological values of native vegetation within the reserves. The delays in acquiring these reserves also mean they will likely require a significantly greater investment to restore and retain these ecological values than if they had been purchased within the intended 10-year timeframe.' [779]

VAGO identified that, in 2020, only 10% of the land needed for the Western Grasslands Reserve had been acquired and, in the meantime, the condition of the reserves had deteriorated and the price of the land increased.[780] By August 2022, a further 8% had been purchased.[781] However, accelerated acquisition is not required for offsetting or to meet the final Commonwealth EPBC Act requirements. Further, the Commonwealth confirmed to DELWP that not acquiring the Western Grasslands Reserve by 2020 did not contravene the EPBC Act.[782]

In February 2022, the Victorian Legislative Assembly's Planning and Environment Committee in its report on environmental infrastructure, recommended that the Victorian Government bring forward its purchase of land to complete the Western Grasslands Reserve. In its submission to the parliamentary inquiry, the City of Wyndham wrote that the reserve 'was a key mechanism established to offset the biodiversity losses associated with urban development and to protect critically endangered grasslands' and 'there is significant concern that the biodiversity values on the remaining private lands within the reserve area are in decline.' [783]

However, even nominally protected grassland can be lost, either through mismanagement, poor administrative processes or through actions by landowners:

> 'In one case on private land in Truganina, which had been designated to be a future Conservation Area [not part of Western Grassland Reserve] under the Melbourne Strategic Assessment, it was found to have been smothered in fill spread by the property development company owning the site.' [784]

DELWP is 'actively seeking to negotiate further acquisitions' and 'PV has taken on the management of the land acquired so far and is undertaking extensive restoration and rehabilitation works to improve the quality of the Natural Temperate Grassland and habitat for threatened species.' [785] There are some grassland species that will be unable to recolonise the restored areas without intervention. This could compromise the biological diversity of the rehabilitated areas. For example, the striped legless lizard will be unable to cross barriers, roads or housing estates to reach restored areas. Historical declines in remnant populations could lead to reduced genetic diversity and limit any efforts towards their genetic rescue.[786]

778. The final Commonwealth approvals of urban development in Melbourne's Growth Areas define the legal requirements. The Commonwealth approvals require offsets to be delivered as development occurs up to 2060.
779. Victorian Auditor-General's Office (VAGO) 2020, 'Protecting critically endangered grasslands', Melbourne, Victoria.
780. The VAGO audit was specific to the Melbourne Strategic Assessment and the Western Grassland Reserve, which only represents a very small proportion of the native grasslands on the Victorian Volcanic Plain.
781. Kinsella E 2022, 'This land in Melbourne is worth $11 million. To some, the grassland that was on it was priceless', *ABC News*, 8 August 2022.
782. Letter from Commonwealth to the Department of Environment Land, Water and Planning (DELWP).
783. City of Wyndham 2020, 'Submission to Legislative Assembly Environment and Planning Committee's Inquiry into environmental infrastructure for growing populations', Parliament of Victoria, Melbourne, Victoria.
784. Kinsella E 2022, 'This land in Melbourne is worth $11 million. To some, the grassland that was on it was priceless', *ABC News*, 8 August 2022.
785. Department of Environment Land, Water and Planning (DELWP), 'Western grassland reserve', Melbourne, Victoria, https://www.msa.vic.gov.au/conservation-actions/western-grassland-reserve/western-grassland-reserve Accessed 11 April 2022.
786. Zoos Victoria, 'Unpublished data', Melbourne, Victoria, Accessed 2022.

The Western Grassland Reserve was agreed to by Victorian and the Commonwealth based on the EVCs known or likely to be present in the proposed area. Fauna assessments were not conducted until after the agreement to use the reserve as an offset under the Melbourne Strategic Assessment.[787]

Those subsequent assessments showed that the proposed reserve was not a stronghold for key threatened fauna, such as the striped legless lizard. Care is needed when using surrogate metrics for certain species or groups of species.[788]

The impact of the Western Grassland Reserve on the protection of grasslands is limited and does not compensate for the historical and ongoing losses in the area. As Figure B11 shows, much of the reserve is degraded (including by weed infestations). The occurrence and density of some important elements, such as the endangered striped legless lizard, is inferior in the proposed reserve compared with those areas where the lizard occurs in high densities and which are being developed.[789]

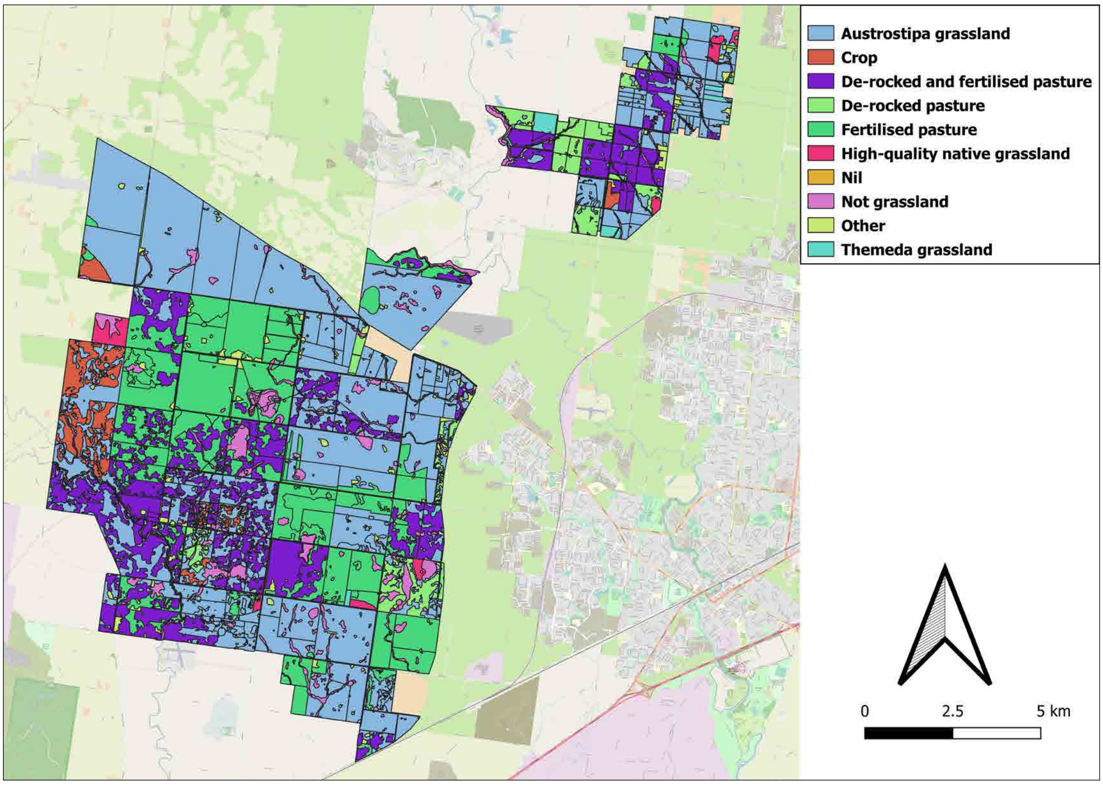


Figure B11: Grassland condition in the Western Grassland Reserve in 2019.[790]

787. Ibid.
788. Zoos Victoria, 'Unpublished data', Melbourne, Victoria, Accessed 2022.
789. Ibid.
790. Arthur Rylah Institute (ARI) 2022, 'Unpublished data', Heidelberg, Victoria.

Indicator B:09 Alpine

B:09 Alpine						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Victorian Alps bioregion	●	↙	●	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator
Data source(s):	DELWP, VEAC					
Measure(s):	Bioregional conservation status Alpine EVCs that have protection coverage above 30% of their current extent or 15% of pre-1750s extent					

Why this indicator?

Alpine areas contain diverse flora and fauna and have significant cultural, social and economic values.

Why this assessment in 2023?

There has been virtually no change in the extent of alpine EVCs since the 1750s, and most have greater than 90% of their remaining area in the protected area network. However, 16 of the 18 EVCs are either endangered, vulnerable or rare, with bushfires, invasive species, timber harvesting and climate change affecting their condition.

Summary of State of the Environment 2018 Report assessment

- New SoE 2023 indicator

Critical data used for the 2023 assessment

- Bioregional Conservation Status of EVCs in 28 Bioregions and Change in EVC Extent Between 1750 and 2015
- Statewide Assessment of Public Land
- Assessing the Impacts of Feral Horses on the Bogong High Plains, Victoria
- Risk Assessment and Management Priorities for Alpine Ecosystems under Climate Change: Milestone 5 Report
- Combating Ecosystem Collapse from the Tropics to the Antarctic

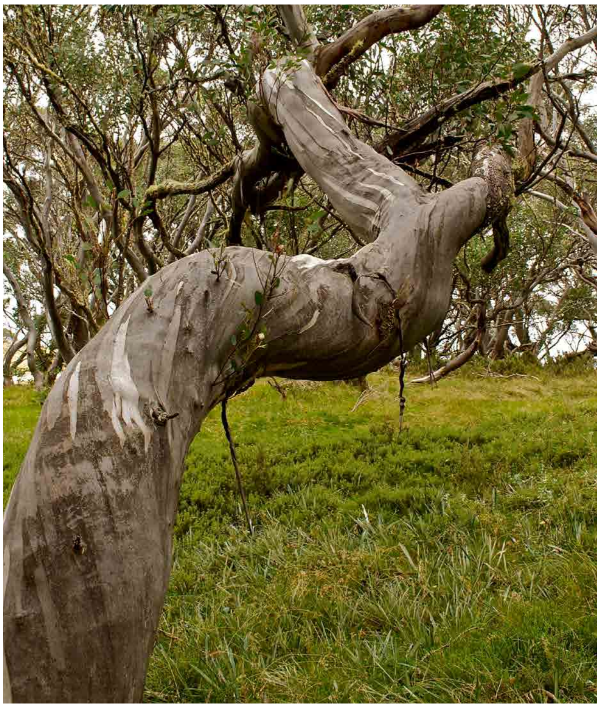
2023 assessment

The Victorian Alps Bioregion is part of the larger Australian Alps bioregion that stretches across Victoria, New South Wales and the Australian Capital Territory. Eighteen alpine EVCs (including mosaics, which have multiple EVs within them) in the bioregion were reviewed for this assessment along with their bioregional conservation status and the percentage of their current and pre-1750s extents in the protected area network, on other public land and on private land.

Although there has been almost no change in their spatial extent since the 1750s, the bioregional conservation status of five alpine EVCs was endangered, two were vulnerable, nine were rare, one of least concern and another with no status assigned. All EVCs currently have at least 30% of their current extent and 15% of their pre-1750s extent in the protected area network.

Very little of their current extent is on private land (although the small areas that are could be potentially degraded by horses, cattle and deer). The use of other public land could increase six of the alpine EVCs to above 90% coverage in the protected area network. Such changes to the level of protection for those EVCs would be dependent on their size, location, condition and degree of fragmentation, and their current use.

Although the level of protection of the EVCs is very high, there are concerns about their future health. Regan et al. (2020) reported that warming rates in alpine systems are higher than at lower elevations, that shrubs are encroaching on grasslands at higher elevations, and that some mammals are moving to higher elevations.[791] Researchers found that 'feral horses were impacting on environmental values across an extensive area of the Bogong High Plains.' [792]



Alpine Ecosystem Falls creek Snow Gum.
Credit: Steven Wright.
© Parks Victoria.

Feral horses are found in larger numbers in the eastern Alps, for example, at places such as Davies Plain, Forlorn Hope Plain, the Cobberas, Native Cat Flat, and where they are damaging habitats for the alpine water skink and alpine bog skink.[793]

Along with the impact of feral horses, especially in the softer and wetter habitats, the condition of alpine EVCs is being degraded by:

- Repeated burning since the extensive 1998 fires (2003, 2006-07, 2009, 2012 and 2019-20) has led to changes in snow gum cover and replacement of grassy plains with dense young regrowth that blocks light to reptile habitats in areas like Davies Plain. Recovery of sub-alpine habitats from repeated burning can be slow, in some cases taking decades.
- The clearing of high-quality habitats for the alpine she-oak skink, mountain skink and alpine tree frog around the Mount Hotham resort.
- Timber harvesting of habitats for the mountain skink and alpine tree frog on and around the Dargo High Plains.
- Recreation activities such as horse riding and campers and 4WD users that push in new tracks and camp sites around places such as King Spur.
- The removal of rocks that are the habitat of mountain skinks to construct fireplaces and cairns.[794]

Bergstom et al. (2021) analysed the current state and trajectories of 19 Australian ecosystems and concluded that each had collapsed or was collapsing.[795] The analysis included snow patch herbfield and montane and sub-alpine forests. Legacy grazing and feral animals were pressures in both ecosystems while clear felling was a key pressure in sub-alpine forests and tourism in the snow patch herbfields. Rising air temperatures, dry lightning, increased fire frequency and reduced snow cover were other drivers of change. For herbfields, species were being replaced by novel species and fire was causing local destruction. In the forests, grazing, clearing and multiple fire recurrences were also taking their toll.

791. Regan T, Tolsma A, Rowland J. Muir A, Ferrer-Paris J, Tóth A, White M 2020, 'Risk assessment and management priorities for alpine ecosystems under climate change: Milestone 5 Report', Arthur Rylah Institute (ARI) for Environmental Research, Heidelberg, Victoria.
792. Tolsma A and Shannon J 2018 'Assessing the impacts of feral Horses on the Bogong High Plains, Victoria', Arthur Rylah Institute (ARI) for Environmental Research, Heidelberg, Victoria, unpublished client report for Parks Victoria.
793. Zoos Victoria, 'Unpublished data', Melbourne, Victoria, Accessed 2022.
794. Ibid.
795. Bergstom D, Wienecke B, van den Hoff J, Hughes L, Lindenmayer D, Ainsworth T, Baker C, Bland L, Bowman D, Brooks S, Canadell J, Constable A, Dafforn K, Depledge M, Dickson C, Duke N, Helmstedt K, Holz A, Johnson C, McGeoch M, Melbourne-Thomas J, Morgain R, Nicholson E, Prober S, Raymond B, Riychie E, Robinson S, Ruthrof K, Setterfield S, Sgrò C, Stark J, Travers T, Trebilco R, Ward D, Wardle G, Williams K, Zylstra P, Shaw J 2021, 'Combating ecosystem collapse from the tropics to the Antarctic', Global Change Biology, pp. 1–12.

Indicator B:10 Mallee

B:10 Mallee						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Lowan Mallee bioregion Murray Mallee bioregion				New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator
Data source(s):	DELWP, PV, VEAC					
Measure(s):	Bioregional conservation status of mallee EVCs Percentage of current and pre-1750s extents within the protected area network of mallee EVCs					

Why this indicator?

Mallee landscapes have been degraded by pastoralism, invasive species and changing fire regimes. However, they continue to provide important refuges for threatened species.

NB: This is a new SoE 2023 indicator that was not included in the SoE 2018 Report.

Why this assessment in 2023?

Sixty percent of EVCs in the Lowan Mallee bioregion, and 70% in the Murray Mallee, are either endangered, vulnerable or depleted. Much of what is left in the Lowan Mallee bioregion is within the boundaries of national parks, nature conservation reserves and state forests, as well as on private land. A lower percentage of EVCs in the Murray Mallee bioregion are within the protected area network. There are reports that the abundances of mallee reptiles and some bird species are in decline.

Summary of State of the Environment 2018 Report assessment

- New SoE 2023 indicator

Critical data used for the 2023 assessment

- Bioregional Conservation Status of EVCs in 28 Bioregions and Change in EVC Extent Between 1750 and 2015
- Statewide Assessment of Public Land

2023 assessment

The Mallee stretches across a flat and sandy landscape covering much of north-western Victoria and characterised by mallee eucalypts.

The pre-1750s extent and current extent of EVCs (including complexes and mosaics, which have multiple EVs within them) in the two bioregions covering the Mallee — Lowan Mallee and Murray Mallee — were reviewed for this assessment, along with their bioregional conservation status and the percentage of their current and pre-1750s extent in the protected area network, on other public land or on private land.

Of the 34 EVCs in the Lowan Mallee bioregion, eight are endangered, five vulnerable, seven depleted and 14 of least concern. Additionally, 30 have at least 30% of their current extent and at least 15% of their pre-1750s extent protected. Of the 45 EVCs in the Murray Mallee bioregion (27 of which also appear in the Lowan Mallee bioregion), eight are endangered, 15 vulnerable, eight depleted and 12 of least concern (two have not been assigned a status). However, 19 EVCs have at least 30% of their current extent and 16 EVCs have at least 15% of their pre-1750s extent within the protected area network.

Of those EVCs with less than 30% coverage in the protected area network, three in the Lowan Mallee could be increased with greater legal protection on private land and other public land could be used for increasing representation within the protected area network for one other EVC. In the Murray Mallee region, 11 of those EVCs with less than 30% coverage in the protected area network could be increased using other public land, 10 by increased legal protection on private land, and five with either public or private land. Such changes to the level of protection for those EVCs would be dependent on their size, location, condition and degree of fragmentation, their current use and whether private landholders were supportive of increasing the legal protection of the remnant EVCs on their land.

Much of what is left of EVCs in the Mallee is within the boundaries of the Murray-Sunset National Park, Wyperfeld National Park, Big Desert Wilderness Park, Little Desert National Park, nature conservation reserves and state forests, as well as on private land. Semi-arid woodland, which is depleted in the Lowan Mallee and vulnerable in the Murray Mallee, is the focus of monitoring and restoration work by PV in the Mallee parks.

The vision of the Mallee Parks Landscape Conservation Action Plan 2019-2024 is to 'increase the resilience of natural assets in the Mallee Parks Landscape and maintain ecosystem services in the face of climate change and other stressors.' [796] Along with semi-arid woodlands, the natural assets include Mallee triodia, sunset plains and swales, heathlands and mallee heathlands, Lowan broombrush and swales, inland saline soaks, inland riverine forests and the Lake Albacutya Ramsar site. The threats to these natural assets include climate change, inappropriate fire regimes, weeds, invasive predators, visitor pressure, as well as grazing, browsing, trampling and wallowing pressure from livestock. The implementation of the action plan has seen:

> 'invasive species controlled and habitat enhanced across vast areas of land. Trapping, ground and aerial shooting programs have reduced the severe grazing impact of goats, pigs, and rabbits across the Mallee.' [797]

The Traditional Owners, represented by the Barengi Gadjin Land Council Aboriginal Corporation and the First People of the Millewa-Mallee Aboriginal Corporation, are involved in the action plan's implementation.

In the Mallee, burn regimes are based on botanical metrics with the assumption being that, if those botanical metrics are met, then local fauna will also benefit. However, reptiles such as the Masters' snake and the Mallee tree dragon are no longer found in Wyperfeld National Park where they were once common (based on pitfall trapping by A. John Coventry in the 1970s and 1980s compared with Zoos Victoria trapping between 2015 and 2017).[798] This loss of Mallee reptiles accords with reported fire-related declines in at least some Mallee birds and among invertebrates.[799]

796. Parks Victoria (PV) 2019, 'Mallee Parks Landscape Conservation Action Plan 2019-2024', Melbourne, Victoria.
797. Parks Victoria, 'A landscape approach to restore the Mallee' https://www.parks.vic.gov.au/news/2022/03/23/23/14/a-landscape-approach-to-restore-the-mallee Accessed 3 April 2022.
798. Zoos Victoria, 'Unpublished data', Melbourne, Victoria, Accessed 2022.
799. Ibid.

Indicator B:11 Heathlands

B:11 Heathlands						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide				New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator
Data source(s):	DELWP, VEAC					
Measure(s):	Bioregional conservation status Percentage of the current and pre-1750s extent of EVCs within the protected area networka					

Why this indicator?

Heathlands generally occur within nutrient-poor and fire-prone landscapes and contain diverse flora and fauna that are dependent on them. They have been reduced in extent through land clearing for urban, industrial and agricultural development. Heathlands remain important areas for conservation, culture and recreation.

NB: This is a new SoE 2023 indicator that was not included in the SoE 2018 Report.

Why this assessment in 2023?

Seventy-five percent of the heathland EVCs have retained more than 80% of their pre-1750s extent. However, their percentages within the protected area network across the bioregions are quite mixed and, for many, much of their remaining extent is on private land.

Summary of State of the Environment 2018 Report assessment

- New SoE 2023 indicator

Critical data used for the 2023 assessment

- Bioregional Conservation Status of EVCs in 28 Bioregions and Change in EVC Extent Between 1750 and 2015
- Statewide Assessment of Public Land

2023 assessment

Heathlands are found across most of Victoria's bioregions where they have retained much of their pre-1750s extent. The remaining heathlands are generally unattractive for agriculture due to being less fertile or they have been incorporated into national parks and other conservation reserves.

Fire is an important element in the ecology of heathlands and plays a role in their regeneration by adding nutrients and opening the canopy for the ground layer of orchids, lilies and other herbs. However, infrequent burns or burns that are too large can undermine their ecology. Bracken and prickly tea-tree have come to dominate some heathland areas that have experienced too-frequent fires and, as a result, their ecology has changed. Heathlands also face threats from *Phytophthora cinnamomi* (a fungal dieback), land clearing and climate change.[800]

Twenty-two heathland EVCs (including complexes and mosaics which have multiple EVs within them) across 17 of Victoria's bioregions were reviewed for this assessment, along with their bioregional conservation status, and the percentage of their pre-1750s and current extent in the protected area network, on other public land or on private land.

Of the 56 EVC entries (11 EVCs appeared in more than one bioregion), 23 are of least concern, nine are rare, 10 are depleted, nine are vulnerable and four are endangered, with one having no status assigned. Heathland EVCs and mosaics containing heathlands in the plains' bioregions, especially on the Gippsland and Glenelg plains, have experienced the greatest spatial changes and their bioregion conservation

800. Keith D, Lindenmayer D, Lowe A, Russell-Smith J, Barrett S, Enright N, Fox B, Guerin G, Paton D, Tozer M, Yates C 2014, 'Heathlands', Chapter 7 in D Lindenmayer, E Burns, E Thurgate, A Lowe (eds), 'Biodiversity and ecological change', CSIRO Publishing, Clayton, Victoria.

status reflects that. EVCs with at least 30% in the protected area network number 35, while seven had zero representation in the network. Of the 56 entries, 36 have at least 15% of their pre-1750s extent in the protected area network. As was the case with riparian EVCs, the Greater Grampians and Wilsons Promontory bioregions have high percentages of their current and pre-1750s extent within the protected area network.

Of those EVC entries with less than 30% of their current extent in the protected area network, 11 could reach 30% protection if other public land was included, four could reach this level of protection with the use of private land, and six with either public or private land. Such changes to the level of protection for those EVCs would be dependent on their size, location, condition and degree of fragmentation, their current use and whether private landholders were supportive of increasing the legal protection of the remnant EVCs on their land.

Threatened species

In January 2021, the platypus was added to Victoria's FFG Threatened List, joining almost 2,000 mammals, birds, reptiles, amphibians, fish, invertebrates, crustaceans and plants that are listed. Of the 1,998 species listed as threatened in Victoria, 54 are recorded as extinct — 30 species of vascular plants and one non-vascular plant, 14 mammals, three insects, two birds, two fish, one reptile and one crustacean.[801]

Wintle et al. (2019) pose the question: 'What will it cost to halt Australia's extinction crisis?'.[802] The scientists estimated that, in 2019, the annual spending by Australian governments on targeted threatened species totalled $122 million. That figure has increased since the 2019-20 bushfires, as governments seek to help impacted species recover. However, Wintle et al. (2019) argue that an investment of at least $1.7 billion each year over decades will be required to halt species extinction.[803]

Amendments to the FFG Act in 2019 made provisions to update the FFG Threatened List. The updated list has two parts, a national section consisting of *EPBC Act*-listed species for which the national conservation status is used, and a state section comprising species considered threatened in Victoria but not at the national level.

The updated FFG Threatened List replaced three advisory lists for threatened invertebrates (2009), threatened vertebrates (2013), and rare and threatened plants released (2014). The FFG Threatened List was prepared using the more-rigorous Common Assessment Method (CAM), which is largely based on the International Union for the Conservation of Nature (IUCN) categories. The new assessment process resulted in many species being upgraded to higher risk categories than they were assigned in the advisory lists. Some species were downgraded, which does not necessarily mean that a species is recovering but could simply be due to the availability of better data.

Three factors are primarily responsible for the trend towards upgrading of the conservation status of threatened species on the updated list and are the availability of new evidence and perspectives including inferences about the likely future impacts of climate change, the application of the critically endangered category for plants and fungi (previous assessments for plants and fungi had not used this category), and the more rigorous assessment approach using the Common Assessment Method criteria.

For the 12 indicators in this sub-theme, the status assessments consider changes in the conservation status of each threatened species, whether an action statement under the FFG Act has been prepared for that species, and its genetic risk rating should one have been assigned.[804] The numbers and conservation status of threatened species on the updated FFG Threatened List are compared with those on the earlier advisory lists. Some caution is

801. Department of Environment, Land, Water and Planning (DELWP), '*Flora and Fauna Guarantee Act* Threatened List' https://www.environment.vic.gov.au/conserving-threatened-species/threatened-list Accessed 24 January 2023.
802. Wintle B, Cadenhead N, Morgain R, Legge S, Bekessy S, Cantele M, Possingham P, James Watson, J, Maron M, Keith D, Garnett S, Woinarski J, Lindenmayer D 2019, 'Spending to save: What will it cost to halt Australia's extinction crisis?', *Conservation Letters*, 2019; 12, pp. e12682.
803. Ibid.
804. Kriesner P, Weeks A, Razeng E, Sunnucks P 2019, 'Assessing genetic risks to Victorian flora and fauna', Cesar and Monash University School of Biological Sciences, Melbourne, Victoria.

required here, as different criteria and assessment processes were used to prepare the earlier lists and the updated FFG Threatened List. However, the comparison does highlight the more robust process used for the updated list and indicates that there are now more threatened species listed. It also indicates that our understanding of the conservation status of threatened species has improved and that many are now at a greater risk of extinction than previously thought. The comparison also indicates an overall trend for an increasing number of species being listed as threatened (i.e. either critically endangered, endangered or vulnerable).

Under the FFG Act, action statements are mandatory for any species, community or potentially threatening process that has been listed. In its 2021 audit of DELWP's implementation of Biodiversity 2037, VAGO found that:

> 'DELWP has developed action statements covering 20% of listed species. Many of these action statements are greater than 10 years old and may no longer reflect a species' status or current and emerging threats to species' persistence.' [805]

However, the preparation and implementation of action statements does not guarantee the on-ground recovery of a species. It is also possible that the distribution and abundance of the species could continue to decline. The production of action statements for every species could also result in fewer resources for recovery programs.

The success or failure of action statements in leading to the recovery of a species is influenced by:

- Whether the statement is contemporary and has factored in the intensification of existing threats, the emergence of new threats and innovations in threat management. For example, few existing action statements have been prepared in the past 15 years, during which habitats have been further degraded, invasive species have continued their spread, bushfires have increased in frequency and intensity, and the awareness and understanding of climate change's impacts have improved. Innovations include the use of the gene drive in the control of invasive species including how such use might affect other species, immunocontraception to reduce feral cat numbers, the genetic modification of invasive fish to ensure only males are produced and the application of eDNA sampling to monitor the distribution and ecology of threatened aquatic species without the need to directly sample individuals.[806, 807, 808,809, 810]
- The availability of resources to implement the actions of the statements. Funding for nature conservation has often been short-term and limited to a small number of species. Since the 2019-20 bushfires, there has been increased investment in species recovery by the Commonwealth and Victorian governments. VAGO reported that 'DELWP acknowledges that it does not have the resources to complete comprehensive up-to-date action statements for all species in a timely manner, as required by the FFG Act' and is seeking to streamline their preparation to reduce the time and resources needed to do so.[811] There are, however, concerns that the streamlining process could produce statements with limited expert engagement, no public consultation, a focus on species persistence rather than recovery, and statements without objectives.[812]

805. Victorian Auditor-General's Office (VAGO) 2021, 'Protecting Victoria's biodiversity', Melbourne, Victoria.
806. Min A, Smidler A, Najjar D, Esvelt K 2018, 'Harnessing gene drive', *Journal of Responsible Innovation*, 5(s1), pp. S40-S65, DOI: 10.1080/23299460.2017.1415586.
807. Nguyen-Robertson C 2022, 'Tackling invasive species', *Science Victoria*, December 2022.
808. Ibid.
809. Lugg W, Griffiths J, van Rooyen A, Weeks A 2018, 'Optimal survey designs for environmental DNA sampling', Methods in Ecology and Evolution, 9, pp. 1049–1059.
810. Goldberg C, Turner C, Deiner K, Klymus K, Thomsen P, Murphy M, Spear S, McKee A, Oyler-McCance S, Cornman R, Laramie M, Mahon A, Lance R, Pilliod D, Strickler K, Waits L, Fremier A, Takahara T, Herder J, Taberlet P 2016, 'Critical considerations for the application of environmental DNA methods to detect aquatic species', *Methods in Ecology and Evolution*, 2016, 7, 1299–1307
811. Victorian Auditor-General's Office (VAGO) 2021, 'Protecting Victoria's biodiversity', Melbourne, Victoria.
812. Zoos Victoria, 'Unpublished data', Melbourne, Victoria, Accessed 2022.

- The level of conflict over the resources contained within the habitat utilised by species covered by the action statements. Urban expansion, timber harvesting and duck shooting are examples, where resource conflicts can emerge between resource users and the species dependent on the habitats in those areas targeted.
- The effective use of nature conservation legislation to support the recovery of threatened species. VAGO's 2022 audit, Protecting Victoria's Biodiversity, found issues with DELWP's use of the FFG Act, including:
  - actions statements not being prepared in accordance with the Act by not keeping pace with listings of threatened species
  - critical habitat determinations having only been declared once (during 1996)
  - flora and fauna management plans and habitat conservation orders not being used
  - no recent use of public authority management agreements.[813]
- Inadequate data and knowledge gaps where VAGO's 2022 audit found that there was no long-term monitoring program for threatened species, and DELWP-funded programs did not 'routinely specify or report against on-ground outcomes.' [814]

Although there are limitations for the success of action statements, monitoring progress on their mandatory preparation and their outcomes is a useful tool in the state of the environment reporting cycle and indicates the level of government commitment to, and resourcing for, the recovery of threatened species.

The first mandated 5-year review of the updated FFG Threatened List will be completed in 2026, prior to the SoE 2028 Report, which will then enable comparisons to be made between the 2021 FFG Threatened list with the reviewed 2026 list to determine changes in the number of threatened species.

Importantly, being listed is not a guarantee that a species will recover. Ward et al. (2022) devised a report card to highlight progress towards the recovery of species listed under the EPBC Act.[815]

The report card comprises four indicators — recovery plans, funding recovery, species-specific habitat protection, species extinction risk trajectories — that the authors regarded as the foundation for species recovery. The four indicators were scored for each of the 1,802 nationally threatened species. Most species scored an 'F' for recovery plans and the federal funding of those. The result was much better for habitat protection, with 529 species scoring an 'A'. However, all but five species were scored an 'F' for improvement in their threat status.

Woinarski et al. (2023) reported good news for some nationally threatened species. After analysing the recovery of 446 species since the enactment of federal threatened species legislation in 2000, it was concluded that one fish, one reptile, four frogs, and 15 mammal species no longer met the criteria for listing as threatened.[816] The recovery of these species, according to the researchers, was due to sustained management actions that included predator-free havens, translocations and predator control. However, they warned that, were the conservation management of the species withdrawn, their recovery would be undermined. The researchers also noted that:

> 'The lack of recovery of invertebrates is possibly because these have received little conservation investment. The limited recovery of fish is due to limited capacity for abating the threats of introduced fish predators and of exploitation and degradation of aquatic systems. Species threatened by habitat loss and degradation, fire and climate change are under-represented in recoveries.' [817]

This inconsistent nature of species recovery, and the under-representation of some groups on threatened species lists, is also apparent in Victoria and is noted in the assessments of several indicators in this theme.

813. Victorian Auditor-General's Office (VAGO) 2021, 'Protecting Victoria's biodiversity', Melbourne, Victoria.
814. Ibid.
815. Ward M, Rout T, Stewart R, Possingham H, McDonald-Madden E, Clark T, Kindler G, Valentine L, Macmillan E, Watson J 2022, 'A report card methodology to showcase progress towards threatened species recovery', *BioRxiV*, pp. 2022-2229, DO - 10.1101/2022.09.06.506545.
816. Woinarski J, Garnett S, Gillespie G, Legge S, Lintermans M, Rumpff L 2023, 'Lights at the end of the tunnel: The incidence and characteristics of recovery for Australian threatened animals', Biological Conservation, https://doi.org/10.1016/j.biocon.2023.109946 Accessed 15 June 2023.
817. Ibid.

Safe havens for species conservation

Safe havens are being used in Victoria (and elsewhere in Australia) to largely conserve threatened mammal species subject to predation from feral cats and foxes and damage to their habitat from feral herbivores. These include:

- the Pheasant Creek Flora and Fauna Reserve, home to the critically endangered Shelley leek orchid and 40 other threatened species, which was burnt in the 2019–20 bushfires. In response, Parks Victoria, DELWP and other agencies conducted integrated weed and herbivore control, including the construction of a five-hectare deer exclusion fence that native fauna can still move through.[818]
- exclosure fences conserving the eastern barred bandicoot at Woodlands Homestead near Melbourne Airport, in the Hamilton Community Parklands and at 'Tiverton' near Dundonnell in western Victoria (currently the largest fenced reserve in Victoria).
- a Victorian population of the brush-tailed rock wallaby which is inside a predator-exclusion compound at the Mt Rothwell Biodiversity Interpretation Centre.
- a project to construct a 10-km predator-proof fence across Yanakie Isthmus in the Wilsons Promontory National Park which is in the design stage. The fence will exclude foxes, deer and cats and support the re-establishment of native fauna, flora and habitats by creating a 50,000-hectare wildlife haven.
- a planned exclosure at Haining Farm, a former dairy farm and now public park where major weed eradication and habitat restoration has been conducted, to provide protection for translocated populations of the critically endangered lowland Leadbeater's possum and the helmeted honeyeater.[819]

Where safe havens successfully expand the populations of the targeted species, some individuals could be used to establish populations in other areas that are not necessarily predator free. Research by Harrison et al (2023), however, showed that woylies (brush-tailed bettongs) lost their anti-predator defences when bred inside fenced predator-free areas.[820] Similar observations have been made for boodies (burrowing bettongs), brushtail possums and eastern bettongs.[821, 822, 823] In each of these studies, the scientists have suggested maintaining low levels of native predators within the fenced areas to ensure the mammals retain their predator-avoidance traits. Otherwise, translocations of the animals to areas that were not predator free could be compromised. In other research by Taylor et al (2020) conducted on Phillip Island, eastern barred bandicoots were 'trained' to avoid predators such as cats.[824]

The use of safe havens, which nationally number more than 125 (100 are islands), has:

> 'prevented 13 mammal species from going extinct, such as boodies and greater stick-nest rats. In total, these havens have protected populations of 40 mammal species susceptible to cats and foxes. This is a good start, but we need more investment in havens to prevent extinctions.' [825]

Species will also need to be represented in more than one haven to avoid inbreeding and impacts such as bushfires.[826]

Safe havens, however, cover less than 1% of Australia and should be combined with other measures including improved management of conservation reserves. [827] Legge et al (2021), while supporting increased investment in safe havens and stronger laws for the control of domestic cats, argue that:

> 'in many parts of Australia, broad-scale habitat management is a more cost-effective way to reduce cat harm. This involves making habitat less suitable for cats and more suitable for native wildlife, for example, by reducing rabbit numbers, fire frequency and grazing by feral herbivores such as cattle and horses.' [828]

By reducing the number of rabbits, a favoured food source for feral cats, and by restoring vegetation, which makes it harder to find prey, cat numbers decline.

818. Primrose K 2020, 'Collaborating after fire', Presentation at a Weed management after fire: supporting native species recovery webinar, 9 December 2020, Weeds at the Early Stage of Invasion (WESI) Project, DELWP, East Melbourne, Victoria.
819. Zoos Victoria, 'Unpublished data', Melbourne, Victoria, Accessed 2023.
820. Harrison N, Wayne A, Dielenberg J Mitchell N 2023, 'Too small and carefree: Endangered animals released into the wild may lack the match fitness to evade predators', The Conversation, 6 June 2023.
821. Moseby K, Van der Weyde L, Letnic M, Blumstein D, West R, Bannister H 2022, 'Addressing prey naivety in native mammals by accelerating selection for antipredator traits', Ecological Applications, 33, e2780.
822. Bannister H, Brandle R and Moseby K 2018 'Antipredator behaviour of a native marsupial is relaxed when mammalian predators are excluded', Wildlife Research, 45(8) pp. 726-736.

Murray Sunset country goanna 2016.
Credit: John Stanisic.

823. Evans M, Batson W, Gordon I, Belton E, Chaseling T, Fletcher D, Harrison M, McElroy T, Mungoven A, Newport J, Pierson J, Portas T, Swain, S. Wimpenny C, Manning A 2021, 'The "goldilocks zone" of predation: The level of fox control needed to select predator resistance in a reintroduced mammal in Australia', *Biodiversity Conservation* 30, pp. 1731–1752.
824. Taylor R, Coetsee A, Doyle R, Sutherland D, Parrott M 2021, 'Sniffing out danger: Rapid antipredator training of an endangered marsupial', *Australian Mammalogy*, 44(1) pp. 109-116.
825. Legge S, Dickman C, Dielenberg J, Woinarski J, Nou T 2021, 'Australia must control its killer cat problem. A major new report explains how, but doesn't go far enough', *The Conversation*, 10 February 2021.
826. Ibid.
827. Ibid.
828. Ibid.

Indicator B:12 Threatened terrestrial and freshwater mammals

B:12 Threatened terrestrial and freshwater mammals						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide						NC*
Data source(s):	DELWP					
Measure(s):	Changes in conservation status Action statements Genetic risk ratings					

Why this indicator?

This is a modified SoE 2023 indicator that allows a greater focus on mammal species than previous SoE reports and was formed by disaggregating the measures of the SoE 2018 indicators 'B:06 Trends in populations and distributions of threatened terrestrial species' and 'B:06B Vertebrates'. The 2018 assessment provided in this report card is for 'B:06B Vertebrates', as its measure is most comparable to that of the modified 2023 indicator.

Why this assessment in 2023?

The number of threatened mammal species on the FFG Act Threatened List has grown over time and populations continue to decline. One-third are listed as extinct, half of those species that are left have had their conservation status upgraded and two-thirds have genetic risk ratings of high to very high. The 2019–20 bushfires placed further pressure on threatened mammals in eastern and north-eastern Victoria.

** NC indicates that comparisons between the SoE 2018 and SoE 2023 assessments for the modified SoE 2023 indicator is inappropriate due to the extensive level of variability in the measures and/or data used in the assessment between SoE reports.*

Summary of State of the Environment 2018 Report assessment

- There is no information within the SoE 2018 assessment specific to this modified 2023 indicator.

Critical data used for the 2023 assessment

- Updated FFG Threatened List

2023 assessment

There are 44 native mammal species on Victoria's updated FFG Threatened List, with 15 identified as extinct, three critically endangered, 11 endangered, 13 vulnerable, one — the rufous-bellied pademelon — threatened, and two listed in 2013 that were not listed in 2022.

Between 2013 and 2022, there have been upgrades of conservation status (the conservation status is now viewed as worse than in 2013) for 14 mammal species and downgrades for five species (the rufous-bellied pademelon was listed as regionally extinct in 2013, whereas in September 2022 it was listed as threatened). For 26 species, 16 of which were considered extinct in both years (another was extinct in 2013 and not listed in 2022), there was no change in conservation status. Although the platypus was not listed in 2013 and the dingo was listed as data deficient, both are now on the 2022 list as vulnerable.

Action statements have been prepared for 14 of the 29 threatened species (excludes extinct species), with nine of those more than 10 years old. Genetic risk ratings for 20 of the 29 species are high to very high.

In 2018, the Australian Threatened Mammal Index reported that, for seven EPBC threatened and IUCN near-threatened species for which data were available, the relative abundance in Victoria had decreased on average by 72% between 1995 and 2016.[829]

829. Threatened Species Recovery Hub, 'Factsheet: A threatened mammal index for Victoria', National Environmental Science Programme, Canberra, Australia.

For individual species, the decline in abundance ranged from 55% to 82%. In 2022, the time series was extended to include 2018. The timeline from 1990 to 2018 for eight threatened and near-threatened terrestrial mammal species is reproduced in Figure B12 and shows that their decline in abundance has continued, although at a slowing rate.[830]

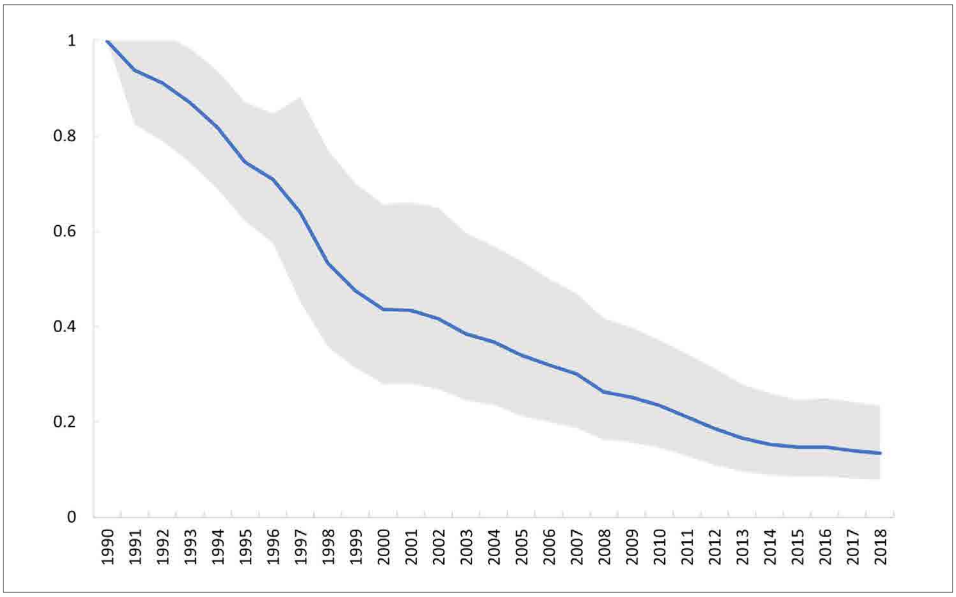


Figure B12: The Australian threatened species index for eight threatened and near-threatened terrestrial mammal species in Victoria from 1990 to 2018.[831]

The Australia State of the Environment 2021 Report assessed the national status of native mammals as very poor and deteriorating.[832] Zoos Victoria is targeting seven threatened mammal species in its Fighting Extinction program, using monitoring and captive breeding to aid their recovery, including:

- brush tailed rock wallaby which has only two populations of 30 individuals in the wild
- eastern barred bandicoot which was extinct on the mainland and is now classified as endangered due to recovery efforts
- smoky mouse which has less than 2,500 individuals in two populations
- southern bent wing bat which has less than 41,000 individuals
- Leadbeater's possum which has less than 40 individuals in the lowland population
- mountain pygmy possum which has less than 2,000 individuals
- pookila which has less than 10,000 individuals.[833, 834]

Burns (2019) determined that the pookila (New Holland mouse) had been lost from seven of the 12 isolated areas in south-eastern Victoria where it once occurred due to habitat loss and fragmentation, invasive predators and genetic isolation.[835] Wilson and Garkaklis (2020) reviewed the long-term monitoring of small-mammal populations at 30 sites across the eastern Otway Ranges and found that, in total, 67% of sites exhibited large to severe decreases in abundance, and only 3% had more than four species compared to 27% in earlier decades. Declines in abundance and species diversity occurred following wildfire and drought.[836]

830. Department of Climate Change, Energy, the Environment and Water (DCCEEW), 'The Australian threatened species index 2022, https://tsx.org.au/tsx2022/?ref=1990&index=Mammals&group=Terrestrial&state=VIC&status_auth=Max&status=NT_VU_EN_CR Accessed 23 January 2023.
831. Ibid.
832. Commonwealth of Australia 2021, 'Australian state of the environment', Canberra, Australian Capital Territory, https://soe.dcceew.gov.au/ Accessed 12 June 2023.
833. Zoos Victoria, 'Fighting extinction' https://www.zoo.org.au/fighting-extinction/ Accessed 20 February 2023.
834. The most-recent count for the lowland population of Leadbeater's possum is now 24 (Dan Harley, Zoos Victoria, pers.comm. 4 May 2023).
835. Burns P 2019, 'Testing the decline of the New Holland mouse (Pseudomys novaehollandiae) in Victoria', *Australian Mammalogy*, 42(2), 185–193.
836. Wilson B, Garkaklis M 2020, 'Patterns of decline of small mammal assemblages in vegetation communities of coastal south-east Australia: identification of habitat refuges', *Australian Mammalogy*, 43(2) 203-220.

The 2019–20 bushfires resulted in koala mortality as well as 50% of their habitat in Budj Bim being burnt. National estimates put the number of koalas impacted by the 2019–20 bushfires at more than 60,000 across Australia, including 11,000 in Victoria.[837] This was at a time when koala populations were already in decline due to habitat loss and fragmentation, disease, and low genetic diversity.

In January 2022, DELWP released new information about the impact of the 2019-20 bushfires on some mammal species .[838] The broad-toothed rat, which had already been suffering population declines, is now facing greater pressure from feral herbivores, predation, the loss of habitat and a potential loss of genetic diversity. The spot-tailed quoll is facing similar pressures, including increased predation by cats and foxes and competition for prey. Site occupancy of the yellow-bellied and southern greater gliders declined by 45%. Other mammal species of most concern in fire-impacted areas included the brush-tailed rock-wallaby, eastern bent-wing bat, eastern horseshoe bat, eastern pygmy-possum, grey-headed flying fox, and the long-footed and long-nosed potoroos.

In encouraging news, the broad-toothed rat has been rediscovered at Wilsons Promontory National Park, 32 years since the last sighting, and the eastern barred bandicoot has been downgraded from extinct in the wild to endangered.[839] As a result, its captive breeding program at Zoos Victoria has now been discontinued.[840]

The platypus

In January 2021, the platypus was added to the FFG Threatened List as vulnerable. Its habitat in eastern Australia declined by 22.6% (199,919 km^2) between 1990 and 2020.[841] Over the same period, platypus records in the Murray-Darling Basin dropped by 30% and by up to 65% in some of the urban catchments of Melbourne. Monitoring by citizen scientists in recent years has shown sparse numbers in the upper Barwon and Coliban rivers, their almost complete disappearance from the upper Campaspe, and a localised extinction in the Curdies River in the Otways.[842] The loss and fragmentation of habitat, river regulation and drought are the main causes of the decline of this species.

Bushfires can also impact platypus habitat by impacting water temperature, water quality and riparian vegetation. In the 2019-20 bushfires, 14% of the modelled habitat of the platypus was within the fire extent, and 6% of that modelled habitat was impacted by high-severity fire.[843] Impacts to other species can also be found within the indicator 'Fi:03 Actual fire regimes compared to optimal fire regimes in public forests' of the 'Fire' chapter

Hawke, Bino and Kingsford (2021) investigated the link between river regulation and the number of platypuses in the Upper Murray, Snowy and Border rivers regions.[844] They found that, in general, platypus numbers were lower downstream of the Dartmouth Dam than upstream, possibly due to changes in the seasonality and temperatures of water flows from the dam. However, there was no difference in numbers upstream and downstream of dams in the Snowy and Border rivers, possibly due to less severe regulation and also habitat restoration being conducted in these areas.

837. World Wildlife Federation (WWF) Australia 2020, 'Impacts of the unprecedented 2019-20 bushfires on Australian animals', Sydney, NSW.
838. Department of Environment Land, Water and Planning (DELWP) 2022, 'Biodiversity bushfire response: Supplementary report on bushfire impacts on species in Victoria', Melbourne, Victoria.
839. Victoria State Government 2022, 'Rare native rodent rediscovered at Wilsons Promontory', Media release by the Premier of Victoria, 5 August 2022.
840. Zoos Victoria, 'Unpublished data', Melbourne, Victoria, Accessed 2022.
841. Cox L 2020, 'Australia's platypus habitat has shrunk 22% in 30 years, report says', The Guardian, 23 November 2020.
842. Severi J 2020, 'Platypus listed as vulnerable in Victoria', https://cesaraustralia.com/blog/platypus-vulnerable-in-victoria/ Accessed 10 May 2021.
843. Department of Environment Land, Water and Planning (DELWP) 2020, 'Victoria's bushfire emergency: biodiversity response and recovery, Version 2', Melbourne, Victoria.
844. Hawke T, Bino G, Kingsford R 2021, 'Damming insights: variable impacts and implications of river regulation on platypus populations', *Aquatic Conservation: Marine Freshwater Ecosystems*, 31, pp. 504–519.

The Great Australian Platypus Search Victoria 2021 used eDNA data collected in waterways across Victoria to systematically assess the distribution of platypus to support conservation efforts.[845] Figure B13 maps the results, from which the authors concluded that:

> 'These results provide support for the recent listing of platypuses as vulnerable under the Victorian FFG Act. While it remains difficult to quantitatively assess declines due to limited historical data, the data broadly support the decline of platypuses in the Wimmera-Avon Basin, Portland Coast Basin, upper Campaspe River, Bass River, and a number of waterways of the greater Melbourne region within the last 30 years. Longer term absences of platypuses from the lower Murray River and Curdies system are also supported by these eDNA results. Of further concern is the limited distribution and fragmentation of populations indicated in other river basins of central and western Victoria as well as low detections in the lowland reaches of many waterways of eastern Victoria that could lead to further fragmentation of populations in tributaries and upper reaches. Previous research has shown that fragmentation will exacerbate negative genetic effects, such as inbreeding, leading to further declines in populations.'

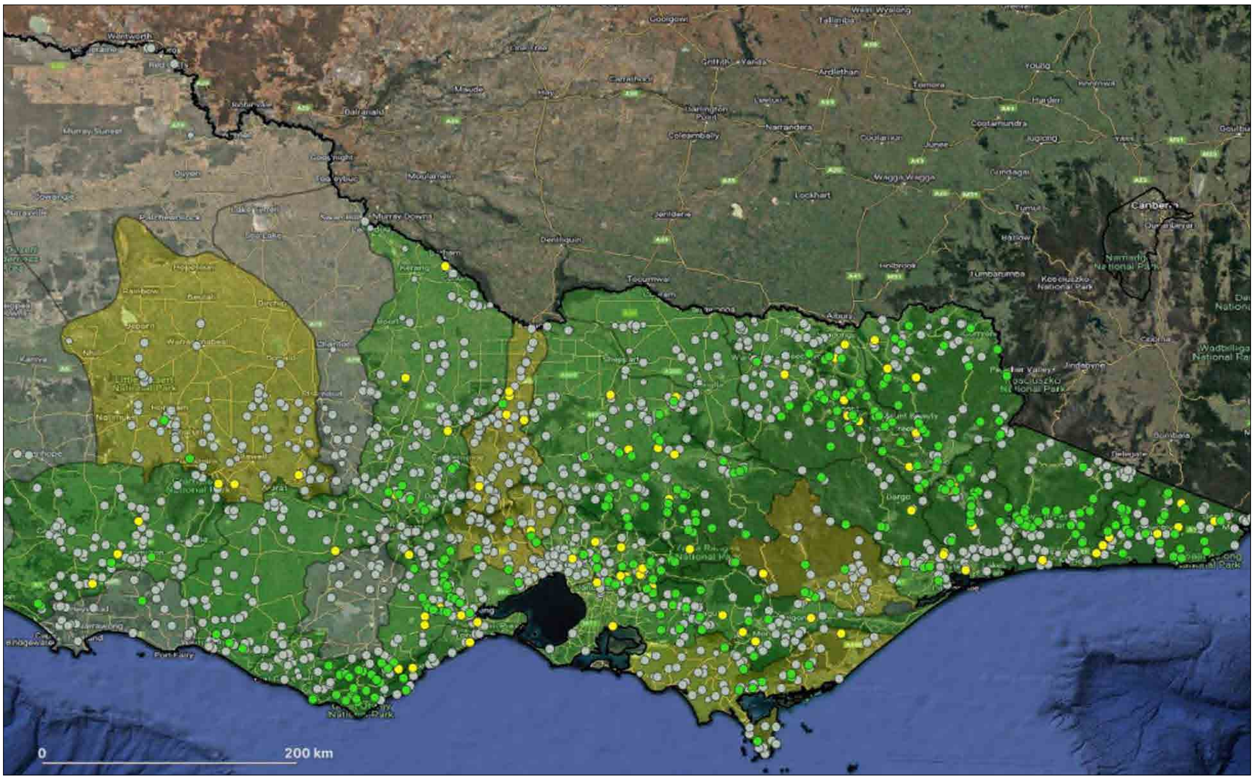


Figure B13: Results of the Great Australian Platypus Search eDNA surveys from 1,611 sites across Victoria in 2022.[846] Green dots represent detection, yellow dots represent possible detection and grey dotes indicate no platypuses were detected.

845. EnviroDNA, Odonata 2022, 'Platypus results report Great Australian Platypus Search', Brunswick, Victoria.
846. Ibid.

Indicator B:13 Threatened wetland-dependent species

B:13 Threatened wetland-dependent species						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide						
Data source(s):	DELWP					
Measure(s):	Changes in conservation status Action statements Genetic risk ratings					

Why this indicator?

Wetlands provide essential services to the environment and communities, including food resources, nurseries and refuges for native wildlife, and as recreational and cultural spaces. The status of wetland-dependent species can be an indicator of wetland health.
NB: This SoE 2023 indicator was 'B:05 Threatened species that are wetland dependent' in the SoE 2018 Report.

Why this assessment in 2023?

Almost three-quarters of the wetland-dependent fauna listed on the FFG Threatened List that were reviewed are either critically endangered or endangered, more than 40% have had their status upgraded, and one-third have genetic risk ratings of high to very high. Action statements have only been prepared for one-third of species. The number of wetland-dependent plants that are regarded as threatened (critically endangered, endangered or vulnerable) has also increased. The ongoing decline of wetlands will increase pressure on these already-threatened species, as will sedimentation in some locations due to the 2019–20 bushfires. Threatened wetland-dependent species are not well monitored.

Summary of State of the Environment 2018 Report assessment

- The majority of threatened wetland-dependent species of fauna are birds, followed by amphibians, fish, reptiles and mammals.
- The highest percentage of wetland-dependent species in each fauna group was associated with amphibians, followed by birds, fish, reptiles and mammals. These five groups were used as a proxy for the percentage of Victoria's threatened wetland-dependent species due to limited data.

Critical data used for the 2023 assessment

- Updated FFG Threatened List

2023 assessment

The updated FFG Threatened List conservation status for 74 wetland-dependant threatened fauna species of amphibians, freshwater fish, birds, invertebrates and reptiles occurring in Victoria's wetlands (although these species may not remain in wetlands throughout their entire life cycle) was reviewed for this assessment. The list of threatened wetland-dependent species was compiled using work by Morris (2016) and Regan et al. (2023), and by choosing only those species included in the updated FFG Threatened List.

In summary, the 2022 conservation status for each fauna group was:

- Amphibians: nine critically endangered, four endangered, one vulnerable
- Freshwater fish: three critically endangered, seven endangered, two vulnerable
- Birds: 11 critically endangered, 15 endangered and 16 vulnerable
- Reptiles: five endangered
- Invertebrates: two endangered.

When a comparison is made between the conservation status of each of the 74 wetland-dependant fauna species in the 2013 advisory list and Victoria's 2022 FFG Threatened List, 32 have had their status upgraded, eight have been downgraded and 33 have remained the same. Specifically:

- 12 threatened amphibians: eight remained the same, two were downgraded and three upgraded
- 12 threatened freshwater fish species: six remained the same, two were downgraded (one from regionally extinct to critically endangered), and four were upgraded
- 42 threatened bird species: 20 remained the same, four were downgraded and 18 upgraded (including one not listed in 2013)
- five threatened reptile species: two remained the same, two were downgraded and one was upgraded.
- Two invertebrate species: one remained the same and one was downgraded.

Twenty-five of the 74 wetland-dependant fauna species have action statements, although only four have been prepared in the past decade. In terms of genetic risk ratings, 29 are very high or high, 18 moderate, 24 low and three are without an assigned rating.

DELWP provided a list of 440 significant wetland-dependent plant species (in part based on the 2014 advisory list of rare and threatened plants) for this indicator assessment.[847] It was used to assess changes in conservation status between the 2014 advisory list and the 2022 FFG Threatened List. Of the 440 wetland-dependant flora species on the advisory list, 362 were found on the FFG Threatened List (most of those not included had insufficient knowledge of their status). Four wetland-dependant flora species were not included in either the 2014 or 2021 lists, four were on the 2014 list but not the 2022 FFG Threatened List, and 63 were listed as poorly known in Victoria in 2014 and not included in the 2022 FFG Threatened List. The number in each conservation status category in 2014 and 2022 are compared in Table B2.

It should be noted that the critically endangered category was not used when preparing the 2014 advisory list (hence the zero in 2014) and the rare category is no longer used in the 2022 FFG Threatened List (hence the zero in 2022). This has contributed to substantial changes in the conservation status assessment of many plants. Of the 362 wetland-dependant flora species, 325 had their conservation status upgraded, one had it downgraded and for 36 species there was no change, with five of those remaining extinct on both lists.

DELWP has developed habitat distribution models for 416 threatened wetland-dependent flora and fauna species which are used to identify where habitat exists for these species. A separate, but complementary, project is underway to model the distribution of wetland EVCs across the state and is due for completion by the end of 2023. The projects will build the understanding of how wetland values are distributed across the landscape. Work is also underway to develop statewide information on the distribution of wetland threats. This will be used with the information on wetland dependent values to form the basis for risk analysis. The results of the projects will support the development of regional waterway strategies, the next statewide waterway strategy, and prioritisation and investment decision making.

Table B2: Change in conservation status of threatened wetland-dependent plants from 2014 to 2021.[848, 849]

Conservation status category	2014	2022
Extinct	5	5
Critically endangered	0	79
Endangered	63	239
Vulnerable	116	39
Rare	189	0
Poorly known	63	0
Not on list	4	0
Total	440	362

847. The list provided by DELWP also identified aquatic and river dependent species, which were excluded from the analysis.
848. Department of Environment and Primary Industries (DEPI) 2014, 'Advisory list of rare and threatened plants', Melbourne, Victoria.
849. Department of Environment, Land, Water and Planning (DELWP), '*Flora and Fauna Guarantee Act 1988* Threatened List', Melbourne, Victoria, https://www.environment.vic.gov.au/__data/assets/pdf_file/0021/655410/FFG-Threatened-List-June-2023.pdf Accessed 12 June 2023.

Indicator B:14 Threatened terrestrial bird species

B:14 Threatened terrestrial bird species						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	Poor (red)	Deteriorating	High (green)	Poor (red)	Deteriorating	NC*
Data source(s):	DELWP					
Measure(s):	Changes in conservation status Action statements Genetic risk ratings					

Why this indicator?

This is a modified SoE 2023 indicator that allows a greater focus on bird species than previous SoE reports and was formed by disaggregating the measures of the SoE 2018 indicators 'B:06 Trends in populations and distributions of threatened terrestrial species' and 'B:06B Vertebrates'. The 2018 assessment provided in this report card is for 'B:06B Vertebrates', as its measure is most comparable to that of the modified 2023 indicator.

Why this assessment in 2023?

The number of terrestrial bird species on the FFG Act Threatened List has grown and populations have declined. More than 60% are either critically endangered or endangered. Fifty percent of listed terrestrial bird species have had had their conservation status upgraded and half of those assigned a genetic risk rating are rated as high to very high. Although 40% have action statements, only one is from the past decade. Along with ongoing threats, the 2019–20 bushfires placed further pressure on threatened bird species in eastern and north-eastern Victoria.

** NC indicates that comparisons between the SoE 2018 and SoE 2023 assessments for the modified SoE 2023 indicator is inappropriate due to the extensive level of variability in the measures and/or data used in the assessment between SoE reports.*

Summary of State of the Environment 2018 Report assessment

- There is no information within the SoE 2018 assessment specific to this modified 2023 indicator.

Critical data used for the 2023 assessment

- Updated FFG Threatened List

2023 assessment

There are 56 terrestrial bird species on Victoria's updated FFG Threatened List, with three identified as extinct, 15 critically endangered, 18 endangered and 20 vulnerable.

A comparison of the 2013 advisory list and the 2022 FFG Threatened List reveals that there have been upgrades in conservation status for 27 threatened bird species, downgrades for four and no change for 25 species. Of the 53 non-extinct threatened bird species, 22 have had action statements prepared. However, only one of those has been prepared in the past decade. In terms of genetic risk, 23 bird species have a high or very high-risk level, 15 have a moderate risk level, eight have a low risk level, and seven bird species have no rating assigned.

In 2018, The Australian Threatened Species Index indicated that, for 18 threatened bird species in Victoria (these include six migratory shorebirds that are not terrestrial species), their relative abundance decreased on average by 61% between 1985 and 2016.[850]

For individual species, the declines ranged from 28% to 77%. In 2022, the time series was extended to 2018. The trend from 1990 to 2018 for 16 terrestrial threatened and near-threatened species is reproduced in Figure B14 and shows that the decline in bird populations has continued.[851]

The Australia State of the Environment 2021 Report assessed the national status of threatened native birds as very poor and deteriorating.[852] Zoos Victoria is targeting six threatened bird species in its Fighting Extinction program and is using captive breeding, translocation and threat management to recover populations of the helmeted honeyeater (<200 in the wild), orange-bellied parrot (<50), plains wanderer (250-1,000), regent honeyeater (<2,000) and the swift parrot (unknown population size).[853]

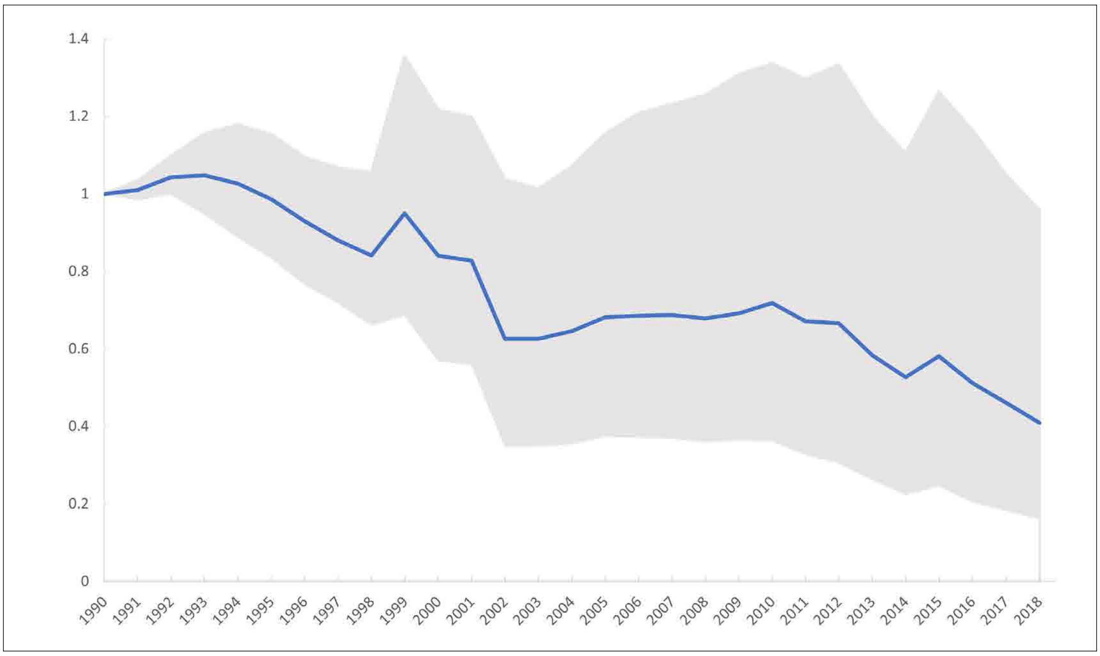


Figure B14: The Australian threatened species index for 16 threatened and near-threatened terrestrial bird species in Victoria from 1990 to 2018.[854]

Lindenmayer, Bowd, and McBurney (2021) analysed the effects of fire and logging on birds and found that these events:

> 'have led to marked losses in the extent of old growth forest in Mountain Ash and Alpine Ash ecosystems. This is a concern given the strong association of most species of birds with old forest relative to younger age cohorts.' [855]

850. Threatened Species Recovery Hub, 'Factsheet: A threatened bird index for Victoria', National Environmental Science Programme (NESP), Canberra, Australia.
851. Department of Climate Change, Energy, the Environment and Water (DCCEEW), 'The Australian threatened species index 2022', https://tsx.org.au/tsx2022/?ref=1990&index=Birds&group=Terrestrial&state=VIC&status_auth=Max&status=NT_VU_EN_CR Accessed 23 January 2023.
852. Commonwealth of Australia 2021, 'Australian state of the environment', Canberra, Australian Capital Territory, https://soe.dcceew.gov.au/ accessed 12 June 2023
853. Zoos Victoria, 'Fighting extinction' https://www.zoo.org.au/fighting-extinction/ Accessed 20 February 2023.
854. Ibid.
855. Lindenmayer D, Bowd E, McBurney L 2021, 'Long-term empirical studies highlight multiple drivers of temporal change in bird fauna in the wet forests of Victoria, south-eastern Australia', Frontiers in Ecology and Evolution, 9, pp. 610147.

In January 2022, DELWP released new information about the impact of the 2019-20 bushfires on some bird species.[856] There had been few detections of large forest owls, including the powerful owl, sooty owl and masked owl. 'However, it is possible that all the targeted owl species have undergone declines due to reductions in key requirements such as prey and hollow-bearing trees.'[857]

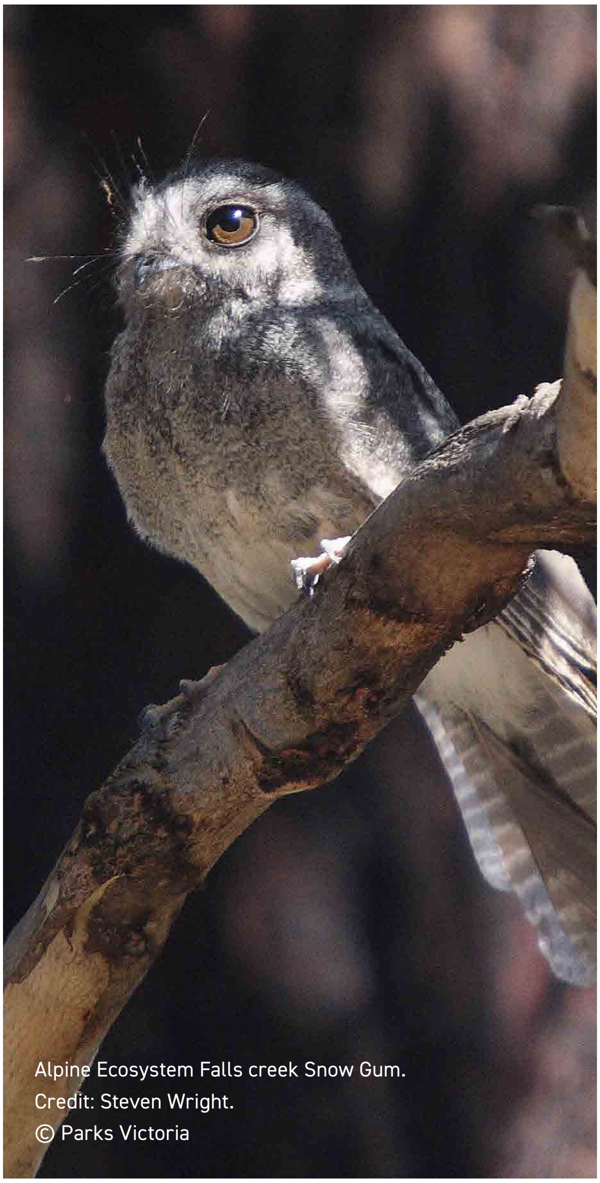
For the glossy black cockatoo, surveys indicated that:

> 'the 2019–20 bushfires are likely to have reduced the Victorian population significantly ... and may therefore take many years for the population to recover. Further widespread fires during this population recovery period will result in further population decline.' [858]

The eastern ground parrot has a patchy distribution in Victoria and the bushfires:

> 'are likely to have reduced the Victorian population by reducing the area of habitat by at least 20%, and probably by 30%. While most of the burnt habitat is likely to become optimal again within a decade or so, the species must survive the intervening period and breed successfully in unburnt refugia.' [859]

In good news, the white-bellied whipbird was re-discovered in the Big Desert Wilderness Park by Latrobe University researchers in 2022. For 40 years this species has been presumed extinct in Victoria.[860]



Alpine Ecosystem Falls creek Snow Gum.
Credit: Steven Wright.
© Parks Victoria

856. Department of Environment Land, Water and Planning (DELWP) 2022, 'Biodiversity bushfire response: supplementary report on bushfire impacts on species in Victoria', Melbourne, Victoria.
857. Ibid.
858. Ibid.
859. Ibid.
860. Clark T, Turner L 2022, 'White-bellied whipbird, presumed extinct, rediscovered in arid north-west Victoria', *ABC* Mildura-Swan Hill, 12 November 2022.

Indicator B:15 Waterbird species in the Murray-Darling Basin

B:15 Waterbird species in the Murray–Darling Basin						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Southern Murray–Darling Basin						
Data source(s):	Centre for Ecosystem Science, DELWP					
Measure(s):	Number, abundance, distribution and conservation status of waterbird species in the Murray–Darling Basin					

Why this indicator?

The Eastern Australian Waterbird survey is a large-scale biodiversity dataset that monitors waterbirds, including threatened species, and the health of rivers and wetlands.

NB: This SoE 2023 indicator was 'B:14 Distribution and abundance of waterbirds in the Murray-Darling Basin' in the SoE 2018 Report.

Why this assessment in 2023?

The annual Eastern Australian Waterbird Survey, which has been conducted since 1983, continues to show a long-term decline in waterbird abundance and distribution. Of 48 species monitored in the surveys, half are showing a declining long-term trend in their population.

Summary of State of the Environment 2018 Report assessment

- Since 1983, the Eastern Australian Waterbird survey has collected and analysed data on waterbird species across the Murray-Darling Basin each year.
- A reduction in water flow has contributed to a long-term decline in the total abundance of waterbirds.

Critical data used for the 2023 assessment

- Annual Eastern Australian Waterbird survey (2018 to 2022)

2023 assessment

The Murray-Darling is Australia's most developed river basin, with 240 dams that can store 29,893 GL. This water resource management has reduced flows and, according to Kingsford, Bino, and Porter (2016), caused long-term ecological impacts for freshwater fauna.[861] In their research they identified:

> 'significant long-term declines in total abundances, functional response groups (e.g. fish-eating birds) and individual species of waterbird, associated with reductions in cumulative annual flow. These trends indicated ecosystem level changes.' [862]

Between 1983 and 2022, the annual Eastern Australian Waterbird survey has surveyed the distribution and abundance of up to 96 waterbird species that includes herons, egrets, large and small waders, migratory shorebirds, ducks and terns.[863] It does this by using observers in fixed-wing aircraft flying along 10 transects, each 30 km in width. Two of the transects cross Victoria, one along the south coast and the other across the northern rivers (southern section of the Murray-Darling Basin).

861. Kingsford R, Bino G, Porter J 2017, 'Continental impacts of water development on waterbirds, contrasting two Australian river basins: Global implications for sustainable water use', Global Change Biology, 2017, pp. 1–12.
862. Ibid.
863. Kingsford R, Porter J, Brandis K, Ryall S 2020, 'Aerial surveys of waterbirds in Australia', Scientific Data, 7, pp, 172.

Annual surveys from 2018 to 2021 found a continuation of the long-term trend of decline in total abundance, breeding index, number of species breeding and the wetland area index. Across the survey's 39 years, the trend in abundance for each of the functional bird groups — ducks, herbivores, large wading birds, piscivores and shorebirds — has been in decline. Five of the bird species subjected to hunting — pacific black duck, Australasian shoveler, grey teal, mountain duck and Australian wood duck — have experienced long-term declines, while another three species subjected to hunting — the hardhead, chestnut teal and pink-eared duck — have shown no trend.

Although the 2022 survey was conducted after two successive La Nina years, total abundance, number of species breeding, and the wetland area index continued to show significant declines over time.[864]

Total waterbirds abundance did increase from 2021 to 2022, however, it remained well below the long-term average of this metric. For game species, the chestnut teal was now showing decline rather than no trend, and the abundance of grey teal, hardhead and pink-eared duck had declined in abundance since 2021.

Clemens, Driessen and Ehmke (2019) conducted an analysis of waterbirds for Birdlife Australia that included 48 of the species surveyed in the Eastern Australian Waterbird Survey and which occur in Victoria.[865, 866] Of the 48 species, 24 are experiencing a declining long-term trend in their population, there is no long-term trend evident for 21 species, and for three species of waterbirds the long-term trend was not available.[867] Nine of the species are listed as threatened on the FFG Act Threatened List. Those listed as vulnerable are the magpie goose, Caspian tern, Australasian shoveler, blue-billed duck, hardhead and musk duck, while those listed as endangered are the gull-billed tern, freckled duck and brolga.

Pelican at Kings Billabong Park 2008.
Credit: Chris Woods.
© Parks Victoria.

864. Porter J, Kingsford R, Francis R, Brandis K, Ahern A 2022, 'Eastern Australian waterbird aerial survey - October 2022 annual summary report', Centre for Ecosystem Science, UNSW Sydney, NSW.
865. Clemens R, Driessen J, Ehmke G 2019, 'Australian Bird Index Phase 2: developing waterbird indices for national reporting', unpublished report for the Department of the Environment. Birdlife Australia, Melbourne.
866. Ibid.
867. Ibid.

Indicator B:16 Threatened terrestrial and wetland reptile species

B:16 Threatened terrestrial and wetland reptile species						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide		↙			↙	NC*
Data source(s):	DELWP					
Measure(s):	Changes in conservation status Action statements Genetic risk ratings					

Why this indicator?

This is a modified SoE 2023 indicator that allows a greater focus on reptile species than previous SoE reports. It was formed by disaggregating the measures of the SoE 2018 indicators 'B:06 Trends in populations and distributions of threatened terrestrial species' and 'B:06B Vertebrates'. The 2018 assessment provided in this report card is for 'B:06B Vertebrates', as its measure is most comparable to that of the modified 2023 indicator.

Why this assessment in 2023?

The number of terrestrial and wetland reptile species on the FFG Act Threatened List has grown. One of the 40 terrestrial and wetland reptile species listed is extinct, and 16 have had their conservation status upgraded. Of the 36 assigned a genetic risk rating, 33 are rated high to very high. Eleven of the 39 species have action statements; however, only two have been prepared in the past decade. Along with ongoing threats, the 2019–20 bushfires placed further pressure on threatened reptiles in eastern and north-eastern Victoria. Data on threatened reptile species are limited in comparison with that for threatened mammal and bird species.

** NC indicates that comparisons between the SoE 2018 and SoE 2023 assessments for the modified SoE 2023 indicator is inappropriate due to the extensive level of variability in the measures and/or data used in the assessment between SoE reports.*

Summary of State of the Environment 2018 Report assessment

- There is no information within the SoE 2018 assessment specific to this modified 2023 indicator.

Critical data used for the 2023 assessment

- Updated FFG Threatened List

2023 assessment

There are 40 terrestrial and wetland reptile species on Victoria's FFG Threatened List, with one extinct, 15 critically endangered, 23 endangered and one vulnerable. A comparison of the 2013 advisory list and 2022 FFG Threatened List reveals that the conservation status of 16 species has been upgraded, five have been downgraded and 18 have had no change. Only 11 of the 39 species (excluding the extinct species) have action statements, with just two of those prepared in the past decade. In terms of genetic risk, 33 have either a high- or very high-risk rating.

Although the grassland earless dragon is listed as critically endangered, it is possibly extinct, with no records since 1969. The death adder, which was listed as data deficient in 2013 and therefore not assessed for the updated FFG Threatened List, is also probably extinct. Another species not listed is the mountain skink, which Zoos Victoria now believe to be critically endangered.[868]

The Australia State of the Environment 2021 Report assessed the national status of native reptiles as poor and deteriorating. The Zoos Victoria Fighting Extinction program is using captive breeding to promote the recovery of the alpine she oak skink (only four populations), Guthega skink (unknown population size) and the Victorian species of the grassland earless dragon (not seen in the wild since 1969).[869]

868. Zoos Victoria, 'Unpublished data', Melbourne, Victoria, Accessed 2022.
869. Zoos Victoria, 'Fighting extinction' https://www.zoo.org.au/fighting-extinction/ Accessed 20 February 2023.

Clemann (2015) reviewed the history of listing threatened reptiles in Victoria, along with their conservation, and found that the 'deteriorating status of Victorian reptile species mirrors worrying documented trends in reptile conservation status around the world', with the threats to most being 'climate change, habitat loss and degradation and elevated rates of predation by exotic predators.' [870] Clemann added that 'the impact of threatening processes has increased over this time, the status of many species has worsened, and the need to mitigate threats has grown ever urgent.'[871]

Clemann, Atkins and Gilbert (2018) surveyed threatened reptiles and frogs in the Victorian Alps during 2017 and 2018. They noted:

> 'continuing, and likely worsening, impacts on the habitat of threatened lizards and the Alpine Tree Frog (Litoria verreauxii alpina), from feral horses and deer, as well as probable emerging damage caused by pigs. These impacts, and the raft of impacts associated with a warming climate, are being exacerbated by human impacts, such as ongoing destruction and fragmentation of Alpine She-oak Skink and Alpine Tree Frog habitat at Mt Hotham, and hikers intentionally disturbing rocks used by Guthega Skinks on the Bogong High Plains.' [872]

In a review of stomach and scat sample analyses, Stobo-Wilson et al. (2021) found that, of Australia's 999 reptile species, foxes preyed upon 108 species and feral cats 263. The authors concluded that they:

> 'are likely to be taking a significant toll on, and contributing to the decline of, Australia's highly distinctive reptile fauna. Effective targeted and broad-scale actions taken to control foxes and cats will provide conservation benefits to this fauna.' [873]

Reptiles were also impacted by the 2019-20 bushfires. A 2022 DELWP analysis revealed that:

> 'these fires demonstrated the potential of a single large events to rapidly worsen the status of some species, and to rapidly compromise areas previously considered strongholds for certain species or groups. Prior to the 2019–20 bushfires, East Gippsland had been considered the stronghold for some species that are rapidly declining elsewhere, such as Swamp Skinks and Lace Monitors. Many populations of Victorian reptiles have become fragmented, and many are on a declining trajectory.' [874]

Other reptile species of most concern from the 2019-20 bushfires included the alpine bog skink, alpine she-oak skink, copper-tailed skink, diamond python, red-throated skink and yellow-bellied water skink.

870. 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.
871. Ibid.
872. Clemann N, Atkins Z, Gilbert D 2018, 'Monitoring and survey of threatened alpine reptiles, frogs and threatening processes in the Victorian Alps: 2017–2018 season', unpublished client report for Zoos Victoria, Arthur Rylah Institute (ARI) for Environmental Research, Heidelberg, Victoria.
873. Stobo-Wilson A, Murphy B, Legge S, Chapple D, Crawford H, Dawson S, Dickman C, Doherty T, Fleming P, Gentle M, Newsome T, Palmer R, Rees M, Ritchie E, Speed J, Stuart J-M, Thompson E, Turpin J, Woinarski J 2021, 'Reptiles as food: Predation of Australian reptiles by introduced red foxes compounds and complements predation by cats', Wildlife Research, 48(5), pp. 470-480.
874. Department of Environment Land, Water and Planning (DELWP) 2022, 'Biodiversity bushfire response: supplementary report on bushfire impacts on species in Victoria', Melbourne, Victoria.

Indicator B:17 Threatened large-bodied freshwater fish species

B:17 Threatened large-bodied freshwater fish species						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide						NC*
Data source(s):	DELWP					
Measure(s):	Changes in conservation status Action statements Genetic risk ratings					

Why this indicator?

Large-bodied fish have a key role in aquatic ecosystems. They are also targeted by recreational fishers in many rivers and streams across Victoria.

NB: This is a modified SoE 2023 indicator that allows a greater focus on large-bodied freshwater fish species than previous SoE reports and was formed by merging the SoE 2018 indicators 'B:04A Trend in population number and distribution of trout cod *(Maccullochella maquariensis)*', 'B:04B Trend in population number and distribution of Macquarie perch (*Macquaria australasica*)' and 'B:13 Distribution and abundance of fish'. The 2018 assessment provided in this report card is for 'B:13 Distribution and abundance of fish', as its measure is most comparable to that of the modified 2023 indicator.

Why this assessment in 2023?

One of the 10 large-bodied fish species on the FFG Act Threatened List is extinct, two are critically endangered and eight are endangered. Four species have had their conservation status upgraded, and two-thirds have genetic risk ratings of high to very high. Although five large-bodied fish species have action statements, only one has been prepared in the past decade. Native Fish Report Cards and other research are improving data on native fish. However, there is no formal analysis of fish status and environmental data.

** NC indicates that comparisons between the SoE 2018 and SoE 2023 assessments for the modified SoE 2023 indicator is inappropriate due to the extensive level of variability in the measures and/or data used in the assessment between SoE reports.*

Summary of State of the Environment 2018 Report assessment

- Stage 5 Victorian Environmental Flows Monitoring and Assessment Program of nine northern and coastal rivers (until 2016) reported 45 fish species across Victoria, of which, 28 are native species that regularly inhabit inland aquatic ecosystems. The dominant native fish species were Australian smelt and flathead gudgeon, but fish biomass was dominated by the European carp.
- Stage 6 Victorian Environmental Flows Monitoring and Assessment Program surveys (2016-2020) investigated immigration, dispersal and distribution and recruitment of fish species across the regulated rivers. Surveys showed 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 also highlighted that improved flow conditions, including environmental water, potentially facilitated this recovery.

Critical data used for the 2023 assessment

- Native Fish Report cards released each year since the SoE 2018 Report
- Updated FFG Threatened List

2023 assessment

There are 10 large-bodied fish species on Victoria's updated FFG Threatened List, with one designated as extinct, one critically endangered and eight endangered. A comparison of the 2013 advisory list and 2022 FFG Threatened List reveals that the conservation status of four have been upgraded, one has been downgraded and four have had no change. The freshwater herring was listed as regionally extinct in 2013 and extinct on the updated Threatened List. Of the nine species remaining in the wild, action statements have been prepared for four, with just one of those prepared in the past decade. Six of the nine species in the wild have a genetic risk rating of high or very high.

The Australia State of the Environment 2021 Report assessed the national status of native fish as poor and deteriorating.[875] A comprehensive analysis of fish data from 2004 to 2013 by Lieschke et al. (2013) calculated the fish health of Victoria's 29 river basins as either extremely poor, very poor, poor, moderate, or good.[876] The most common rating was poor, largely due to the moderate to major decline of native fish species across the state and the predominance of alien species. The highest fish health ratings were in the far east and west of southern Victoria, while the lowest were in central-northern Victoria and the far north-east.[877]

Koehn, Raymond, Stuart et al. (2020) listed key threats to native fish as including:

> 'reduced longitudinal and lateral connectivity, altered flows, loss of refugia, reductions in both flowing (lotic) and slackwater riverine habitats, degradation of wetland habitats, alien species interactions and loss of aquatic vegetation.' [878]

The authors found that golden perch and silver perch were heavily impacted by barriers to connectivity and flow-related impacts. Decreased water quality and in-stream structures were significant threats for the Murray cod, while threats for trout cod were identified as altered flow seasonality, loss of riverine habitats, recreational fishing and decreased in-stream structure.

The Native Fish Report Card program monitors the status of nine large-bodied native species from a waterway in each of the 10 catchment management regions, however, the report cards do not analyse the interactions between the species and their environment. The waterways that are part of the program include the Gellibrand River, Glenelg River, Gunbower Creek, the Lindsay River and Mullaroo Creek system, Lower Goulburn River, Mitchell River, Ovens River, the Thomson and Macalister River system, Wimmera River and Yarra River.

The species targeted by the program are large-bodied species with high recreational and/or conservation value. The program uses six performance measures of population health including long-term trends in catch rates (abundance) and fish size structure (presence of multiple year classes, mature fish and recent recruits) which together provide an overall rating for each species in Victoria.

Although there are instances where good recruitment is occurring, there is generally little to no recruitment for the fish species across the various rivers. This is also the case for some fish species where stocking has occurred. Between 2016 and 2022, Murray cod restocking occurred in the Goulburn (430,000 released), Gunbower Creek (400,690) and Lindsay and Mullaroo (27,000 in 2021), while for the Macquarie perch, 100,575 fingerlings were released into the Ovens River.

DELWP's August 2020 bushfire response and recovery report identified three large-bodied fish species of most concern that were affected by the 2019-20 bushfires. The Gippsland blackfish and eastern Victorian populations of the Australian grayling may have been affected, although the percentage of the modelled habitat within the fire extent was unknown. Whereas approximately 20% of the modelled habitat for the Macquarie perch was within the fire extent. 'High sediment and ash levels generated by rain events in the weeks and months post fire are likely responsible for the decline in the Macquarie Perch population.'[879]

Habitat restoration, restocking and environmental water delivery are being used to help recover the populations of native large-bodied freshwater fish species in Victoria. In the aftermath of the 2019-20 bushfires, OzFish, Landcare Australia, the North East CMA, Corryong Angling Club and the Women in Recreational Fishing Network have worked together to restore the Cudgewa Creek in the Upper Murray. Log structures, bed-seeding boulders and tree plantings have been used to diversify habitat, provide refuges for young fish, and reduce bank erosion and sedimentation to support Murray cod, trout cod and the mountain galaxias.[880]

875. Commonwealth of Australia 2021, 'Australian state of the environment', Canberra, Australian Capital Territory, https://soe.dcceew.gov.au/ 12 June 2023.
876. Lieschke J, Dodd L, Stoessel D, Raadik T, Steelcable A, Kitchingman A, Ramsey D 2013, 'The status of fish populations in Victorian rivers 2004–2011 – Part A', Arthur Rylah Institute (ARI) for Environmental Research Technical Report Series No. 246, Heidelberg, Victoria.
877. Ibid.
878. Koehn J, Raymond S, Stuart I, Todd C, Balcombe S, Zampatti B, Bamford H, Ingram B, Bice D, Burndred K, Butler G, Baumgartner L, Clunie P, Ellis I, Forbes J, Hutchison M, Koster W, Lintermans M, Lyon J, Mallen-Cooper M, McLellan M, Pearce L, Ryall J, Sharpe C, Stoessel D, Thiem J, Tonkin Z, Townsend A, Ye Q 2020, 'A compendium of ecological knowledge for restoration of freshwater fishes in Australia's Murray-Darling Basin', Marine and Freshwater Research, 71, pp. 1391–1463.
879. Department of Environment Land, Water and Planning (DELWP) 2020, 'Victoria's bushfire emergency: biodiversity response and recovery, Version 2', Melbourne, Victoria.
880. OzFish, 'Cudgewa Creek and trout cod' https://ozfish.org.au/projects/cudgewa-creek-vic/ Accessed 11 January 2022.

Indicator B:18 Threatened small-bodied freshwater fish species

B:18 Threatened small-bodied freshwater fish species

Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		↙			↙	NC*

Data source(s):	DELWP
Measure(s):	Changes in conservation status Action statements Genetic risk ratings

Why this indicator?

Small-bodied freshwater fish species, such as the galaxiids, have experienced significant reductions in abundance and distribution, and are at an increasing risk of extinction.

NB: This is a modified SoE 2023 indicator that allows a greater focus on small-bodied freshwater fish species than previous SoE reports and formed by narrowing the measure for the SoE 2018 indicator 'B:13 Distribution and abundance of fish'.

Why this assessment in 2023?

Seventy-five percent of small-bodied freshwater fish species on the FFG Act Threatened List are either critically endangered or endangered. Six of the 20 remaining have had their conservation status upgraded, and 85% have genetic risk ratings of high to very high. Although six have action statements, only three have been prepared in the past decade. There is no formal analysis of fish status and environmental data. Along with ongoing threats, the 2019–20 bushfires placed further pressure on threatened small-bodied freshwater fish species in eastern and north-eastern Victoria.

**NC indicates that comparisons between the SoE 2018 and SoE 2023 assessments for the modified SoE 2023 indicator is inappropriate due to the extensive level of variability in the measures and/or data used in the assessment between SoE reports.*

Summary of State of the Environment 2018 Report assessment

- There is no comparable information within the SoE 2018 assessment for this modified 2023 indicator.

Critical data used for the 2023 assessment

- Updated FFG Threatened List

2023 assessment

There are 21 small-bodied fish species on Victoria's updated FFG Threatened List, with one species designated as extinct, 12 critically endangered, four endangered and four vulnerable. There were eight small-bodied fish on the FFG Act at the time of the 2013 advisory list, with an additional six nominated for listing, however, with the number of galaxiid species increasing due to their formal description (from the *Galaxias olidus* complex), the number of threatened small-bodied fish is likely to increase. A comparison of the 2013 advisory list and 2022 FFG Threatened List reveals that the conservation status of six species has been upgraded (including one not on the advisory list), and two have been downgraded (including one changed from regionally extinct to critically endangered), and the status of 12 species did not change. Of the 20 listed species remaining in the wild (excluding the extinct species), only six have action statements, with just three prepared in the past decade. Genetic risk ratings for the 20 species in the wild are 17 high or very high, two having a moderate risk rating and one was not assessed.

Lintermans et al. (2020) found that small-bodied fish with greater than 70% likelihood of extinction were the Shaw galaxias (highest risk), West Gippsland galaxias (second-highest risk), tapered galaxias, Dargo galaxias and the Morwell galaxias. Those with a 50% to 69% likelihood of extinction were McDowall's galaxias, Yalmy galaxias, East Gippsland galaxias and the Moroka galaxias.[881]

881. Lintermans M, Geyle H, Beatty S, Brown C, Ebner B, Freeman R, Hammer M, Humphreys W, Kennard M, Kern P, Martin K, Morgan D, Raadik T, Unmack P, Wager R, Woinarski J and Garnett S 2020, 'Big trouble for little fish: identifying Australian freshwater fishes in imminent risk of extinction', Pacific Conservation Biology, 26(4), pp. 365–377.

Shaw galaxias, the most imperilled species, is known from only one population of 80 individuals living above a waterfall that prevents the arrival of predatory trout. A small range — from 4 km^2 to 36 km^2 — makes it especially at risk from catastrophic events such as bushfires or trout incursion. The Yalmy galaxias population before the 2019–20 bushfires was estimated to be 2,500, however, post-fire monitoring found only two individuals in separate areas.[882]

Raadik (2014) identified 15 separate species in the *Galaxias olidus* complex and concluded that:

> 'the degree of salmonid impact on biodiversity in Australian non-migratory galaxiids has been seriously under-estimated' ... and ... 'trout are implicated in the decline and/or fragmentation in range of 10 of the 15 species within the complex.' [883]

In January 2022, DELWP released new information about the impacts of the 2019-20 bushfires on freshwater fish species, stating that they had:

> 'severely exacerbated the impacts of in-stream sedimentation and population factors, further reducing species' resilience and increasing their risk of extinction. This is particularly a concern for species already in decline, e.g. existing as a single, small population, or with just a few small, isolated populations.' [884]

DEECA is running a pilot trout control program, which includes barriers, trout removal, genetic analysis and fish conservation in priority locations.[885] However, the stocking of trout in Victoria's rivers continues. DEECA is also investing in a captive breeding program directly targeting freshwater species affected by the 2019-20 bushfires. The endangered species to be bred at the new hatchery at Snob Creek include several galaxiid species from Gippsland.[886]

882. Costa J 2020, 'Shaw galaxias freshwater fish species in "dire straits" and on brink of extinction, study finds', ABC Gippsland, 24 August 2020.
883. Raadik T 2014, 'Fifteen from one: a revision of the *Galaxias olidus* Günther, 1866 complex (Teleostei, Galaxiidae) in south-eastern Australia recognises three previously described taxa and describes 12 new species', Zootaxa, 3898 (1), pp. 1–198.
884. Department of Environment, Land, Water and Planning (DELWP) 2022, 'Biodiversity bushfire response: supplementary report on bushfire impacts on species in Victoria', Melbourne, Victoria.
885. Department of Environment, Land, Water and Planning (DELWP), 'Unpublished data', Melbourne, Victoria, Accessed 2022.
886. Premier of Victoria 2022, 'Hatching a plan to protect native fish populations', Media Release by the Minister for Environment and Climate Change, 12 August 2022.

Indicator B:19 Threatened frog species

B:19 Threatened frog species						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	🔴	↙	🟡	🔴	↙	🟢
Data source(s):	DELWP					
Measure(s):	Changes in conservation status Action statements Genetic risk ratings					

Why this indicator?

There have been declines in the populations of native frog species (threatened and non-threatened species) over the past few decades due to habitat loss and degradation, introduced fish species and the chytridiomycosis disease.

NB: This is a modified SoE 2023 indicator formed by merging the SoE 2018 indicators 'B:04D Trend in population number and distribution of spotted tree frog (*Litoria spenceri*)', 'B:04E Trend in population number and distribution of Booroolong tree frog *(Litoria booroolongensis*)', 'B:04F Trend in population number and distribution of Baw Baw frog (Philoria frosti)' and 'B:12 Distribution and abundance of frogs'. The 2018 assessment provided in this report card is for 'B:12 Distribution and abundance of frogs', as its measure is most comparable to that of the modified 2023 indicator.

Why this assessment in 2023?

Fourteen of the 15 frog species on the FFG Act Threatened List are either critically endangered or endangered, three have had their conservation status upgraded and all but one have genetic risk ratings of high to very high. Forty percent have action statements; however, only two have been prepared in the past decade. Only a small number of threatened frog species are the subject of research. Along with ongoing threats, the 2019–20 bushfires have placed further pressure on threatened frogs in eastern and north-eastern Victoria.

Summary of State of the Environment 2018 Report assessment

- There had been declines in the abundance of native frog species (threatened and non-threatened species) over the past few decades.
- There were 37 amphibian species in Victoria, with 17 species listed as threatened.
- In the last 20 years, the number of threatened frog species on the FFG Act list had doubled.

Critical data used for the 2023 assessment

- Updated FFG Threatened List

2023 assessment

There are 15 frog species on Victoria's updated FFG Threatened List. Nine species are critically endangered, five endangered and one vulnerable.

Three frogs considered data deficient in 2013 were not assessed for the updated FFG Threatened List. A comparison of their conservation status on the 2013 advisory list and 2022 FFG Threatened List reveals that three have been upgraded, three downgraded and nine have not changed. Of the 15 listed frog species, six have action statements, however, only two have been prepared in the past decade. In terms of genetic risk, 14 are high or very high and one is uncertain.

The Australia State of the Environment 2021 Report assessed the national status of threatened native amphibians as poor and deteriorating.[887] Zoos Victoria is targeting five threatened frog species in its Fighting Extinction program and is using captive breeding and monitoring to promote recovery of populations of the large brown tree frog (population size unknown), giant burrowing frog, Baw Baw frog (greater than 88% decline since 19880s and less than 1,000 individuals in the wild), spotted tree frog (less than 12,000) and the southern population of the stuttering barred frog (not seen in Victoria since 1983).[888]

887. Commonwealth of Australia 2021, 'Australian state of the environment', Canberra, Australian Capital Territory, https://soe.dcceew.gov.au/ Accessed 12 June 2023.
888. Zoos Victoria, 'Fighting extinction' https://www.zoo.org.au/fighting-extinction/ Accessed 20 February 2023.

Chytridiomycosis is a known, or probable, key factor in the loss and declines of many populations of susceptible frog species. However, it is very difficult to control, along with the impacts of climate change, underscoring the need to mitigate preventable impacts such as habitat loss, barriers and invasive species (e.g. trout).[889]

Populations of the spotted tree frog and Booroolong frog have been declining due to the infectious disease chytridiomycosis and the introduction of predatory fish — brown trout and rainbow trout, European carp, redfin perch and mosquito fish — which prey on tadpoles.

Surveys of the spotted tree frog after the 2019-20 bushfires found significant impacts from the fires, subsequent flooding and the chytrid fungus, with exotic fish species also a factor.[890] Before the bushfires, the frog's population was estimated at 1,500 individuals, whereas afterwards it is thought to have declined to 1,000.[891] The eight distinct populations in north-eastern Victoria and southern New South Wales were reduced to seven, some with populations now in the tens, whereas prior to the fires there would have been hundreds.[892]

The Baw Baw frog is Victoria's only endemic frog species. Reasons for the decline in its numbers and distribution include habitat loss and degradation in their restricted range (only 135 km^2 in total) on the Baw Baw Plateau and escarpment as well as the spread of chytridiomycosis. Geyle et al. (2021) assessed the Baw Baw frog as having a 65% chance of extinction, while the spotted tree frog was assessed as having a 36% chance. For frogs in general, the scientists concluded that 'increased resourcing and management intervention are urgently needed to avert future extinctions of Australia's frogs.'[893]

Martin's toadlet is another frog listed as critically endangered on the FFG Threatened List. In 2022, it was proposed for listing as endangered on the threatened species list of the EPBC Act after assessment by the Threatened Species Scientific Committee.[894] The toadlet has a restricted range and small occupancy area in the wetlands and ponds of forests, woodlands and heathlands of East Gippsland's coastal lowlands (and in the south-east corner of NSW). Habitat loss and fragmentation from vegetation clearance for agriculture, timber harvesting and roads have been, and continue, to be its main threats. Other threats include its inability to disperse and colonise new areas, altered hydrology, habitat damage by feral deer and pigs, the introduced mosquito fish preying on eggs and tadpoles, Chytridiomycosis, and the drying of habitat due to climate change.[895] The 2019-20 bushfires spread across 31% of its modelled habitat and one-third of its known sites were burnt. The ash and sediment that flowed into waterways after the fires buried shelter and breeding habitats.[896]

In January 2022, DELWP released new information about the impact of the 2019-20 bushfires on some frog species:

> 'Introduced fish threaten stream-breeding frogs during the recovery period post fire. Predation on eggs and tadpoles could be more severe during these periods (due to reduced aquatic vegetation cover) and threaten frog populations (with small numbers of adults remaining, populations have a higher risk of extinction if recruitment fails). Hog and samba deer were impacting water quality at some sites'... and... 'Input of ash, silt, and sediment, particularly after rainfall events buries instream habitat, stream banks and sand banks. This is likely to render these areas unusable as frog habitat, potentially leading to longer term loss of breeding for riverine frogs that lay their eggs in the spaces between rocks and shelter sites.'[897]

889. Hunter D, Clemann N, Coote D, Gillespie G, Hollis G, Scheele B, Phillips A, West M 2018, 'Frog declines and associated management response in south-eastern mainland Australia and Tasmania', Chapter 6 in H Heatwole and J Rowley (eds) 2018 'Status of conservation and decline of amphibians: Australia, New Zealand and Pacific Islands, pp.39-58, CSIRO Publishing, Clayton, Victoria.
890. Zoos Victoria, 'New hope for wild future of critically-endangered Victorian frogs', https://www.zoo.org.au/melbourne/whats-on/news/new-hope-for-wild-future-of-critically-endangered-victorian-frogs/ Accessed 3 August 2023.
891. Webb C 2021, 'Frog-et them not: "Decades-long" quest starts to save endangered frog', The Age, 8 July 2021.
892. Ibid.
893. Geyle H, Hoskin C, Bower, Catullo R, Clulow S, Driessen M, Daniels K, Garnett S, Gilbert D, Heard G, Hero J-N, Hines H, Hoffmann P, Hollis, Hunter D, Lemckert F, Mahony M, Marantelli G, McDonald K, Mitchell N, Newell, Roberts J, Scheele B, Scroggie M, Vanderduys E, Wassens S, West M, Woinarski J, Gillespie G 2021, 'Red hot frogs: identifying the Australian frogs most at risk of extinction', Pacific Conservation Biology, https://doi.org/10.1071/PC21019.
894. Department of Climate Change, Energy, the Environment and Water (DCCEEW) 2022, 'Consultation on species listing eligibility and conservation actions: *Uperoleia martini* (Martin's toadlet)' https://www.dcceew.gov.au/environment/biodiversity/threatened/nominations/comment/uperoleia-martini Accessed 28 January 2023.
895. Ibid.
896. Ibid.
897. Department of Environment Land, Water and Planning (DELWP) 2022, 'Biodiversity bushfire response: supplementary report on bushfire impacts on species in Victoria', Melbourne, Victoria.

Perons tree frog, Gippsland 2016.
Credit: Start Rodney.
© Museum Victoria

Indicator B:20 Threatened freshwater invertebrate species

B:20 Threatened freshwater invertebrate species						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	●	↙	●	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator
Data source(s):	DELWP					
Measure(s):	Changes in conservation status Action statements Genetic risk ratings					

Why this indicator?

Freshwater invertebrates have been poorly studied; however, their importance in aquatic ecosystems is now being more recognised as research expands.

NB: Freshwater invertebrates, such as water bugs and water beetles, were the focus of the SoE 2018 indicator 'B:15 Distribution and abundance of macroinvertebrates'. This new SoE 2023 indicator assesses freshwater crustaceans, mussels, dragonflies, stoneflies, caddisflies and damselflies that are connected to freshwater systems during part, or all, of their life cycle.

Why this assessment in 2023?

Research on freshwater invertebrates is limited and, as a result, the number included on the FFG Threatened List is relatively low. Seventy percent of the crustaceans and mussels assessed here are either critically endangered or endangered. One-third have had their conservation status upgraded and 14 of the 17 have genetic risk ratings of high to very high. One-quarter of threatened crustacean and mussel species have action statements; however, only one has been prepared in the past decade. Nine of the 23 species of dragonflies, stoneflies, caddisflies and damselflies are either critically endangered or endangered and have had their conservation status upgraded. Only one of the species has had an action statement prepared and it was released more than 20 years ago. Of the four assigned a genetic risk rating, all were either high or very high.

Summary of State of the Environment 2018 Report assessment

- New SoE 2023 indicator

Critical data used for the 2023 assessment

- Updated FFG Threatened List

2023 assessment

Victoria's updated FFG Threatened List contains 45 freshwater crayfish, copepods, isopods, mussels and shrimp. Of those 45 listed species, nine are critically endangered, 22 endangered, 12 vulnerable, one threatened and one extinct. A comparison of the 2009 advisory list and the 2022 FFG Threatened List reveals that 15 have been upgraded, one has been downgraded and 29 have not changed. Twelve of the 45 species have action statements, however, only one of those has been prepared in the past decade. There are 14 species with a genetic risk rating of high or very high, three moderate and three uncertain. The remaining species have not been assessed for genetic risk.

The key threats to spiny crayfish are over-exploitation, habitat fragmentation and climate change, however, post-fire runoff after the 2019-20 bushfires could have impacted 40% of known *Euastacus* species.[898]

The Murray spiny crayfish, the world's second-largest freshwater crayfish, occurs in the southern Murray-Darling Basin, grows up to 50 cm in length and three kg in weight, and can live for 25 years or more. Its distribution and abundance have declined since the 1950s. Habitat change, river regulation, pesticides and pollutants, recreational harvesting and events of low dissolved oxygen have contributed to declines in its distribution and abundance.

898. Whiterod N, Furse J, Lutz M, Lintermans M, McCormack R, Zukowski S, Thompson R, Raadik T, Marshall J, Miller A, Austin C, Ahyong S 2022, 'The 2022 action plan for priority 2019–20 bushfire-impacted species from Australia's endemic freshwater crayfish genus Euastacus (Parastacidae)', a report to the Department of Agriculture, Water and the Environment (DAWE), Aquasave–Nature Glenelg Trust, Victor Harbor.

Murray spiny crayfish were harvested commercially until 1987 and recreational fishing occurred up until 1983 when the fishery was closed until 1991. From 1991, the recreational fishing for the species has occurred under regulations that include allowable fishing effort (gear type and seasons) and bag and size/slot limits. A 2017 review of the recreational fishery for the Murray spiny crayfish identified:

> 'moderate to high relative abundance of the species in three areas – the mid-Goulburn River (from Seymour to upstream of Shepparton), the lower Ovens River (downstream of Wangaratta to Murray junction) and Wodonga Creek' — but 'have undergone declines in abundance over the past 25 years.' [899]

Elsewhere, the study found the species in low abundance or absent from sample sites.[900] A conservation stocking program began in 2017 translocating 200 crayfish to a downstream area of the Murray River where their numbers had declined significantly.[901]

In 2022, DELWP released information on the impacts of the 2019-20 bushfires on biodiversity, including post-fire surveys of seven species of freshwater crayfish and three species of freshwater mussels.[902] 'The impact of the bushfires has severely exacerbated the impacts of in-stream sedimentation and population factors, further reducing resilience among species and increasing their risk of extinction. This is particularly a concern for species already in decline (e.g. existing as a single, small population, or with just a few small, isolated populations). Freshwater fish, crayfish and mussels were extracted from fire-affected waterways in eastern Victoria and kept in captivity until conditions were safe for their return.

Victoria's FFG Threatened List also includes 23 species of dragonflies, stoneflies, caddisflies and damselflies. Four species are listed as critically endangered, five as endangered and 14 as vulnerable. Six of the species have had their conservation status upgraded since 2009, four have been downgraded and 13 have had no change. Only one of the species has had an action statement prepared, however, it was released more than 20 years ago. In terms of genetic risk, four are high or very high and three are uncertain. The remainder of species have not been assigned a rating.

A bushfire recovery research project funded by the Commonwealth Government, 'Conserving Victoria's unique alpine stonefly genus *Thaumatoperla*', is assessing the impacts of the 2019–20 bushfires on the alpine stonefly to determine its the distribution and identify priority actions to support recovery and conservation efforts. As part of the project, three dogs have been trained to search for and find the flightless stonefly, which is only 50 mm in length.[903]

899. Whiterod N and Zukowski S 2017, 'The status of the Murray crayfish recreational fishery in Victoria', Aquasave – Nature Glenelg Trust, Goolwa Beach, South Australia.
900. Ibid.
901. Lovett S 2018, 'Population models help assess risk for threatened Murray crayfish', *Finterest* 12 March 2018.
902. Department of Environment Land, Water and Planning (DELWP) 2022, Biodiversity bushfire response: supplementary report on bushfire impacts on species in Victoria', Melbourne, Victoria.
903. Loos T 2022, 'Dogs trained to find endangered insects' https://cosmosmagazine.com/earth/sustainability/dogs-trained-to-find-endangered-insects/

Indicator B:21 Threatened terrestrial invertebrate species

B:21 Threatened terrestrial invertebrate species						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide						
Data source(s):	DELWP					
Measure(s):	Changes in conservation status Action statements Genetic risk ratings					

Why this indicator?

Invertebrates are critically important to the function of terrestrial ecosystems. For example, the loss of terrestrial invertebrate species could have significant consequences for the pollination of plants, the construction of good soil conditions and the food available to birds.

NB: This SoE 2023 indicator was 'B:06C Invertebrates' in the SoE 2018 Report.

Why this assessment in 2023?

There is limited information on threatened terrestrial invertebrate species in Victoria and this is reflected by the relatively small number on the FFG Threatened List compared to the number of listed vertebrate and vascular plant species. Seventy-five percent of listed terrestrial invertebrate species are either critically endangered or endangered. Forty percent have had their conservation status upgraded, while 30% have action statements, none of which were prepared in the past decade. Of the 16 assigned a genetic risk rating, all were rated high to very high. Along with ongoing threats, the 2019–20 bushfires placed further pressure on threatened terrestrial invertebrates in eastern and north-eastern Victoria.

Summary of State of the Environment 2018 Report assessment

- There is limited trend information on the number of threatened invertebrates.
- In 2018, 178 known species were considered threatened with 20 listed as critically endangered, 28 endangered and 79 vulnerable.

Critical data used for the 2023 assessment

- Updated FFG Threatened List

2023 assessment

There are 41 threatened terrestrial invertebrate species on Victoria's updated FFG Threatened List, including butterflies, moths, ants, land snails, beetles, one bee and an earthworm species. Of the 41 listed species, three extinct, nine are critically endangered, 22 endangered, six vulnerable, and one threatened.

A comparison of the conservation status on the 2009 advisory list and the 2022 FFG Threatened List reveals that 15 species have been upgraded, 10 downgraded, 16 have had no change and two were not on the 2009 advisory list. Action statements have been prepared for 11 of the 38 remaining species (one covers five species), however, none have been prepared in the past decade.

The Australia State of the Environment 2021 Report assessed the national status of native invertebrate species as poor. However, the trend was unclear and confidence in the assessment was considered very limited.[904] The Zoos Victoria Fighting Extinction program is using research and land management to promote the recovery of the golden rayed butterfly (unknown population size) and Keys matchstick grasshopper (not seen in Victoria for decades).[905]

904. Commonwealth of Australia 2021, 'Australian state of the environment', Canberra, Australian Capital Territory, https://soe.dcceew.gov.au/ Accessed 12 June 2023.
905. Zoos Victoria, 'Fighting extinction' https://www.zoo.org.au/fighting-extinction/ Accessed 20 February 2023.

The number of listed invertebrate species is far fewer than the number of listed vertebrate and plant species, even though there are more invertebrate species in Victoria. This has occurred because invertebrates:

- lack the charisma of many vertebrate and vascular plant species
- are poorly known and attract little research
- have rarely been described
- are difficult to find and monitor
- suffer from a lack of baseline data on their abundance and distribution.

Terrestrial invertebrates are critical to the survival of other species and the functioning of ecosystems. For example, the population of the bogong moth crashed from 4.4 billion in 2016 to being barely detectable in 2017 and 2018. This was attributed to low rainfall and drought conditions in their breeding grounds and, as these moths are a primary food source of the endangered mountain pygmy-possum, led to reduced litters.[906] Zoos Victoria launched 'Moth Tracker', a citizen science project aimed at monitoring the moth's migration, raise its profile in the community and encourage community support for actions such as habitat protection and improvement as well as reduced light pollution along the moth's 1,000-km migratory path from Queensland to Victoria.[907] The flooding rains of 2022 saw moth numbers increase, however, they still remain critically low.[908]

Geyle et al. (2021) reviewed the status and listing of 26 Australian butterfly taxa which are most at risk of extinction, four of which are in the top 12 for probability of extinction in Victoria — Mildura ogyris butterfly (endangered in Victoria), Banks' brown (not on Victorian list), western bright-eyed brown butterfly (critically endangered in Victoria) and golden-rayed blue butterfly (endangered in Victoria).[909] Another five species included in the review are on the Victorian Threatened List. Key threats identified included inappropriate fire regimes, drainage of wetlands, habitat clearance, invasive species such as rabbits, and increased temperatures and drought associated with climate change.

Bruce (2020) conducted a special needs elicitation for five threatened invertebrate species with the help of a number of experts.[910] The purpose of the analysis was to identify key threats and actions required to minimise the risk of population declines among invertebrate species as the result of future disturbances. For the giant Gippsland earthworm, the scientist recommended actions that included permanent protection, the prevention of soil cultivation, disturbance and compaction, the avoidance of pesticides, and the elimination of wastewater and stormwater. Permanent protection was also recommended for the Otway black snail, along with fire suppression.

906. Carruthers D, McLeod E, Costa K, Miller K, Parrott M 2020, 'Migrating moths and alpine possums: mobilising community across eastern Australia', *International Zoo Educators Association Journal*, 2020.
907. Ibid.
908. Walker A, Deacon B 2022, 'Drought decimated bogong moth numbers. Now flooding rains are bringing them back to the Australian Alps', ABC Goulburn Murray, 27 December 2022.
909. Geyle H, Braby M, Andren M, Beaver E, Bell P, Byrne C, Castles M, Douglas F, Glatz R, Haywood B, Hendry P, Kitching R, Lambkin T, Meyer C, Moore M, Moss J, Nally S, New T, Palmer C, Petrie E, Potter-Craven J, Richards K, Sanderson C, Stolarski A, Taylor G S, Williams M, Woinarski J, Garnett S 2021, 'Butterflies on the brink: Identifying the Australian butterflies (Lepidoptera) most at risk of extinction', Austral Entomology, 60, pp. 98– 110.
910. Bruce M 2020, 'Biodiversity bushfire response: taxon group specific needs – Terrestrial invertebrates', unpublished client report for the Department of Environment Land, Water and Planning (DELWP) Biodiversity Division, Arthur Rylah Institute (ARI) for Environmental Research, Heidelberg, Victoria.

Indicator B:22 Threatened terrestrial vascular plant species

B:22 Threatened terrestrial vascular plant species						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide						
Data source(s):	DELWP					
Measure(s):	Changes in conservation status Action statements					

Why this indicator?

The SoE 2018 Report noted an increasing trend in the number of endangered, vulnerable and rare vascular plants in Victoria.

NB: This SoE 2023 indicator was 'B:06A Vascular plants' in the SoE 2018 Report.

Why this assessment in 2023?

There are 1,527 vascular plant species on the FFG Threatened List, with more than 85% listed as either critically endangered or endangered. Only 10% of listed vascular plant species have action statements. The Australian Threatened Species Index indicates declining populations of vascular plants in Victoria. Along with ongoing threats, the 2019–20 bushfires placed further pressure on threatened vascular plant species in eastern and north-eastern Victoria.

Summary of State of the Environment 2018 Report assessment

- There had been an increasing trend of endangered, vulnerable and rare vascular plants in Victoria.
- Of the 3,330 known Victorian vascular plant species, 49 were extinct and 2,097 (63%) were on the Victorian threatened species advisory lists.

Critical data used for the 2023 assessment

- Updated FFG Threatened List

2023 assessment

There are 1,527 vascular plant species on Victoria's updated FFG Threatened List, including 30 that are extinct, 426 critically endangered, 885 endangered, 255 vulnerable and one threatened. Of the 1,497 species (excluding those extinct) listed, just 152, or 10%, of species have action statements.

There are some differences between the 2014 advisory list and 2022 FFG Threatened List in terms of categorisation and number of plants assessed. The number of endangered or vulnerable plants in 2014 numbered 882, whereas in 2022 the number was 1,100.

In addition, plants in the new critically endangered category numbered 426. Three factors are primarily responsible for the trend towards upgrading and include new evidence and perspectives such as the inferences about the likely future impacts of climate change, the application of the critically endangered category (not used previously for plants and fungi) which replaced the rare category, and the more rigorous Common Assessment Method.

In 2018, the Australian Threatened Species Index for Victoria was calculated using data on 22 plant taxa and revealed that 'on average the size of threatened plant populations in our dataset have decreased by 65% between 1995 and 2015.' [911] In 2022, the timeline for the index was extended to 2018. The trend from 1990 to 2018 for 24 terrestrial threatened plant species found in Victoria is reproduced in Figure B15 and shows that the decline in their abundance continued after 2016, although at a slower rate.[912]

911. Threatened Species Recovery Hub, 'Threatened plant index of Australia: 2020 results', https://www.nespthreatenedspecies.edu.au/news-and-media/media-releases/threatened-plant-index-of-australia-2020-results Accessed 10 May 2021.
912. Department of Climate Change, Energy, the Environment and Water (DCCEEW), 'The Australian threatened species index 2022', https://tsx.org.au/tsx2022/?ref=1990&index=Plants&state=VIC&status_auth=Max&status=NT_VU_EN_CR Accessed 23 January 2023.

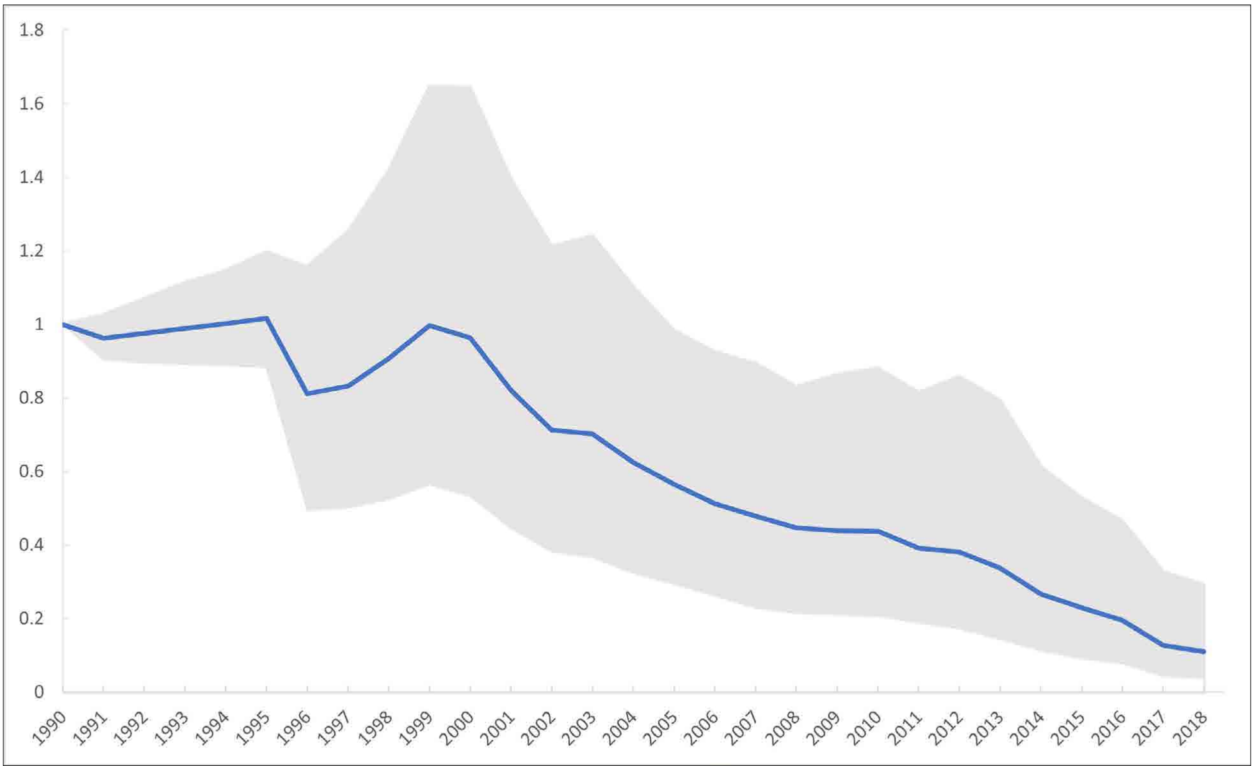


Figure B15: The Australian threatened species index for 24 threatened plant species in Victoria from 1990 to 2018.[913]

The Australia State of the Environment 2021 Report assessed the national status of native and threatened plants as poor and deteriorating. For plants in high-density human population areas, including urban and peri-urban areas, and in intensive agricultural areas, particularly in south-east and south-west Australia, the assessment was very poor and deteriorating.[914]

DELWP has estimated that there were more than 3,000 plant species located in the fire-impacted area of the 2019-20 bushfires. Of those, 688 were vascular plants and ferns identified as rare or threatened. Further analysis identified 489 of these species to have at least one known population in an area burnt at high severity.[915]

Subsequent on-ground surveys revealed that 'three-quarters of the threatened plant species searched for were found and were regenerating successfully post fire', and although 'immediate threats were generally minor, a 'long fire-free period is now required to allow many species to reach viable reproductive maturity.' [916] The surveys also found that 'vegetation structure was greatly affected by high fire severity at most sites'... and... 'tree canopy cover in severely burnt forests remained at only 5% to 10%, and shrub cover was largely absent'...and... the 'ground-layer vegetation generally showed strong recovery.' [917]

913. Department of Climate Change, Energy, the Environment and Water (DCCEEW), 'The Australian threatened species index 2022', https://tsx.org.au/tsx2022/ Accessed 23 January 2023.
914. Commonwealth of Australia 2021, 'Australian state of the environment', Canberra, Australian Capital Territory, https://soe.dcceew.gov.au/ Accessed 12 June 2023.
915. Department of Environment Land, Water and Planning (DELWP) 2022, 'Biodiversity bushfire response: supplementary report on bushfire impacts on species in Victoria', Melbourne, Victoria.
916. Department of Environment Land, Water and Planning (DELWP) 2022, 'Biodiversity bushfire response: supplementary report on bushfire impacts on species in Victoria', Melbourne, Victoria.
917. Ibid.

In burnt rainforests:

> 'The understorey composition is currently very different to that of unburnt rainforest, and is dominated by short-lived species that are substantially less common in unburnt rainforest. Recruitment of eucalypts into rainforest stands may lead to long-term changes in forest structure. Observed threats to rainforest condition included deer activity, alteration of the canopy due to invasion by eucalypt species, weeds, and gully erosion. However, the greatest long-term threat to the remaining stands of rainforest is climate change, which may act directly through reduced rainfall, or indirectly through increases in the frequency and intensity of fire.' [918]

Threatened plants with small ranges and low populations are susceptible to habitat loss caused by feral grazers, weeds, inappropriate fire regimes and climate change.[919] Before the 2019–20 bushfires, the population of Victoria's critically endangered and endemic Colquhoun grevillea was estimated to range from 1,000 to 1,600 plants. It is only found in nine locations across 11 km^2 in the Colquhoun State Forest in East Gippsland.[920] After the bushfires, DELWP estimated that 56% of the grevillea's distribution had been within the fire extent, of which 24% was classified as having experienced high-severity fire.[921] A majority, if not all, of its populations were impacted and its genetic risk was rated as very high.

Woowookarung Regional Park, 2016.
Credit: Peter Kervarec. © Parks Victoria.

918. Department of Environment Land, Water and Planning (DELWP) 2022, 'Biodiversity bushfire response: supplementary report on bushfire impacts on species in Victoria', Melbourne, Victoria.
919. Auld T 2020, 'Conservation of Australian plants', presentation to the 'Halting the decline: efforts to track and save Australia's threatened plants' webinar by the National Environmental Science Program, 8 December 2020.
920. Department of Sustainability and Environment (DSE) 2009, 'Action statement no 211: Colquhoun grevillia Grevillea celata', Melbourne, Victoria.
921. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Victoria's bushfire emergency: biodiversity response and recovery Version 2', Melbourne, Victoria.

Indicator B:23 Threatened terrestrial fungi, lichen, moss and liverwort species

B:23 Threatened terrestrial fungi, lichen, moss and liverwort species						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	● (red)	?	● (red)	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator
Data source(s):	DELWP					
Measure(s):	Changes in conservation status Action statements					

Why this indicator?

Fungi, lichen, moss and liverwort species are a critical component of ecosystems, decomposing organic matter, providing food and shelter for various species, and conserving soil. They also act as pioneer plants that make areas more suitable for other organisms. They were not represented by an indicator in previous state of the environment reports.

Why this assessment in 2023?

There is limited research of fungi, lichen, moss and liverwort species, and only 68 species are included on the FFG Act Threatened List. Ninety-four percent of species are either critically endangered or endangered and one is extinct. Of the 67 remaining in the wild, 60 have had their conservation status upgraded, and none have had an action statement prepared. Along with ongoing threats, the 2019–20 bushfires placed further pressure on the species in eastern and north-eastern Victoria.

Summary of State of the Environment 2018 Report assessment

- New SoE 2023 indicator

Critical data used for the 2023 assessment

- Updated FFG Threatened List

2023 assessment

There are 68 threatened terrestrial fungi, lichen, moss and liverwort species on Victoria's updated FFG Threatened List which includes eight fungi and lichen species and 60 moss and liverwort species. Of the 68 listed species, 29 are critically endangered, 35 endangered, three vulnerable and one extinct. The conservation status of 60 has been upgraded, two have been downgraded and six have had no change. None of the threatened non-vascular plants have had action statements prepared or genetic risk ratings assigned.

The Australia State of the Environment 2021 Report assessed the national status of fungi and other microorganisms as poor and with an unclear trend. This was also the report's assessment of fungi and other microorganisms in highly modified and largely unmodified ecosystems.[922]

The black-beard lichen was last recorded near Falls Creek in 1977 and the foliose lichen was last recorded in 1988. The clasping hypocreopsis has likely disappeared from two of its three known locations on the Mornington Peninsula and coastal Gippsland. However, threatened fungi, lichen, moss and liverwort species have not garnered the same level of interest for research as other threatened species considered in this sub-theme. This illustrates the lop-sided nature of the updated FFG Threatened List, which also has limited coverage of invertebrate species. It was not until 2016 that fungi were included in the definition of biodiversity in Commonwealth and state government SoE reports.[923]

922. Commonwealth of Australia 2021, 'Australian state of the environment', Canberra, Australian Capital Territory, https://soe.dcceew.gov.au/ Accessed 12 June 2023.
923. Fungimap, 'How well are they conserved?' https://fungimap.org.au/about-fungi/how-well-are-they-conserved/ Accessed 30 January 2023.

Fungimap is a not-for-profit citizen science project that aims to increase community awareness, scientific research and conservation of Australia's fungi, noting that few species are yet to even be described. The Fungimap website lists the reasons for the lack of protection for fungi which include:

- lack of community awareness of the importance of fungi
- absence of undergraduate courses focussed on mycology
- recent research focus on this group as agricultural pests
- their inclusion as plants in state conservation listings (the FFG Threatened List has them as non-vascular plants)
- lack of visibility for large parts of the year
- small number of mycologists in Australia
- difficulty in defining biological characteristics such as population size that are needed for their inclusion on threatened species lists.

Expert elicitation was used to identify priority medium-term actions to support the conservation of the tea-tree fingers, a fungus found primarily in three locations — Launching Place (Trust for Nature property), Western Port Woodlands (three of four sites in nature conservation reserves), and French Island National Park. Fencing to exclude disturbance from trail bikes, horse riding and bushwalking along with fire prevention and permanent protection were favoured actions. Although most of the known sites are in conservation reserves, the Adams Creek Nature Conservation Reserve is surrounded by land earmarked for sand mining.[924]

There are approximately 2,000 moss, liverwort and hornwort species, which are collectively known as bryophytes.[925] Like fungi and lichens, they are poorly represented on threatened species lists for reasons similar to the above.

Bartramia subsymmetrica is a moss species found in scattered pools and boggy sites in the Bogong High Plains (and Kosciuszko National Park in NSW). Its main threats are trampling by feral deer and horses and changing hydrology due to the drying effect of climate change.[926] Expert elicitation coordinated by DELWP after the 2019-20 bushfires identified pest animal control, exclosure fencing, and weed control as key actions to support the recovery of these species.[927]

Threats and responses

Kearney et al. (2019) reviewed the threats facing Australia's 1,533 native species listed under the EPBC Act using the IUCN threat classification scheme.[928] The results are summarised in Figure B16, which shows that the major threats are invasive species (82% of total listed species), ecosystem modification (74%) and agricultural activity (57%), although there are variations in these numbers between taxon groups.

924. Fungimap, 'How well are they conserved?' https://fungimap.org.au/about-fungi/how-well-are-they-conserved/ Accessed 30 January 2023.
925. Australian National Herbarium, 'What is a bryophyte?' https://www.anbg.gov.au/bryophyte/what-is-bryophyte.html Accessed 30 January 2023.
926. Australian Bryological Network, 'Bryophyte of the month' https://australian-bryological-network.github.io/bryophyte-of-the-month/2018/02/17/bartramia-subsymmetrica Accessed 30 January 2023.
927. Department of Environment Land, Water and Planning (DELWP) 2021, 'Biodiversity response and recovery supplementary report: an assessment to prioritise medium term conservation actions and identify knowledge gaps', Melbourne, Victoria.

	Total (1533)	Invertebrates (48)	Plants (1212)	Vertebrates (272)	Amphibians (29)	Birds (84)	Fish (34)	Mammals (74)	Reptiles (51)	Critically Endangered (178)	Endangered (646)	Vulnerable (709)
Invasive species	82%	79.2%	79.5%	94.1%	100%	95.2%	97.1%	97.3%	82.4%	80.9%	86.5%	78.1%
Ecosystem modifications	74.1%	79.2%	75.7%	66.5%	65.5%	72.6%	79.4%	62.2%	54.9%	64.6%	79.1%	71.9%
Agricultural activity	56.9%	72.9%	53.5%	69.9%	69%	82.1%	47.1%	73%	60.8%	51.1%	60.2%	55.4%
Human disturbance	38.4%	20.8%	40.3%	33.1%	51.7%	35.7%	38.2%	27%	23.5%	34.8%	43%	35%
Climate change	34.8%	45.8%	32.1%	44.9%	44.8%	56%	55.9%	37.8%	29.4%	43.3%	36.2%	31.3%
Transportation	30.3%	14.6%	34%	16.9%	41.4%	16.7%	2.9%	17.6%	11.8%	27.5%	34.4%	27.4%
Overexploitation	27.4%	50%	24.6%	36%	48.3%	40.5%	52.9%	28.4%	21.6%	25.8%	26.3%	28.8%
Urban development	22.2%	31.2%	21.4%	24.6%	24.1%	26.2%	29.4%	14.9%	33.3%	23.6%	22.6%	21.6%
Energy production	18.9%	10.4%	18.2%	23.5%	10.3%	20.2%	47.1%	16.2%	31.4%	19.7%	20.4%	17.2%
Pollution	17.8%	25%	16.2%	23.9%	44.8%	19%	61.8%	6.8%	19.6%	15.7%	21.8%	14.7%
Geological Events	1%		1.3%							0.6%	0.6%	1.6%

Figure B16: The prevalence of threats to Australian threatened taxa across broad taxonomic groups and extinction risk categories in 2019.[929] Red cells represent species groups for which 100% are affected by a particular threat category. Blue cells represent groups of which only a small percentage of species are threatened. Blank cells represent groups of species in which none are affected by a particular threat.

It is estimated that, each year, 20 new environmental weed species are growing in Australia, while invasive animals, such as deer, are increasing in number and range.[930] There are 1,810 species on the 2022 Victorian Advisory List of Environmental Weeds, which is three times the number recognised in 1993.[931]

On their own, invasive species pose a significant risk to ecosystem health and many native species — threatening up to 80% with extinction in Australia.[932] However, their impacts are exacerbated when combined with other threats, including climate change, habitat disturbance and fragmentation. The main drivers of habitat loss and fragmentation are industrial, urban and peri-urban development, timber harvesting, invasive species, bushfires, climate change and agriculture. The results can include reduced ecosystem resilience, small populations of species that become more isolated and more vulnerable to other threats, increased soil erosion and acidification, and reduced water quality.

The 12 indicators in this sub-theme include the threats from invasive freshwater plants and animal species and invasive terrestrial herbivores and predators, along with the government and community responses of priority weed, herbivore and predator control. Two further indicators cover efforts to expand suitable habitat for threatened species and to achieve a net gain in the extent of native vegetation.

The weed, herbivore and predator control indicators are also Biodiversity 2037 indicators (as are two in the next sub-theme) and their assessment is part of this chapter's review of the plan's implementation. One such review has been completed by VAGO where an independent assurance report was released in October 2021, 'Protecting Victoria's Biodiversity'.[933] The report was an assessment of 'how well DELWP is acquitting its responsibilities under the FFG Act and in Protecting Victoria's environment – Biodiversity 2037 to better protect threatened species.'[934]

928. Kearney S, Carwardine J, Reside A, Fisher D, Maron M, Doherty T, Legge S, Silcock J, Woinarski J, Garnett S, Wintle B and Watson J 2019, 'The threats to Australia's imperilled species and implications for a national conservation response', *Pacific Conservation Biology*, 2019, 25, pp. 328.
929. Ibid.
930. Dodd A, Burgman M, McCarthy M, Ainsworth N 2015, 'The changing patterns of plant naturalization in Australia', Diversity and Distributions, 2015 21, pp. 1038–1050.
931. White M, Cheal D, Carr G, Adair R, Blood K, Meagher D 2022, 'Advisory list of environmental weeds in Victoria 2022', Arthur Rylah Institute (ARI) for Environmental Research, Heidelberg, Victoria.
932. Department of Environment Land, Water and Planning (DELWP) 2019, 'Weeds and pests on public land: Program activities and achievements 2018–19', Melbourne, Victoria.
933. Victorian Auditor-General's Office (VAGO) 2021, 'Protecting Victoria's biodiversity', Melbourne, Victoria.
934. Ibid.

VAGO found that:

> 'DELWP cannot demonstrate if, or how well, it is halting further decline in Victoria's threatened species populations. DELWP aims to choose cost-effective protection actions that benefit the greatest number of threatened species. To this end, it uses modelling tools to support its decisions. These tools are better practice by design. However, much of the data used in the models is old and likely outdated, and has some critical gaps. This raises questions about the reliability of the modelled outputs and the decisions they support. DELWP's cost-benefit approach can also miss endangered threatened species at extreme risk of extinction. DELWP has no transparent, risk-based process to prioritise these species for management. Further, DELWP continues to make limited use of available legislative tools to protect threatened species. Funding available to DELWP to protect species falls significantly short of what it predicts is needed. However, DELWP has not provided detailed, evidence-based advice to the government about the cost and benefits of protecting and monitoring threatened species to support further investment. It also lacks performance indicators and reporting to demonstrate the impact of its management interventions on halting the decline of threatened species.' [935]

In considering the statutory role of the Commissioner for Environmental Sustainability in assessing DELWP's progress in the implementation of Biodiversity 2037, VAGO found that:

> 'Under the FFG Act, the Commissioner is responsible for reporting progress against Biodiversity 2037 every five years. This includes reporting threatened species' trends and statuses. The first report is due in 2023. The Commissioner relies on DELWP's data and analysis and therefore may not be able to report on the progress of Biodiversity 2037.' [936]

VAGO's October 2021 report observed a disjunct between the objectives of the FFG Act and Biodiversity 2037. The FFG Act has six objectives, which includes:

> 'to guarantee that all of Victoria's flora and fauna' 'can persist and improve in the wild', and 'prevent' 'flora and fauna from becoming threatened and to recover threatened' species so that 'their conservation status improves'.[937]

The FFG Act also expects there to be no increase in the number of threatened species. However, the objectives of Biodiversity 2037 are to ensure the greatest number of species and communities do not become endangered, halt the overall decline of threatened species and secure the greatest possible numbers in the wild.[938]

In response to the VAGO assurance report, DELWP reported that its on-ground programs deliver benefits for at least 80% of Victoria's threatened species that includes vulnerable, endangered and critically endangered species.

Biodiversity 2037 is not Victoria's first biodiversity plan. Victoria's Biodiversity: Our Living Wealth was released in 1997 and had in its opening pages a section entitled 'Victorian Biodiversity in the year 2020: A history of the future'.[939] This section contained forecasts such as 'the historical loss of native vegetation was reversed by the turn of the millennium and Victoria has for 20 years been in a situation of net gain.' [940] That elusive future is now the target of Biodiversity 2037.

935. Victorian Auditor-General's Office (VAGO) 2021, 'Protecting Victoria's biodiversity', Melbourne, Victoria.
936. Ibid.
937. Department of Energy, Environment and Climate Action, 'Victoria's Framework for Conserving Threatened Species' https://www.environment.vic.gov.au/conserving-threatened-species/victorias-framework-for-conserving-threatened-species Accessed 19 June 2023.
938. bid.
939. Department of Natural Resources and Environment (DNRE) 1997, 'Victoria's biodiversity: Our living wealth', Melbourne Victoria.
940. Ibid.

Indicator B:24 Invasive freshwater plant species

B:24 Invasive freshwater plant species						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?			?	
Data source(s):	DELWP					
Measure(s):	Number, abundance and distribution of freshwater invasive plant species					

Why this indicator?

Invasive freshwater plants can alter freshwater habitats, threaten their long-term function and undermine the outcomes of previous investment in waterway management.

NB: This is a modified SoE 2023 indicator that allows greater focus on invasive freshwater plant species and was formed by disaggregating the measures of the SoE 2018 indicator 'B:01 Invasive freshwater plants and animals' into two separate modified indicators in this report.

Why this assessment in 2023?

There is a lack of comprehensive and accurate statewide data on population numbers and trends of invasive freshwater plants and their threatening processes, especially their impacts on native aquatic flora and fauna. Most data are from standing water bodies, irrigation channels and the Murray–Darling Basin. It is likely that the status is poor. Although there are insufficient data to determine trends, there are significant localised programs to remove willows and other aquatic weeds.

Summary of State of the Environment 2018 Report assessment

- Recent investments in the control of invasive freshwater species had focused on arrowhead (an aquatic weed) and willows.
- There was a lack of comprehensive and accurate statewide data on population numbers and trends of invasive freshwater pest plants and their threatening processes.

Critical data used for the 2023 assessment

- Knowledge Document of the Impact of Priority Wetland Weeds: Part 1 – Selection of the Priority Wetland Weeds
- Knowledge Document of the Impact of Priority Wetland Weeds: Part 2 – Impacts of Priority Wetland Weeds

2023 assessment

Weis, Dugdale and Frood (2017a and 2017b) presented the results of a survey of land managers involved in weed management that identified 41 priority invasive wetland species.[941, 942] The focus was on those weeds under active management and excluded state prohibited weeds, species that are primarily terrestrial, and native species in engineered waterways.[943] Knowledge gaps identified by the research were the impacts of the invasive species on wetland ecological values and native fauna as well as potential control measures. Most of the available information was related to their socio-economic impacts, such as on recreation, navigation, and the blockage of drains and irrigation channels.

941. Weiss J, Dugdale T, Frood D 2017a, 'Knowledge document of the impact of priority wetland weeds: Part 1 – Selection of the priority wetland weeds', report prepared for the Department of Environment, Land, Water and Planning (DELWP) Water and Catchments Group by Agriculture Victoria, Melbourne, Victoria.
942. Weiss J, Dugdale T, Frood D 2017b, 'Knowledge document of the impact of priority wetland weeds: Part 2 – Impacts of priority wetland weeds', Report prepared for the Department of Environment, Land, Water and Planning (DELWP) Water and Catchments Group by Agriculture Victoria, Melbourne, Victoria.
943. State prohibited weeds are the highest category of declared noxious weeds in Victoria. They are: alligator weed; branched broomrape; camel thorn; hawkweed; horsetails; karoo and giraffe thorn; knotweed; lagarosiphon; mesquite; Mexican feather grass; parthenium weed; perennial ragweed; poverty weed; salvinia; tangled hypericum; water hyacinth. It is an offence to buy, sell, display or transport these weeds within Victoria.
944. Department of Environment Land, Water and Planning (DELWP) 2016, 'Managing willows in Victoria', Melbourne, Victoria.

Willow trees were introduced to south-eastern Australia to control riverbank erosion and enhance rural scenery. Since then, they have invaded thousands of kilometres of rivers and become the target of control programs in the past 20 years.[944] Willows outcompete native plants, reduce available habitat for native birds, mammals and fish, can lead to bank erosion, change river flows, and use water required by aquatic habitats and species.

Protection of the spotted tree frog after the 2019–20 bushfires was the major aim of a willow control project conducted in the Wongungarra River near Dargo. Although remote and largely inaccessible, the area had been colonised by willows that were impacting the frog's habitat. Six months after the fires, highly skilled contractors removed the juvenile willows and seedlings while walking along the river for 5 to 10 days, travelling up to 15 km per day, carrying their food and chemical rations and camping on the riverbanks.[945]

Hauser et al. (2021) considered that 'broad-scale surveillance tools, population modelling and prioritisation are needed to help narrow down where on-ground visitation will be most effective for identifying previously-unknown incursions.'[946] Their focus was on current willow threats to conservation values and future dispersal as part of analysis to prioritise willow management actions in the Goulburn Broken, East Gippsland, North East and West Gippsland CMAs. The scientists identified 27 species of flora and fauna and the community of alpine bogs and associated fens as conservation values that could be impacted by willow infestations. The likely affected species included three skinks, five frogs, three mammals, seven crayfish, five galaxiids and four plants.

To address current willow threats to conservation values, Hauser et al. (2021) found the most cost-effective action was to target the Bogong High Plains, Dargo High Plains, Baw Baw Plateau, Wonnangatta-Moroka, and East Gippsland waterways that provide habitat for threatened crayfish and galaxiids. To address future dispersal threats, the approach deemed most cost-effective was to target river valleys of the North East CMA, the Bogong High Plains, Dargo High Plains and the valleys of the Tambo and Buchan rivers in East Gippsland.

There are also statewide programs to eradicate certain high-threat aquatic weeds from Victoria. These programs have prevented the further spread or local elimination of alligator weed and removed all known infestations of salvinia and water hyacinth. Early detection and removal of high-threat species that have not yet established in Victoria can contribute to the prevention of further deterioration. A program that aims to reduce the abundance and impacts of a major established aquatic weed is the development and release of biological control agents for *Sagittaria*.[947]

945. Birleson M 2020, 'Weed management in a remote catchment: Protecting the critically endangered spotted tree frog', presentation at a 'Weed management after fire: supporting native species recovery' webinar, 9 December 2020, Weeds at the Early Stage of Invasion (WESI) Project, Department of Environment Land, Water and Planning (DELWP), Melbourne, Victoria.
946. Hauser C, White M, Carter S, Moore J 2021, 'Targeting surveillance for willow management', unpublished client report for Waterways and Catchments Group, Arthur Rylah Institute (ARI) for Environmental Research, Heidelberg, Victoria.
947. Agriculture Victoria (AgVic), 'Unpublished data', Melbourne, Victoria, Accessed 2022.

Indicator B:25 Invasive freshwater animal species

B:25 Invasive freshwater animal species						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	🔴	↙	🟡	⚪	?	🔴

Data source(s):	AgVic, DELWP
Measure(s):	Number, abundance and distribution of freshwater invasive animal species

Why this indicator?

Invasive freshwater animal species prey on threatened small-bodied fish and frog species, and outcompete native large-bodied fish.

NB: This is a modified SoE 2023 indicator that allows greater focus on invasive freshwater animal species and was formed by disaggregating the measures of the SoE 2018 indicator ‘B:01 Invasive freshwater plants and animals’ into two separate modified indicators in this report.

Why this assessment in 2023?

Brown and rainbow trout, redfin perch and other invasive freshwater animal species impact threatened frogs and small-bodied fish. Invasive trout have established self-sustaining populations in many waterways and have been identified as the main threat to galaxiids and other threatened freshwater fish species at high risk of extinction.

Summary of State of the Environment 2018 Report assessment

- There is no comparable information within the SoE 2018 assessment for this modified 2023 indicator.

Critical data used for the 2023 assessment

- Fifteen from One: A Revision of the Galaxias olidus Günther, 1866 Complex (Teleostei, Galaxiidae) in South-eastern Australia Recognises Three Previously Described Taxa and Describes 12 New Species
- Big Trouble for Little Fish: Identifying Australian Freshwater Fishes in Imminent Risk of Extinction

2023 assessment

The Victorian Fisheries Authority lists 179 noxious aquatic species such as the European carp, marron, mosquito fish and weather loach, however, the list does not include the brown or rainbow trout.[948] The IUCN lists rainbow and brown trout in the world’s top 100 worst invasive alien species.[949]

The main invasive fish species in Victorian waterways were introduced for aquaculture (carp 1850-80), acclimatisation projects — roach (1860-80), redfin perch (1862), brown trout (1864), tench (1876), goldfish (1876) and rainbow trout (1894) — and for biocontrol (eastern gambusia in 1925).[950]

In a comprehensive analysis of survey data, Lieschke et al. (2013) analysed data on native and alien fish species captured in surveys across Victoria’s 29 river basins from 2004 to 2011.[951] The 10 alien species captured (number of basins where they occurred in brackets) were as follows: brown trout (26), eastern gambusia (25), European carp (23), goldfish (22), redfin (21), rainbow trout (13), tench (12), roach (6), oriental weatherloach (2) and crucian carp (1).[952]

948. Victorian Fisheries Authority (VFA), ‘List of noxious aquatic species in Victoria’, https://vfa.vic.gov.au/operational-policy/pests-and-diseases/noxious-aquatic-species-in-victoria/noxious-aquatic-species-in-victoria Accessed 9 May 2021.
949. Lowe S, Browne M, Boudjelas S, De Poorter M 2000, ‘100 of the world’s worst invasive alien species: a selection from the Global Invasive Species Database’, The Invasive Species Specialist Group of the Species Survival Commission of the World Conservation Union (IUCN), updated and reprinted version: November 2004.
950. Lintermans M 2004, ‘Human-assisted dispersal of alien freshwater fish species in Australia’, *New Zealand Journal of Marine and Freshwater Research*, 38: 481–501.
951. Lieschke J, Dodd L, Stoessel D, Raadik T, Steelcable A, Kitchingman A, Ramsey D 2013, ‘The status of fish populations in Victorian rivers 2004–2011 – Part A’, Arthur Rylah Institute for Environmental Research Technical Report Series No. 246, Heidelberg, Victoria.
952. Ibid.

Although alien fish species were found across the state, they made up a higher proportion of the fish fauna in the northern river basins.[953] The percentage abundance of native species outweighed alien abundance in all but three basins and the alien biomass exceeded the biomass of native species in 20 of the 29 basins. In seven of the basins, alien biomass ranged from 93% to 96% of total fish biomass, while in five basins it ranged from 83% to 87%.[954]

In a major review of Australia's threatened freshwater fish by Lintermans et al. (2020), 22 species were identified as having a high risk of extinction, with nine only occurring in eastern Victoria and one in south-west Victoria. The review found that invasive trout and gambusia posed the greatest threat.[955]

Introduced into Australian aquatic environments in 1864, trout have established self-sustaining populations, spread widely and become popular targets of recreational fishers whose pastime is partially supported by the stocking of hatchery-bred trout.[956] Figure B17 maps the distribution of brown trout throughout Victoria's rivers. In 2015, the Victorian wild trout fishery was estimated to be worth $750 million and contributed towards supporting up to 11,600 jobs in the state.[957]

More than 5 million salmonids were released into Victoria's lakes and pondages, water storages and waterways from 2018 to 2022.[958] Although most stocking of brown trout (and other salmonids) occurs in lakes and pondages, between 2018 and 2022 they were released into 12 rivers and creeks that included 110,000 in the Macalister River, 100,000 in each of the Jamieson and King rivers, 79,000 in the Merri River, 59,000 in Mt Emu Creek, 50,367 in the Goulburn River, 50,000 in the Dargo River, 33,000 in the Moyne River, 30,000 in the Hopkins River and 18,500 in Corryong Creek. In previous years, the fish have also been released into the Acheron, Jamieson, Tarwin, Barwon, Lang Lang and Yarra rivers, and Cudgewa, Jackson and Rainbow and Ryans creeks.

Raadik (2014) identified 15 separate species in the *Galaxias olidus* complex and concluded that introduced 'trout are implicated in the decline and/or fragmentation in range of 10 of the 15 species within the complex.'[959] Five years after Raadik's study, DELWP reported that the main threat to galaxiids was trout and stated that 'Preventing trout from moving upstream over the barriers protecting the galaxiids, or removing them immediately if they have done so, is critical to galaxiid survival.' [960]

Under the FFG Act, the 'Introduction of live fish into waters outside their natural range within a Victorian river catchment after 1770' is a potentially threatening process. The establishment of self-sustaining populations in many rivers means that not all recreational angling depends on the release of hatchery trout. In those rivers, the cessation of stocking (where it still occurs) would not actually reduce trout numbers — active control measures would be needed. DEECA is funding aquatic predator control and translocation projects and leading a feasibility assessment for trout control and a pilot trout control program (including barriers, trout removal, genetic analysis and fish conservation) for management in priority locations.[961] Trout anglers are working alongside DEECA and university researchers on a number of projects to better understand the impacts of trout on native fish and frog populations.

953. Lieschke J, Dodd L, Stoessel D, Raadik T, Steelcable A, Kitchingman A, Ramsey D 2013, 'The status of fish populations in Victorian rivers 2004–2011 – Part A', Arthur Rylah Institute for Environmental Research Technical Report Series No. 246, Heidelberg, Victoria.
954. Ibid.
955. Lintermans M, Geyle H, Beatty S, Brown C, Ebner B, Freeman R, Hammer M, Humphreys W, Kennard M, Kern P, Martin K, Morgan D, Raadik T, Unmack P, Wager R, Woinarski J and Garnett S 2020, 'Big trouble for little fish: identifying Australian freshwater fishes in imminent risk of extinction', Pacific Conservation Biology, 26(4), pp. 365–377.
956. Nicoletti J 2017, 'On this day: Trout arrive in Australia', Australian Geographic, 3 May 2017.
957. Ernst and Young 2015, 'Economic study of recreational fishing in Victoria', Melbourne, Victoria.
958. Victorian Fisheries Authority (VFA), 'Salmonid releases', https://vfa.vic.gov.au/db/annual-salmonid-release-summary Accessed 7 August 2022.
959. Raadik T 2014, 'Fifteen from one: a revision of the Galaxias olidus Günther, 1866 complex (*Teleostei, Galaxiidae*) in south-eastern Australia recognises three previously described taxa and describes 12 new species', Zootaxa, 3898 (1), pp. 1–198.
960. Department of Environment Land, Water and Planning (DELWP) 2019, 'Conservation of endemic and threatened Victorian galaxiid species', Melbourne, Victoria.
961. Department of Environment, Land, Water and Planning (DELWP), 'Unpublished data', Melbourne, Victoria, Accessed 2022.

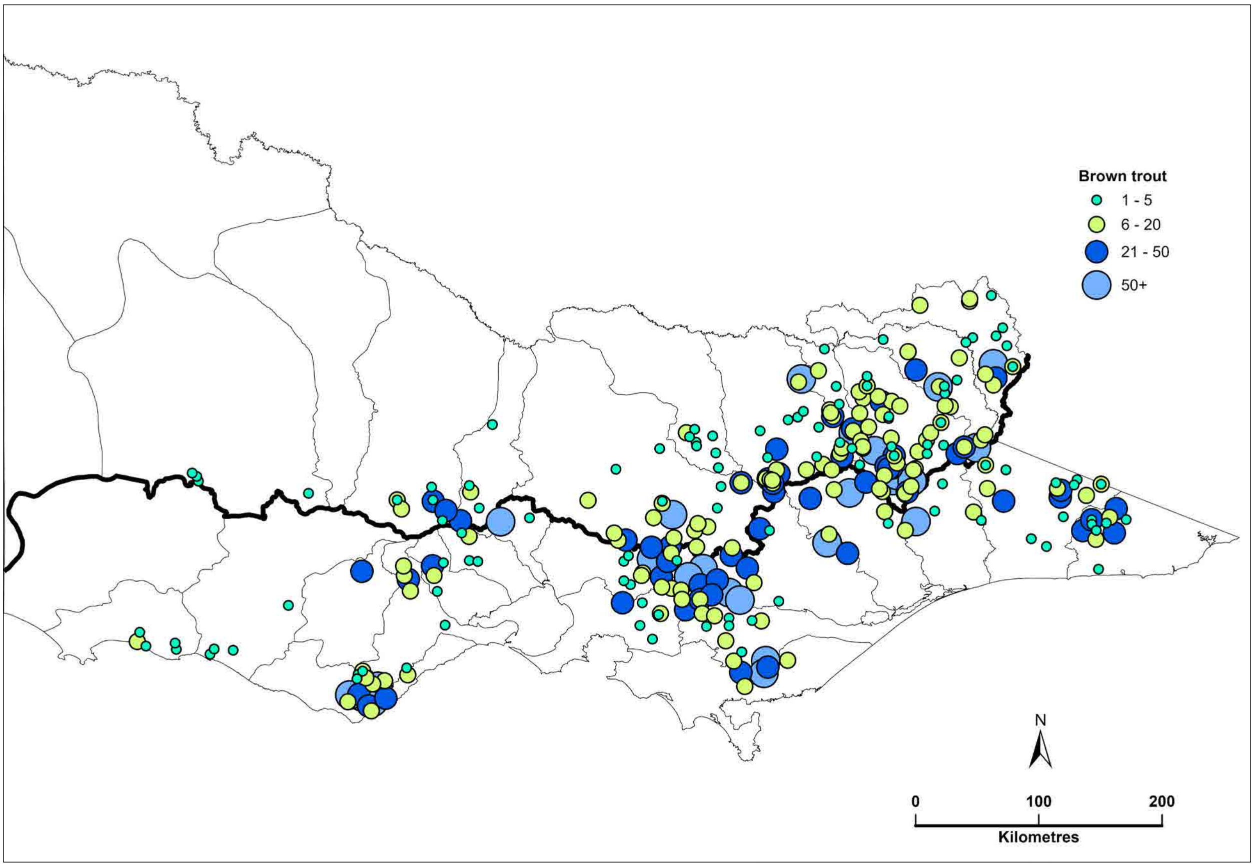


Figure B17: Distribution of brown trout in Victoria between 2004 and 2011.[962]

Barengi Gadjin/Wimmera River from Ackle Bend Campground, Little Desert National Park.
Credit: Nick Esser. © Parks Victoria.

962. Lieschke J, Dodd L, Stoessel D, Raadik T, Steelcable A, Kitchingman A, Ramsey D 2013, 'The status of fish populations in Victorian rivers 2004–2011 – Part A', Arthur Rylah Institute (ARI) for Environmental Research Technical Report Series No. 246, Heidelberg, Victoria.

Indicator B:26 Trend in carp

B:26 Trend in carp						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide		↙			↙	
Data source(s):	DELWP					
Measure(s):	Abundance and distribution of carp					

Why this indicator?

Carp is considered a pest species because it dominates aquatic environments to the detriment of native fish species and freshwater ecosystems.

NB: This indicator was 'B:01A Trend in carp (*Cyprinus carpio*) distribution' in the SoE 2018 Report.

Why this assessment in 2023?

The European carp is a highly successful and invasive fish species that has increased in abundance and range and remains a major threat to native aquatic species. It can represent up to 90% of fish biomass in some rivers. The National Carp Control Plan has focused on research into the effectiveness and impacts of the potential release of a carp virus. A decision on the release is yet to be made.

Summary of State of the Environment 2018 Report assessment

- European carp are prolific in waterways across south-eastern Australia and impact native fish and aquatic habitats.
- In 2016, the Commonwealth Government initiated the National Carp Control Plan to estimate carp numbers and inform decisions on the release of a carp biocontrol agent, cyprinid herpesvirus 3, and the subsequent carp clean-up.

Critical data used for the 2023 assessment

- Research initiated by the National Carp Plan

2023 assessment

European carp were introduced into Australia in the nineteenth century. However, they were not widespread until major floods in the Murray-Darling Basin during the 1970s. They now constitute up to 90% of fish biomass at some sites and continue to expand their range, tripling in number between 2004 and 2014.[963, 964, 965] Their impacts include:

- uprooting and eating aquatic plants, which increases turbidity and reduces light in the water column
- increasing nutrients by excretion, which can lead to phytoplankton growth (algal blooms)
- preying on zooplankton and benthic invertebrates, native fish, their eggs and larvae, and frog eggs and tadpoles (e.g. spotted tree frog)
- competing for space and food e.g. with waterbirds who feed on plants and invertebrates.

Figure B18 maps the distribution of carp in Victoria based on data from 2004 to 2011. Of the seven inland Ramsar sites considered in Indicator 'B:03 Health and status of Victorian inland Ramsar wetlands', four have high carp biomass.

963. Stuart I, Fanson B, Lyon J, Stocks J, Brooks S, Norris A, Thwaites L, Beitzel M, Hutchison M, Ye Q, Koehn J, Bennett A 2019, 'A national estimate of carp biomass for Australia', unpublished client report by Arthur Rylah Institute (ARI) for Environmental Research, Heidelberg, Victoria.
964. Department of Environment Land, Water and Planning (DELWP) 2021, 'Impacts of carp in wetlands', Melbourne, Victoria.
965. Fisheries Research and Development Corporation (FRDC), 'National carp control plan', https://carp.gov.au Accessed 8 May 2021.

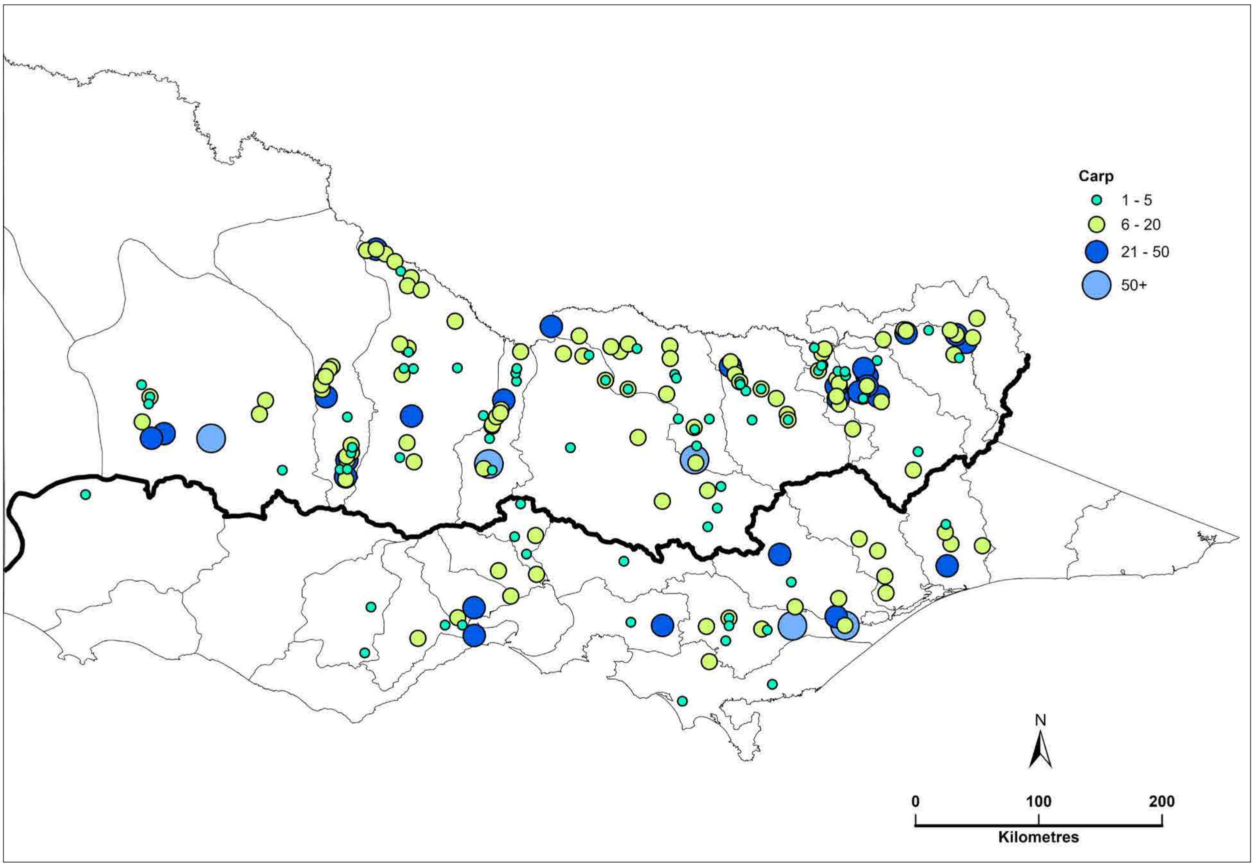


Figure B18: Distribution of carp in Victoria between 2004 and 2011.[966]

In 2016, the Australian Government initiated the National Carp Control Plan to support research into potential control actions, with the focus on the feasibility of releasing a carp herpes virus. In conducting research for the plan, Stuart et al. (2021) estimated that carp occupied an area of 17,264 km^2 of aquatic habitat and were found in 33 of Australia's 191 major river drainages.[967] The density threshold for ecological impacts of 80 kg/ha to 100 kg/ha was exceeded in 54% of wetland area, 70% of stream area for all rivers, and 97% of stream area in large lowland rivers. The total biomass for south-eastern Australia was estimated at 205,774 tonnes in a dry scenario, while in a wet scenario, the estimate was 368,357 tonnes. The highest carp densities in Victoria were along the Murray River, in the east of the state (although carp are absent east of the Snowy River), and in some rivers of south-western Victoria.

Nichols et al. (2019) surveyed and held workshops with experts to determine expectations on the likely outcomes of various carp control scenarios.[968] For the 'do-nothing scenario', the experts expected the environment to continue its decline. They also believed that, to achieve an outcome of at least 30% to 70% environmental improvement, greater than 70% reduction in carp numbers would be required. Any sustained ecological recovery would also require the mitigation of other ecological stressors.

Boutier et al. (2019) argue that the risks from the release of the herpes virus, including the potential infection of other native fish species, are too high.[969]

966. Lieschke J, Dodd L, Stoessel D, Raadik T, Steelcable A, Kitchingman A, Ramsey D 2013, 'The status of fish populations in Victorian rivers 2004–2011 – Part A', Arthur Rylah Institute (ARI) for Environmental Research Technical Report Series No. 246, Heidelberg, Victoria.

967. Stuart I, Fanson B, Lyon J, Stocks J, Brooks S, Norris A, Thwaites L, Beitzel M, Hutchison M, Ye Q, Koehn J, Bennett A 2021, 'Continental threat: How many common carp (*Cyprinus carpio*) are there in Australia?', Biological Conservation, 254, pp. 108942.

968. Nichols S, Gawne B, Richards R, Lintermans M, Thompson R 2019, 'NCCP: The likely medium- to long-term ecological outcomes of major carp population reductions, final report', FRDC Project No 2017-104, Fisheries Research and Development Corporation (FRDC), Canberra, Australian Capital Territory.

969. Boutier M, Donohoe O, Kopf R, Humphries P, Becker J, Marshall J, Vanderplasschen A 2019, 'Biocontrol of carp: the Australian plan does not stand up to a rational analysis of safety and efficacy', *Frontiers in Microbiology,* 10(882).

Biodiversity

Ecological risk assessments conducted as part of the research for the National Carp Control Plan identified the impacts that the death and decay of large numbers of carp could cause any of the following:

- reduced levels of dissolved oxygen and water quality
- increased risk of algal blooms
- proliferation of disease-causing bacteria harmful to humans and other animals
- loss of a food source for native species including fish and waterbirds
- a switch by carp predators to native species
- increased numbers of other introduced fish such as goldfish, redfin and mosquito fish
- botulism outbreaks affecting native fauna
- reduced water quality in ephemeral and dryland river systems
- impact on Victorian Ramsar wetlands with high carp biomass (Barmah Forest, Gunbower Forest, Hattah-Kulkyne Lakes and Kerang Lakes).[970]

The rapid removal of carp carcasses could minimise these risks, along with carefully timed water releases. However, carp removal could be difficult in isolated and sparsely populated areas, especially where waterways become disconnected in dry periods.

After six years, the National Carp Control Plan was finally released in November 2022. The plan will now inform the decision making by the Australian and state governments on whether to release the herpes virus.[971] The plan reports that the virus could reduce and suppress carp populations by approximately 40% to 60% (and by up to 80% in less resilient carp populations).[972] It recommended more research into the potential for the herpes virus to infect native fish species.

970. Department of Agriculture, Fisheries and Forestry (DAFF), 'National carp control plan' https://www.agriculture.gov.au/biosecurity-trade/pests-diseases-weeds/pest-animals-and-weeds/national-carp-control-plan Accessed 20 January 2023
971. Ibid.
972. Ibid.

Indicator B:27 Invasive terrestrial plant species

B:27 Invasive terrestrial plant speciesa						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	🔴	↙	🟡	🔴	↙	🟢
Data source(s):	AgVic, DELWP					
Measure(s):	Number, abundance and distribution of terrestrial invasive plant species					

Why this indicator?

Environmental weeds threaten Australia's biodiversity by displacing native plant species, disrupting ecological processes and altering the genetic composition of native plant populations.

NB: This indicator was 'B:02 Invasive terrestrial plants' in the SoE 2018 Report.

Why this assessment in 2023?

The number of naturalised plants and environmental weeds in Victoria continues to grow and their control is a major focus of actions by government agencies, landholders and communities. One-third of the environmental weeds in Victoria have genetic risk ratings ranging from high to very high.

Summary of State of the Environment 2018 Report assessment

- In Victoria there were at least 1,451 naturalised plants, of which 1,235 species were environmental weeds established in native vegetation, almost double the 584 recorded in 1992.

Critical data used for the 2023 assessment

- 2022 list of Victorian environmental weeds with risk ratings

2023 assessment

Two invasive plant categories are:

- Naturalised flora taxa: taxa that originate from either outside Australia or interstate, or taxa that are Victorian natives that have become established long-term and formed self-sustaining populations outside their pre-European range e.g. spotted gum. Naturalised flora taxa may not adversely impact native plants and/or animals or functioning ecosystems.
- Environmental weeds: these are a subset of naturalised taxa. They 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 e.g. coast wattle.

White et al. (2018) assessed the risk ratings for environmental weeds in Victoria by considering five attributes, including the impact on natural systems, area of potential distribution remaining; potential for invasion, rate of dispersal, and range of susceptible habitat types.[973]

973. White M, Cheal D, Carr G, Adair R, Blood K, Meagher D 2018, 'Advisory list of environmental weeds in Victoria 2018', Arthur Rylah Institute (ARI) for Environmental Research, Heidelberg, Victoria.

The advisory list was updated in 2022 and now contains:

- 1,810 vascular and non-vascular plant species (up from 1,786 in 2018), of which, 1,251 are environmental weeds (up from 1,235 in 2018)
- 52 species native to Victoria but are now naturalised well beyond their pre-European distribution (up from 49 in 2018)
- 113 species previously naturalised but now considered extinct in the wild
- 360 species currently considered to be casual or ruderal (on waste ground or in rubbish) in Victoria
- 86 species likely to become environmental weeds in Victoria in the future (up from 82 in 2018).[974, 975]

Species	Common Name	Impact on natural systems	Impact	Area of potential distribution remaining	Potential spread	Residual Risk	Potential for invasion	Invasivness	Rate of dispersal	Dispersal	Urgency	Range of susceptible habitat types	Habitat	Risk Ranking Score
Billardiera fusiformis	Australian Bluebell	Typically significant	30	Extensive potential for further spread	30	30	Highly Invasive	3	Rapid	3	3	Extensive	0.3	33.3
Acer negundo	Box Elder	Typically significant	30	Extensive potential for further spread	30	30	Somewhat Invasive	1	Rapid	3	1	Extensive	0.3	31.3
Plantago coronopus	Buck's-horn Plantain	Occasionally significant	20	Minor potential for further spread	10	10	Highly Invasive	3	Rapid	3	3	Extensive	0.3	13.3
Cakile edentula	American Sea Rocket	Rarely significant	10	Minor potential for further spread	10	10	Highly Invasive	3	Moderate	2	2	Restricted	0.1	12.1

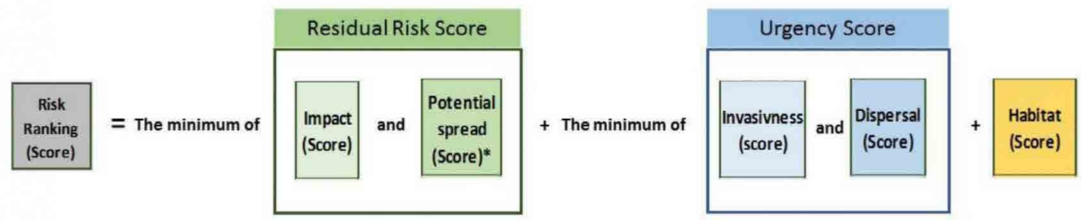


Figure B19: Process for determining the environmental weed risk ranking.[976]

974. White M, Cheal D, Carr G, Adair R, Blood K, Meagher D 2018, 'Advisory list of environmental weeds in Victoria 2018', Arthur Rylah Institute (ARI) for Environmental Research, Heidelberg, Victoria.
975. These figures are not meant to add-up as there is an overlapping category: 'species that are native to Victoria but have become naturalised well beyond their pre-European distribution' are also environmental weeds.
976. White M, Cheal D, Carr G, Adair R, Blood K, Meagher D 2018, 'Advisory list of environmental weeds in Victoria 2018', Arthur Rylah Institute (ARI) for Environmental Research, Heidelberg, Victoria.

Risk ranking is calculated by adding the residual risk score to the urgency score and habitat score (Figure B19). The residual risk score 'is intended to characterise the magnitude and spatial extent of anticipated biodiversity impacts. The urgency score 'reflects the rate at which weed species will invade native ecosystems', while the habitat score is the range of habitat types susceptible to invasion. In Figure B19, the Australian bluebell is given a risk ranking score of 33.3, which would be rated as high risk. With a risk ranking score of 12.1, the American searocket would be rated as medium risk. Of the 1,810 species listed, 608 were rated as high or very high risk (Table B3).

In Victoria, there remains very limited presence-only records for most weed species and no long-term data sets. There is also a biased distribution of records and effort across land-use types and habitats, with very little data on invasive plants and their management on private land.[977]

Table B3: Environmental weed risk ranking scoring system and numbers of ranked plants.[978]

Risk rating	Risk rating score range	No. on list
Very high	31.3-33.3	235
High	22.2-31.2	373
Moderately high	13.2-22.1	310
Medium	11.1-13.1	330
Lower [1]	Default of 0	476
Potential [2]	-	86
Total	-	1810

[1] *Species not currently environmental weeds are rated lower risk.*
[2] *Anticipated environmental weeds have a precautionary rating of potential risk.*

977. Agriculture Victoria (AgVic), 'Unpublished data', Melbourne, Victoria, Accessed 2022.
978. White M, Cheal D, Carr G, Adair R, Blood K, Muir A, Meagher D 2022, 'Advisory list of environmental weeds in Victoria 2022', Arthur Rylah Institute (ARI) for Environmental Research, Heidelberg, Victoria.

Indicator B:28 Priority weed control

B:28 Priority weed control						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide		?		New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator
Data source(s):	DELWP					
Measure(s):	Achievement of targets for priority weed control					

Why this indicator?

Environmental weeds impact native species and their habitats, as well as agricultural productivity. Weed control in priority locations can begin to mitigate these impacts.

NB: This is a new SoE 2023 indicator. Priority weed control was one of five measures considered within 'B:21 Area of management in priority locations' in the SoE 2018 Report. The five measures of the SoE 2018 indicator have been disaggregated into five separate indicators in this report to better target each priority response.

Criteria used for status assessment

Good: ≥75% of target for priority weed control is met

Fair: 50% to <75% of target for priority weed control is met

Poor: <50% of target for priority weed control is met

Why this assessment in 2023?

Although environmental weeds remain a serious problem on both private and public land, control programs, especially after the 2019–20 bushfires, have significantly increased the area of weed management by government agencies. However, data on outcomes for biodiversity are limited, while the available data are insufficient to determine status and trend. The two years of data on achievements since the release of Biodiversity 2037 indicate that they are below its targets. Although environmental weeds remain a serious problem on both private and public land, control programs, especially after the 2019–20 bushfires, have significantly increased the area of weed management by government agencies. However, data on outcomes for biodiversity are limited, while the available data are insufficient to determine status and trend. The two years of data on achievements since the release of Biodiversity 2037 indicate that they are below its targets.

Summary of State of the Environment 2018 Report assessment

- New SoE 2023 indicator

Critical data used for the 2023 assessment

- The available data were insufficient for this assessment

2023 assessment

The contributing target for Biodiversity 2037 (the area of management in priority locations that needs to be achieved and maintained) is 1.5 million hectares of weed control per annum in priority locations by 2037. A priority location refers to areas identified within the highest-ranked, cost-effective actions in the Strategic Management Prospects, a key process that helps to integrate and compare information on the expected benefits and indicative costs of conservation actions across species and locations.

Table B4 provides priority weed control data for 2018-19 and 2019-20. These are insufficient data to determine status or trend.

Table B4: Weed control in priority locations of Victoria for 2081-19 and 2019-20.[979]

Indicator measures	2018-19	2019-20
Total Annual Hectares of Action Statewide (Priority and Non-Priority Locations)	220,028	584,622
Annual Hectares of Action in Non-Priority Locations	150,302	382,765
Annual Hectares of Action in Priority Locations	69,726	201,857
Annual Target Hectares of Actions in Priority Locations	1,500,000	1,500,000

DELWP's Weeds and Pests on Public Land program, which covers approximately 10% of the state, aims to support the objectives of Biodiversity 2037 by reducing threats from invasive species and aiding the recovery of threatened species through 10 landscape-scale Eden and Ark projects. Eden projects target weeds and Ark projects target invasive animals. The Weeds at the Early Stages of Invasion project builds the capability of land managers to respond to early invader weeds.[980]

Weeds have also been a focus of programs including Roadside Weeds and Pests Program, Peri-Urban Weed Partnership Program, Bushfire Biodiversity Response and Recovery Program, Good Neighbour Program, Land for Wildlife and Landcare programs. Some local councils have local laws to penalise landholders who do not comply with the Catchment and Land Protection Act provisions for noxious weed control. Other councils may target certain weeds not declared noxious under the Act.

Private landowners are also tackling weeds on their properties. For example, Bush Heritage and the Dja Dja Wurrung are actively managing the largest infestation of wheel cactus in Victoria. In early 2022, Bush Heritage purchased the 452-hectare property of Buckrabanyule to protect it from subdivision, deal with the 400-hectare wheel cactus infestation and 'create the space for Dja Dja Wurrung people (Djaara) to return to and heal Djandak (Country).' [981] Effectively controlling the cactus, a Weed of National Significance, is resource and time intensive. Although treatment is largely by injection of herbicide into the plant, Djandak Rangers have been successfully trialling other methods, such as mulching.

979. Department of Environment, Land, Water and Planning (DELWP), 'Unpublished data', Melbourne, Victoria, Accessed 2022.
980. Department of Environment Land, Water and Planning (DELWP), 'Weeds and pests on public land program' https://www.environment.vic.gov.au/invasive-plants-and-animals/invasive-species-on-public-land/weeds-and-pests-on-public-land-program Accessed 10 May 2021.
981. Bush Heritage, 'Protecting Country and culture at Buckrabanyule' https://www.bushheritage.org.au/blog/protecting-buckrabanyule Accessed 3 November 2022.

Indicator B:29 Invasive terrestrial herbivore species

B:29 Invasive terrestrial herbivore species						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	🔴	↙	🟡	🔴	↙	NC*
Data source(s):	AgVic, DELWP					
Measure(s):	Number, abundance and distribution of invasive terrestrial herbivore species					

Why this indicator?

Established invasive terrestrial herbivore species in Victoria – deer, horses, rabbits, goats and pigs – are major threats to the state's biodiversity, environmental health, and cultural, economic and social values.

NB: This is a modified SoE 2023 indicator formed by merging the SoE 2018 indicators 'B:03 Invasive terrestrial animal species', 'B:03A Trend in deer populations and their distributions' and 'B:03B Trend in horse populations and their distributions'. The 2018 assessment provided in this report card is for 'B:03 Invasive terrestrial animal species', as its measure is most comparable to that of the modified 2023 indicator.

Why this assessment in 2023?

Invasive terrestrial herbivores are an ongoing threat to native flora and fauna and their habitats. There is no evidence to suggest that the trend is being slowed or reversed.

**NC indicates that comparisons between the SoE 2018 and SoE 2023 assessments for the modified SoE 2023 indicator is inappropriate due to the extensive level of variability in the measures and/or data used in the assessment between SoE reports.*

Summary of State of the Environment 2018 Report assessment

- Invasive terrestrial animals had established long-term, self-sustaining populations
- The number of feral deer, horses, rabbits, goats, and pigs had increased over recent decades
- The populations and distributions of sambar, fallow, red and hog deer were expanding, with sambar deer the most common and widespread
- Australia had the world's largest population of feral horses, with significant numbers in Victoria's Alpine and Barmah national parks.

Critical data used for the 2023 assessment

- Recent research investigating environmental and economic impacts of invasive herbivores
- Victorian Deer Control Strategy

2023 assessment

Long-term data on invasive terrestrial herbivores is limited and statewide pest animal population numbers in Victoria are currently unknown.

Sambar, red, fallow and hog deer have been expanding their distribution and numbers across public and private land since their introduction, impacting biodiversity, water quality, public safety, agriculture and cultural heritage (Figure B20). Sambar deer are found throughout eastern Victoria, fallow deer are in many areas scattered across the state, red deer are mainly found in the Grampians and small pockets elsewhere, and hog deer are concentrated along the coast from Wilsons Promontory to Point Hicks.

The Victorian Deer Control Strategy, released in October 2020, identified deer as a threat to 13 threatened flora species and 12 threatened ecological communities. It also reported that more than 1,000 native flora and fauna species would benefit if deer were successfully controlled.[982]

982. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Victorian deer control strategy', Melbourne, Victoria.

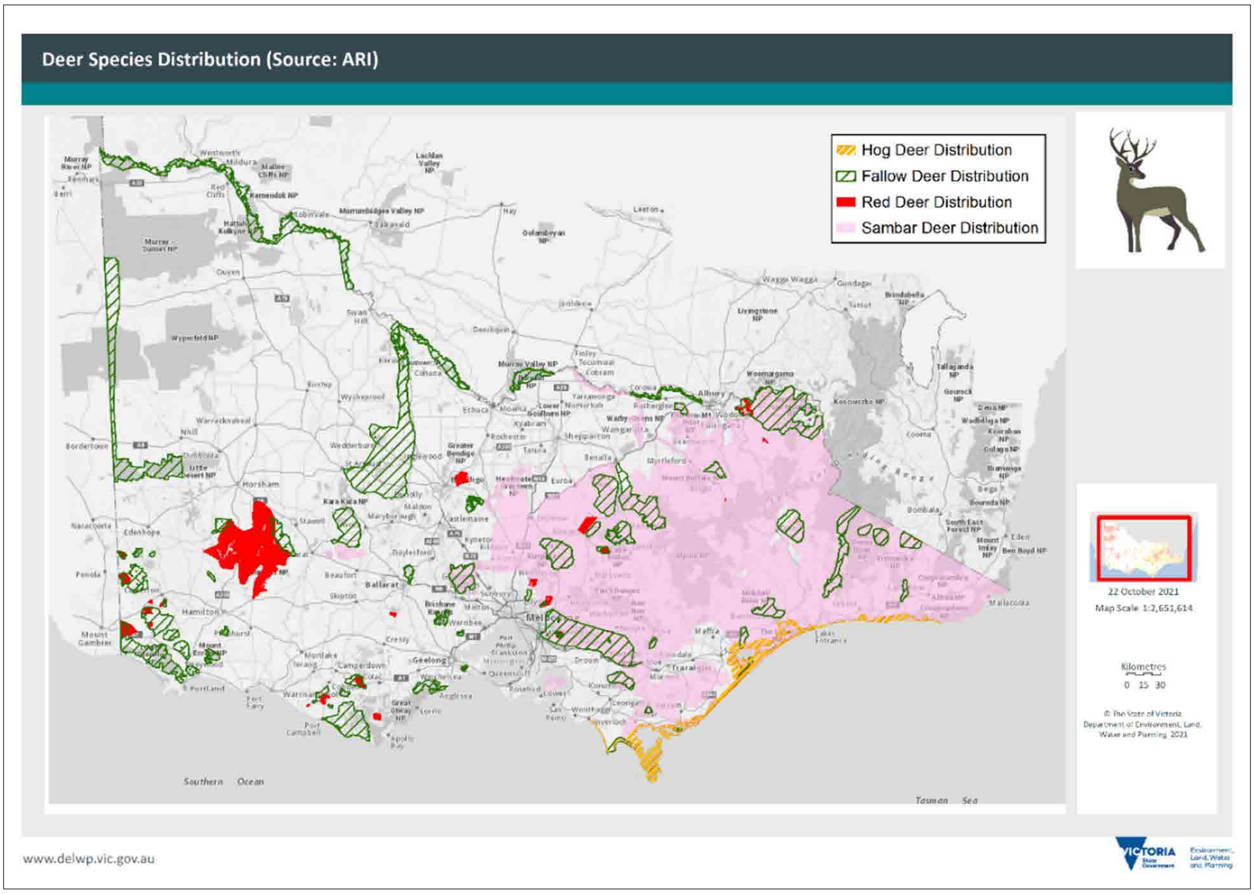


Figure B20: Estimated breeding distribution of four deer species in Victoria in 2021.[983]

Estimates of total deer numbers range between 'several hundred thousand up to one million', and some are now encroaching on Melbourne's peri-urban areas.[984] As part of the Victorian Deer Control Strategy, the first of three regional plans were released in 2021 for the peri-urban areas to the east of Melbourne. An analysis of deer densities at three water supply reservoirs in the hills surrounding Melbourne found mean densities of sambar deer to range from 3.93 to 11.94 deer per square kilometre, fallow deer at 2.09 and red deer at 24.57 deer per square kilometre.[985]

Research for Melbourne Water conducted at 15 exclusion plots in the wet forests of the Yarra Ranges found 'that deer are largely responsible for impacts on and reduced cover of tree ferns, as well as the reduced cover of climbers, while both deer and native fauna contribute to impacts on understorey trees and shrubs.'[986]

The four main deer species are protected wildlife ('game' species for hunting) under the Wildlife Act, and defined as game for licensed deer hunters, to provide for recreational hunting. However, their control on private land is effectively deregulated. Where deer are causing damage on private land, they can be controlled without a permit. Permits are still required under the Wildlife Act to control them on public land. In May 2021, the Senate Environment and Communications References Committee called for all Australian jurisdictions to 'ensure that wild deer are treated as an environmental pest.'[987]

983. Department of Environment Land, Water and Planning (DELWP) 2021, 'Peri-urban deer control plan 2021-26', Melbourne, Victoria.
984. Department of Environment Land, Water and Planning (DELWP) 2020, 'Victorian deer control strategy', Melbourne, Victoria.
985. Bengsen A, Forsyth D, Ramsey D, Amos M, Brennan, M Pople A, Comte, Crittle T, 2022, 'Estimating deer density and abundance using spatial mark-resight models with camera trap data', *Journal of Mammalogy*, 103(3):711–722, 2022.
986. Greet J, Fedrigo M, and Bennett A 2022, 'Deer impacts on the vegetation composition and structure of wet forests in the Yarra Ranges', The Waterway Ecosystem Research Group Technical Report 22.3, The University of Melbourne, Carlton, Victoria.
987. Senate Environment and Communications References Committee 2021, 'Impact of feral deer, pigs and goats in Australia', Parliament of Australia, Canberra, Australian Capital Territory.

Frontier Economics has estimated that the cost of not controlling deer in Victoria could range from $1.5 billion and $2.2 billion over the next 30 years due to lost agricultural and forestry production, vehicle accidents and reductions to the recreational values of national and state parks.[988] They also estimated that without significant management action, feral deer numbers could increase to between 1.7 million and 4.6 million by 2050.[989]

Feral horses in Victoria are found in the Alpine and Barmah national parks where they damage wetlands, alpine peatlands and stream banks. Aerial surveys are providing improved data on horse numbers in the Alpine National Park and Barmah National Park.

The number of feral horses in Barmah were estimated at 520 in 2019, while the estimate for the eastern Victorian Alps increased from 4,316 in 2014 to 8,518 by 2019.[990, 991] From 2008 to 2018, between 150 and 200 horses were removed annually from the Alpine National Park. This was not sufficient to reduce the overall annual population or mitigate the damage caused by feral horses in the national park and other contiguous areas.[992] The above two surveys indicated an increase of approximately 15% per year in horse numbers from 2014.

Feral horse population surveys have shown that without management control and severe natural events such as fire, feral horse populations can increase by 10% to 20% every two to four years. Although court action to prevent a culling program was eventually unsuccessful, it delayed PV's control programs, which commenced in 2021–22.

Although the distribution of rabbits appears stable according to Scroggie and Ramsey (2022), the carrying capacity of rabbits is positively related to increases in mean annual temperature, particularly where summers are wet (hot and dry summers reduce food availability and breeding).[993] This suggests that rabbit numbers could grow as climate change continues its impact on Victoria.

Information on the distribution of feral goats is limited. However, they are often seen in state and regional parks as well and forested areas of the Grampians, Alpine and East Gippsland regions or semi-arid areas in the north-west where they can find water, food and shelter from predators.[994] They cause damage to soils, overgraze native plants including trees that they can climb, compete with native animals for food and water, and can pollute waterways.

Feral pigs have spread into many areas of Victoria and risk culturally significant sites, agriculture, human health and the environment (Figure B21). The pigs compete with native animals for food, prey on some small animals, damage vegetation, reduce water quality, eat the eggs of birds and reptiles, and can spread of *Phytopthora cinnamomi*, which leads to the dieback of vegetation.

Although the economic impact of feral pigs on agriculture is poorly understood, they can have a devastating impact through their rooting and wallowing behaviour and their ability to spread disease, foul waterways and prey on small lambs. They also cause a wide range of damage to infrastructure, such as fences, gates and dams, and can potentially lead to the transfer of the mosquito-borne virus Japanese encephalitis from pigs to people. Although monitoring data are limited, feral pig ecology and biology indicates that populations thrive from an abundance of water and food availability. The wet years of 2021 and 2022 provided them with excellent conditions.

988. Frontier Economics 2022, 'Counting the doe: an analysis of the economic, social and environmental cost of feral deer in Victoria', a report for the Invasive Species Council, Melbourne, Victoria.
989. Ibid.
990. Cairns S. 2020, 'Analysis of the 2019 aerial survey of the feral horse population in the Barmah National Park, Victoria', Armidale, New South Wales.
991. Cairns S 2019, 'Feral horses in the Australian Alps: the analysis of aerial surveys conducted in April-May, 2014 and April-May 2019', Armidale, New South Wales.
992. Parks Victoria (PV) 2021, Protection of the Alpine National Park feral horse action plan 2021', Melbourne, Victoria.
993. Scroggie M, Ramsey D 2022, 'Predicting the dynamics of south-eastern Australian rabbit populations under climate change', Arthur Rylah Institute (ARI) for Environmental Research, Heidelberg, Victoria.
994. Agriculture Victoria (AgVic), 'Goats (feral or wild)', https://agriculture.vic.gov.au/biosecurity/pest-animals/priority-pest-animals/goat-feral-or-wild Accessed 21 July 2022.

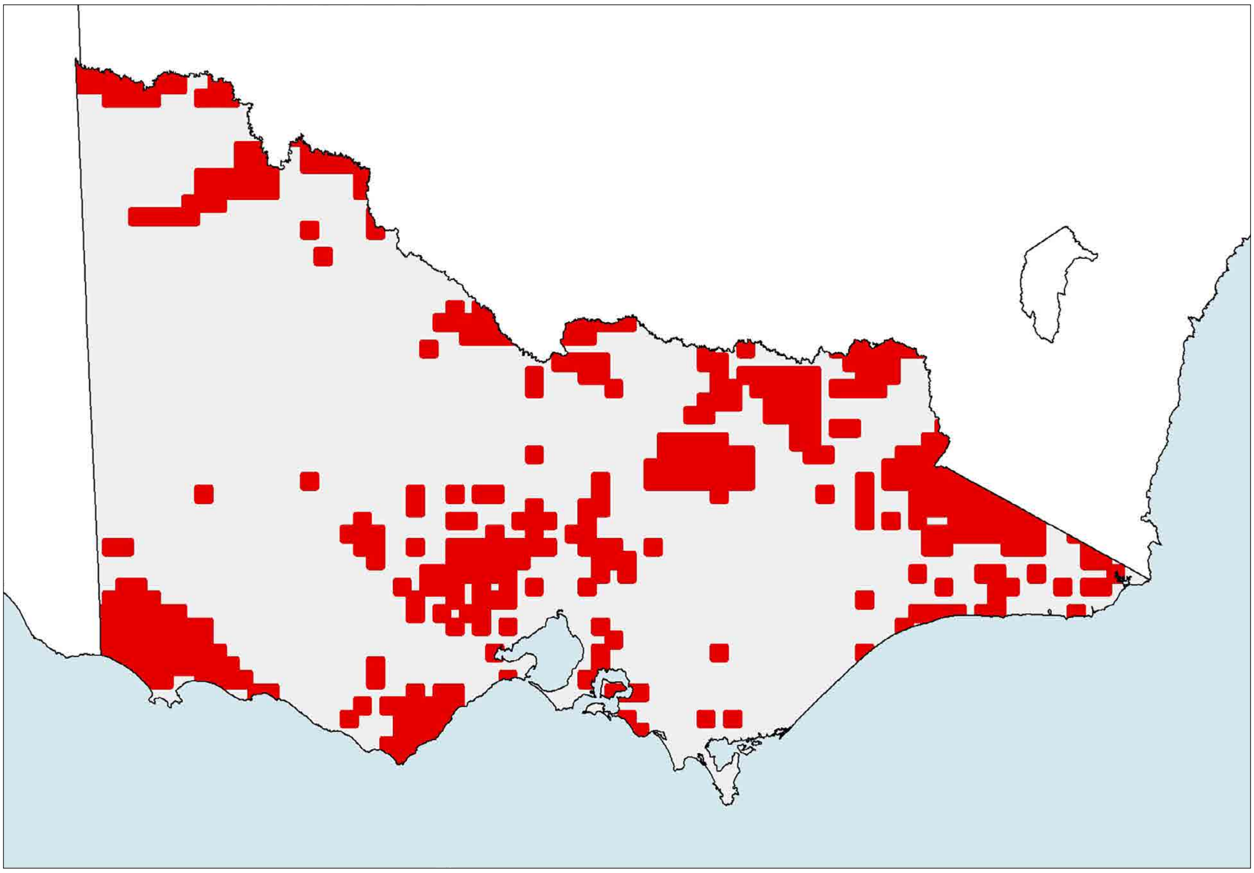


Figure B21: Distribution of feral pigs in Victoria in 2023.[995, 996]

995. Department of Environment, Land, Water and Planning (DELWP), 'Unpublished data', Melbourne, Victoria, Accessed 2022.
996. The Victorian feral pig distribution map has been prepared using data from public land managers including Parks Victoria, DELWP, Catchment Management Authorities and several water agencies. Data have also been sourced from Agriculture Victoria, FeralScan (Centre for Invasive Species Solutions), Atlas of Living Australia, Department of Agriculture, Water and Environment and the Australian Bureau of Agricultural and Resource Economics and Sciences.

Indicator B:30 Priority pest herbivore control

B:30 Priority pest herbivore control						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	●	?	●	New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator
Data source(s):	DELWP					
Measure(s):	Achievement of targets for priority pest herbivore control					

Why this indicator?

The distribution of invasive terrestrial herbivore species in Victoria is widespread, which means that management resources must be applied in priority locations, where the best results can be achieved. Priority pest herbivore control is a Biodiversity 2037 indicator.

NB: This is a new SoE 2023 indicator. Priority pest herbivore control was one of five measures considered within 'B:21 Area of management in priority locations' in the SoE 2018 Report. The five measures of the SoE 2018 indicator have been disaggregated into five separate indicators in this report to better target each priority response.

Criteria used for status assessment

Good: ≥75% of the target for priority pest herbivore control is met

Fair: 50% to <75% of the target for priority pest herbivore control is met

Poor: <50% of the target for priority pest herbivore control is met

Why this assessment in 2023?

Although there are significant localised pest herbivore control programs, there is no evidence to suggest that the trend is being slowed or reversed. Control programs were expanded in the wake of the 2019–20 bushfires due to concerns that invasive herbivores would flourish and increase the risks to native species. The available data are insufficient to determine status and trend. The two years of data on achievements since the release of Biodiversity 2037 indicate that they are below the targets for control pest herbivores.

Summary of State of the Environment 2018 Report assessment

- New SoE 2023 indicator

Critical data used for the 2023 assessment

- The available data were insufficient for this assessment

2023 assessment

Pest herbivore control activities have been focussed on East Gippsland, Wilsons Promontory, the Otway Ranges, Grampians National Park, Mallee national parks and the north-eastern and far south-western (in Budj Bim) areas of Victoria. Table B5 provides two years of pest herbivore control data for 2018-19 and 2019-20. These are insufficient data to determine status or trend.

Table B5: Pest herbivore control in priority locations of Victoria for 2018-19 and 2019-20.[997]

Indicator measures	2018-19	2019-20
Total annual hectares of action statewide (priority and non-priority locations)	553,112	1,674,138
Annual hectares of action in non-priority locations	225,730	785,381
Annual hectares of action in priority locations	327,382	888,757
Annual target hectares of action in priority locations	4,000,000	4,000,000

In response to the likely increased impacts of deer on fire-affected areas, deer control by government agencies intensified across the extent of the 2019–20 bushfires. DELWP and PV began an 11-week post-fire aerial and ground shooting operation between 10 February 2020 and 8 May 2020 in national parks and state forests in eastern Victoria.[998] More than 1,500 animals were removed, including 1,400 sambar deer and smaller numbers of foxes, fallow deer, feral pigs, goats and cattle. Preliminary estimates suggest a 50% reduction in population numbers within managed areas.[999]

After the 2019-20 bushfires, 1,100 feral animals were controlled in April and May of 2021 over an eight-day period at the Budj Bim World Heritage Area, representing more than 80 feral animals per square kilometre.[1000]

As part of the Victorian Deer Control Strategy, a regional plan for the peri-urban area to the north and east of Melbourne was released in 2021, the first of three regional plans. Figure B22 maps the priority investment locations for deer management in the peri-urban area, which includes localised areas for eradication such as Silvan, Cardinia and Sugarloaf water storages and high-priority areas in the north and east of the state.

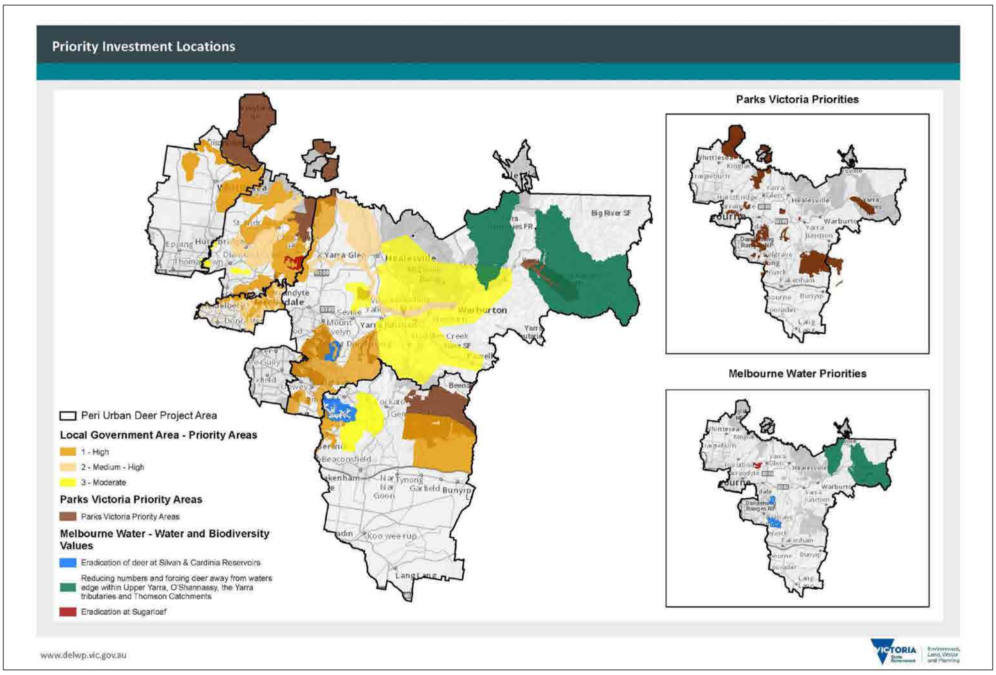


Figure B22: Locations of priority investment for deer management in the peri-urban area of Victoria in 2021.[1001]

997. Department of Environment, Land, Water and Planning (DELWP), 'Unpublished data', Melbourne, Victoria, Accessed 2022.
998. Department of Environment Land, Water and Planning (DELWP) 2020, 'Bushfire response operation gives native species best chance of survival', Media release, 11 February 2020, Melbourne, Victoria.
999. Department of Environment Land, Water and Planning (DELWP) 2020, 'Emergency response aerial shooting operation, summary report', Melbourne, Victoria.
1000. Zoos Victoria, 'Unpublished data', Melbourne, Victoria, Accessed 2022.
1001. Department of Environment Land, Water and Planning (DELWP) 2021, 'Peri-urban deer control plan 2021-26, Melbourne, Victoria.

The Protection of the Alpine National Park: Feral Horse Action Plan 2021 is a 10-year plan to manage feral horses in the Alpine National Park and adjacent state forests using trapping and rehoming, shooting by professional shooters, and the fencing of small-scale exclusion areas.[1002] Feral horse control is also a major focus of PV's Strategic Action Plan: Protection of Floodplain Marshes in Barmah National Park and Barmah Forest Ramsar Site (2020–2023).[1003] The horses have been identified as the main driver in the 96% decline of moira grass, a critical vegetation community in the park.[1004] The Joint Management Plan for Barmah National Park also includes actions to manage feral horses.[1005]

RabbitScan Phillip Island maps rabbit activity, records control works and is being used by land managers and the community to manage rabbit numbers as part of the Teaming Up to Tackle Rabbits project. This follows the successful elimination of foxes from the island and the establishment of a long-tern program to manage feral cats.[1006]

Genetic analysis is being used by ARI scientists to determine the population structure of feral pigs in south-eastern Australia. The research will help understand whether pig populations are self-contained or whether individuals disperse to establish new populations. This will guide management on whether to eradicate discrete groups or contain spreading populations.[1007]

DEECA, PV and Agriculture Victoria (AgVic) work closely to share data and knowledge. Feral pig monitoring and control programs are most successful when a cross-tenure, integrated program (with multiple control techniques) is implemented. The use of technology to continuously monitor and adjusting control programs is critical to keeping populations at manageable densities.

Since 2018, PV has been working with the Moogji Aboriginal Council to remove feral pigs from the Snowy River National Park and Eastern Alps. Around 20% of the conservation project area was burnt by the 2019–20 bushfires, and pigs have now been observed further south, having likely moved along the burnt corridor of the Snowy River towards Buchan and Orbost.[1008]

The National Feral Pig Action Plan 2021-2031 is a collaboration between primary producers, governments, Indigenous communities, researchers and land managers.[1009] To help implement the plan, a national Feral Pig Management Coordinator was appointed in 2019, and a Victorian coordinator in 2021. The Victorian coordinator promotes community and cross-tenure approaches to measure, monitor and manage feral pig impacts.

PV and the Conservation Ecology Centre are working together to monitor pigs in the Otways, part of the Otways initiative that includes feral pig and deer eradication projects funded by the Commonwealth Government, with a view to their eradication.[1010]

1002. Parks Victoria (PV), 'Feral horse action plan 2021' https://www.parks.vic.gov.au/projects/feral-horse-action-plan-2021 Accessed 30 January 2023.
1003. Parks Victoria (PV), 'Strategic action plan: Protection of floodplain marshes in Barmah National Park and Barmah Forest Ramsar site (2020–2023)', https://www.parks.vic.gov.au/projects/barmah-strategic-action-plan#:~:text=Parks%20Victoria%20released%20the%20Strategic,for%20current%20and%20future%20generations Accessed 19 June 2023.
1004. Parks Victoria (PV) 2020, 'Strategic Action Plan: protection of floodplain marshes in Barmah National Park and Barmah Forest Ramsar site 2020–2023', Melbourne, Victoria.
1005. Yorta Yorta Traditional Owner Land Management Board 2020, 'Joint management plan for Barmah National Park', Shepparton, Victoria.
1006. Bass Coast Landcare, 'Teaming up to tackle rabbits' https://www.basscoastlandcare.org.au/tacklerabbits.html Accessed 21 July 2022.
1007. Arthur Rylah Institute (ARI) for Environmental Research, 'Determining the population structure of feral pigs using genetics', https://www.ari.vic.gov.au/research/pests-weeds-and-overabundant-species/determining-the-population-structure-of-feral-pigs-using-genetics Accessed 27 December 2022.
1008. Parks Victoria (PV) 2020, 'Partnership project protects parks from pigs'.
1009. National Feral Pig Program, 'National feral pig action plan', https://feralpigs.com.au/the-plan/#ActionPlan Accessed 19 June 2023.
1010. Corangamite Catchment Management Authority (CMA) 2022, 'Sights set on controlling feral pigs in the Otway region', https://ccma.vic.gov.au/threatened-species/sights-set-on-controlling-feral-pigs-in-the-otway-region/ Accessed 11 July 2022.

Indicator B:31 Invasive terrestrial predator species

B:31 Invasive terrestrial predator species						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	Red	↙	Yellow	Red	↙	NC*
Data source(s):	AgVic, DELWP					
Measure(s):	Number, abundance and distribution of invasive terrestrial predators					

Why this indicator?

Foxes and cats kill tens of millions of native animals across Australia each year. They have been a major cause of past species' extinctions and are increasing the risk of future extinctions.
NB: This is a modified SoE 2023 indicator that was formed by narrowing the measure of the SoE 2018 indicator 'B:03 Invasive terrestrial animal species'.

Why this assessment in 2023?

Foxes and cats are continuing to increase in number and spread, and data indicate that their impact on native animals is increasing.

** NC indicates that comparisons between the SoE 2018 and SoE 2023 assessments for the modified SoE 2023 indicator is inappropriate due to the extensive level of variability in the measures and/or data used in the assessment between SoE reports.*

Summary of State of the Environment 2018 Report assessment

- There is no information within the SoE 2018 assessment specific to this modified 2023 indicator.

Critical data used for the 2023 assessment

- New research on environmental impacts of cats and foxes

2023 assessment

Foxes and cats are the main terrestrial invasive predators and are increasing in number and spread in Victoria.[1011] Feral cat management and research in Australia is estimated to cost $2 million each year, whereas the economic loss, based on bird predation alone, is $144 million annually.[1012]

After assessing the spatial variations in the numbers of vertebrates killed by foxes and feral cats, Stobo-Wilson et al. (2022) concluded that the 'ongoing predation pressure is likely to be causing declines in many prey populations, or reducing their resilience to other threats.' [1013] The researchers also estimated that feral and roaming domestic cats (estimated population of 6.6 million) and red foxes (estimated population of 1.66 million) across Australia killed a total 697 million reptiles, 510 million birds and 1,435 mammals (frogs and insects were not included in the study).[1014]

In Victoria, domestic cat numbers are estimated at more than 4 million, according to the Inquiry into Ecosystem Decline in Victoria.[1015] Research by the Australian National University for the Biodiversity Council, Invasive Species Council and Birdlife Australia estimated that Melbourne's pet population numbered a little over 1 million, with 729,202 of those roaming.

1011. Agriculture Victoria (AgVic), 'Unpublished data', Melbourne, Victoria, Accessed 2022.
1012. Parliament of Victoria Legislative Council Environment and Planning Committee 2020, 'Inquiry into ecosystem decline in Victoria,', Melbourne, Victoria.
1013. Stobo-Wilson A, Murphy B, Legge S, Caceres-Escobar, H, Chapple D, Crawford H, Dawson S J, Dickman, C, Doherty T, Fleming P, Garnett S, Gentle M, Newsome T M, Palmer R, Rees M, Ritchie E, Speed J, Stuart, J-M, Suarez-Castro A, Woinarski J 2022, 'Counting the bodies: estimating the numbers and spatial variation of Australian reptiles, birds and mammals killed by two invasive mesopredators', Diversity and Distributions, 28, pp. 976–991.
1014. Ibid.
1015. Parliament of Victoria Legislative Council Environment and Planning Committee 2020, 'Inquiry into ecosystem decline in Victoria', Melbourne, Victoria.s

The annual death toll for vertebrates from predation by domestic cats was estimated at over 105 million, which included over 62 million native vertebrates. The daily toll was 298,843 for all vertebrates and 171,412 for native vertebrates.[1016]

Legge et al. (2021) reported that, across Australia, cats are a major cause of the extinction of 34 mammal species and also threaten the extinction of another 120 species.[1017]

Woinarski et al. (2020) estimated that the annual per capita consumption of frogs by feral cats in wild environments across Australia was 44, with a total consumption of 92 million frogs. Pet cats were estimated to nationally take a total of one million frogs each year.[1018]

Research by Robley et al. (2016) showed that foxes are responsible for 93% of nest predation of the Murray River tortoise and contribute to the spread blackberries and other weeds.[1019]

Caption: Red fox creeping around farm in Central Victoria.
Credit: Tracie Louise.

1016. Chung L 2023, 'The staggering death toll of roaming pet cats finally revealed', Sydney Morning Herald, 9 June 2023.
1017. Legge S, Dickman C, Dielenberg J, Woinarski J, Nou T 2021, 'Australia must control its killer cat problem. A major new report explains how, but doesn't go far enough', The Conversation, 10 February 2021.
1018. Woinarski J, Legge S, Woolley L, Palmer R, Dickman C, Augusteyn J, Doherty T, Edwards G, Geyle H, McGregor H, Riley J, Turpin J, Murphy B 2020, 'Predation by introduced cats Felis catus on Australian frogs: compilation of species records and estimation of numbers killed', Wildlife Research, 47(8).
1019. Robley A, Howard K, Lindeman M, Cameron R, Jardine A, Hiscock D 2016, 'The effectiveness of short-term fox control in protecting a seasonally vulnerable species, the eastern long-necked turtle (Chelodina longicollis)', Natural Sciences, 17(1), pp. 63–69.

Indicator B:32 Priority pest predator control

B:32 Priority pest predator control						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide		?		New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator
Data source(s):	DELWP					
Measure(s):	Achievement of targets for priority pest predator control					

Why this indicator?

Foxes and cats have a wide distribution, which means that management resources must be applied in priority locations, where the best results can be achieved.

NB: This is a new SoE 2023 indicator. Priority pest predator control was one of five measures considered within 'B:21 Area of management in priority locations' in the SoE 2018 Report. The five measures of the SoE 2018 indicator have been disaggregated into five separate indicators in this report to better target each priority response.

Criteria used for status assessment

Good: ≥75% of the target for priority pest predator control is met

Fair: 50% to <75% of the target for priority pest predator control is met

Poor: <50% of the target for priority pest predator control is met

Why this assessment in 2023?

Although there are localised control programs, there is no evidence to suggest that the trend in fox and cat numbers is being slowed or reversed. The available data are insufficient to determine status and trend. The two years of data on achievements since the release of Biodiversity 2037 indicate that they are below its targets.

Summary of State of the Environment 2018 Report assessment

- New SoE 2023 indicator

Critical data used for the 2023 assessment

- The available data were insufficient for this assessment

2023 assessment

Priority locations for pest predator control in 2019-20 were in East Gippsland, the High Country, Otway Ranges, Grampians National Park and south-west and north-west Victoria. Table B6 provides two years of priority pest predator control data for 2018-19 and 2019-20. These are insufficient data to determine status or trend.

Table B6: Pest predator control in priority locations of Victoria for 2018-19 and 2019-20.[1020]

Indicator measures	2018-19	2019-20
Total annual hectares of action statewide (priority and non-priority locations)	1,916,232	2,105,220
Annual hectares of action in non-priority locations	1,092,497	1,239,892
Annual hectares of action in priority locations	823,735	865,328
Annual target hectares of action in priority locations	1,500,000	1,500,000

1020. Department of Environment, Land, Water and Planning (DELWP), 'Unpublished data', Melbourne, Victoria, Accessed 2022.

The focus of the Southern Ark project is fox control to protect the long-footed potoroo and other at-risk threatened species in East Gippsland. Although the 2019–20 bushfires destroyed most of the 3,500 baiting stations, along with camera monitoring sites, subsequent monitoring has demonstrated the resilience of the long-footed potoroo as well as the effectiveness of landscape-scale predator control.

Fox control strategies, thus far, have been less successful in the Glenelg Ark Project. It was established in 2005 to support the recovery of southern brown bandicoot, long-nosed potoroo and common brushtail possum — native species preyed upon by the red fox. The bandicoot and potoroo have shown no significant response to fox control, and possum numbers have largely increased in correlation with rainfall patterns.[1021]

Phillip Island was declared fox-free in 2017, followed by the release of the endangered eastern barred bandicoot. The bandicoots were also released on fox-free French Island, where a program to remove cats is underway.[1022]

A project to construct a 10-km predator-proof fence across Yanakie Isthmus in the Wilsons Promontory National Park is in the planning stage. The fence will exclude foxes, deer and cats and support the re-establishment of native fauna, flora and habitats by creating a 50,000-hectare wildlife haven.[1023]

Cat curfews are increasingly being used by local councils in Victoria to control the movements of domestic cats and minimise their impact on native animals. Of Victoria's 79 councils, 10 have 24-hour cat curfews, 27 have night-time curfews and 17 are considering the introduction of cat curfews (as at July 2022).[1024]

The National Feral Cat and Fox Management Coordinator, established in 2021, is working with communities and stakeholders to expand the knowledge base, raise community awareness, and promote best-practice control methods and outcomes that protect wildlife and agriculture.[1025]

Caption: Southern Brown Bandicoot. Mount Rothwell Sanctuary, Victoria.
Photographer: Heath Warwick. © Museums Victoria.

1021. Robley A, Moloney P, Stringer L, Donald S 2020, 'Glenelg Ark 2005–2019: long-term predator and native mammal response to predator control', Arthur Rylah Institute (ARI) for Environmental Research Technical Report Series No. 318. Heidelberg, Victoria.
1022. Department of Environment Land, Water and Planning (DELWP) 2020, 'Submission to the Legislative Council Environment and Planning Committee Inquiry into ecosystem decline in Victoria', Parliament of Victoria, Melbourne, Victoria.
1023. Parks Victoria (PV), 'Unpublished data', Melbourne, Victoria, Accessed 2022.
1024. Moreland City Council, 'Impacts of a cat curfew' https://conversations.moreland.vic.gov.au/cat-curfew/impacts-cat-curfew Accessed 21 July 2022.
1025. The Centre for Invasive Species Solutions, 'National feral cat and fox management coordinator' https://invasives.com.au/research/national-feral-cat-and-fox-management-coordinator/ Accessed 27 January 2023.

Indicator B:33 Net gain in the extent and condition of native vegetation

B:33 Net gain in the extent and condition of native vegetation						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide						
Data source(s):	DELWP					
Measure(s):	Estimates of the overall rate of change in extent and condition of native vegetation on public and private land in Victoria					

Why this indicator?

Victoria is the nation's most cleared state, which has severely impacted its biodiversity. Urban expansion, bushfires, invasive species and climate change are some of the factors leading to the ongoing loss of native vegetation in Victoria. Habitat loss and fragmentation are second only to invasive species as drivers of the increased risk to native species. The success of efforts to reverse the loss of habitat is measured by this indicator, which is also a Biodiversity 2037 indicator.

NB: This SoE 2023 indicator was 'B:18 Net gain in extent and condition of native vegetation' in the SoE 2018 Report.

Criteria used for status assessment

Good: There is a net gain in the extent and condition of native vegetation

Fair: There is no net gain or loss in the extent and condition of native vegetation

Poor: There is a net loss in the extent and condition of native vegetation

Why this assessment in 2023?

There is a continuing net loss (habitat hectares) of native vegetation on private land in Victoria, with a smaller net gain on public land.[1030] The main contributors are grazing, removal of trees and fallen logs, environmental weeds, clearing exempt from requiring a permit (e.g. fences and fire protection) and illegal clearing, which has proven difficult to quantify.

Summary of State of the Environment 2018 Report assessment

- There had been a net loss in native vegetation on public and private land between 2008 and 2014.
- The largest contributors to net loss in native vegetation on private and freehold land were entitled uses (e.g. grazing and removal of trees and fallen logs for personal use), unmanaged threats beyond legislative obligations (e.g. environmental weeds) and clearing that was exempt from requiring a permit (e.g. fences and fire protection).

Critical data used for the 2023 assessment

- 2020 Net Gain Accounting Qualitative Update

1026. 'Habitat hectares' is a method of assessing native vegetation, in terms of both quality and extent. Quality is assessed by scoring habitat attributes at a site in comparison to a reference point (benchmark) for the relevant vegetation type – this provides a 'habitat score'. The habitat score is multiplied by the area of vegetation to determine the amount of habitat hectares. For example, 10 hectares with a habitat score of 60% is six habitat hectares.

2023 assessment

In its 2020 submission to the Legislative Council Environment and Planning Committee Inquiry into Ecosystem Decline in Victoria, DELWP reported that:

> 'Victoria has a legacy of loss, degradation and fragmentation of habitats that is evident across the state. The effects of this legacy are continuing, creating more pressure on species and increasing their vulnerability to other threats … This trajectory is largely the result of activities and unmanaged threats that are outside the regulatory framework, such as the exempted removal of native vegetation from fence lines and roadsides (resulting in loss of extent of native vegetation) together with insufficient management of threats, such as introduced weeds and pest herbivores or inappropriate fire regimes (resulting in loss of quality).' [1027]

Approximately two-thirds of Victoria is private land and 79% of that has been cleared of native vegetation.[1028, 1029, 1030] Although much of it is fragmented, the remaining 21% supports 30% of Victoria's threatened species.[1031] Biodiversity 2037 committed to a net gain in the extent and condition of native habitats over the 20-year life of the plan.

DELWP's 2020 Net Gain Accounting Qualitative Update estimated an annual net loss of 6,600 habitat hectares in 2020.[1032] Figure B23 summarises the gains and losses across public and private land from the 2020 Net Gain update. These figures are compared with those for 2008 and 2015, which had net losses of 4,000 habitat hectares and 8,200 habitat hectares, respectively (Table B7).[1033] It should be noted that the qualitative update indicated that the estimates in the report, which used modelled data, were subject to 'high variability and poorly quantified levels of uncertainty', and 'broad assumptions' for losses.[1034]

In calculating the net gain, the qualitative update used three categories of change:

- Gain activities included government investment, general management, voluntary actions, improved security, offsets for permitted clearing and unallocated native vegetation credits.
- Loss activities included entitled uses (e.g. grazing, removal of trees/fallen logs for personal use), exemptions (e.g. strategic fuel breaks, fencing), controlled management regimes (e.g. planned burning is included as a loss where it has resulted in native vegetation being burnt below the tolerable fire interval) and insufficient threat management on crown or freehold land (e.g. environmental weeds), and losses due to permitted clearing. The clearing of fuel breaks during bushfires, such as along the Princes Highway during the 2019-20 bushfires, can remove habitat permanently, however it is not regarded as a loss.
- Neutral activities included wildfire, forest harvesting and regeneration. It is assumed in the calculations that native vegetation will regenerate itself after fire and harvesting.

1027. Department of Environment Land, Water and Planning (DELWP) 2020, 'Submission to the Legislative Council Environment and Planning Committee Inquiry into ecosystem decline in Victoria', Parliament of Victoria, Melbourne, Victoria.
1028. Trust for Nature, 'Statewide conservation plan for private land in Victoria', https://trustfornature.org.au/wp-content/uploads/2020/11/Trust-for-Nature-Statewide-Conservation-Plan.pdf Accessed 3 August 2023.
1029. The proportion of Victorian land that is private was reported as 57.6% in the SoE 2018 Report. Trust for Nature, which focusses on the conservation of biodiversity on private land, now reports it as being 62%. This should not be interpreted as an increase; it is a recalculation of the spatial extent of private land.
1030. Victorian Auditor-General's Office (VAGO) 2022, 'Offsetting native vegetation loss on private land', Melbourne, Victoria.
1031. Ibid.
1032. Department of Environment Land, Water and Planning (DELWP) 2020, '2020 net gain accounting qualitative update', Melbourne, Victoria.
1033. Ibid.
1034. Ibid.

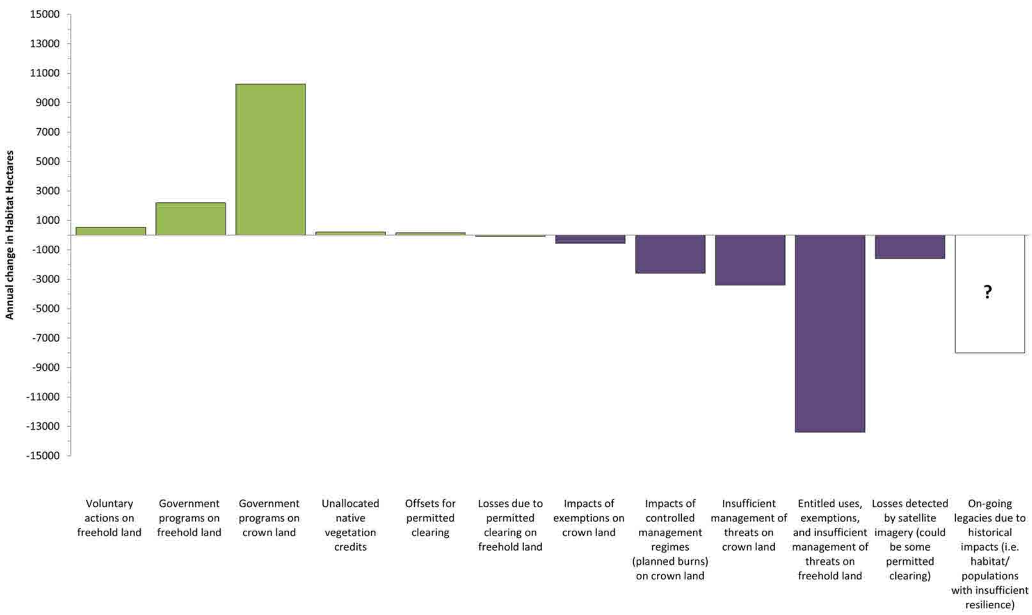


Figure B23: Native vegetation gains and losses (in habitat hectares) for 2020.[1035]

Table B7: Net outcome over time in habitat hectares per year in Victorian Crown and freehold land during 2008, 2015 and 2020.[1036]

	Crown land (habitat hectare/year)			Freehold land (habitat hectare/year		
	2008	2015	2020	2008	2015	2020
Gains subtotal	+8,760	+10,500	+10,260	+4,560	+3,100	+3,090
Losses subtotal	-2,860	-8,400	-6,540	-14,550	-13,400	-13,470
Net outcome	+5,900	+2,100	+3,720	-9,990	-10,300	-10,380

A critical component of net gain accounting is the regulation and management of the clearing of native vegetation for resource extraction and the expansion of infrastructure, urban areas, industry and agriculture. In Victoria, the overall objective under the clearing regulations is no net loss of biodiversity (i.e. no reduction in the state's biodiversity value from the approved removal of native vegetation).

This has to be achieved through the application of a three-step process:

- Step 1 is to avoid removal, destruction or lopping native vegetation when possible
- Step 2 is to minimise impacts when removal cannot be avoided
- Step 3 is to offset native vegetation removal when it cannot be avoided.

1035. Department of Environment Land, Water and Planning (DELWP) 2020, '2020 net gain accounting qualitative update', Melbourne, Victoria.
1036. Ibid.

Offsetting the loss of native vegetation is the last step, or a position of last resort, if steps 1 and 2 are not deemed achievable. There are two types of offsets:

- First party: a private landholder applies for an offset on their own land.
- Third-party trade: a landowner seeking to clear land pays a third party for the offset on another property.

Offset trades to third parties numbered 2,914 in Victoria between 20 May 2014 and 17 January 2023. Within the 10 CMAs. Port Phillip and Westernport had 40.3% of the trades, North central 14.8% Goulburn Broken 11.2%, Corangamite 8.9%, West Gippsland 6.4%, Glenelg Hopkins 4.2%, East Gippsland 1.2%, the Wimmera 1.4%, and both the Mallee and North East were at 3.2% of the trades. For 5.3% of trades, no CMA was identified.[1037]

VAGO released its independent assurance report on Offsetting Native Vegetation Loss on Private Land in May 2022.[1038] It found that Victoria was not achieving its objective of no net biodiversity loss from native vegetation clearing on private land. The report found that this was partly due to illegal clearing and the failure of local councils to 'effectively manage native vegetation clearing in their areas', and DELWP's slowness in supporting the councils to implement native vegetation clearing regulations.[1039]

The VAGO assurance report also found that DELWP's native vegetation reports did not report outcomes (only outputs and processes), that data quality issues impacted DELWP's oversight of the regulations and their implementation, and that it did not consistently monitor third-party offset sites.

With regards to local councils, which are tasked with implementing the native vegetate clearing regulations, the VAGO assurance report found that the councils were:

- inconsistently applying the mitigation hierarchy (avoid; minimise; offset)
- limited in their knowledge of the number of permits they issued
- not ensuring whether clearing was either permitted or exempted
- ineffectively monitoring and enforcing compliance with permits or exemptions
- not preventing or taking action on unauthorised clearing
- not monitoring first-party offset sites.

The main reasons for these failures were inadequate staff resourcing, knowledge and capability, budget constraints, and poor outcomes from past enforcement actions (costs of actions far outweighed fines imposed).

An alternative framework for offsetting has been developed by an international working group and produced with the support of the Science for Nature and People Partnership, a collaboration of the Nature Conservancy, the Wildlife Conservation Society, and the National Center for Ecological Analysis and Synthesis. The new framework, outlined in Simonds et al. (2019), is for target-based ecological compensation.[1040] Simonds et al. (2019) argue that:

> 'Loss of habitats or ecosystems arising from development projects (e.g. infrastructure, resource extraction, urban expansion) are frequently addressed through biodiversity offsetting. As currently implemented, offsetting typically requires an outcome of "no net loss" of biodiversity, but only relative to a baseline trajectory of biodiversity decline. This type of "relative" no net loss entrenches ongoing biodiversity loss, and is misaligned with biodiversity targets that require "absolute" no net loss or "net gain."'[1041]

1037. Department of Energy, Environment and Climate Change (DEECA), 'I want to establish a third party offset site' https://www.environment.vic.gov.au/native-vegetation/native-vegetation-removal-regulations/offsets-for-the-removal-of-native-vegetation/i-want-to-establish-a-native-vegetation-credit-site Accessed 20 February 2020.
1038. Victorian Auditor-General's Office (VAGO) 2022, 'Offsetting native vegetation loss on private land', Melbourne, Victoria.
1039. Ibid.
1040. Simmonds J, Sonter L, Watson J, Bennun L, Costa H, Dutson G, Edwards S, Grantham H, Griffiths V, Jones J, Kiesecker J, Possingham H, Puydarrieux P, Quétier F, Rainer H, Rainey H, Roe D, Savy C, Souque M, Kate K, Victurine R, von Hase A, Maron M 2019, 'Moving from biodiversity offsets to a target-based approach for ecological compensation', Conservation Letters, 13, pp. e12695.
1041. Ibid.

Although the use of offsets to allow the clearing of native vegetation can increase the protection of the land in the offset, the overall result is a net loss of habitat.

In the case of grasslands in the Melbourne Strategic Assessment, the Western Grassland Reserve is being established to not only increase protection but to also offset the loss of grasslands elsewhere in the Melbourne area. However, the protection does not create new grassland as the act of simply re-planting an area, even if successful over time, does not mean that it has the same value and native species as when it was cleared. Some species, especially small terrestrial fauna, cannot recolonise such areas, either because they no longer occur in the area or because barriers, such as roads, prevent recolonisation.[1042]

Under target-based ecological compensation, the aim is for outcomes that are aligned with science-based and measurable biodiversity targets at the jurisdictional level. These targets could, for example, refer to desired species populations or the minimum extent of ecosystems. Where the biodiversity feature is at the target level, then 'no net loss' would be required. In the case of the feature being below the target, 'net gain' would be needed to reach the target and, in some circumstances where the target is exceeded, 'managed net loss' might be appropriate. In both the 'no net loss' and 'net gain' outcomes, an increase in the extent and/or condition of the biodiversity feature, such as restoration or increased populations, will be required. Where this is not possible, the first steps in mitigation should be applied.

Caption: Alpine Ecosystem Falls creek.
Credit: Steven Wright. © Parks Victoria.

1042. Zoos Victoria, 'Unpublished data', Melbourne, Victoria, Accessed 2022.

Indicator B:34 Change in suitable habitat for threatened native species

B:34 Change in suitable habitat for threatened native species						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide		?			→	
Data source(s):	DELWP					
Measure(s):	Estimating net improvement in suitable habitats of threatened native species across the state under climate change Threatened species target					

Why this indicator?

Habitat loss has severely impacted native species in Victoria. What habitat remains can be compromised by invasive species, fire and other factors and become less suitable for native species. This indicator measures estimates of net improvement in suitable habitat achieved for individual species by implemented actions compared with a 'no action' scenario. This is a Biodiversity 2037 indicator.

NB: This indicator was 'B:20 Change in suitable habitat' in the SoE 2018 Report.

Criteria used for status assessment

Good: ≥75% of the target for change in suitable habitat is met

Fair: 50% to <75% of the target for change in suitable habitat is met

Poor: <50% of the target for change in suitable habitat is met

Why this assessment in 2023?

Data from 2019 and 2020 show that the average percentage change in suitable habitat in 50 years for selected threatened species is 11.4%, based upon on-ground management actions. For some species, the percentage change in suitable habitat was much higher than the average (e.g. 30.2% for frogs and 31.4% for mammals). The available data, only up to 2020, were insufficient to determine trend. However, the calculated increases are well below the 100% target in Biodiversity 2037.

Summary of State of the Environment 2018 Report assessment

- The indicator target is for a 100% net positive change (on average) in suitable habitat for threatened species in 50 years, as stated in Biodiversity 2037.
- According to Biodiversity 2037, achieving the 100% change (on average) in suitable habitat target will require the establishment and maintenance of management actions (e.g. weed and feral predator removal) and undertaking the most cost-effective actions identified in the Strategic Management Prospects tool.

Critical data used for the 2023 assessment

- DELWP data (2015-16, 2017-18 and 2019-20)

2023 assessment

Change in suitable habitat is the increase in the likelihood that a species will persist at a location at a future time (e.g. 50 years) in response to the sustained management of relevant threats, such as invasive animals and plants. It is expressed as the proportional increase (percentage) in hectares of Suitable Habitat that a species has received under a sustained management regime, compared with no management.

Climate change will likely impact the future distribution and amount of suitable habitat across Victoria. It will also influence the benefit achieved by particular conservation actions, both in terms of magnitude and where that benefit can be achieved. DEECA is currently working on better ways to consider that for future reporting.

Table B8 shows the change in suitable habitat and the number of species that would benefit after long-term pest herbivore control.

Based on a set of actions undertaken, threatened species underwent an average of 11.4% change in suitable habitat in 50 years, with 80.6% of all species having a net improvement (2% to more than 50% change in suitable habitat; Table B9).[1043] For some species, the percent change in suitable habitat was much higher than the average. For example, 414 threatened species (664 for all species) had a change in suitable habitat greater than 10%. The achievement of these figures is reliant upon sustained, well-resourced and effective management actions and, for more than 50% of all species and almost 50% of threatened species, there was no improvement or only a 2% to 5% change in suitable habitat. This is well below the 100% target in Biodiversity 2037.

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 (on average) percent net change in suitable habitat in 50 years for threatened species may be due to several factors, including:

- 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
- only partial control of threats to the species due to the lack of fully integrated management (e.g. managing all predators or all herbivores in a landscape)
- for plants, increased grazing pressure due to, for example, control of invasive predator species leading to increased numbers of rabbits
- missing spatial data regarding actions already being undertaken that may impact on change in suitable habitat
- the need for further management action through increased investment
- the exclusion of actions by private landholders and community organisations to improve habitat.

1043. Net improvement in suitable habitat is defined as a positive change in suitable habitat greater than 2%. This threshold was chosen to limit the effect that benefits in marginal/edge of range/low suitability modelled habitat for species may have on the overall reporting results.

There are some limitations to the calculation of change in suitable habitat:

- The focus of management is on the control of invasive species and revegetation. As Indicator B:38 shows, there has been little progress on revegetation in priority locations. The management of threats, if occurring, from bushfires, limited genetic diversity, land clearance, urban development, timber harvesting, river regulation, physical disturbance, hunting, stocking of alien fish, disease and climate change is not included in the calculations for change in suitable habitat. Without effective management of these other threats, or the inclusion of any relevant management actions, the calculation of a change in suitable habitat could be of limited value.
- Ensuring management actions are maintained for 50 years will be challenging due to resourcing constraints, the continued impacts of climate change on species and their habitat, as well as the impacts of emerging threats. For example, it would be difficult to improve the suitable habitat for the Guthega skink in high-elevation alpine area by 100% as the climate warms and the habitat extent and condition decline.
- Managing the threat for one species, and thus changing its suitable habitat, might not improve the habitat for other species. For example, if foxes were controlled in alpine areas, there may be a change in habitat suitability for some species but there would be no change in suitable habitat for other species such as the alpine water skink, for example.
- Ensuring that data on species, their threats and the benefits from management actions are up to date is challenging, especially when there are few monitoring programs in place to determine the responses of targeted species to management even if there is a calculated increase in suitable habitat.
- Climate change will likely impact the future distribution and amount of suitable habitat across Victoria. It will also influence the benefit achieved by particular conservation actions, both in terms of magnitude and where that benefit can be achieved. DEECA is currently working on better ways to consider that for future reporting.

Table B8: Percentage change in suitable habitat in 50 years for five taxon groups.[1044]

Taxon Group	Average % net change in suitable habitat in 50 YearsSoE 2018 Report*	Average % net change in suitable habitat in 50 Years
Threatened species	5.24	11.4
Birds	2.56	15.4
Frogs	3.45	30.2
Mammals	27.11	31.4
Plants	4.33	10.4
Reptiles	19.02	13.7
Average Change in Suitable Habitat	5.3	11.4

* *Based on data for from the years 2015–16 and 2017–18.*

Table B9: Percentage change in suitable habitat for threatened species in 2019-20.[1045]

Change in suitable habitat value range	Percentage of threatened species (Total = 1347)	Percentage of all species (Total= 3942)
No net improvement	24.7	19.4
2-5%	24.8	39.9
5-10%	19.7	23.9
10-50%	28.1	15.7
>50%	2.7	1.1

1044. Department of Environment, Land, Water and Planning (DELWP), 'Unpublished data', Melbourne, Victoria, Accessed 2022.
1045. Ibid.

Indicator B:35 Climate-sensitive ecosystems

B:35 Climate-sensitive ecosystems						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide		?			?	
Data source(s):	DELWP					
Measure(s):	Ecosystem impacts of climate change					

Why this indicator?

This indicator monitors the impacts of climate change and the level of climate risk for Victoria's natural ecosystems.

NB: This SoE 2023 indicator was 'CC13: Extent and condition of key climate-sensitive ecosystems' in SoE 2018 Report.

Why this assessment in 2023?

Alpine regions, rain forests and red gum forests are examples of ecosystems under threat from climate change. Climate sensitivity will vary from ecosystem to ecosystem, with some more sensitive than others.

Summary of State of the Environment 2018 Report assessment

- Victoria has been experiencing biodiversity loss, partly due to reduced resilience under climate change (e.g. repeated fires inhibiting growth of alpine ash trees).
- Climate change is likely to exacerbate the impacts of invasive species.
- Native fauna has little, if any, predictable resilience to significant change in crucial environmental factors.

Critical data used for the 2023 assessment

- DELWP's Climate Science Report 2019

2023 assessment

DELWP's Climate Science Report 2019 showed that, since 1910, temperatures in Victoria has increased by more than 1.0°C, average rainfall has declined and fire danger had increased.[1046] The report also estimated that, by 2050, average annual temperatures could increase by up to 2.4°C, alpine snowfall could drop by 35% to 75%, the number of very hot days could double and there could be up to 60% more very high fire danger days.

For biodiversity, a warming climate will place further stress on species and communities already under extreme pressure from other threats. Some species will move south or to higher elevations, however, others, like alpine species, will be unable to move higher to find cooler conditions.

1046. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Victoria's climate science report 2019', Melbourne, Victoria.

At the same time, habitat disturbance and fragmentation will encourage the invasion of pest plants and animals that prey on or outcompete native species, while increases in fire severity and frequency could undermine the survival of vegetation communities. The report of the Inquiry into Ecosystem Decline in Victoria found that:

> 'Climate change is driving more frequent and severe bushfires in Victoria. More frequent and severe fires are devasting native faunal populations and threatening the viability of the State's ash forests, rainforest and other sensitive flora populations.' [1047]

The depth of snow cover in the Australian Alps, which is projected to decline by 30-70% by 2050 relative to 1990 levels under a low emissions scenario, has implications for alpine flora and fauna, river flows in the Murray-Darling Basin (snow melt provides more than 45% or river flows), snow tourism and hydroelectricity generation in the Snowy Scheme.[1048]

The plants and animals that are part of ecosystems are also sensitive to climate change. A 2020 DELWP risk assessment identified 48 threatened species and communities that are at high, or significant, risk from climate change. The species included the Booroolong frog, McDowall's galaxias, red-tailed black-cockatoo (south-eastern), grey-headed flying-fox, Ben Major grevillea, swamp skink and Strzelecki warm temperate rainforest.[1049] The numbers of at-risk species and communities varied across regional forest agreement regions, with 11 in the North East, 12 identified in the Central Highlands, 19 in the West, 24 in Gippsland and 25 in East Gippsland.

PV has identified nine main ecosystems that could be potentially impacted by climate change in Victoria (Table B10).

1047. Parliament of Victoria Legislative Council Environment and Planning Committee 2020, 'Inquiry into ecosystem decline in Victoria', Melbourne, Victoria.
1048. Research Centre for Applied Alpine Ecology 2020, 'Why should we care about snow in the mountains?', https://rcaae.org/2020/11/17/why-should-we-care-about-snow-in-the-mountains/ Accessed 23 August 2022.
1049. Department of Environment Land, Water and Planning (DELWP) 2020, 'Threatened species and communities risk assessment, Victoria's regional forest agreements', Melbourne, Victoria.

Table B10: Potential impacts of climate change on Victoria's nine main ecosystems.

Ecosystem	Impacts of climate change
Wetlands and waterways	• Decreased rainfall, river flows and groundwater levels reduce the extent and condition of wetlands • Changing flooding cycles and declining river flows decline, affecting fish, other animals and aquatic plants and changing flooding cycles • Increasing river water temperatures and declining dissolved oxygen lead to fish deaths and algal blooms • Permanent wetlands may become seasonal • Increased fire frequency damages peatlands and adds to sediment loads in wetlands and waterways • Rising sea levels flood coastal or led to saltwater intrusion
Grasslands	• Replacement of grasses by woody plants • Reduced resilience to other threats • Changing composition of herbaceous ground layer from perennial to annual grasses • Loss of moisture-dependent plants
Mallee	• Exacerbate habitat loss, fragmentation and other threats • If rainfall intensity increases, shallow groundwater levels may increase leading to soil salinity. Intense rainfall could also increase soil erosion. • Create new niches for invasive plants and increase vulnerability to defoliation by insect attack • Increased fire frequency affects species composition and may encourage weed invasion • Reduced habitat for species dependent on old growth trees
Heathlands	• Reduced rainfall affects flower production, seed set, seedling establishment and nutrient cycling which then affects food for mammals and nectar-dependent birds • Increased fire frequency affects species composition and may encourage weed invasion
The Alps	• Declining snow cover and volume increases vulnerability of snow-dependent fauna, such as the mountain pygmy possum. • Reduced extent or disappearance of alpine wetlands and reduced waterbird breeding • Increased fire frequency and severity changes plant composition (e.g. alpine ash unable to reach maturity and produce seed) and mammal abundance (e.g. southern brown bandicoots which need rarely burnt habitat) • Dieback of tree canopy (e.g. snow gums due to infestations of longicorn beetles encouraged by warmer conditions) • Environmental weeds and invasive animals encouraged by warmer conditions, as are pathogens and diseases • Species at high altitudes will be unable to move higher to escape rising temperatures
Dry forests and woodlands	• Increased fire frequency and severity • Changes in species composition, growth rates, flowering times and regeneration capacity • Reduced soil moisture • Reduced food supply for forest-dependent species • Reduced habitat for species dependent on old growth trees
Wet forests and rainforests	• Increased fire frequency and severity, resulting in transition to drier ecosystems • Reduced canopy cover and drier conditions on forest floor • Invasion by plant species suited to drier conditions • Reduced habitat for species dependent on old-growth trees
Coast	• Rising sea levels increase coastal erosion and inundation with the loss of mangroves, saltmarsh, seagrass and sand dunes, along with and cultural heritage sites • Loss of habitat for marine and coastal species • Saltwater intrusion into estuaries
Marine	• Increased water temperatures • Ocean acidification • Changes in strength of ocean currents • Migration of marine species to the south • Changes in marine food webs by changing the productivity of phytoplankton and zooplankton

Conservation and community engagement

Released in April 2017, Biodiversity 2037 is the Victorian Government's policy response to addressing the decline in the state's biodiversity.[1050] It presents a long-term vision for Victoria's biodiversity supported by two goals: 'Victoria's natural environment is healthy' and 'Victorians value nature'. Biodiversity 2037 sets targets for both goals with contributing targets.

The overarching target for the goal 'Victoria's environment is healthy' is a 100% change (on average) in suitable habitat in 50 years for threatened species, with co-benefits for non-threatened species. Intermediate targets, listed below, provide performance measures relevant to the overarching target and include the suite of contributing targets (covered in indicators B:28, B:30, B:32, B:36 and B:38):

- a net improvement in the outlook across all species by 2037 as measured by change in suitable habitat
- no vulnerable or near threatened species will have become endangered
- that all critically endangered and endangered species will have at least one option available for being conserved ex-situ or re-established in the wild (where feasible under climate change) should they need it
- a net gain of the overall extent and condition of habitats across terrestrial, waterway and marine environments.

The statewide targets associated with 'Victorian's value nature' are that, by 2037:

- all Victorians connecting with nature
- five million Victorians acting to protect the natural environment
- all Victorian Government organisations that manage environmental assets contribute to environmental-economic accounting.

Along with these targets, Biodiversity 2037 has a Monitoring, Evaluating, Reporting and Improvements (MERI) Framework with targets, actions and key performance indicators.[1051] The Biodiversity Knowledge Framework is a major element of the MERI Framework and supports the identification of knowledge gaps to better target investment in biodiversity research, monitoring and data collection.

Biodiversity 2037 has also been developed to ensure that Victoria's biodiversity policies and actions are consistent with national biodiversity strategies and complement the UN Sustainable Development Goals and Aichi Biodiversity Targets. Maintaining ecosystem health and biodiversity is of crucial importance to human wellbeing.

The five indicators in this section include two that are Biodiversity 2037 indicators (another three were in the previous 'Threats and responses' sub-theme). The other three consider progress towards increased conservation on public land, how Victorians are valuing nature and the integration of data reporting by government agencies.

1050. Department of Environment Land, Water and Planning (DELWP) 2017, 'Protecting Victoria's environment: Biodiversity 2037', Melbourne, Victoria.
1051. Department of Environment Land, Water and Planning (DELWP) 2017, 'Biodiversity 2037 monitoring, evaluation, reporting and improvements framework (MERF)', Melbourne, Victoria.

Indicator B:36 New, permanently protected areas on private land

B:36 New, permanently protected areas on private land						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide		?		New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator
Data source(s):	DELWP, Trust for Nature					
Measure(s):	Achievement of the Biodiversity 2037 target for new, permanently protected areas on private land					

Why this indicator?

To achieve a comprehensive, adequate and representative protected areas network, which is a national goal, Victoria must fill a gap of 2.1 million hectares. In some regions, the filling of that gap can only be achieved by establishing permanent protection of native vegetation on private land. This indicator assesses progress on filling that gap and is also a Biodiversity 2037 indicator.

NB: This is a new SoE 2023 indicator formed by merging the SoE 2018 indicators 'B:07 The conservation and management of Victorian ecosystems on private land', 'L:10 Land management activities' and disaggregating 'B:21 Area of management in priority locations' into five separate indicators.

Criteria used for status assessment

Good: ≥75% of the annual target for 10,000 hectares of new, permanently protected areas on private land is met
Fair: 50% to <75% of the annual target for 10,000 hectares of new, permanently protected areas on private land is met
Poor: <50% of the annual target for 10,000 hectares of new, permanently protected areas on private land is met

Why this assessment in 2023?

Trust for Nature continues to slowly expand the number of its reserves and works with landowners to establish covenants to secure native vegetation on their properties. CMAs as well as Landcare and other organisations also work with landholders to improve the conservation and management of biodiversity on private land. Although there have been small increases in permanent protection on private land, the achievements in the two years since the release of Biodiversity 2037 are below its targets. The available data are insufficient to determine trend.

Summary of State of the Environment 2018 Report assessment

- New SoE 2023 indicator

Critical data used for the 2023 assessment

- Trust for Nature's Annual Reports
- Trust for Nature Statewide Conservation Plan 2021-2030

2023 assessment

Victoria is the most-cleared state in Australia, with 66% of native habitat removed since 1835.[1052] On private land, which covers approximately 62% of Victoria, 80% of native habitat has been lost.[1053, 1054] Almost 90% of the ecological vegetation classes that are poorly represented in parks and reserves are found on private land.[1055] However, only 1% to 2% of private agricultural land is managed for conservation, for example, native vegetation protection, revegetation and livestock exclusion, with only 0.5% being managed under a conservation agreement.[1056] The way in which private land is used and managed in the future will be critical in Victoria's efforts to secure, restore and conserve biodiversity.

1052. Trust for Nature 2020, 'Trust for Nature: Covenanting for conservation' https://connectingcountry.org.au/the-concept-of-covenanting-for-conservation/ Accessed 7 May 2021.
1053. Trust for Nature, 'Statewide conservation plan for private land in Victoria', https://trustfornature.org.au/wp-content/uploads/2020/11/Trust-for-Nature-Statewide-Conservation-Plan.pdf Accessed 3 August 2023.
1054. The proportion of Victorian land that is private was reported as 57.6% in the SoE 2018 Report. Trust for Nature, which focusses on the conservation of biodiversity on private land, now reports it as being 62%. This should not be interpreted as an increase; it is a recalculation of the spatial extent of private land.
1055. Trust for Nature, 'Victoria's ecosystems' https://trustfornature.org.au/resources/victorian-ecosystems/ Accessed 7 May 2021.
1056. Victorian National Parks Association (VNPA), 'Private land conservation', https://vnpa.org.au/future-parks/private-land-conservation/ Accessed 9 May 2021.

Biodiversity

Trust for Nature (the Trust) was established by an Act of Parliament in 1972, with a mission to protect and restore biodiversity on private land across Victoria. Since then, Trust for Nature has secured more than 100,000 hectares of native habitat. This includes 72,906 hectares in 1,567 covenants on private land, and another 36,000 hectares in 43 reserves owned by the Trust [1057, 1058]

The Trust for Nature Revolving Fund was the first of its kind established in Australia and enables the Trust to engage in the property market to buy and sell land for conservation benefit. The proceeds from the sale of Trust properties are deposited in the revolving fund, which is used to purchase other properties and then on-sell them with a conservation covenant. The proceeds from these sales are returned to the Revolving Fund. Since 1972, the Trust has bought 79 properties and sold 74 and, in doing so, has protected 7,084 hectares.[1059] In 2021-22, the total value of the revolving fund was $4,056,486.

Trust for Nature's 10-year Statewide Conservation Plan 2021-2030 includes spatially explicit targets for six conservation objectives and associated goals focusing on terrestrial and aquatic ecosystems and priority species on private land.[1060] The overarching objective of the conservation plan is 'to achieve an additional 100,000 hectares of permanently protected habitat on private land by 2030, through direct or enabled protection.' This is to support the Victorian Government's objective under Biodiversity 2037 to achieve 200,000 hectares of new, permanently protected areas on private land the revegetation of 200,000 hectares in priority areas for increasing connectivity between habitats by 2037.

Trust for Nature's Statewide Conservation Plan has identified 18 focal landscapes representing 2,099,189 hectares of land, of which 89% (1,872,970 ha) is on private land. In total, these landscapes encompass:

- 13.5% of all private land in Victoria
- 62% of the Trust's protected areas (including both covenants with landholders and Trust properties) on private land
- representation of every under-represented Interim Biogeographic Regionalisation for Australia bioregion and subregion in Victoria, together comprising 89% of the private-land extent
- 36% of all native vegetation remaining on private land in Victoria
- 40% of the extent of under-represented EVCs occurring on private land
- 45% of the extent of climate refuges occurring on private land.

Although the Trust for Nature and DEECA have been working to significantly increase the area of native vegetation that is conserved on private land, the outcomes are currently well below the annual target of 10,000 hectares needed to meet the Biodiversity 2037 target of 200,000 hectares of new, permanently protected areas on private land (Table B11).

The BushBank program is seeking to restore and protect 20,000 hectares of habitat on private land across targeted areas of Victoria and contribute to a reduction in carbon emissions. As the approved delivery partner, Cassinia Environmental will work with DEECA, Trust for Nature and more than 20 other partners to assist private landowners to enter the land restoration and carbon markets. Grants will also be made to Traditional Owners to participate in habitat restoration and carbon markets.[1061] How much of this restored land will be permanently protected is currently unknown.

Table B11: Priority new permanently protected areas on private land in Victoria.[1062]

Indicator measures	2018-19	2019-20
Total annual hectares of action statewide	3,601	5,373

1057. Trust for Nature 2021, 'Annual report 2020-21', Melbourne, Victoria.
1058. Ibid.
1059. Ibid.
1060. Trust for Nature 2021, 'Statewide conservation plan 2021-2030', Melbourne, Victoria.
1061. Department of Energy, Environment and Climate Change (DEECA), 'BushBank program', https://www.environment.vic.gov.au/bushbank Accessed 30 January 2023.
1062. Department of Environment, Land, Water and Planning (DELWP), 'Unpublished data', Melbourne, Victoria, Accessed 2022.

Indicator B:37 The conservation of Victorian ecosystems on public land

B:37 The conservation of Victorian ecosystems on public land						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	Fair (yellow)	Stable (→)	High (green)	Fair (yellow)	Stable (→)	Good (green)
Data source(s):	DELWP, PV					
Measure(s):	Progress towards a comprehensive, adequate and representative protected area network					

Why this indicator?

Protected areas, such as national parks and reserves on public land, are the main driver of nature conservation in Victoria and a key indicator for biodiversity health.

NB: This indicator was 'B:08 Conservation of Victorian ecosystems' in the SoE 2018 Report.

Criteria used for status assessment

Good: ≥75% of the annual target of 100,000 hectares to achieve a comprehensive, adequate and representative protected area network by 2037 is met

Fair: 50% to <75% of the annual target of 100,000 hectares to achieve a comprehensive, adequate and representative protected area network by 2037 is met

Poor: <50% of the annual target of 100,000 hectares to achieve a comprehensive, adequate and representative protected area network by 2037 is met

OR

Good: ≥75% of the annual target of 350,000 hectares to meet the 30% by 2030 is met

Fair: 50% to <75% of the annual target of 350,000 hectares to meet the 30% by 2030 is met

Poor: <50% of the annual target of 350,000 hectares to meet the 30% by 2030 is met

Why this assessment in 2023?

The spatial extent of the protected area network has changed little in recent years and continues to constitute nearly 18% of Victorian lands. There remains a gap of 2.1 million hectares between the current parks estate and what is needed for a comprehensive, adequate and representative network.

Summary of State of the Environment 2018 Report assessment

- In the parks managed by PV, the top three endangered ecological vegetation divisions were high-altitude alpine sphagnum bogs and associated fens, closed-forest, and damp scrub.
- The three Victorian bioregions with the poorest representation of EVCs in protected areas were the Strzelecki Ranges, Gippsland Plain and Central Victorian Uplands.

Critical data used for the 2023 assessment

- State of the Parks Report 2018
- Other PV data

2023 assessment

Many of Victoria's high conservation value areas are within the statewide protected area network on public land managed by PV. There are 45 national parks that cover more than 11% of the state, while the entire network covers 17.6% of the state.

The Australian Government has committed to protecting 30% of lands and seas by 2030 in its Threatened Species Action Plan.[1063]

1063. Department of Climate Change, Energy, the Environment and Water (DCCEEW) 2022, '2022-2032 Threatened species action plan: Towards zero extinctions', Canberra, Australian Capital Territory.

Biodiversity

In December 2022, the Convention of the Parties (COP 15) of the UN Convention on Biodiversity Conservation agreed on the following goals to be achieved by 2030:

- effective conservation and management of at least 30% of the world's lands, inland waters, coastal areas and oceans, with an emphasis on areas of particular importance for biodiversity and ecosystem functioning and services
- restoration to be completed or underway on at least 30% of degraded terrestrial, inland waters, and coastal and marine ecosystems
- reduction in the loss of areas of high biodiversity importance to near zero, including ecosystems of high ecological integrity.[1064]

The effective conservation and management of 30% of land by 2030 figure is one target used when assessing this indicator. Currently 17.6% (3,996,874 ha) of Victoria's land surface is within the protected area network.[1065] To achieve the target would require an additional 2,826,438 hectares to be included, or more than 350,000 hectares added, each year. It should be noted that the Australian Government's commitment to 30% protection by 2030 does not make any reference to ecosystem types or their representation across bioregions, nor is there clarity on what approach or measures may contribute to the target's achievement. In addition, the Victorian Government has not made any announcement about a commitment to meeting the 30% by 2030 target.

An alternative target is to bridge the gap of 2.1 million hectares by 2037, the final year of Biodiversity 2037. The gap is the difference between the existing protected areas network and what is required for it to become comprehensive, adequate and representative. To do this would require about an additional 100,000 hectares be given protection each year (from 2017, when Biodiversity 2037 was released).

A consideration of total hectares within the existing and future protected area network in Victoria should not ignore the needs of individual EVCs. VEAC analysed shortfalls in the representation of EVCs in protected areas across the state's bioregions, using the JANIS criteria as a measure for the level of representation. The JANIS criteria, which were agreed to by Commonwealth and state jurisdictions in 1997 as part of the regional forest agreements process, require at least 15% of the pre-1750s extent of each forest ecosystem be included in protected areas.[1066] The VEAC analysis identified three clusters where there were shortfalls in the representation of EVCs in protected areas:

- South west cluster comprised of the Glenelg Plain and Dundas Tablelands bioregions and the western part of the Wimmera bioregion, and could also include the Warrnambool Plain and western part of the Victorian Volcanic Plain
- Strzelecki Ranges and Gippsland Plain bioregions cluster
- Central Victorian Uplands bioregion cluster comprised of the Central Victorian Uplands bioregion and could also include adjoining bioregions with significant shortfalls, such as the Northern Inland Slopes, Goldfields and Highlands-Southern Fall bioregions.

Assessments in the 'Ecosystem health sub-theme' reviewed the bioregional conservation status and extent of protection for EVCs across multiple bioregions in riparian vegetation (status of poor), floodplains (poor), grasslands (poor), alpine areas (fair), the Mallee (fair) and heathlands (fair). Endangered and vulnerable EVCs were common, and many EVCs will have to rely on their conservation on other public land or private land to reach 30% coverage in the protected area network and to be given improved representation.

Priority 18 of Biodiversity 2037 is to maintain and enhance a world-class system of protected areas. However, protection levels for Victoria's ecosystems have been largely stable since then, with only small additions to the protected areas network. In 2020, national park protection was given to 3,076 hectares of the Kuark Forest in East Gippsland where it was included in Errinundra National Park.

1064. Convention on Biological Diversity 2022, 'Nations adopt four goals, 23 targets for 2030 in landmark UN Biodiversity Agreement', Media release, 19 December 2022.
1065. Department of Climate Change, Energy, the Environment and Water (DCCEEW), 'Terrestrial CAPAD 2020 Vic summary' https://www.dcceew.gov.au/environment/land/nrs/science/capad/2020 Accessed 21 July 2022.
1066. Joint ANZECC/MCFFA National Forest Policy Statement Implementation Sub-committee 1997, 'Nationally agreed criteria for the establishment of a comprehensive, adequate and representative reserve system for forests in Australia', Canberra, Australian Capital Territory.

In response to the 2019 VEAC Central West Investigation recommendations, the Victorian Government committed to new national parks (incorporating two existing State parks), conservation parks, and nature and bushland reserves in the central west of Victoria (Central Victorian Uplands bioregion) in June 2021, which will lead to a 50,000-hectare net increase in protected areas. The new national parks will be the Wombat-Lerderderg National Park of approximately 44,700 hectares, the Pyrenees National Park of 15,126 hectares and the Mount Buangor National Park of 5,282 hectares.

Two of the new national parks will include existing state parks which are already recognised as protected areas, hence, the net addition in protected areas equals approximately 50,000 hectares. However, the new parks are yet to be legislated and gazetted, and timber harvesting continues in some areas of the proposed parks. There are currently no other proposals by the Victorian Government to further expand the protected area network. The combined total of the Kuark Forest's protection and the yet-to-be gazetted parks mentioned above is approximately 53,000 hectares, which represents an increase of almost 11,000 hectares per year (or in total an increase of 0.002% of the state included in the network). This is well short of the target required to bridge the gap of 2.1 million hectares by 2037, and further behind what would be required to increase the coverage of the protected area network to 30% of the state's land area by 2030.

The gap of 2.1 million hectares could, in part be filled by increasing the protection of native vegetation on private land, the target for which is 200,000 hectares (or 10,000 hectares per year) by 2037. However, the assessment of indicator 'B:36 New, permanently protected areas on private land' shows that the Victorian Government is well short of achieving that target. Were the target to be achieved, a gap of 1.9 million hectares would still remain.

The Victorian Government has committed to ending the harvesting of timber in native forests by 2030. This has now been brought forward to the beginning of 2024 due to the impact on timber supply of the 2019-20 bushfires and court decisions that found some state timber harvesting operations illegal under environment legislation. The end of timber harvesting occurring in state forests, which cover an area of 3.14 million hectares and includes eucalypt forests and woodlands (1.8 million ha were subject to the Timber Harvesting Allocation Order), provides opportunities for the expansion of the conservation estate.[1067, 1068, 1069]

In its media release on the cessation of timber harvesting, the Government stated that it:

> 'will establish an advisory panel to consider and make recommendations to Government on the areas of our forests that qualify for protection as National Parks, the areas of our forests that would be suitable for recreation opportunities — including camping, hunting, hiking, mountain biking and four-wheel driving — and opportunities for management of public land by Traditional Owners.' [1070]

Recommendation 7 in this SoE 2023 Report recommends that the Victorian Government commission VEAC to investigate and recommend additions to the protected area network to support the achievement of Priority 18 in Biodiversity 2037, which is to maintain and enhance a world-class system of protected areas. This will include accelerating the establishment of new, permanently protected areas on private land, especially in high-priority ecosystems and landscapes.

Figure B24 shows that state forests and parks and reserves adjoin in most areas. Expansion of the protected areas network to meet protection targets could be achieved by incorporating state forests into existing parks and reserves. In addition, the Greater Glider Action Statement, released in 2019, gave protection to more than 96,000 hectares of forest (Immediate Protection Areas) across Victoria that were exempt from logging.[1071] These areas could also be added to the state's conservation estate.

1067. Department of Energy, Environment and Climate Change (DEECA), 'Forests and reserves' https://www.forestsandreserves.vic.gov.au Accessed 14 January 2023.
1068. Government of Victoria 2023, 'Delivering certainty for timber workers', Joint media release by the Victorian Premier and the Minister for Agriculture, Minister for Regional Development, Minister for Environment and the Member for Eastern Victoria, 23 May 2023, https://www.premier.vic.gov.au/delivering-certainty-timber-workers Accessed 15 June 2023.
1069. Department of Energy, Environment and Climate Change (DEECA), 'Forests and reserves' https://www.forestsandreserves.vic.gov.au Accessed 14 January 2023.
1070. Ibid.
1071. Department of Environment, Land, Water and Planning (DELWP) 2019, 'Action statement no. 267 greater glider (*Petauroides volans* subsp. *volans*)', Melbourne, Victoria.

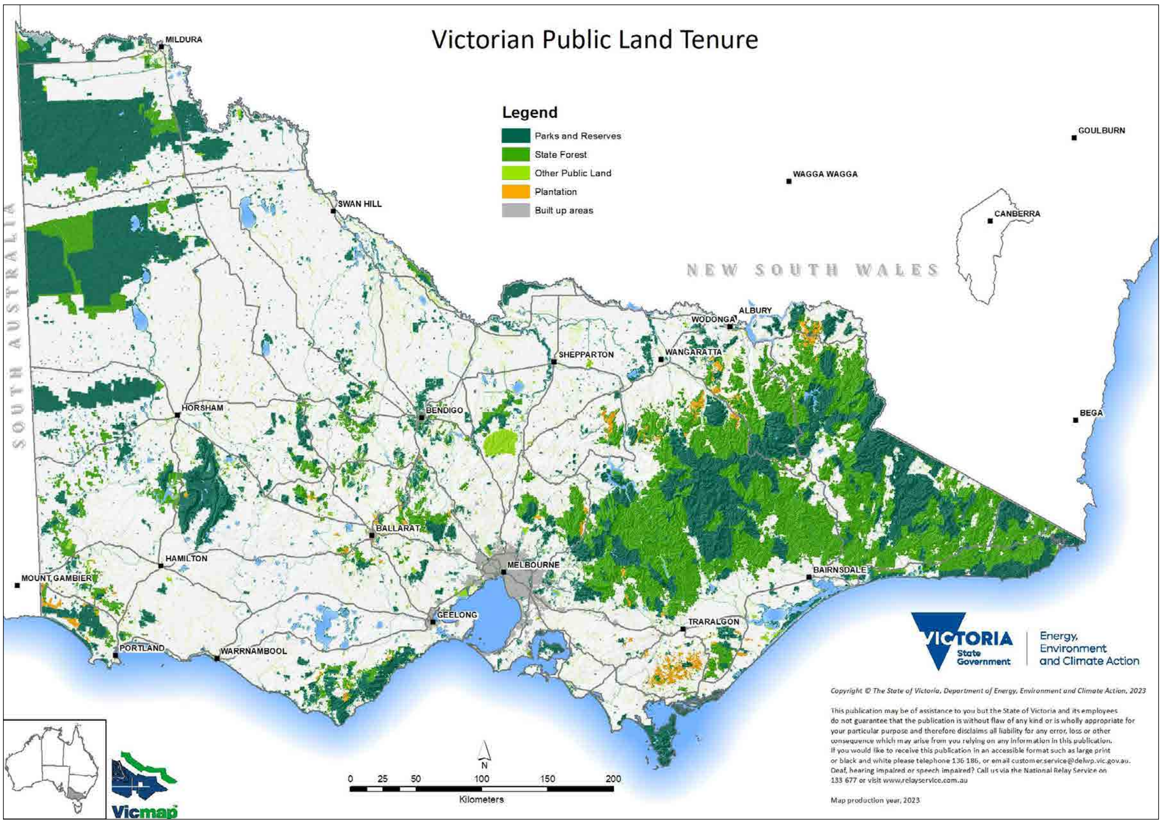


Figure B24: Land tenure in Victoria for 2023.[1072]

The spatial extent of the protected area network is one measure for this indicator's assessment. Another is the health of the areas within the network. According to park managers surveyed for the State of the Parks 2018 Report, the condition of terrestrial systems in the park estate were rated as good or very good in 54% of the parks.[1073] The most common threats to the park estate were identified as weeds and pest animals.[1074] For weeds, the threat was largely rated as moderate, with small areas in the far north-west and south-east and along the Murray River rated as major.

Figure B25 maps the severity of pest animals across the park estate. Their impact was rated as extreme for parks in the north-east and major in the north-west, south-east and in the Grampians. Since 2013, however, the impacts had increased in the north-east, south-west and south-east, although the situation was improving in the north-east. Park managers were also asked about the impact of fire on conservation values in the park estate. Figure B26 was mapped before the 2019–20 bushfires, although some parks were experiencing an increasing impact from fire. The 2019-20 bushfires resulted in:

- 425,094 hectares of national parks and reserves impacted by fire, including 285,462 hectares affected by high-severity fires
- 25 national parks and reserves and 36 other parks and reserves having between 90% to 100% of their area burnt
- five EPBC listed and eight FFG listed communities impacted
- more than 100 native flora and fauna species having 80% or more of their habitat impacted.[1075]

1072. Department of Energy, Environment and Climate Action (DEECA) 2023, Unpublished data', Melbourne, Victoria.
1073. Parks Victoria (PV) 2018, 'State of the parks 2018 report', Melbourne, Victoria.
1074. Ibid.
1075. Department of Environment Land, Water and Planning (DELWP) 2020, 'Victoria's bushfire emergency: biodiversity response and recovery Version 2', Melbourne, Victoria.

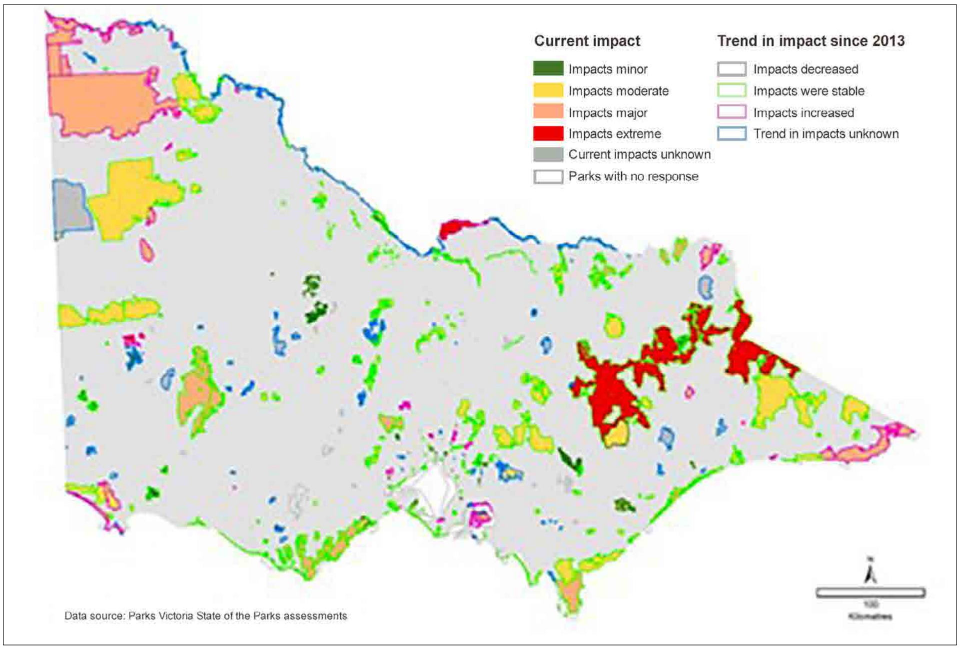


Figure B25: Impact of pest animals on the park estate of Victoria since 2013.[1076]

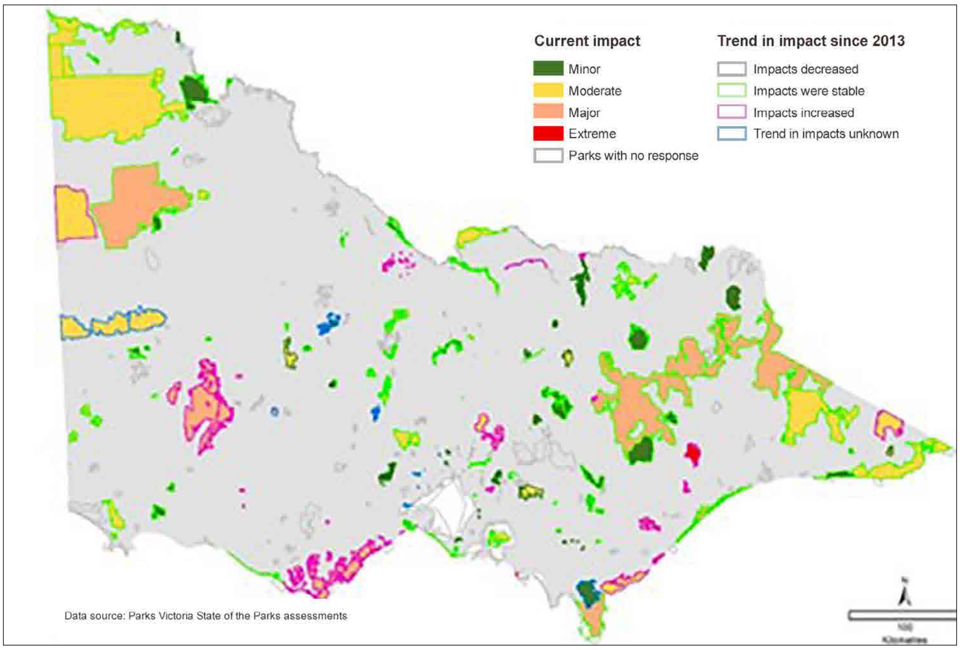


Figure B26: Impact of fire on conservation values in the park estate of Victoria since 2013.[1077]

The State of the Parks 2018 Report also found that there had been a decline in the control of impacts from invasive species and visitors, a decline in meeting nature conservation objectives in terrestrial parks and nature conservation reserves, poor to very poor stream condition in some landscapes, and a high number of management plans that were more than 15 years old. Since the report, PV has implemented weed, pest animal and habitat restoration for a number of parks as well as developed conservation action plans, reduced threats to high-priority conservation values, and finalised management plans.[1078]

1076. Parks Victoria (PV) 2018, 'State of the parks 2018 report', Melbourne, Victoria.
1077. Ibid.
1078. Parks Victoria (PV), 'Summary of relevant Parks Victoria and governmental initiatives developed since the 2017-2018 State of the Parks assessment,' https://www.parks.vic.gov.au/-/media/project/pv/main/parks/documents/get-into-nature/conservation-and-science/state-of-the-parks-fourth-edition/updates-since-the-state-of-the-parks-fourth-edition.pdf?la=en&rev=8ea1ebf9e813458795552c72b37e07ae&hash=3B26DC2A775AD3DDFFF31574D73D886F4F8CBC17 Accessed 30 January 2023.

Indicator B:38 Priority revegetation

B:38 Priority revegetation						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?		New SoE 2023 indicator	New SoE 2023 indicator	New SoE 2023 indicator
Data source(s):	DELWP					
Measure(s):	Area (ha) of revegetation in priority locations for connectivity between habitats					

Why this indicator?

The loss of habitat is a major factor in the decline in abundance and distribution of native species and their increasingly threatened status. Revegetation can expand and link habitats, and benefit culture, agricultural productivity and recreation. This indicator measures progress in revegetation and is also a Biodiversity 2037 indicator.

NB: This is a new SoE 2023 indicator. Priority revegetation was one of five measures considered within 'B:21 Area of management in priority locations' in the SoE 2018 Report. The five measures of the SoE 2018 indicator have been disaggregated into five separate indicators in this report to better target each priority response.

Criteria used for status assessment

Good: ≥75% of the target for priority revegetation is met

Fair: 50% to <75% of the target for priority revegetation is met

Poor: <50% of the target for priority revegetation is met

Why this assessment in 2023?

Insufficient data were available to determine status or trend for this indicator.

Summary of State of the Environment 2018 Report assessment

- New SoE 2023 indicator

Critical data used for the 2023 assessment

- The available data were insufficient for this assessment

2023 assessment

Biodiversity 2037 has a target of 200,000 hectares of revegetation in priority locations by 2037. To achieve that target requires an annual revegetation area of 10,000 hectares. Table B12 provides spatial data on priority revegetation for the two years from 2018-19 and 2019-20, which also shows that actual outcomes are below the target. However, there are insufficient data to determine status or trend.

Table B12: Revegetation in priority locations in Victoria for 2018-19 and 2019-20.[1079]

Indicator measures	2018-19	2019-20
Total Annual Hectares of Action Statewide (Priority and Non-Priority Locations)	7,274 since 2017	9,135 since 2017
Annual Hectares of Action in Non-Priority Locations	7,211	9,061
Annual Hectares of Action in Priority Locations	63 since 2017	74 since 2017

1079. Department of Environment, Land, Water and Planning (DELWP), 'Unpublished data', Melbourne, Victoria, Accessed 2022.

The shortfall in revegetation has seen the Victorian Government launch the Bush Bank program in April 2022 which is aimed at rapidly expanding biodiversity restoration and carbon capture on private land. In September 2022, the delivery partner for the program, Cassinia Environmental, was chosen to:

> 'help private landholders to revegetate parcels of land and restore our precious biodiversity to an area five times the size of the City of Melbourne. Cassinia will secure co-funding in excess of the Government's investment and has in principle support to leverage more than $50 million of co-funding in partnership with a range of organisations including Land Life Company, South Pole, Greenfleet, WWF-Australia, Global Evergreening Alliance and One Tree Planted.' [1080]

The initial target for revegetation is 20,000 hectares and includes habitat restoration for threatened species, such as Major Mitchell's cockatoo, red tailed black cockatoo, mallee fowl, southern brown bandicoot and long-nosed potoroo.

Native seed collection and propagation

The Royal Botanic Gardens Victoria established the Victorian Conservation Seedbank in 2005. It now houses the seeds of more than 1,000 plant species and 50% of Victoria's threatened plant species. The seeds can be used for research, propagation and the translocation of plant species.

Seed banks are also found in the Wimmera, Murray Mallee, Goulburn Broken, Portland and Ballarat regions, each supplying native seed to revegetation projects.[1081] For example, the Goulburn Broken Indigenous Seedbank is a not-for-profit seedbank established in 2001 and part of the Euroa Arboretum. Its mission is to provide genetically healthy seed to support landscape restoration activities.[1082]

To meet Biodiversity 2037 targets for revegetation will require large volumes of native seeds. However, there are several issues facing the sector, as identified by Broadhurst, Waters and Coates (2017), including:

- a limited supply of seed
- reliance on a small number of species for seed collection
- seed collection mostly conducted from existing native vegetation 'despite longstanding concerns regarding the sustainability of this practice and the globally recognised impacts of vegetation fragmentation on seed production and genetic diversity'
- reliance on federal, state and local government funding
- lack of national standards.[1083]

In 2021, Greening Australia established Project Phoenix, A Strategy for the Australian Native Seed Sector.[1084] The strategy was in response to the challenges that faced the seed collection sector, including the impact of the 2019-20 bushfires on native vegetation and the need for restorative action. Project Phoenix has two core objectives:

- The full diversity of Australian native plant species and their genetics need to be available for future generations and active use.
- The Australian native seed sector needs to attract, retain and grow the resources to sustain its skills and capacity to respond when required.

1080. Premier of Victoria 2022, 'Regenerating ten thousand MCGs of habitat', Minister for the Environment and Climate Change, media release, 4 September 2022.
1081. Seeding Victoria, 'Seeding Victoria seedbanks', https://www.seedingvictoria.com.au/cb_pages/seed_banks.php Accessed 7 June 2021.
1082. Goulburn Broken Catchment Management Authority (CMA), 'Goulburn Broken indigenous seedbank https://www.gbcma.vic.gov.au/our-region/land_and_biodiversity/resources_publications/goulburn_broken_indigenous_seed_bank Accessed 10 May 2021.
1083. Broadhurst L, Waters C, Coates D 2018, 'Native seed for restoration: A discussion of key issues using examples from the flora of southern Australia', *The Rangeland Journal*, 39(6), pp. 487-498.
1084. Greening Australia 2021, 'Project Phoenix: A strategy for the Australian native seed sector', Melbourne, Victoria.

Indicator B:39 Victorians value nature

B:39 Victorians value nature						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide	(Target 1: All Victorians are connected to nature) (Target 2: More than five million Victorians acting for nature)					
Data source(s):	DELWP					
Measure(s):	Achievement of targets for 'Victorians value nature': • Target 1: All Victorians are connected to nature • Target 2: More than five million Victorians are acting for nature					

Why this indicator?

'Victorians value nature' is one of two goals for Biodiversity 2037. The goal has two targets: 'All Victorians are connected to nature' and 'More than five million Victorians are acting for nature'.

NB: This SoE 2023 indicator was 'B:22 Victorians value nature' in the SoE 2018 Report.

Criteria used for status assessment

Good: ≥75% of the target for 'Victorians value nature' is met

Fair: ≥50 to <75% of the target for 'Victorians value nature' is met

Poor: <50% of the target for 'Victorians value nature' is met

Why this assessment in 2023?

The 2019–20 bushfires and the COVID-19 pandemic have restricted the people's engagement in nature-based activities and the achievement of targets under Biodiversity 2037. Surveys show that the target of 'More than five million Victorians acting for nature, has been met' while there has been a shortfall in meeting the target for 'All Victorians connected to nature'.

Summary of State of the Environment 2018 Report assessment

- There was an estimated 100,000 Victorians participating in environmental volunteering each year across diverse volunteer groups and mostly structured programs. These include citizen science programs, marine and coastal volunteers, water programs, Landcare, 'Friends' groups, parks volunteers, outdoor enthusiast groups, Zoos Victoria, climate change and sustainability networks, gardening, wildlife programs, corporate volunteering, not-for-profits, and local government and government agency programs.

Critical data used for the 2023 assessment

- Updated DELWP data

2023 assessment

Target 1: All Victorians are connected to nature

DELWP has developed a 'connection to nature' instrument, the CN-12, to measure progress towards achieving the 'All Victorians are Connected to Nature' target. This 12-question instrument has been used in the 2019, 2020 and 2021 Victorians Volunteering Naturally Statewide surveys, and was applied to recalculate the results of the first survey from 2018 (see 'The CN-12 questions' below). The CN-12 scores are on a scale of 1 to 7 (1 is a weak connection with nature, 5 is moderate and 7 is a high connection).

The 2018 survey was open to any respondents over 18 years of age and aimed to be representative of the Victorian public with respect to age, gender, and geographical location. The 2019, 2020 and 2021 surveys prioritised resampling a subset of the respondents who completed the 2018 survey. New respondents were also recruited to meet the target sample size to help address gaps in representation of the Victorian population. Table B13 summarises the data and reveals that up to 66% of Victorians connected to nature between 2018 and 2021.

Table B13: Number of Victorians connected to nature between 2018 and 2021.[1085]

	2018	2019	2020	2021
Number of Victorians surveyed	3090	1141	1024	1521
Mean CN-12 score* (± SD)	5.23 (±1.03)	5.26 (±1.05)	5.28 (±1.09)	5.37 (1.02)
Estimated percentage of Victorians reporting a score above 5 (moderate to very high connections with nature score)	62%	63%	61%	66%

* *Average score for the 12-question connection to nature instrument.*

The CN-12 questions

Identity dimension questions

1. I think of myself as someone who is very concerned about taking care of nature
2. My relationship to nature is a big part of how I think about myself
3. I feel uneasy if I am away from nature for too long
4. I feel right at home when I am in nature
5. Feeling connected to nature helps me deal with everyday stress

Experience dimension questions

6. I feel a strong emotional connection to nature
7. I enjoy spending time in nature
8. I like to get outdoors whenever I get the chance
9. Being in nature allows me to do the things I like doing most

Philosophy dimension questions

10. Everything in nature is connected (e.g. animals, plants, humans, water, air, land, fire, etc.)
11. Human beings and nature are connected by the same 'energy' or 'life-force'
12. Human wellbeing depends upon living in harmony with nature.

1085. Department of Environment, Land, Water and Planning (DELWP), 'Unpublished data', Melbourne, Victoria, Accessed 2022.

Target 2: 5 million Victorians acting for nature

DELWP identified six headline actions to understand the actions that Victorians could engage in and which were likely to have the most impact on biodiversity. These selected actions contributed to calculating the acting for nature target, which is 5 million Victorians acting for nature. The headline actions are:

- planting trees, providing habitat, or removing weeds outside of your property (on-ground volunteering)
- planting trees, providing habitat, or removing weeds on your own property (wildlife gardening)
- advocating for the environment (personally or through support of advocacy organisations)
- collecting data for citizen science projects (e.g. Water Watch, Frog Census, Aussie Backyard Bird Count)
- picking up other people's litter (when visiting parks or natural areas)
- being a responsible pet owner (e.g. containing your cat, complying with dog leashing regulations).

'Acting for nature' is defined as engaging in these headline actions 'sometimes', 'often' or 'very often' on a scale of 'never' to 'very often.' In the case of pet ownership behaviours, owners were included only if they 'always' did these behaviours. Table B14 summarises the results and shows that more than five million Victorians acted for nature, exceeding the Biodiversity 2037 target. However, the level of positive impact on biodiversity will vary across these headline actions.

Table B14: Number of Victorians acting for nature between 2018 and 2021.[1086]

	2018	2019	2020	2021
Sample (n)	3090	1141	1024	1521
Victorian population (ABS Data for June)	6,418,168	6,530,852	6,606,149	6,548,040
Estimated percentage of the Victorian population engaging in at least one headline action	84% (5.39 million)	82% (5.36 million)	75% (4.96 million)	82% (5.45 million)
Estimated percentage of the Victorian population engaging in at least two headline actions	61% (3.92 million)	59 (3.86 million)	41% (2.17 million)	58% (3.85 million)

Table B15 breaks down these numbers as a percentage of survey respondents (sample n = 152) according to their responses to the headline statements. For the on-ground volunteering headline statement, 24.2% of the population engaged 'sometimes', 'often' or 'very often', for citizen science 17%, for advocacy 30.7%, for litter 60.1% and for wildlife gardening 57.6%. In population terms, based on the June 2021 population of 6,548,040 Victorians, on-ground volunteering engaged 1.6 million Victorians, citizen science 1.1 million, advocacy 2.0 million, litter 4.5 million and wildlife gardening 3.7 million Victorians.

Table B16 provides data on five headline actions for 2018, 2019 and 2021. Except for the low figure for wildlife gardening in 2021, the numbers are reasonably stable.

For cat owners surveyed in 2021, 14.7% provided no cat containment, 28.4% partial containment and 56.9% complete containment, up from 53% in 2020. Similarly, 43.2% of dog owners were leashing compliers in 2021, up from 32.4% in 2020.

1086. Department of Environment, Land, Water and Planning (DELWP), 'Unpublished data', Melbourne, Victoria, Accessed 2022.

Table B15: Percentage of 2021 survey respondents engaging in the five of the headline actions.[1087]

Frequency of engagement	On-ground volunteering (%)	Citizen science (%)	Advocacy (%)	Litter (%)	Wildlife gardening (%)
Never	60.6	75.0	53.7	22.2	31.4
Rarely	15.3	8.1	15.6	17.7	11.1
Sometimes	16.3	11.1	19.7	39.9	24.8
Often	6.0	4.6	9.2	14.7	20.3
Very Often	1.9	1.3	1.8	5.5	12.6

Table B16: Percentage of survey respondents engaging in the five headline actions either sometimes, often or very often during 2018, 2019 and 2021.[1088]

Headline action	2018	2019	2021
On-ground volunteering	23.2%	20.6%	24.2%
Citizen science	18.2%	20.9%	17.0%
Advocacy	27.8%	24.8%	30.7%
Litter	58.2%	53.3%	60.1%
Wildlife gardening	65.7%	66.6%	57.6%

1087. Department of Environment, Land, Water and Planning (DELWP), 'Unpublished data', Melbourne, Victoria, Accessed 2022.
1088. Ibid.

Indicator B:40 Number of Victorian Government organisations that manage environmental assets that contribute to DELWP Standard Output Data

B:40 Number of Victorian Government organisations that manage environmental assets that contribute to DELWP Standard Output Data						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?			?	
Data source(s):	DELWP					
Measure(s):	Percentage of NRM organisations that manage environmental assets that contribute to Standard Output Data					

Why this indicator?

The target is for 100% of organisations to contribute Standard Output Data. This aims to ensure that all data for the management of environmental assets are collected and reported to DEECA to provide a statewide picture of the outputs.

Criteria used for status assessment

Good: ≥75% of the target for the number of Victorian Government organisations that manage environmental assets that contribute to DELWP Standard Output Data is met

Fair: ≥50% to <75% of the target for the number of Victorian Government organisations that manage environmental assets that contribute to DELWP Standard Output Data is met

Poor: <50% of the target for the number of Victorian Government organisations that manage environmental assets that contribute to DELWP Standard Output Data is met

Why this assessment in 2023?

The SoE 2018 Report showed that only 12% of Victorian Government organisations that manage Victoria's natural assets have contributed to environmental-economic accounting. Data were unavailable for determining the status and trend in 2023.

Summary of State of the Environment 2018 Report assessment

- This indicator's target is to have 100% of Victorian Government organisations that manage environmental assets contributing to DELWP Standard Output Data
- A total of 12% of Victorian Government organisations who manage Victoria's natural assets had contributed some data. In most cases, the data were incomplete and did not reflect all on-ground works those organisations had delivered or funded.

Critical data used for the 2023 assessment

- New data were unavailable for this indicator

2023 assessment

New data were unavailable for the assessment of this indicator.

Caption: Kangaroo, Woowookarung Regional Park 2017.
Credit: Peter Kervarec. © Parks Victoria.

Commissioner
for Environmental
Sustainability
Victoria

Land (L)

Victorian State of the Environment 2023 Report

Rural land in The Murray, makers and creators 2020.
Credit: Rob Blackburn.

Key findings

Land use and land health are inextricably linked. The types of land use, and changes in their spatial extent or management, can either improve or degrade land cover and land health. The indicators in this chapter assess land health — soil carbon storage, soil erosion, soil acidity and dryland salinity — and the natural resource management (NRM) actions being undertaken by government agencies, Traditional Owners, scientists, farmers, land managers and community organisations to maintain, restore and improve it (Table L1).

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

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

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

By changing land management to sequester carbon in soil, agriculture can help mitigate climate change. However, the science indicates that there is still much to learn about soil carbon, and how to measure, store and increase it. The Commonwealth and Victorian governments have developed carbon-farming projects to encourage farmers to sequester carbon in their soil, a process that could take at least 25 years if it is to be successful.[1089]

Dryland salinity is receding in the state's northern river basins that flow into the Murray River, due to improved land management and a major reduction in groundwater levels caused by the Millennium Drought (1998–2009). Dry years lower the groundwater levels and reduce the volume of saline groundwater discharged to the land surface. As a result, the area of dryland salinity is reduced. The reverse occurs in wet years. Although wet years have recharged much of the groundwater lost, groundwater discharges have not returned to previous levels.

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

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

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

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

1089. Robertson F, Nash D 2013, 'Limited potential for soil carbon accumulation using current cropping practices in Victoria', Agriculture, Ecosystems and Environment, 165, pp. 130-140, https://www.sciencedirect.com/science/article/abs/pii/S0167880912004276 Accessed 9 June 2023.

Table L1: Land indicators assessed in this chapter with comparisons to SoE 2018 assessments.

Land

2023 Indicator	2023 status	2023 trend	2023 confidence
L:01 Land-cover classes in Victoria	N/A	N/A	Grey
L:02 Changes in Victoria's land-cover classes	Red	?	Green
L:03 Changes in land tenure	N/A	→	Grey
L:04 Greenfield and infill development in Melbourne	Yellow	↙	Yellow
L:05 Soil organic carbon storage	Grey	?	Grey
L:06 Area affected by dryland salinity	Yellow (Murray River catchment) Grey (elsewhere)	↗ (Murray River catchment) ? (elsewhere)	Yellow (Murray River catchment) Grey (elsewhere)
L:07 Soil acidification	Grey	?	Grey
L:08 Soil erosion	Green (wind) Yellow (water)	?	Red
L:09 Contaminated sites	Yellow	?	Red
L:10 Participation in natural resource management activities	Green	↗	Green
L:11 Use of best practice for sustainability outcomes on agricultural lands	Grey	↗	Grey

2018 Indicator	2018 status	2018 trend	2018 data quality
L:01 Land-use types in Victoria	Yellow	N/A	Green
L:02 Changes in major land uses in Victoria	N/A	→	Green
L:03 Changes in land tenure	Yellow	→	Green
L:04 Greenfield and infill development in Melbourne	Yellow	→	Green
L:05 Soil organic carbon storage	Grey	?	Yellow
L:06 Area affected by salinity	Yellow (Murray River catchment) Grey (elsewhere)	↗ (river catchments that drain to the Murray River) ? (elsewhere)	Yellow (Murray River catchment) Red (elsewhere)
L:07 Soil acidification	Grey	?	Yellow
L:08 Soil erosion	Yellow	↙	Red
L:09 Contaminated sites	Grey	?	Yellow
L:11 Participation in natural resource management activities	Green	↗	Green
L:12 Use of best practice on agricultural lands	Grey	?	Red

Victorian Government progress on State of the Environment 2018 Report recommendations

The State of the Environment (SoE) 2018 Report included recommendations to the Victorian Government to improve environmental sustainability outcomes. Presented below is the recommendation specific to this theme as well as:

- the full government response to the recommendations, including the level of support, as published in the Victorian Government Response to the State of the Environment 2018 Report
- a description of progress made on the implementation of the recommendation over the past five years. No information was provided by Government in relation to the progress on this recommendation. Instead, the content of this section is derived from the synthesis of information that is publicly available in referenced reports, legislation and websites. Importantly, this section summarises the progress made since 2018 in relation to the recommendation; it is not an audit of the extent and quality of the completed work.

Recommendation 7 of the SoE 2018 Report recommended:

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

Government response in 2020:

SUPPORT IN PRINCIPLE

1090. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Victorian Government response to the state of the environment 2018 report', Melbourne, Victoria.

'The Victorian Government agrees that soil and land condition underpins agricultural productivity and maintenance of healthy ecosystems. The Government also recognises that improved soil conditioning and monitoring systems could allow private land managers to understand the impacts of a more variable climate including extremes of temperature, rainfall and wind and improve the decision-making processes used by farmers, other land managers and policy makers.' [1090]

'Agriculture Victoria has a long-term strategy to enhance Victorian agriculture's global competitiveness, innovation and resilience. Key initiatives underpinning this strategy and delivering on long-term objectives for soil health and land condition include:

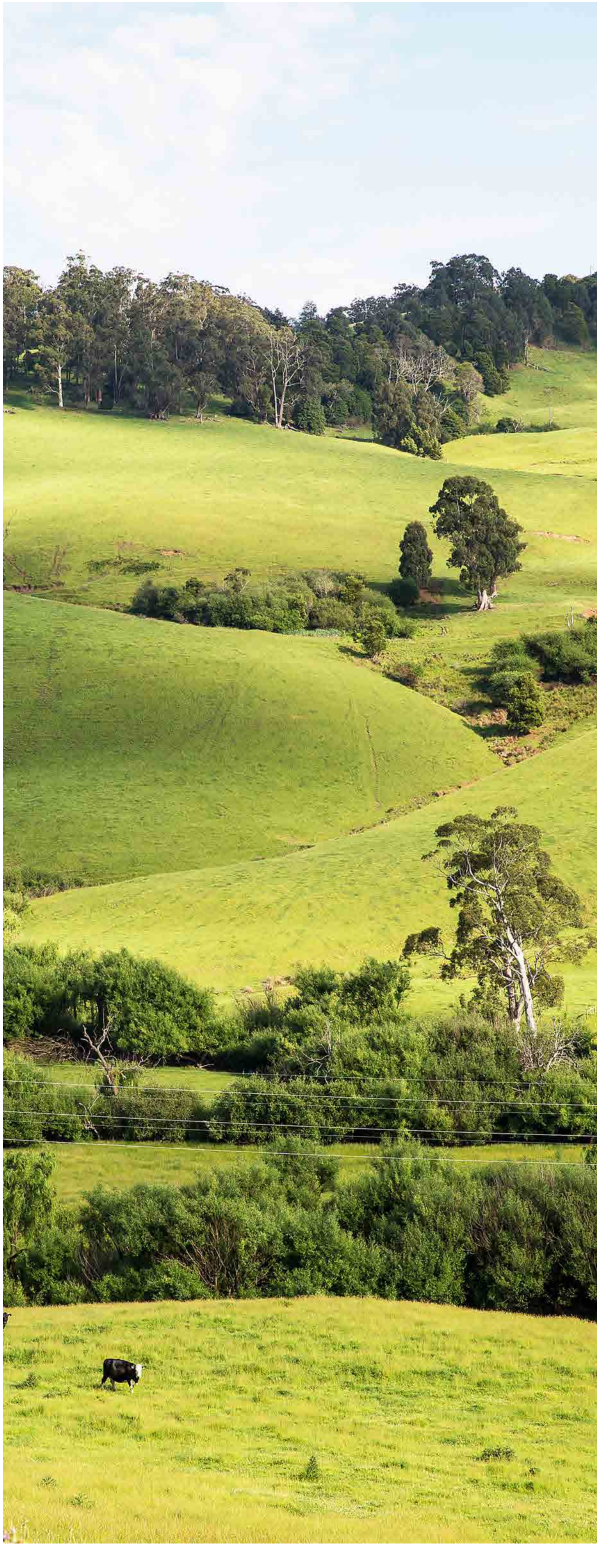
- The National Soil Research, Development and Extension Strategy: This strategy coordinates soils research, development and extension that meets the needs of stakeholders. Agriculture Victoria is a member of the Australian Soil Network who coordinates this strategy. A key initiative under the strategy is to resolve soil data systems issues and data sharing arrangements via a national Soil Information Facility. Agriculture Victoria Research is also part of the Australian Collaborative Land Use and Management Program. This partnership ensures national approaches to land use and land management practices data for Australia. Complementing national initiatives, Agriculture Victoria Research has created a Soil Application Programming Interface that increases access and utility of Victoria's land and soil data and is the custodian of Victoria's soil data.
- Grains 21: This is Agriculture Victoria Research's strategy for the grains sector. As part of this strategy, Agriculture Victoria Research partners with industry investors including the Grains Research and Development Corporation and agribusinesses to undertake research and innovation to improve adaptation and resilience of grain production systems. This includes research that considers multiple soil constraints. This research is developing new sensors and diagnostic technologies that accurately map soils, identifying where, when and in what combinations soil constraints reduce crop yields.

- The Land Health Program: This program supports private land managers to adopt practices which improve the management of soil, water and vegetation on their land; minimise on and off-site impacts to priority natural assets; manage risks relating to climate change and land use; and reduce the impacts of natural disasters through preparation and accelerated recovery.' [1091]

'The design of a national or statewide monitoring system is a complex task that would require research partners from across governments, industry, universities, CSIRO and the Cooperative Research Centre for High Performing Soils to allocate and prioritise significant resources over a long period of time. Agriculture Victoria will continue to work with key stakeholders to ensure positive and tangible outcomes for soil health. While Agriculture Victoria recognises the potential future benefit of a new soil and land condition monitoring system, delivery of such a monitoring program would need to be cost-effective, adequately resourced and not duplicate existing activity.' [1092]

Progress made since 2018

It appears that no progress has been made in relation to establishing the arrangements recommended in the SoE 2018 Recommendation 8. However, there have been developments that could support the implementation of a statewide monitoring and mapping program (Recommendation 8 in this report). These include the 'Strong, Innovative and Sustainable: A new strategy for agriculture in Victoria', the declaration of distinctive areas and landscapes, the reforms associated with the proposed Public Lands Act and the implementation of the Climate Adaptation Plans for the built environment, education and training, health and human services, natural environment, primary production, transport, and the water cycle sectors under the *Climate Change Act 2017*.



Grand Ridge Road, Gippsland 2017.
Credit: Josie Withers. © Visit Victoria.

1091. Department of Environment, Land, Water and Planning (DELWP) 2020, 'Victorian Government response to the state of the environment 2018 report', Melbourne, Victoria.
1092. Ibid.

Land

Background

Victoria's land stretches across 22.8 million hectares. [1093] National parks, conservation reserves and forest reserves cover 39.8% of the state and primary production 51.8%.[1094] The remaining land area is used for residential areas, roads, infrastructure, industry and commerce.

Most public land is managed by the Department of Energy, Environment and Climate Action (DEECA), Parks Victoria, 79 local councils (managing 3,000 reserves) and 1,200 committees of management with more than 8,000 volunteers (managing 1,500 reserves).[1095]

Private land covers approximately 62% of Victoria.[1096,1097] Agriculture is the dominant use, with mixed farming and grazing (23.2 % of Victoria), cropping (16.5%) and livestock grazing and production (8.4%).[1098] Victorian agriculture comprises more than 20,000 farm businesses, 77,000 jobs, an annual production value of $16 billion, and a $7 billion contribution to the state's economy each year. Victoria is Australia's leading producer of milk, sheep meat, wool, fruit and nuts, table and dried grapes, and the number one exporter of dairy, sheep meat, wool, horticulture, poultry and food and fibre.[1099]

Victoria's development since the early 1800s has led to extensive clearing of the land. According to the Australian State of the Environment 2021 Report: 'Land clearing can also lead to processes that degrade soils, such as erosion, salinisation, loss of organic matter and depleted fertility. Native vegetation clearing in Australia is driven mainly by expansion of land dedicated to agriculture and, to a lesser extent, forestry and infrastructure, including urban development.'[1100]

The two forms of salinity that affect soil in Victoria are dryland and irrigation salinity. They both interact with underground salt deposits formed over geological time from rock erosion and ocean deposition. Irrigation salinity is caused by irrigation raising the water table and bringing ancient salt to the surface. Where the land has been cleared, there is less vegetation to use the rain that falls. The rain seeps deeper underground, the water table rises, brings salt to the surface and leads to land degradation.

Each year, CMAs assess the condition of the land in their regions and rate the 5-year trend as either positive, neutral or concerned, and rate the condition as either good, moderate, poor or unknown. The most recent CMA assessments are presented in Table L2, which shows that half of the 10 CMAs rated the 5-year trend for their land condition as neutral, three as concerned, one as good and another as positive. In terms of overall condition, two were rated as good, seven as moderate and one unknown. Their positive comments about land condition included increased total vegetation cover and reduced soil exposure due to wet years, and improved land management practices, while negative comments included declining native vegetation, poor health of public land and the legacy of past land clearing.

Land health and good land management are critical to biodiversity, agricultural productivity and public health outcomes through the protection of drinking-water catchments and urban greening and cooling to reduce the urban heat island effect. Adopting sustainable land-use and management practices can help improve the status of the indicators assessed in this chapter.

1093. Victorian Environmental Assessment Council (VEAC) 2017, 'Statewide assessment of public land discussion paper', Melbourne, Victoria.
1094. Ibid.
1095. Department of Environment Land, Water and Planning (DELWP) 2021, 'Realising the value of public land. Renewing Victoria's public land legislation', Melbourne, Victoria.
1096. Trust for Nature, 'Statewide conservation plan for private land in Victoria', https://trustfornature.org.au/wp-content/uploads/2020/11/Trust-for-Nature-Statewide-Conservation-Plan.pdf Accessed 3 August 2023.
1097. The proportion of Victorian land that is private was reported as 57.6% in the SoE 2018 Report. Trust for Nature, which focusses on the conservation of biodiversity on private land, now reports it as being 62%. This should not be interpreted as an increase; it is a recalculation of the spatial extent of private land.
1098. Department of Economic Development, Jobs, Transport and Resources (DEDJTR), 'Victorian Land Use Information System 2016-17', Melbourne, Victoria.
1099. Agriculture Victoria (AgVic) 2021, 'Victorian agriculture industry overview', Melbourne, Victoria.
1100. Commonwealth of Australia 2021, 'Australian state of the environment', Canberra, Australian Capital Territory https://soe.dcceew.gov.au/ Accessed 7 June 2023.

Land

Table L2: CMA assessments of land condition and trend in their region in 2022.[1101]

CMA	5-year trend	Condition	Comment
Corangamite	Concerned	Moderate	Decreased soil exposure. Declining native vegetation and expansion dryland cropping and hardwood plantations. Working to enhance sustainable agricultural practices
East Gippsland	Good	Good	High seasonal rainfall increased soil cover. Pressures from agriculture and development on small percentage of land
Goulburn Broken	Neutral	Moderate	Land health improvement plateaued. This is in part due to historical land management practices (such as vegetation clearing and fuel reduction burning), current land management practices not alleviating soil structural issues (such as compaction and low soil carbon), emerging issues (such as subsoil acidity) and the increasing impact of climate. Public land health poor. Increasing pressure from visitors, illegal firewood collection, rubbish, feral grazing
Glenelg Hopkins	Neutral	Moderate	Exposed soil low. Productive agricultural area. Challenge for managing impacts of land use
Mallee	Neutral	Moderate	Dryland: Improvements in vegetation cover and soil health over past 30 years. Impacts continue, however. Total Vegetation Cover exceeded targets, however dry conditions reduced soil cover and led to erosion and declines in soil health. Dryland farmers continuing to adopt best-practice management. Need ongoing support. Irrigated land: improved management practices have decreased subsurface drainage and reduced salinity.
North Central	Positive	Moderate	Additional protection and restoration works. Good management. Sustainable agriculture. La Nina improved soil moisture, Total Vegetation Cover and agricultural productivity
North East	Concerned	Moderate	Ongoing soil health challenges due to post-colonisation land use, bushfires and climate change. Intensification of agriculture from dryland to irrigation; increased use of groundwater in agriculture
Port Phillip and Westernport	Concerned	Unknown	Biodiversity declining due to urban expansion, invasive species and climate change
West Gippsland	Neutral	Moderate	Increased soil moisture due to wet year. No droughts, fires or outbreaks of pests. Variable weather conditions. Area covered by landholder agreements and management plans increased. Deer expanding distribution. Conversion to large-scale horticulture and urbanisation (increased runoff)
Wimmera	Neutral	Good	Low levels of soil exposure. Landholders continuing to manage ground with no-till cropping, stubble retention and rotational grazing. Industry support for farmer capacity to improve resilience of land.

1101. Department of Energy, Environment and Climate Change (DEECA) 2022, 'Draft catchment condition report 2021-22', Melbourne, Victoria.

Land

Policy and legislative settings

Legislation that influences the use of private and public land includes that which covers agriculture, forestry, conservation, and rural and urban planning.

The *Environment Protection Act 2017* (EP Act) includes provisions regarding the structure, functions and powers of the Environment Protection Authority (EPA) Victoria. EPA Victoria is responsible for protecting Victoria's land from pollution and waste. It monitors industry and administers the environmental audit system and the Priority Sites Register. [1102] As part of its role, the authority provides land guidance to businesses, including identifying and assessing site contamination and managing risk. The *Environment Effects Act 1978* requires the environmental effects of certain types of works to be assessed prior to commencement.

The *Plant Biosecurity Act 2010* provides for the prevention, monitoring, control and eradication of plant pests and diseases; the packaging, labelling and description of plants and plant products; and facilitates the movement of plants, plant products, used packages, used equipment and earth material within, into and out of Victoria. The *Plant Biosecurity Act* is one of three key statutes covering plant and animal biosecurity, with the others being the *Livestock Management Act 2010* and the *Livestock Disease Control Act 1994*. Consultation is currently underway on proposals by the Victorian Government to reform the legislation relating to animal biosecurity, plant biosecurity, and the management of pests relating to biosecurity.

The *Planning and Environment Amendment (Distinctive Areas and Landscapes) Act 2018* enables the government to declare distinctive areas and landscapes. After declaration, a Statement of Planning Policy must be prepared for the area and could include long-term settlement boundaries being introduced. Four areas have thus far been declared: Bass Coast, Bellarine Peninsula, Surf Coast and the Macedon Ranges.

The Victorian Government is to consolidate three existing Crown Land Acts *(Crown Land (Reserves) Act 1978, Forests Act 1958 and Land Act 1958)* with a new Public Land Act. Public engagement on a consultation paper occurred in 2021 and a consultation summary capturing the key feedback received was released in 2022. Work continues to finalise the policy to guide the development of the renewed legislation.

It is proposed that the reformed legislation would:

- advance Traditional Owners' self-determination in relation to public land
- support communities realise the value of public land through the appropriate use of public land
- provide appropriate tools to support the management of public land, including responding to future emergencies and crises to ensure community safety on public land.[1103]

The key elements of the new Public Land Act would be:

- a simplified legislative framework, with clear objectives for public land management and setting out public land management (decision-making) principles
- simple and clear public land categories and accompanying purposes
- a modernised public land manager framework
- contemporary public land management tools
- a streamlined framework for tenures (e.g. leases and licences) and other authorisations
- modernised compliance, enforcement and regulation provisions.

Concurrent with the review of the Crown Land Acts, it is proposed to refine the Victorian National Parks Act 1975, which will operate alongside the new Public Land Act.

The portfolio of the Department of Energy, Environment and Climate Action (DEECA) includes more than 100 major agencies and 1,200 small committees of management of Crown Land reserves. Climate change, energy, waterways and water resources, biodiversity, fire management and public land management are the key themes in the work of the department's divisions.

1102. The Priority Sites Register is a list of sites where EPA Victoria has issued a notice requiring active management to clean up, monitor, or prevent pollution of land and/or groundwater contamination e.g. improvement notice, prohibition notice, environmental action notice or site management order.
1103. Department of Environment Land, Water and Planning (DELWP) 2021, 'Realising the value of public land. Renewing Victoria's public land legislation', Melbourne, Victoria.

Land

The Victorian Government Land Use Policy and Guidelines released in 2017 establish a framework that enables a strategic, whole-of-government approach to government land-use decision-making to maximise public value for Victorian communities from government land use. [1104] The policy identifies Strategic Land Use Assessments as a process by which land-use options are considered and public value can be assessed. Strategic Land Use Assessments provide a structured process to gather, analyse and assess the relevant evidence to support good land-use decision-making.

Land Use Victoria is part of DEECA and is the state's key agency for land registration, spatial data services and maps, surveying, government land policy and advice, and land transaction oversight. Within Land Use Victoria, the Victorian Government Land Monitor independently analyses proposed government land transactions to ensure fairness and transparency.

Victoria's ten CMAs are responsible for the integrated planning and coordination of land, water and biodiversity management in their region through regional catchment strategies. The Regional Catchment Strategies Outcomes Framework aims to ensure a consistent approach and enable CMAs to demonstrate how regional outcomes align with state policies.

Agriculture Victoria (AgVic) scientists, agronomists, economists and veterinarians conduct research and deliver programs to support the growth of the state's agriculture. The agency also provides land management advice directly to primary producers and administers grants and programs that can benefit local communities and agricultural investment and infrastructure.

Plan Melbourne 2017-2050 is a strategic framework for guiding the growth and development of Melbourne. [1105] It sets the strategy for supporting jobs, housing, and transport, while building on Melbourne's legacy of distinctiveness, liveability and sustainability. It supports the productive use of land and resources in Melbourne's non-urban areas and provides policy to protect agricultural land and support agricultural production in Melbourne's green wedge and peri-urban areas. The Plan Melbourne 5-Year Implementation Plan includes relevant action on supporting strategic planning for agriculture, reviewing green wedge planning provisions and Green Wedge Management Plans.

Victoria's eight planning regions each have a regional growth plan which gives broad direction to regional land use and development and are reviewed every four to six years.

A number of other key statutes of relevance to the indicators assessed in this chapter are described in the 'Policy and legislative settings' section of the 'Biodiversity' chapter. These are the: Catchment and Land Protection Act 1994, Conservation, Forests and Lands Act 1987, Flora and Fauna Guarantee Act 1988, Wildlife Act 1975, National Parks Act 1975, Planning and Environment Act 1987 and the Victorian Environment Assessment Council Act 2001.

The Victorian Conservation Trust Act 1972 established the Trust for Nature, which seeks to expand the conservation of significant habitat and species on private land. To increase the incentives for landholders to conserve native vegetation on their land, those who have an existing Trust for Nature conservation covenant or who establish one will be exempt from land tax from 1 January 2024.[1106]

The Strong, Innovative and Sustainable: A New Strategy for Agriculture in Victoria was released in 2020 with five themes: Recover, Grow, Modernise, Protect and Promote. The Protect theme focuses on protecting agriculture from climate change, pests, weeds and pathogens, and 'sustainability' is focussed on maintaining and growing agriculture to be a resilient and significant sector in the state's economy.

Climate Adaptation Plans, a requirement of the Climate Change Act 2017, have now been prepared for seven sectors: built environment, education and training, health and human services, natural environment, primary production, transport, and the water cycle.

1104. Land Use Victoria 2017, 'Victorian Government land use policy and guidelines', Department of Environment, Land, Water and Planning (DELWP), Melbourne, Victoria.
1105. Department of Environment, Land, Water and Planning (DELWP) 2017, 'Plan Melbourne 2017-2050', Melbourne, Victoria.
1106. State Revenue Office (SRO) 2023, 'State Budget 2023-24 announcement', Melbourne, Victoria.

Indicator assessments

Refer to 'Guide to the indicator assessments' at the start of Part 3 for the accompanying definitions and legends related to the indicator assessment summary tables.

SoE indicator suite adjustments

State of the environment indicators are the foundational tools for evaluating and communicating the impact our activities have on the environment. The assessments of SoE 2018 indicators provided a scientific baseline of the state of Victoria's environment from which future SoE reports build upon.

However, as new pressures, challenges and data sources emerge, the SoE indicator suite must also evolve to ensure their collective assessments provide a comprehensive account of the condition of Victoria's natural values. The SoE 2023 indicator suite has been adjusted, with some indicators either being disaggregated to improve the focus of assessments, merged to enable inter-connected indicators to be evaluated as a whole, or modified in terms of the scope, breadth of measures or to align with policy targets. Refer to Appendix C of the Summary Report for a complete account of the changes that have been made to the SoE 2018 indicator suite in this report.

Changes to the indicator suite for this chapter are outlined below.

- The SoE 2018 indicators 'L:10 Land management activities' and 'L:11 Participation in natural resource management activities' have been merged to form the modified SoE 2023 indicator 'L:10 Participation in natural resource management activities'.
- The SoE 2018 indicators 'L:12 Use of best practice on agricultural lands' and 'L:13 The proportion fo agricultural area under productive and sustainable agriculture' have been merged to form the modified SoE 2023 indicator 'L:11 Use of best practice for sustainability outcomes on agricultural land'.

Land

Indicator L:01 Land-cover classes in Victoria

L:01 Land-cover classes in Victoria						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	N/A	N/A	(grey)	(yellow)	N/A	(green)
Data source(s):	AgVic, DELWP					
Measure(s):	Percentage of Victoria's area classified by each land-cover class					

Why this indicator?

This indicator monitors the mix of land-use and land-cover classes in Victoria, which can influence land health.

Why this assessment in 2023?

Land-cover classes associated with human activities have continued to increase, while natural land-cover classes have continued to decline. However, there are no clear targets regarding a desirable mix of land-cover classes, which prevents an assessment of status.

Summary of State of the Environment 2018 Report assessment

- Half of Victoria's land use is defined as primary production, which includes mixed farming and grazing, cropping and livestock grazing.
- Most of the remaining area of the state comprises national parks, conservation areas and state forests

Critical data used for the 2023 assessment

- DELWP 2020 data for the 2015-19 epoch
- Victorian Land-cover Time Series

2023 assessment

Although the land-cover classes associated with agriculture, urban areas and nature conservation are relatively stable in their percentage of Victoria's land mass, the spatial extent and intensity of individual agricultural uses can vary from year to year depending on such matters as market prices and the weather. However, in general, land-cover classes associated with human-based activities have continued to increase, while natural land-cover classes have continued to decline.

The mix of uses, and the way those uses are managed, directly influences the degree to which land health and biodiversity are impacted. Healthy land is critical to the future of agriculture in Victoria. The notable American conservationist Aldo Leopold defined land health as 'the capacity for self-renewal in the soil, water, plants, and animals that together make up the land.'[1107]

The growth of urban areas, the spread of invasive plants and animals, and the expansion of agriculture have led to the loss of native vegetation and significant degradation of Victoria's land health after European settlement. Large areas of Victoria have been affected by soil erosion, soil acidification and dryland salinity. Further, the use of fertilisers and herbicides/insecticides have impacted water quality and natural food webs. These impacts, although better managed, persist to different degrees today. Urban expansion also impacts land health through land clearance, the generation of stormwater, wastewater and hard waste, and the pollution of local waterways and land. Although the other major form of land use in the state, nature conservation, generally maintains land health, it can be impacted by invasive plants and animals.

1107. The Aldo Leopold Foundation, 'Caring for land following Leopold' https://www.aldoleopold.org/visit/the-land/ Accessed 11 September 2022.

Land

Data on land-use classes are limited. Land-cover classes have been used as a proxy and are mapped in Figure L1. The distribution of each land-cover class in the 2015-19 epoch shows that dryland cropping dominates north-western Victoria, 'Exotic pasture/grassland' in south-western and north-eastern Victoria and South and West Gippsland, while 'Treed native vegetation' covers much of eastern Victoria and is scattered in the Grampians, Central Highlands, Otway Ranges and the far north-west and south-west of the state.

Government agencies, including CMAs, and community organisations have been working over the past few decades to reverse that damage and to prevent it occurring in the future. The next indicator (L:02) considers how land-cover classes are changing in Victoria.

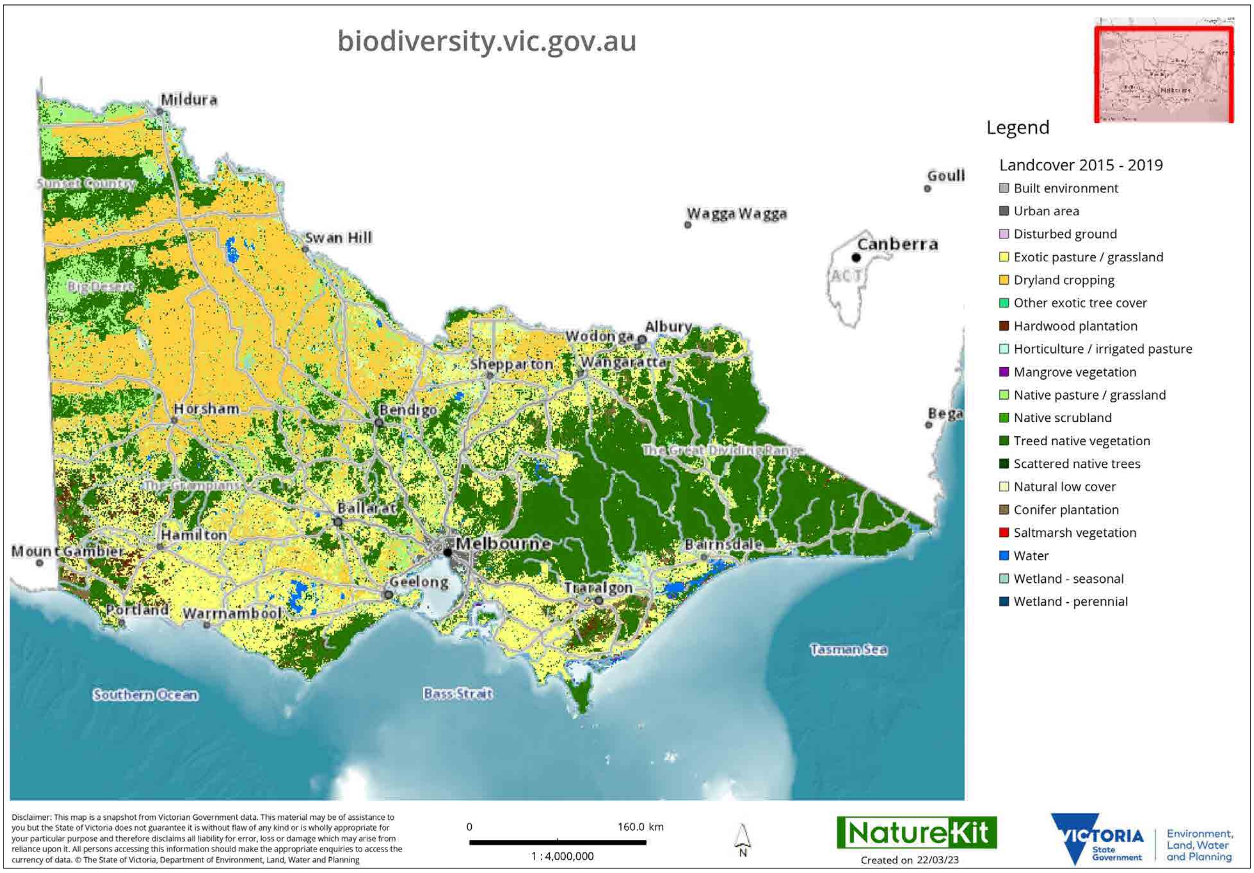


Figure L1: Land-cover classes during the 7th epoch (2015-19).[1108]

1108. Department of Environment Land, Water and Planning (DELWP), 'NatureKit', https://maps2.biodiversity.vic.gov.au/Html5viewer/index.html?viewer=NatureKit Accessed 17 July 2022.

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

L:02 Changes in Victoria's land-cover classes						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	Red	?	Green	N/A	→	Green
Data source(s):	AgVic, DELWP					
Measure(s):	Changes in the mix and spatial extent of Victoria's land-cover classes					

Why this indicator?

Monitoring change in land cover can provide a statewide view of the loss of natural areas and threats to biodiversity, and guide policy and on-ground action.

NB: This SoE 2023 indicator was 'L:02 Changes in major land uses in Victoria' in the SoE 2018 Report and investigated land-use changes rather than changes in land-cover classes.

Why this assessment in 2023?

Analysis of DELWP's Land Cover Time Series across Victoria shows an increased area of land-cover classes that are development-based and an overall decrease in those that are nature-based. The long-term trend has been evident across the seven epochs since 1985 and has placed more pressure on Victoria's biodiversity. However, it is not possible to determine a 2023 trend until data on the 8th epoch are released.

Summary of State of the Environment 2018 Report assessment

- 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.
- A preference for living in coastal or rural areas close to Melbourne is resulting in the loss of natural ecosystems and agricultural land.
- Status was not determined because the data did not pertain to environmental condition.

Critical data used for the 2023 assessment

- DELWP 2020 data for the 2015-19 epoch
- Victorian Land-cover Time Series

2023 assessment

Indicator 'B:01 Changes in land cover' also considers change in land cover over seven epochs beginning in 1985-90 (1st epoch), with the most recent in 2015-19 (7th epoch). In general, the evidence demonstrates that landscapes associated with human-based activities have continued to increase, while natural landscapes have continued to decline.

Table L3 lists and describes each of the 19 land-cover classes in the time series, while Figure L2 provides more detail on percentage increases and decreases in land-cover classes across Victoria over the seven epochs (the coloured bars represent different epochs under each land-cover class). The next time epoch, the eighth, will be released in 2025 and covers the period 2020-24.

Table L4 presents data on the spatial extent in hectares for each land-cover class across the seven epochs. It shows that, in the 1st epoch (1985-90), the urban land-cover class stretched across 189,343 hectares. However, by the 7th epoch (2015-19), this land-cover class had expanded by 54% to 291,316 hectares. In contrast, native grass herb reduced from 2,281,518 hectares in the 1st epoch (1985-90) to 2,005,135 hectares in the 7th epoch (2015-19), a decline of 12%.

Land-cover classes that demonstrated the greatest increase in spatial extent from 1985 to 2019 were exotic woody, built-up, urban, hardwood plantation, and disturbed ground. By contrast, those land-cover classes that experienced the greatest level of decrease were native shrub, wetland perennial, wetland seasonal and native scattered trees.

The proportion that each land -cover class represents in the statewide mix has also changed between the 1st epoch (1985-90) and 7th epoch (2015-19; Table L5). For example, the proportion of total land cover represented by dryland cropping has increased from 19% to 22%, while the pasture not native land-cover class has decreased from 25% to 22%. This illustrates the trend in which farmers have been replacing cereal crops and annual pasture rotations with more intensive cropping and the growing of pulses and oil seeds such as canola. Urban has increased from less than 1% to slightly more than 1%, and that expansion has led to the loss of grasslands, which has also occurred in the western suburbs of Melbourne as the city continues to expand to accommodate population growth. Intermittent and seasonal wetlands are now occupying a smaller proportion of the Victorian landscape, due to drainage, cropping and climate change, along with native shrub and native scattered trees.

In general, it can be said that land-cover classes associated with human-based activities have continued to increase, while native vegetation cover has declined. However, the picture varies when the data are analysed at the regional scale.

Table L6 summarises the percentage change in land cover classes on a statewide basis and in each CMA region between the 1st and 7th epochs. The greatest level of decline in spatial extent has been generally in the natural land-cover classes, however, the CMA level demonstrates significant variation in the percentage change. For example, the native scattered trees land-cover class declined by 9% in the Corangamite CMA region between the 1st and 7th epochs, whereas in the West Gippsland CMA region the decline was 59%. While at the statewide scale, the spatial extent of the native scattered trees land-cover class declined by 23%. Table L6 also presents (in brackets) the percentage change in the land-cover classes between the 5th (2005-10) and 7th epoch. On a statewide basis, the declining trend continued. However, at the CMA level, some of the changes have reversed for some land-cover classes, for example, pasture not native, native shrub and wetland perennial demonstrated increases in cover across epochs. Reasons for this pattern are unclear.

Table L7 summarises the percentage change in those land-cover classes that have increased in spatial extent at both the statewide and CMA region scales. Eight of the ten land-cover classes demonstrating a higher level of cover are human based and have experienced the greatest percent increases. Hardwood plantations is such an example, which increased across the state by 54% between the 1st and 7th epochs and also demonstrated the largest percent increases at the CMA scale. Spatial extent of hardwood plantations was particularly high within the North Central (899%), Glenelg Hopkins (1066%) and Wimmera (1126%) CMA regions. Table L7 also includes (in brackets) the percentage change in the land-cover classes between the 5th and 7th epochs. On both the statewide CMA level, the increasing trend for these 10 land-cover classes continues.

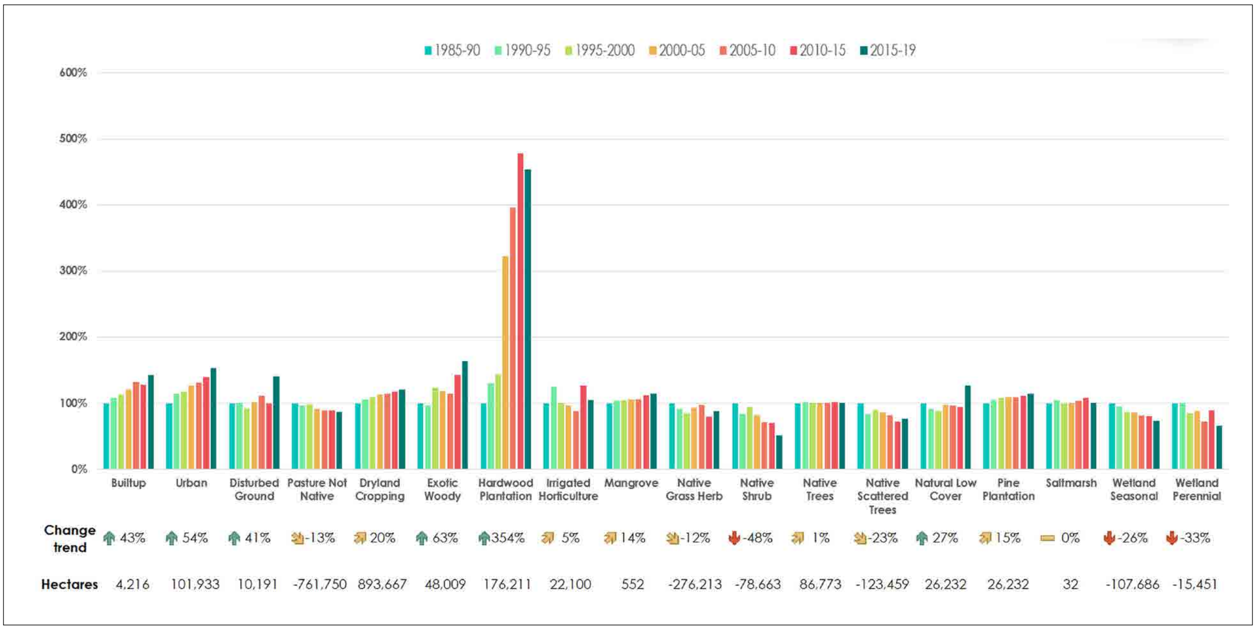
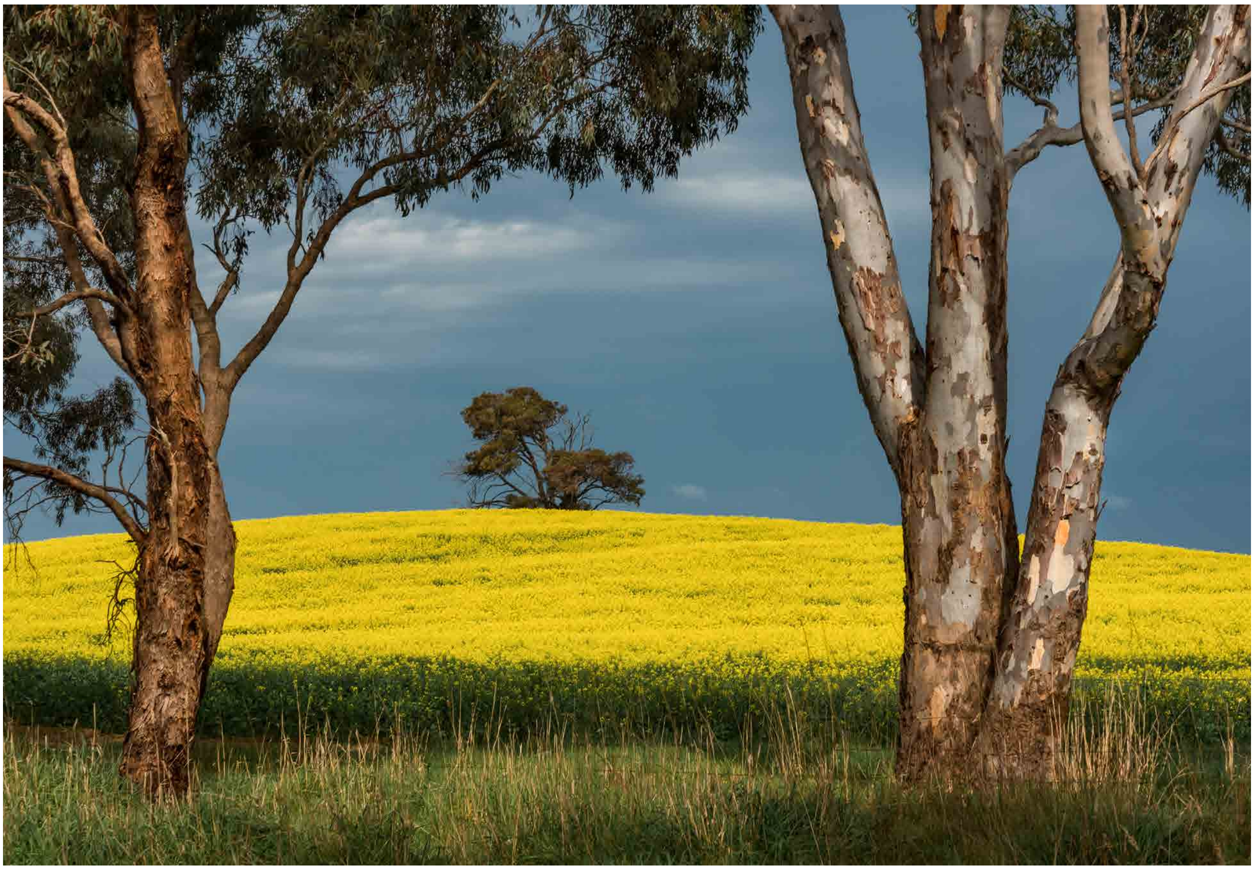


Figure L2: Statewide percentage change in land-cover classes from the 1st epoch (1985-90) to the 7th epoch (2015-19).[1109]



Avoca canola fields, 2022.
Credit: Anna Morely. © Visit Victoria.

1109. Department of Environment Land, Water and Planning (DELWP), 'Victorian land cover time series' https://www.environment.vic.gov.au/biodiversity/Victorias-Land-Cover-Time-Series Accessed 31 January 2023.

Table L3: Land-cover classes and their descriptions.[1110]

Land-cover class	Description
Built	Persistent unvegetated areas that are the result of commercial or industrial development.
Urban	The admixture of streets, houses and gardens that characterises much of the medium to low density urban landscape typical of Australian cities.
Disturbed ground	Persistent unvegetated areas that are the result of anthropogenic activity other than urban development, such as mining.
Pasture not native	Herbaceous pastures that are predominantly composed of non-indigenous species.
Dryland cropping	Regions that are regularly cropped and are not irrigated.
Exotic woody	Non-native tree-cover including conifer windbreaks, willows along streams and rivers and varied ornamental plantings.
Hardwood plantation	Tree plantations predominantly blue gum *(Eucalyptus globulus)*
Irrigated horticulture	Regions of crop, pasture and parkland regularly subject to irrigation, particularly in dry months
Mangrove	Intertidal native vegetation supporting grey mangrove *(Avicennia marina)*
Native grass herb	Grasslands and pastures that are predominantly composed of indigenous species grasses and/or low chenopod shrubs. Includes grasslands that have been 'derived' through the clearing of tree and/or shrub cover
Native shrub	Native shrub cover
Native trees	Native tree cover
Native scattered trees	Native trees scattered in paddocks and woodland along roadsides and streams.
Natural low cover	Environments that naturally have low to negligible vegetation cover such as coastal fore-dunes, saline lake beds, claypans and rock-outcrops.
Pine plantation	Tree plantations principally radiata pine *(Pinus radiata)*
Saltmarsh	Intertidal wetlands supporting native vegetation that are not mangroves
Water	Persistent surface water either fresh or saline – includes rivers, lakes, dams, wetlands and the ocean
Wetland seasonal	Seasonal or ephemeral, typically herbaceous cover comprised of native plant species that are tolerant of episodic inundation or waterlogging
Wetland perennial	Persistent, typically herbaceous cover comprised of native plant species that are tolerant of inundation or waterlogging.

1110. Department of Environment Land, Water and Planning (DELWP), 'Victorian land cover time series' https://www.environment.vic.gov.au/biodiversity/Victorias-Land-Cover-Time-Series Accessed 31 January 2023.

Table L4: Statewide extent (ha) of land-cover classes in each epoch.[1111]

Cover-class type	1st epoch (1985-90)	2nd epoch (1990-95)	3rd epoch (1995-'00)	4th epoch (2000-05)	5th epoch (2005-10)	6th epoch (2010-15)	7th epoch (2015-19)	Overall % change
Built-up	9,961	10,738	11,313	12,070	13,159	12,798	14,187	43
Urban	189,343	217,301	222,776	240,421	248,689	265,169	291,316	54
Disturbed ground	25,198	25,437	23,210	25,590	28,023	25,023	35,395	41
Pasture not native	5,839,746	5,615,544	5,735,180	5,323,443	5,230,894	5,228,045	5,078,016	-13
Dryland cropping	4,390,252	4,678,955	4,798,491	4,980,953	5,036,528	5,146,058	5,283,947	20
Exotic woody	75,752	73,084	93,885	89,821	86,740	108,553	123,766	63
Hardwood plantation	49,791	64,879	71,625	160,385	197,026	238,189	226,012	354
Irrigated horticulture	456,605	568,828	459,847	441,298	402,092	580,124	478,755	5
Mangrove	5,695	6,011	6,081	6,116	6,175	6,483	6,584	16
Native grass herb	2,281,518	2,081,468	1,943,432	2,121,414	2,218,043	1,820,874	2,005,135	-12
Native shrub	163,849	137,515	154,766	134,182	116,648	115,080	85,011	-48
Native trees	7,728,922	7,841,927	7,819,239	7,822,450	7,822,787	7,904,620	7,815,795	1
Native scattered trees	536,195	449,150	486,816	462,281	441,187	388,255	412,625	-23
Natural low cover	100,942	92,037	89,781	98,680	97,401	95,483	127,629	27
Pine plantation	203,502	213,213	219,220	222,569	223,234	227,356	233,397	15
Saltmarsh	11,014	11,536	11,076	11,118	11,437	11,724	10,769	-2
Water	1,024,756	1,023,915	1,007,092	1,002,201	998,245	1,003,585	988,074	-4
Wetland seasonal	407,952	388,896	354,106	351,331	335,489	328,709	300,146	-26
Wetland perennial	46,380	46,939	39,435	41,063	33,581	41,262	30,869	-33
Grand total	23,547,373	23,547,372	23,547,372	23,547,384	23,547,378	23,547,388	23,547,426	

1111. Department of Environment Land, Water and Planning (DELWP), 'Victorian land cover time series' https://www.environment.vic.gov.au/biodiversity/Victorias-Land-Cover-Time-Series Accessed 9 May 2021.

Table L5: Percentage of total land cover represented by each land-cover class in the 1st epoch (1985-90) and 7th epoch (2015-19).[1112]

Land-cover class	Percent of total extent of all classes in 1st epoch	Percent of total extent of classes in 7th epoch
Built-up	0	0
Urban	1	1
Disturbed ground	0	0
Pasture not native	25	22
Dryland cropping	19	22
Exotic woody	0	1
Hardwood plantation	0	1
Irrigated horticulture	2	2
Mangrove	0	0
Native grass herb	10	9
Native shrub	1	0
Native trees	33	33
Native scattered trees	2	2
Natural low cover	0	1
Pine plantation	1	1
Saltmarsh	0	0
Water	4	4
Wetland seasonal	2	1
Wetland perennial	0	0

Note: Percentages have been rounded up or down. Anything below 0.5% was recorded as zero. Anything above 0.5% was recorded as one.

1112. Department of Environment Land, Water and Planning (DELWP), 'Victorian land cover time series' https://www.environment.vic.gov.au/biodiversity/Victorias-Land-Cover-Time-Series Accessed 9 May 2021.

Land

Table L6: Land-cover classes that have declined in spatial extent statewide between the 1st and 7th epochs by CMA region. Figures in brackets denote the percentage change between the 5th epoch (2005-10) and the 7th epoch (2015-19).[1113]

CMA region	Percent change pasture not native	Percent change native grass herb	Percent change native shrub	Percent change native scattered trees	Percent change water	Percent change wetland seasonal	Percent change wetland perennial
Statewide	-13 (-3)	-12 (-10)	-48 (-27)	-23 (-6)	-4 (-1)	-26 (-11)	-33 (-8)
Corangamite	-17 (-5)	-8 (-24)	+5 (+14))	-9 (-2)	-3 (0)	-15 (-4)	-23 (+3)
East Gippsland	-8 (0)	+5 (-22)	-28 (-22)	-84 (-7)	+1 (1)	-32 (-19)	-16 (-10)
Glenelg Hopkins	-14 (+6)	-51 (-47)	-27 (-13)	-11 (-6)	-2 (-1)	-27 (-10)	-41 (+3)
Goulburn Broken	-9 (-4)	+7 (-3)	-17 (+5)	-30 (-14)	-33 (-17)	-34 (-17)	-37 (-11)
Mallee	-54 (+28)	+2 (+6)	-89 (-74)	-17 (2)	0 (0)	-23 (+7)	-53 (+121)
North Central	-21 (-8)	-13 (-5)	-1 (+40)	-33 (-13)	-30 (-6)	-24 (-14)	-41 (-4)
North East	-1 (+2)	-1 (-20)	-10 (+20)	-45 (-24)	+4 (+6)	-38 (-13)	-24 (-4)
Port Phillip and Westernport	-11 (-4)	-8 (-15)	0 (+1)	-39 (-13)	0 (0)	-41 (-16)	-41 (-21)
West Gippsland	-9 (-4)	+17 (-15)	-21 (-14)	-59 (+3)	0 (+1)	-25 (-10)	-40 (-19)
Wimmera	-24 (+2)	-33 (-24)	-40 (-36)	+5 (+25)	-65 (-54)	-6 (-2)	-34 (+73)

Note: Percentages have been rounded up or down. In the case of zeroes, anything below 0.5% was recorded as zero. Anything above 0.5% was recorded as one.

1113. Department of Environment Land, Water and Planning (DELWP), 'Victorian land cover time series' https://www.environment.vic.gov.au/biodiversity/Victorias-Land-Cover-Time-Series Accessed 9 May 2021.

Table L7: Land-cover classes that increased in spatial extent statewide between the 1st and 7th epochs by CMA region. Figures in brackets denote the percentage change between the 5th epoch (2005-10) and the 7th epoch (2015-19).[1114]

CMA region	Percent change built-up	Percent change urban	Percent change disturbed ground	Percent change dryland cropping	Percent change exotic woody	Percent change hardwood plantation	Percent change irrigated horticulture	Percent change native trees	Percent change natural low cover	Percent change pine plantation
Statewide	+42 (+8)	+54 (+17)	+40 (+26)	+20 (+5)	+63 (+43)	+54 (+15)	+5 (+19)	+1 (0)	+26 (+31)	+15 (+5)
Corangamite	+33 (+7)	+61 (+22)	+35 (+7)	+247 (+22)	+88 (+39)	+152 (+13)	-15 (+59)	+2 (0)	+22 (+24)	+33 (+8)
East Gippsland	+32 (+10)	+52 (+18)	-9 (+17)	+58 (+35)	+45 (+91)	+69 (+24)	+83 (+28)	+1 (0)	-32 (-15)	+61 (+9
Glenelg Hopkins	+30 (+6)	+96 (+38)	-18 (-11)	+489 (+29)	52 (+20)	+1066 (+10)	+157 (+184)	+4 (+2)	-11 (+1)	+20 (+6)
Goulburn Broken	+43 (+13)	+87 (+28)	+149 (+59)	+44 (+14)	+70 (+103)	+208 (+45)	-30 (-7)	+4 (+1)	+19 (+20)	+3 (+2)
Mallee	+56 (+6)	+58 (+28)	+92 (+35)	+2 (0)	+14 (+8)	+42 (-12)	+86 (+31)	-3 (-5)	+67 (+43)	-34 (+526)
North Central	+37 (+9)	+77 (+27)	+63 (+52)	+21 (+5)	+46 (+26)	+899 (+21)	-34 (+1)	+8 (+2)	-22 (+1)	+8 (+3)
North East	+22 (-2)	+77 (+20)	+33 (-6)	+378 (+7)	+44 (+76)	+378 (+114)	+56 (+22)	+1 (0)	-21 (0)	+6 (+1)
Port Phillip and Westernport	+47 (+8)	+42 (+11)	+53 (+37)	+86 (+18)	+77 (+77)	+190 (+236)	-12 (+15)	0 (-1)	+21 (+19)	+50 (+52)
West Gippsland	+3 (0)	+70 (+26)	+35 (+6)	+102 (+40)	+91 (+96)	+49 (+12)	+77 (+33)	-1 (0)	+3 (+5)	+9 (+3)
Wimmera	+60 (+21)	+64 (+31)	-16 (+17)	+21 (+6)	+66 (+47)	+1126 (+36)	+124 (+108)	+1 (+3)	+36 (+82)	+191 (+35)

1114. Department of Environment Land, Water and Planning (DELWP), 'Victorian land cover time series' https://www.environment.vic.gov.au/biodiversity/Victorias-Land-Cover-Time-Series Accessed 9 May 2021.

Land

Population growth is a major driver of changes in land use, especially the spread of residential development. The growth of the demographic shifts of tree-change (people moving to inland population centres and lifestyle properties) and sea-change (people moving to coastal areas) is evident in the Surf Coast, Western Port and Bass Coast, west of Melbourne, around centres such as Bendigo and Ballarat, and along the Hume Highway north to the New South Wales border. These changes in peri-urban areas are placing pressure on agricultural land and biodiversity from urban development and the subdivision of agricultural land into small-acre allotments. This process in the metropolitan area of Melbourne is discussed in L:04.

Changing land use, such as clearing of vegetation for the agriculture and forestry sectors and to accommodate urban sprawl, impacts biodiversity and land health and releases carbon (a greenhouse gas) from soil and vegetation. Grazing livestock also emit methane, another greenhouse gas.

In 2020, the agriculture sector's share of Victoria's greenhouse gas emission was 19% (up from 14% in 2017), while that of the land use, land-use change and forestry (LULUCF) sector was -25% (previously -10% in 2017) due to its carbon sequestration. The agriculture sector's emissions can vary over time due to drought and market conditions, affecting livestock numbers. Between 1990 and 2020, the 5% decline in agriculture sector emissions was due to a reduction in sheep numbers and their emissions from enteric fermentation:

> 'Enteric fermentation has been responsible for the largest share of agriculture emissions for three decades but its share of emissions has declined from 79% in 1990 to 69% in 2020 while the share of other sub-categories has increased over the same period, including agriculture soils (from 13% to 18%), manure management (from 7% to 9%), and urea application (from 0.3% to 2.4%).' [1115]

Figure L3 shows the emissions for each category of the LULUCF sector which, in most years since 1990, has been a net sink for emissions. In the past decade 'land remaining as forest', 'land remaining as grassland' and 'land converted to forest land' have been the main sinks, while the 'conversion of forest to other uses' has been the main emitter.

This indicator demonstrates that changes in land use can affect more than just land health and biodiversity, it can also impact efforts to mitigate climate change. Indicator L:04 looks more closely at the impacts of land-use change in urban and peri-urban areas of Metropolitan Melbourne, which is placing pressure on agricultural land and biodiversity.

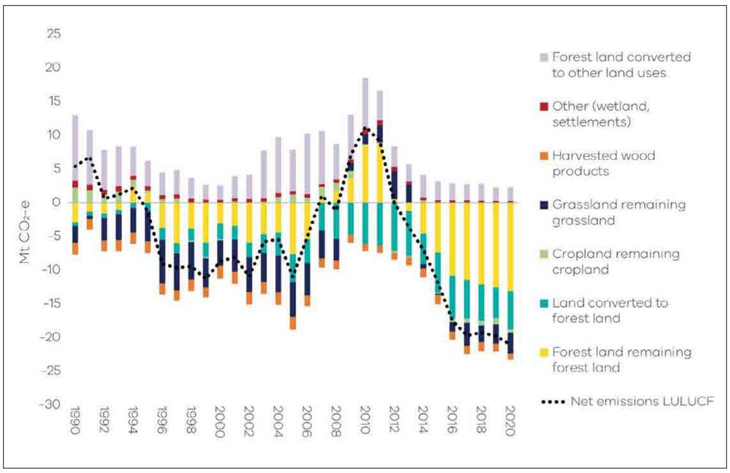


Figure L3: Emissions from LULUCF sub-categories in Victoria from 1990 to 2020.[1116]

1115. Department of Environment Land, Water and Planning (DELWP) 2022, 'Victorian greenhouse gas emissions report 2020', Melbourne, Victoria.
1116. Ibid.

Indicator L:03 Changes in land tenure

L:03 Changes in land tenure						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	N/A	→	Grey	Yellow	→	Green
Data source(s):	DELWP					
Measure(s):	Percentage of Victoria's area classified as public or private land					

Why this indicator?

Changes in land tenure and, as a result, land management practices and land use, can potentially lead to changes in land cover and land health.

Why this assessment in 2023?

A status for this indicator has not been determined. The data available simply identify the statewide mix of publicly, and privately, owned land. There has been no significant shift in public and private land tenure percentages since the SoE 2018 Report.

Summary of State of the Environment 2018 Report assessment

- Public land is mainly divided between parks and reserves, managed under the National Parks Act, and the Crown Land (Reserves) Act, unreserved public land under the Land Act, which also includes state forests managed under the Forests Act. State forests are managed for multiple purposes, including timber harvesting, conservation, recreation and water production.
- 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.

Critical data used for the 2023 assessment

- Victorian Public Land Tenure Map 2023

2023 assessment

Figure L4 maps the distribution of public land in Victoria during 2023, with the unshaded areas representing private land. Public land in Victoria is largely occupied by conservation reserves and state forests. The distribution of both public and private land tenures is largely the same as it was in the SoE 2018 Report. Changes in land tenure are slow and cover small parcels in local areas.

Land

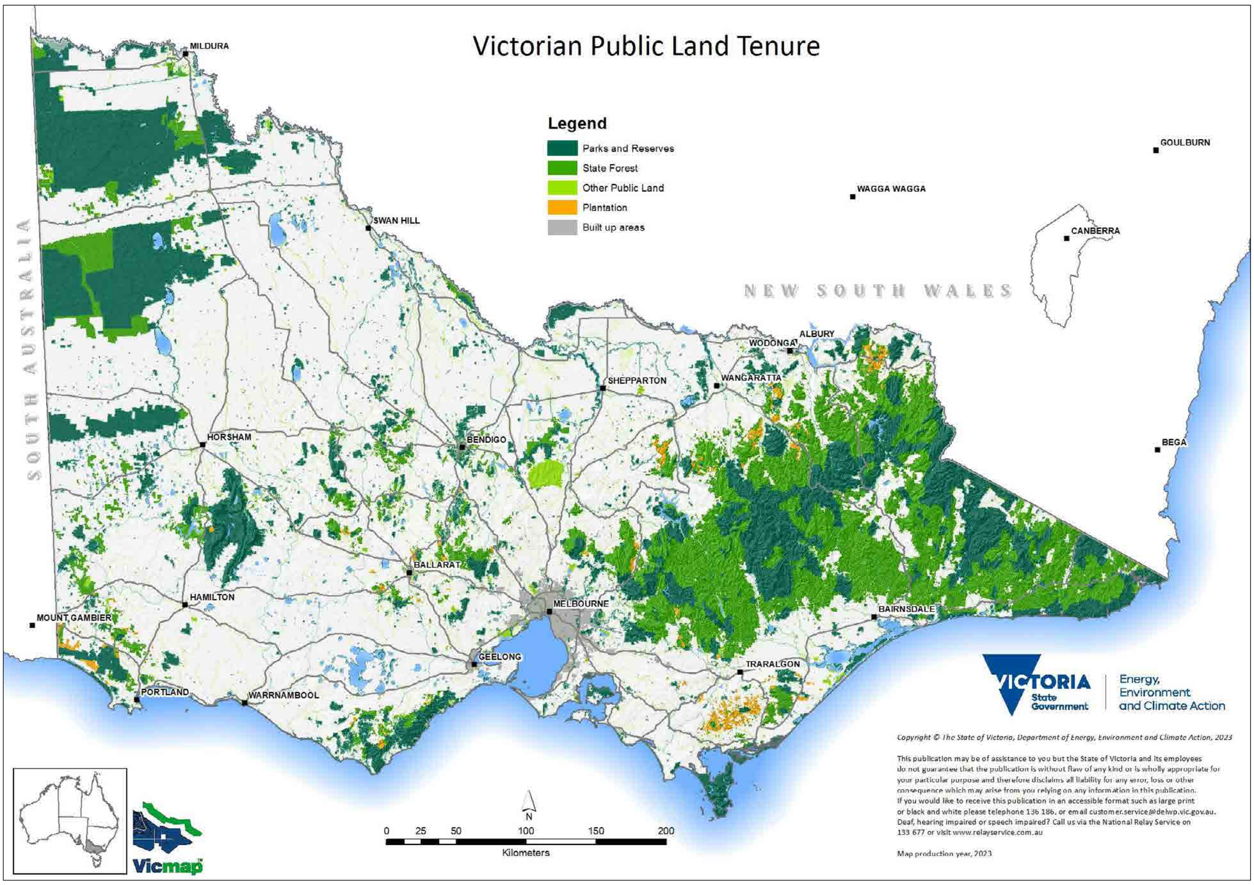


Figure L4: Land tenure in Victoria in 2023.[1117]

Bank Australia Park Reserve.
© Bank Australia, Barengi Gadjin Land Council (BGLC), Greening Australia, Trust for Nature (TfN)

1117. Department of Energy, Environment and Climate Action (DEECA) 2023, Unpublished data', Melbourne, Victoria.

Indicator L:04 Greenfield and infill development in Melbourne

L:04 Greenfield and infill development in Melbourne						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Melbourne metropolitan area	Yellow	Deteriorating (↙)	Yellow	Yellow	Stable (→)	Green
Data source(s):	DTP, IV					
Measure(s):	Infill and greenfield development in Melbourne					

Why this indicator?

Urban development in Melbourne can come at the expense of land health and productive agricultural land, and increase pressure on biodiversity.

Why this assessment in 2023?

Both forms of urban development (greenfield and infill) have their advantages and disadvantages; however, greenfield development can increase pressure on biodiversity and agricultural land. Data on the outcomes for land health from land-use change in Melbourne are limited.

Summary of State of the Environment 2018 Report assessment

- Housing development increased at record levels across Melbourne in the five years to 2016. In the established areas of Melbourne, 10,000 more dwellings were constructed in 2016 than 2012 — the majority being apartment developments.
- Greenfield development was also at record levels and delivered approximately 30% of housing development across the five years. Greenfield development and associated infrastructure increased the urban area of Melbourne by approximately 7,400 hectares from 2012 to 2016.
- With the expanding populations in green wedge LGAs, the importance of green wedge areas to protect environmental values was increasing.

Critical data used for the 2023 assessment

- Department of Transport and Planning (DTP) annual data on greenfield development and redevelopment

2023 assessment

The Australia State of the Environment 2021 Report observed that:

> 'Our cities and towns are growing, and there is increasing demand for land to be used for built infrastructure to support population growth. As a result, the built environment is outcompeting other land uses, and leading to removal of land from agricultural production or clearing of natural areas.'[1118]

The report also noted that for natural areas and green spaces, the expansion of urban areas by greenfield development led to:

- land clearing, which is the main cause of biodiversity loss in Australia
- less greenspace and tree canopy cover
- fewer gardens and thus biodiversity.
- greater pressure on coasts and waterways.[1119]

1118. Commonwealth of Australia 2021, 'Australian state of the environment', Canberra, Australian Capital Territory https://soe.dcceew.gov.au/ Accessed 7 June 2023.
1119. Ibid.

Land

The Australian State of the Environment 2021 Report also observed that changes in settlement patterns, for example urban expansion, 'have also changed our bushfire exposure, requiring a rethink about how to live with Australia's sclerophyllous native vegetation, which is inherently flammable.' [1120]

In 2017, the Victorian Government released its Plan Melbourne 2017-2050 (Plan Melbourne), which predicts that Melbourne will grow to a population of eight million by 2050. [1121] The plan aims to protect agricultural land and support agricultural production in Melbourne's green wedge and peri-urban areas, which have been under pressure for many years, while 'existing policy and planning measures are no longer effective as we see:

- increasing land speculation and pressure to convert farmland to other uses
- increasing appetite for rural lifestyles and use of these areas for a range of urban activities
- incremental and irreversible loss of land that is agriculturally productive or has important nonurban uses
- more land use conflicts, particularly where urban areas adjoin rural areas.' [1122]
- The growth of Melbourne has converted agricultural land uses to urban and industrial uses, replacing fruit growing around Doncaster and Park Orchards, vegetable growing in the Moorabbin, Oakleigh and Springvale areas, and market gardens in parts of the Cranbourne and Mornington Peninsula areas. [1123] Areas of biodiversity, such as grasslands in the expanding northern and western suburbs, have also been replaced by urban and industrial development.

To protect agricultural and green wedge areas, and to guide urban growth, Plan Melbourne commits to maintaining a permanent urban growth boundary and has an aspirational target of 70% of new dwellings to be built in established urban areas by 2051 (e.g. a 70:30 ratio for infill:greenfield development).

For many years, a corridor-wedge approach was used in Melbourne's planning, with growth corridors separated by green wedge areas for agriculture and conservation. Buxton (2014) reported that green wedge areas were expanded by 10,900 hectares in 1990. [1124] However, since then, they have been reduced in area by almost 5,000 hectares. From 2003 to 2012, the urban growth boundary was moved outward on four occasions to include an additional 61,732 hectares for the expansion of residential allotments. [1125] Buxton (2014) argues that Australian cities have failed to contain urban sprawl, with any strategic plans either modified or abandoned.[1126]

Infill land can be un-used or under-used urban land, former contaminated industrial or commercial land (brownfield land), uncontaminated (greyfield land) and demolished residential areas. Major infill is land within the established area of a settlement that is greater than one hectare in area. These pieces of land are often remnant greenfield land identified in consultation with local councils.

Greenfield land is considered to be undeveloped land identified for residential or industrial/commercial development, generally on the fringe of metropolitan Melbourne where it could be former grazing land or, in some cases, native grassland. Residential growth numbers do not necessarily capture all uses being built in greenfield or infill land. Those uses are not included as greenfield supply, nor are smaller lots that may be able to be developed.

Development on major development sites in Melbourne largely comprises apartment buildings of four or more storeys, representing 80% of the 148,394 dwellings proposed or under construction in December 2021. [1127] For inner Melbourne, 83% of such dwellings were of 10 storeys or greater. In the middle-ring suburbs there is a greater mix of dwelling types, with 10-storey apartment buildings representing around 40% of the total stock. [1128] Supply of minor infill developments of less than 10 dwellings is not monitored.[1129]

1120. Ibid.
1121. Department of Environment Land, Water and Planning (DELWP) 2017, 'Plan Melbourne 2017-2050', Melbourne, Victoria.
1122. Ibid.
1123. Buxton M 2014, 'The expanding urban fringe: Impacts on peri-urban areas, Melbourne, Australia', in B Maheshwari, R Purohit, H Malano, V Singh, P Amerasinghe (eds), The security of water, food, energy and liveable cities', Springer Science and Business Media, Dordrecht, The Netherlands.
1124. Buxton M 2014, 'The expanding urban fringe: Impacts on peri-urban areas, Melbourne, Australia', in B Maheshwari, R Purohit, H Malano, V Singh, P Amerasinghe (eds), The security of water, food, energy and liveable cities', Springer Science and Business Media, Dordrecht, The Netherlands.
1125. Ibid.
1126. Ibid.
1127. Department of Transport and Planning (DTP), 'Redevelopment land supply 2021' https://www.planning.vic.gov.au/land-use-and-population-research/urban-development-program/redevelopment-2021 Accessed 13 December 2022.
1128. Ibid.
1129. Ibid.

Land

Melbourne's growth areas for greenfield residential development (largely detached houses covering much of the allotment) are in Casey, Cardinia, Hume, Mitchell (Wallan), Melton, Whittlesea and Wyndham LGAs. During consultation, when Plan Melbourne 2017-50 was being prepared, concerns were expressed that the 70:30 ratio was too simplistic, or would lead to lost amenity or constrained infrastructure in established areas. [1130] The City of Casey was 'strongly opposed to any assumed reduction in the need for infrastructure investment in the growth areas and outer ring suburbs as a result of a target of 70% of new housing in Melbourne's established areas and 30% in greenfield growth areas.' [1131]

There has been a decrease in the size of residential lots in Melbourne's growth areas, leading to a denser urban form. The last decade has seen a gradual, and significant, change in growth-area lot sizes. Currently, 89% of 2021 lots with a title in the growth areas have an area of less than 500 m^2. This is a significant change when compared with the 2006-07 period when only a third of lots were below 500 m^2. Furthermore, lots less than 300 m^2 make up nearly 35% of new lots. Over the last decade the number of larger lots (more than 500 m^2) has declined significantly.

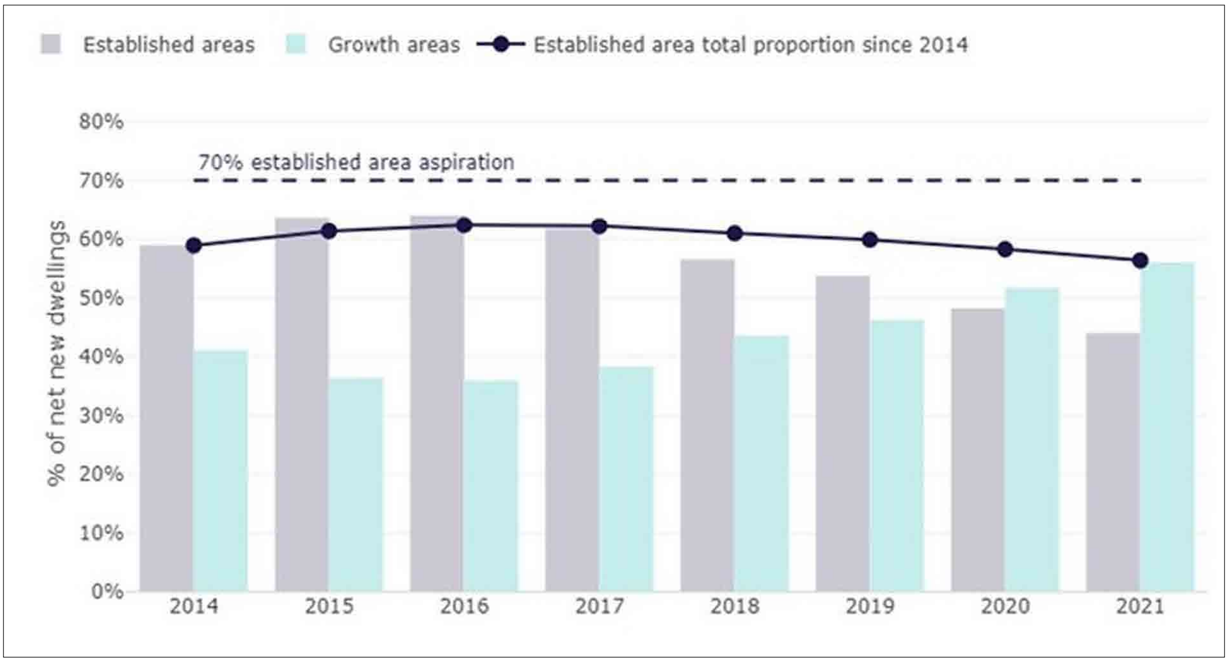


Figure L5: Share of net additional dwellings within established Melbourne and growth areas between 2014 and 2021.[1132]

Figure L5 presents net additional dwellings for Greater Melbourne from 2014 to 2021. Since 2016, the share of dwelling approvals occurring in the established parts of Melbourne has declined from 64% to 44% in 2021. Over that time period, the ratio of infill to greenfield development (infill:greenfield) changed from 64:36 to 44:56. This decline in the share of net dwelling approvals can be attributed to continued strength in greenfield development.

Demand for greenfield housing remained strong, driven by federal and state stimulus initiatives, such as Homebuilder, to maintain construction and development activity during the COVID-19 pandemic, and which enabled development to be brought forward. This pattern of change is the reverse to what is required to achieve Plan Melbourne's aspirational 70:30 ratio.

1130. Department of Environment Land, Water and Planning (DELWP) 2016, 'Plan Melbourne refresh. Summary of submissions May 2016', Melbourne, Victoria.
1131. City of Casey 2015, 'Submission to Plan Melbourne refresh' https://www.planmelbourne.vic.gov.au/__data/assets/pdf_file/0003/382476/281-Casey-City-Council.pdf Accessed 13 September 2022.
1132. Department of Environment, Land, Water and Planning (DELWP), 'Unpublished data', Melbourne, Victoria, Accessed 2022.

Land

Both forms of development have their advantages and disadvantages, which are summarised in Table L8 based on a literature review.[1133, 1134, 1135, 1136, 1137, 1138] Greenfield development can threaten Melbourne's green wedges and agricultural land, while infill development can increase traffic congestion, place greater pressure on existing urban infrastructure and amenities, and undermine streetscapes.

Table L8: Potential advantages and disadvantages of infill and greenfield development.[1139, 1140, 1141, 1142, 1143, 1144]

Development	Potential advantages	Potential disadvantages
Greenfield	Lower-cost housing; although the housing market drives the types of housing, which can vary in cost Cleaner air Higher-quality housing Flexibility in design and use of public open space Urban construction employment Growth in stages Room for expansion	Increased greenhouse emissions: higher car ownership and greater travel distances Increased energy consumption Mental health costs of isolation, lack of services Increased costs of infrastructure and human services: water, sewerage, drainage, gas/electricity, roads, health, education Loss of agricultural land and green wedges Increased pressure on emergency services at interface of urban areas and fire-prone areas
Infill	Replace and reinvent derelict sites Reduced cost of development in service provision and infrastructure: water, sewerage, drainage, gas/electricity, roads, health, education Reduce urban sprawl Reduce commuting distances Protect agricultural land and green wedges. Health benefits from increased active transport i.e. walking and cycling, and reduced greenhouse gas emissions Increase access to health care facilities, parks, educational facilities, transportation, social interaction and employment opportunities, proximity to leisure activities	Limited room for expansion Demolition and remediation costs Air pollution Traffic congestion Mental health costs due to higher density living Costs of widening roads Health costs of higher density living Damage urban amenity where existing houses are replaced by high-rise or medium density living Cost of expanding/updating infrastructure for increased population Changed urban hydrology by increasing demand for water and generating more stormwater Reduced amenity in affected suburbs, including loss of heritage housing and Victorian-era shopping strips Pressures on open space Loss of permeable surfaces and tree cover, adding to heat-island effect

1133. Biddle T, Bertoia T, Greaves S, Stopher P 2006, 'The costs of infill versus greenfield development: a review of recent literature', 29th Australasian Transport Research Forum.
1134. Hamilton C, Kellett J 2017, 'Cost comparison of infrastructure on greenfield and infill sites', *Urban Policy and Research*, 35(3), pp. 248-260.
1135. Diss K 2016, 'Perth urban infill much cheaper than greenfield development: report', *ABC News Perth*, 3 June 2016.
1136. Zapata-Diomedi B, Boulangé C, Giles-Corti B, Phelan K, Washington S, Veerman J, Gunn L 2019, 'Physical activity-related health and economic benefits of building walkable neighbourhoods: a modelled comparison between brownfield and greenfield developments', *International Journal of Behavioral Nutrition and Physical Activity*, 2019, 16(11).
1137. Sochacka B, Kenway S, Bertram N, London G, Renouf, Sainsbury O, Surendran S, Moravej M, Nice K, Todorovic T, Tarakemehzadeh N, Martin D 2021, 'Water sensitive outcomes for infill development, final report', Cooperative Research Centre for Water Sensitive Cities, Clayton, Victoria.
1138. Foster H, Towers B, Whittaker J, Handmer J, Lowe T 2013, 'Peri-urban Melbourne in 2021: Changes and implications for the Victorian emergency management sector', *Australian Journal of Emergency Management*, 28(3).
1139. Biddle T, Bertoia T, Greaves S, Stopher P 2006, 'The costs of infill versus greenfield development: a review of recent literature', 29th Australasian Transport Research Forum.
1140. Hamilton C, Kellett J 2017, 'Cost comparison of infrastructure on greenfield and infill sites', *Urban Policy and Research*, 35(3), pp. 248-260.
1141. Diss K 2016, 'Perth urban infill much cheaper than greenfield development: report', *ABC News Perth*, 3 June 2016.
1142. Zapata-Diomedi B, Boulangé C, Giles-Corti B, Phelan K, Washington S, Veerman J, Gunn L 2019, 'Physical activity-related health and economic benefits of building walkable neighbourhoods: a modelled comparison between brownfield and greenfield developments', *International Journal of Behavioral Nutrition and Physical Activity*, 16(11).
1143. Sochacka B, Kenway S, Bertram N, London G, Renouf, Sainsbury O, Surendran S, Moravej M, Nice K, Todorovic T, Tarakemehzadeh N, Martin D 2021, 'Water sensitive outcomes for infill development, final report', Cooperative Research Centre for Water Sensitive Cities, Clayton, Victoria.
1144. Foster H, Towers B, Whittaker J, Handmer J, Lowe T 2013, 'Peri-urban Melbourne in 2021: changes and implications for the Victorian emergency management sector', *Australian Journal of Emergency Management*, 28(3).

Land

Urban development can severely impact biodiversity, including habitat loss and fragmentation, the introduction of exotic species, alteration of local climates via the urban heat island, and increased levels of chemical, light and noise pollution.[1145] The loss of urban biodiversity can also impact human health and wellbeing as people lose their connection with nature. After an extensive literature review, Garrard et al. (2017) developed a framework for implementing biodiversity-sensitive urban design (BSUD). [1146] The framework has five principles:

- maintain existing and create new resources for nature
- support animal movement across the landscape
- reduce threats to and disturbance of nature
- protect natural cycles and ecological communities
- create opportunities for positive interactions between people and nature.[1147]

The Green Building Council of Australia has now included BSUD principles in voluntary performance tools, and they are also being applied in development plans for established and growth areas.[1148]

Urban development is also influencing the level of tree canopy cover in Melbourne, which has implications for efforts to mitigate the impacts of climate change. Hurley et al. (2019) analysed tree canopy data (excluding grasslands) in metropolitan Melbourne covering the period from 2014 to 2018. [1149] They found that, although the city-wide average for tree cover was 14%, this varied considerably from 6% in the western suburbs to 23% in the eastern suburbs. However, there were small, but significant, losses in the eastern suburbs due to the re-development of residential land. There were also small, but significant, increases in the western suburbs due to tree planting programs of local councils, largely in parklands and along streets. A Monash University study found that low levels of tree cover could intensify urban heat islands.[1150] In the case of Footscray and Sunshine in the western suburbs, a tree cover of just 9% raised temperatures by 14%.[1151]

1145. Garrard G 2021, 'Biodiversity-sensitive urban design: The future of cities', https://www.nespthreatenedspecies.edu.au/news-and-media/latest-news/biodiversity-sensitive-urban-design-the-future-of-cities
1146. Garrard G, Williams N, Mata L Thomas J, Bekessy S 2017, 'Biodiversity-sensitive urban design', *Conservation Letters*, September 2017, 00(0), 1–9.
1147. Ibid.
1148. Garrard G 2021, 'Biodiversity-sensitive urban design: the future of cities', https://www.nespthreatenedspecies.edu.au/news-and-media/latest-news/biodiversity-sensitive-urban-design-the-future-of-cities
1149. Hurley J, Saunders A, Both A, Sun C, Boruff B, Duncan J, Amati M, Caccetta P, Chia J 2019, 'Urban vegetation cover change in Melbourne 2014—2018', Centre for Urban Research, RMIT University, Melbourne, Victoria.
1150. Richardson L 2021, 'With our cities getting hotter, it's time for a radical tree change', *Lens*, 13 May 2021 https://lens.monash.edu/@science/2021/05/13/1383127/with-our-cities-getting-hotter-its-time-for-a-radical-tree-change.
1151. Ibid.

Indicator L:05 Soil organic carbon storage

L:05 Soil organic carbon storage						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide		?			?	
Data source(s):	AgVic					
Measure(s):	Victorian SOC at various depths					

Why this indicator?

Soil organic carbon (SOC) helps retain soil nutrients, soil structure and soil moisture. Increasing the storage of SOC can help mitigate climate change and enhance farm productivity.

Why this assessment in 2023?

There is a growing interest in the measurement of SOC and a government and community desire to increase it to help mitigate climate change. However, the science indicates that this will be difficult, and a broader carbon-farming initiative could have more chance of success. There are no targets, and available data are insufficient to determine status.

Summary of State of the Environment 2018 Report assessment

- The results of a major study found an extremely wide range in soil organic carbon (SOC) stocks across Victorian cropping and pasture soils.
- 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).

Critical data used for the 2023 assessment

- There are limited data on SOC storage levels
- Emissions Reduction Fund Register

2023 assessment

The amount of soil organic carbon (SOC) storage is the balance between inputs (mainly from plants) and losses (decomposition, erosion or removal at harvest) and is influenced by such features as soil depth, clay content and soil density. For example, sandy soils will have lower amounts of SOC than clay soils.

SOC is critical to agricultural productivity by slowly releasing nutrients and is important to soil structure and water-holding capacity. It can also help reduce the risk of erosion, buffer against soil acidity, and increase the diversity and abundance of soil biota. Increasing the storage of SOC in Australia's soils is now also seen as important in efforts to mitigate climate change. However, the science suggests that Victorian soils have limited potential for carbon sequestration in existing cropping areas and could take 25 years to be measurable. [1152] It also indicates that there is still much to learn about soil carbon, its measurement and how to increase it.

1152. Robertson F, Nash D 2013, 'Limited potential for soil carbon accumulation using current cropping practices in Victoria', *Agriculture, Ecosystems and Environment*, 165, pp 130-140.

However, Dooley et al. (2022) argue that climate mitigation by tree planting is limited when compared with the scale of the reductions in greenhouse emissions required to meet the temperature goals of the Paris Agreement:

> 'Growing commitments to net-zero emissions by 2050 to achieve the Paris Agreement goals are a welcome step forward on climate action but have also seen an increasing focus on nature restoration to remove carbon dioxide from the atmosphere. This risks over-relying on land for mitigation at the expense of phasing out fossil fuels. At the same time, a wide range of activities are being labelled "nature restoration," some of which, such as monoculture tree plantations, degrade nature- destroying biodiversity, increasing pollution, and removing land from food production.' [1153]
>
> 'We conclude that additional carbon sequestration via nature restoration is unlikely to be done quickly enough to notably reduce the global peak temperatures expected in the next few decades. Land restoration is an important option for tackling climate change but cannot compensate for delays in reducing fossil fuel emissions.' [1154]

Robertson et al. (2016) reviewed the opportunities for increasing SOC in Victoria's cropping and pasture systems, where SOC varied by 15% to 20% across the state. [1155] They found that the greatest influence on SOC was climate (rainfall, temperature, humidity), followed by the properties of the soil and management class (pasture type and cropping), with land-management practices the least effective: 'Management practices such as stubble retention, minimum cultivation, perennial pasture species, rotational grazing and fertiliser inputs were not significantly related to SOC stock.' [1156] Although less effective in building SOC, such management practices can have other benefits such as a reduced risk of erosion.

Lam et al. (2013) also found that the potential for increased storage of SOC in Australian soils was 'limited to the surface (0-10 cm) of soil and diminishes with time. None of these widely adopted practices is currently financially attractive under Australia's new legislation known as the Carbon Farming Initiative.' [1157]

There are many challenges to increasing soil carbon in Australian soils, these include variations in climate, soils, geology and vegetation, various methods to measure and model soil organic carbon, and the effects of soil acidity and soil compaction. The Australian State of the Environment 2021 Report assessed soil carbon stocks as follows:

- Above- and below-ground carbon: Good but deteriorating
- Above- and below-ground carbon in intensive land-use zone: Poor and deteriorating
- Above- and below-ground carbon in extensive land-use zone: Good but deteriorating
- Above- and below-ground carbon in relatively natural zone: Good with an unknown trend. [1158]

Increasing SOC storage in soils could be an elusive target for Victorian farmers. More success at climate change mitigation could be achieved with a broader carbon-farming initiative, which is now being supported by the Commonwealth and Victorian governments. Carbon farming aims to maximise carbon storage on the farm and minimise the greenhouse gasses emitted. This can involve tree planting, maintaining year-round ground cover, using different feed to reduce livestock emissions, protecting wetlands and reducing tillage.

1153. Dooley K, Nicholls Z, Meinshausen M 2022, 'Carbon removals from nature restoration are no substitute for steep emission reductions', *One Earth* 5, pp. 812-824.
1154. Ibid.
1155. Robertson F, Crawford D, Partington D, Oliver I, Rees D, Aumann C, Armstrong R, Perris R, Davey M, Moodie M, Baldock J 2016, 'Soil organic carbon in cropping and pasture systems of Victoria, Australia', *Soil Research*, 2016, 54, pp. 64–77.
1156. Ibid.
1157. Shu Kee Lam S, Chen D, Mosier A, Roush R 2013, 'The potential for carbon sequestration in Australian agricultural soils is technically and economically limited', *Scientific Reports*, 3, pp. 2179, doi: 10.1038/srep02179.
1158. Commonwealth of Australia 2021, 'Australian state of the environment', Canberra, Australian Capital Territory https://soe.dcceew.gov.au/ Accessed 7 June 2023.

The Victorian Government's Carbon Farming Program supports private landholders to 'plant agroforestry and shelterbelt trees, access existing carbon markets and realise on-farm benefits and new income streams.'[1159] The Commonwealth Government's Carbon + Biodiversity Pilot, which is being trialled in NRM regions, including North Central and Goulburn Broken CMA regions in Victoria, is developing market arrangements that will provide new income to farmers for biodiversity improvements and carbon abatement. [1160] The planting projects must first satisfy Emissions Reduction Fund requirements, be native trees and shrubs planted on land that has been cleared for more than five years, and be maintained for 25 years. For participating farmers, the Commonwealth Government covers the cost of professional advice and provides a biodiversity improvement payment, while the project could also generate Australian Carbon Credit Units.

The Commonwealth and Victorian governments' carbon-farming initiatives focus on tree planting, re-forestation and agroforestry, which may assist SOC storage but also have direct benefits for biodiversity and land health.

Evans et al. (2016) viewed carbon farming in a broader ecological context and argued that the natural regeneration in agricultural landscapes with low to intermediate degradation 'may provide a cost-effective mechanism for offsetting carbon emissions while delivering co-benefits for biodiversity through ecosystem restoration.'[1161]

This was reiterated in the Australian State of the Environment 2021 Report, which assessed the management of carbon in its Land chapter as partially effective with a stable trend:

> 'It is important to ensure that management of carbon is integrated with management of all other natural capital assets. Restoring vegetation, soil, biodiversity and carbon are integrated processes – not separate – thus schemes that encourage co-benefits across different types of natural capital are better placed for landscape-scale success. These activities for varied purposes represent an accelerating new economy in landscape recovery.' [1162]

Regen Farmers Mutual is a farmer-owned company by limited guarantee formed in 2020 to help farmers access environmental markets. Services to farmers include access to an agronomist who can help determine a farm's carbon footprint and also prepare a whole-of-farm assessment that covers carbon, biodiversity and native species potential. The company also brings farmers and their organisations together to coordinate land management activities and to share in joint outcomes. One of these is the Carbon + Biodiversity Corridor project in North Central Victoria which involves the planting of shelterbelts for stock that qualify as carbon sinks whilst participating in a corridor connecting to currently disconnected populations of grey-crowned babblers. [1163]

There are 112 current Victorian projects listed on the Commonwealth's Emissions Reduction Fund Register as carbon farming initiatives. Of the 112 projects:

- 38 projects aim to sequester carbon by rejuvenating pastures through changes to grazing patterns
- 35 projects aim to sequester carbon through the application of fertilisers, stubble retention and a move towards no-tillage practices
- 25 projects aim to sequester carbon by tree planting
- five projects aim to sequester carbon by rejuvenating pastures through seeding
- one project aims to sequester carbon by using a combination of seeding and grazing management
- one project aim to sequester carbon by combining grazing changes and the application of fertiliser.[1164]

1159. Agriculture Victoria, 'Agriculture and climate change' https://agriculture.vic.gov.au/climate-and-weather/policy-programs-action Accessed 17 May 2021.
1160. Department of Climate Change, Energy, the Environment and Water (DCCEEW), 'Carbon + biodiversity pilot', https://www.dcceew.gov.au/environment/environmental-markets/agriculture-stewardship/c-b-pilot Accessed 3 August 2023.
1161. Evans M, Carwadine J, Fensham R, Butler D, Wilson K, Possingham H, Martin T 2015, 'Carbon farming via assisted natural regeneration as a cost-effective mechanism for restoring biodiversity in agricultural landscapes', *Environmental Science and Policy*, vol. 50, pp 114-129.
1162. Commonwealth of Australia 2021, 'Australian state of the environment', Canberra, Australian Capital Territory https://soe.dcceew.gov.au/ Accessed 7 June 2023.
1163. Regen Farmers Mutual, 'Landscape scale impacts' https://regenfarmersmutual.com/stories/ Accessed 3 November 2022.
1164. Clean Energy Regulator, 'Emissions Reduction Fund Register' https://www.cleanenergyregulator.gov.au/ERF/project-and-contracts-registers/project-register Accessed 15 February 2023.

Land

Indicator L:06 Area affected by dryland salinity

L:06 Area affected by dryland salinity						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	(Murray River catchment) (elsewhere)	(Murray River catchment) (elsewhere)	(Murray River catchment) (elsewhere)	(Murray River catchment) (elsewhere)	(river catchments that drain to the Murray River) (elsewhere)	(Murray River catchment) (elsewhere)
Data source(s):	AgVic, DELWP					
Measure(s):	The extent of land affected by dryland salinity					

Why this indicator?

Dryland salinity is a threat to productive land uses and biodiversity.

Why this assessment in 2023?

Although salt-affected areas have receded in the northern river basins, dryland salting remains a significant concern. However, there are limited contemporary data on the spatial extent of dryland salinity. The improving trend assessment represents increasing land health due to a reduction in the area of land affected by salinity, not an increase in the area affected by salinity.

Summary of State of the Environment 2018 Report assessment

- Dryland salinity occurrence has not been systematically remapped since the Millennium Drought.
- Data on salinity is not systematically collected beyond the Murray-Darling Basin.

Critical data used for the 2023 assessment

- Northern Victoria Dryland Salinity 2020 Condition Report

2023 assessment

Salinity occurs naturally in soil and water and can be found in salt pans, salt lakes and saltmarshes. This is referred to as primary salinity. Secondary salinity is caused by human activities that include:

- irrigation, which can raise the water table and bring salt to the surface, a process known as irrigation salinity
- waste discharges that have high salt concentrations
- intrusion of sea water in areas where coastal aquifers have been overexploited, which is further exacerbated by rising sea levels
- land clearance, and the replacement of vegetation cover with plants that use less water, can lead to rising groundwater levels after rain.

Where groundwater reaches the surface at groundwater discharge points, the saline water can spread out onto the land, reduce vegetation cover and create salt pans that are no longer suitable for agriculture. This is referred to as dryland salinity and is the focus of this indicator.

Land

A report on dryland salinity in northern Victoria showed that the threat of dryland salinity had receded, based on analysis over 40 years of bore data.[1165] The recession has been caused by landholder management action, such as tree planting, the onset of the Millennium Drought as well as the use of perennial pastures, salt-tolerant plants, and improved grazing management (1998-2009). Groundwater levels declined during the drought and, although they partially recovered in subsequent wet years (2010-2011 and 2016), they were:

> 'unable to provoke the excess recharge that led to the salinity problems of the last century. In combination with improved catchment vegetation cover and land management practices, dryland salinity is no longer a substantial threat.' [1166]

> 'Salinity might increase locally in wet conditions, but substantial and obvious sequences of above average and recharge effective wet years would be needed to cause a reversal of this longer-term declining trend.' [1167]

The ongoing research into groundwater levels, and their link to dryland salinity, has made it much easier to predict how future years of above-average rainfall could impact existing groundwater discharges. Such research has also found that 'the majority of the groundwater flow systems in the northern Victorian catchments have approached or are approaching dynamic equilibrium.'[1168]

The State Observation Bore Network provides continuous monitoring of bores in the at-risk areas across the state. However, the network is primarily focussed on groundwater resource condition, not catchment condition, so it is not a good indicator of salinity condition.

Kaniva sheep, grain and cropping property in the Mallee 2021.

1165. Gill B, Cheng X 2020, 'Northern Victoria dryland salinity 2020 condition report', Agriculture Victoria Research Technical Report October 2020, Melbourne, Victoria.
1166. Ibid.
1167. Ibid.
1168. Ibid.

Land

Indicator L:07 Soil acidification

L:07 Soil acidification						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide		?			?	
Data source(s):	AgVic					
Measure(s):	Changes in the extent of strongly and very strongly acidic soils					

Why this indicator?

Soils that are too acidic, or too alkaline, can restrict growth in crops and pastures and can lead to farming responses that can impact land health.

Why this assessment in 2023?

Levels of soil acidification vary across the state. Agricultural production has elevated soil acidity in medium-rainfall areas. The application of lime is the primary way that farmers reduce soil acidity. There are insufficient data available to determine status and trend for this indicator.

Summary of State of the Environment 2018 Report assessment

- Soil acidity and acidification is an issue for the high rainfall agriculture regions in the south-west and east of Victoria, whereas soil alkalinity is an issue for agriculture in the low rainfall north-western region of the state.
- There are few 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.

Critical data used for the 2023 assessment

- There are limited data on soil acidification in Victoria

2023 assessment

In 2002, the then Department of Natural Resources and Environment reported that lost production due to acidic soils was occurring on 23% of Victorian agricultural land.[1169] Reduced productivity and the inability to grow crops of higher economic value restricts farm income, while acidification can also lead to increased salinity and erosion, a decline in soil structure, and impacts on water quality.

Acidic soils are found in high-rainfall and coastal areas due to leaching and chemical and biological reactions. These areas include the Eastern Uplands and Western Uplands, the Strzelecki and Otway ranges and north-eastern Victoria. Alkaline soils are found in the Mallee and Wimmera regions of north-western Victoria.

The acidification of soils is a natural process that involves the weathering of rock and the accumulation of organic matter over millennia. Soils can be either naturally acidic or alkaline, which can be measured by using the pH scale. A pH of 7 is considered neutral, whereas a pH below 7 is increasingly acidic and a pH above 7 is increasingly alkaline. A pH ranging between 5 and 8 is usually ideal for plant growth. In Victoria, the pH of soils ranges between 4 and 10.[1170]

Acidification has, however, been accelerated by agricultural production in the medium-rainfall areas of Victoria. Soils outside the optimal pH range limit can prevent or restrict plant growth in agricultural crops and pastures, reduce productivity and limit economic returns. Harvesting of agricultural products, application of ammoniacal fertilizers, losses of soil nitrate (from legumes such as sub-clover and grain legumes) and the accumulation of soil organic matter can, and have, increased soil acidity. The application of agricultural lime is widely used to reduce acidity. In a 2021 national survey of the farm practices used by grain producers, 80% of farms in the Victorian high-rainfall region and 64% of farms in the New South Wales/Victorian slope regions were applying lime to reduce soil acidity.[1171]

1169. Slattery B, Hollier C 2002, 'The impact of acid soils in Victoria', Department of Natural Resources and Environment (DNRE), Rutherglen, Victoria.
1170. Agriculture Victoria, 'Soil pH' https://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/surface-soil-pH Accessed 10 September 2022.
1171. Umbers A, Watson D 2021, 'GRDC farm practices survey report 2021', report prepared for the Grain Research and Development Corporation (GRDC), Barton, Australian Capital Territory.

Indicator L:08 Soil erosion

L:08 Soil erosion						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	(wind) (water)	?			↙	
Data source(s):	AgVic, National Landcare Project					
Measure(s):	TVC targets in relation to wind and water erosion					

Why this indicator?

A reduction in total vegetation cover (TVC) can lead to soil erosion by wind and water, and impact agricultural land use, while sedimentation from erosion can impact infrastructure, waterways and wetlands.

Criteria used for status assessment

Wind erosion

Good: 8 of Victoria's 10 CMA regions have a TVC of >50%

Fair: 5 to 7 of Victoria's 10 CMA regions have a TVC of >50%

Poor: 0 to 4 of Victoria's 10 CMA regions have a TVC of >50%

Water erosion

Good: 8 of Victoria's 10 CMA regions have a TVC of >70%

Fair: 5 to 7 of Victoria's 10 CMA regions have a TVC of >70%

Poor: 0 to 4 of Victoria's 10 CMA regions have a TVC of >70%

Why this assessment in 2023?

Based on the above criteria, there were only two NRM regions in 2018–19 that did not meet the wind erosion target of >50% TVC, and just three NRM regions that did not meet the water erosion target of >70% TVC. However, the available data are for just one year, a period too short for determining trend. A new measure, TVC, has been used for this indicator and explains the difference between the 2018 and 2023 assessments.

** The SoE 2023 assessment criteria are based on a different measure to that used in the SoE 2018 Report. The SoE 2018 Report used percentage of bare ground cover in dryland areas at risk of erosion. This report uses percentage of each CMA region covered by vegetation. This measure is now used to monitor TVC across Australia. The percentage targets are based on Leys et al. (2020), with >50% TVC for wind erosion and >70% TVC for water erosion.* [1172] *It should be noted that AgVic recommends >70% TVC for pastures on flat and slightly sloping ground (3% slope), 80% to 90% on lighter more erosion-prone soils, and 90% to 100% for steep hill country (>10% slope) on light and erosion-prone soils.*[1173]

Summary of State of the Environment 2018 Report assessment

- Soil erosion can be accelerated by human activities, including vegetation clearing, some cropping activities, soil compaction from farm traffic and livestock, forestry activities, mining, and the development of land for residential and other purposes.
- Relatively wet catchments, such as West and East Gippsland, have the lowest dryland erosion risk in the state, while more arid regions (like Mallee) have a much greater erosion risk.

Critical data used for the 2023 assessment

- National Landcare Project data for each CMA region

1172. Leys J, Howorth J, Guerschman J, Bala B, Stewart J 2020, 'Setting targets for National Landcare Program monitoring and reporting vegetation cover for Australia', Office of Environment and Heritage, Sydney, New South Wales.
1173. Agriculture Victoria, 'Monitoring groundcover and soil degradation' https://agriculture.vic.gov.au/farm-management/soil/erosion/monitoring-groundcover-and-soil-degradation Accessed 10 September 2022.

Land

2023 assessment

In 2010, the Victorian Auditor-General's Office (VAGO) conducted an audit into the management of soil health. The report noted that up to 60% of Victoria's soils were prone to erosion and soil structure decline, and that around 30% of agricultural land was being severely degraded. [1174] The Australian State of the Environment 2021 Report assessed the management of soils as partially effective with a deteriorating trend, stating that:

> 'Land-use intensification and climate change continue to interact, making it harder for land managers to maintain groundcover and meet minimum targets to protect soils from wind and water erosion.' [1175]

Soil erosion comes in several forms that are driven by water in the case of gully, sheet, rill and tunnel (and landslips and streambank erosion), or by wind. The loss of vegetation cover is the primary driver of both wind and water erosion, with land clearance creating extreme examples of gully, tunnel and sheet erosion. Fire is another important driver of soil erosion. Post-fire erosion can result in significant soil losses from the upper part of catchments, leading to sedimentation and excess nutrients in waterways and wetlands that can harm aquatic life and promote blue-green algal blooms.

The percentage of an area that is covered by bare ground is a good measure of the risk of water and wind erosion. Vegetation cover, which includes crops, pastures and native and planted vegetation, reduces soil erosion and evaporation, increases water infiltration and water holding capacity, enhances agricultural productivity, and facilitates carbon sequestration. Vegetation cover can decline due to overgrazing, clearing, drought, cropping, and excessive tillage and compaction by equipment. Seasonal changes in farm practices and year-to-year fluctuations in annual rainfall can also cause variations in vegetation cover.

Using satellite imagery, the National Landcare Program has developed objectives for percentages of total vegetation cover (TVC) and soil erosion risk for each CMA region in Australia. [1176] Table L9 summarises 2018-19 data for the percentage of the TVC target for an agricultural area to be protected from wind as >50%, and for water >70% generally and >80% in high-risk areas of high rainfall, high slope and erodible soils.

All but the Mallee region met the wind erosion target. The >70% water erosion target was not met by the Mallee, North Central and Wimmera regions, while only three regions met the >80% target. Water erosion, however, is not significant in the Mallee or Wimmera due to limited surface drainage.

The Australia State of the Environment 2021 Report assessed soil health as poor in general, as very poor within intensive land-use zones, as poor within extensive land-use zones and good in relatively natural zones. [1177] The report also noted that:

> 'Improving soil health is a key investment priority of the National Landcare Program's Regional Land Partnerships (RLP) and Smart Farms programs'...'The RLP program is funding on-ground and sustainable agriculture projects from June 2018 to July 2023. The RLP program will monitor and report on groundcover as a key indicator for soil erosion regionally at the mid-point (2021) and the end of the program (2023). This RLP indicator measures the area of agricultural land protected from soil erosion above a threshold throughout the year.' [1178]

1174. Victorian Auditor-General's Office (VAGO) 2020, 'Soil health management', Melbourne, Victoria.
1175. Commonwealth of Australia 2021, 'Australian state of the environment', Canberra, Australian Capital Territory https://soe.dcceew.gov.au/ Accessed 7 June 2023.
1176. Leys J, Howorth J, Guerschman J, Bala B, Stewart J 2020, 'Setting targets for National Landcare Program monitoring and reporting vegetation cover for Australia', Office of Environment and Heritage, Sydney, New South Wales.
1177. Commonwealth of Australia 2021, 'Australian state of the environment', Canberra, Australian Capital Territory https://soe.dcceew.gov.au/ Accessed 7 June 2023.
1178. Ibid.

Table L9: Percent area of each natural resource management region meeting the target of soil erosion protection during 2018-19.[1179]

NRM Region	Percent area >50% TVC in 2018-19 (months below target)	Percent area >70% TVC in 2018-19 (months below target)	Percent area >80% TVC in 2018-19 (months below target)
Corangamite	99.7 (2)	93.7 (3)	74.3 (2)
East Gippsland	100 (2)	99.3 (4)	93 (3)
Glenelg Hopkins	99.9 (2)	96.0 (2)	79.9 (3)
Goulburn Broken	99.7 (5)	91.2 (5)	68.7 (5)
Mallee	40.9 (3)	2.2 (3)	0.1 (3)
North Central	89.4 (2)	42.0 (3)	19.3 (2)
North East	99.9 (5)	97.1 (5)	83.8 (5)
Port Phillip and Western Port	99.5 (5)	89.8 (1)	71.4 (1)
West Gippsland	99.9 (5)	99.1 (7)	91.9 (6)
Wimmera	95.4 (0)	50.0 (0)	24.7 (0)

Grand Ridge Road.
Credit: Nicky Cawood. © Destination Gippsland.

1179. Leys J, Howorth J, Guerschman J, Bala B, Stewart J 2020, 'Setting targets for National Landcare Program monitoring and reporting vegetation cover for Australia', Office of Environment and Heritage, Sydney, New South Wales.

Indicator L:09 Contaminated sites

L:09 Contaminated sites						
Regions(s)	2023 status	2023 trend	2023 confidence	2018 status	2018 trend	2018 data quality
Statewide		?			?	
Data source(s):	DELWP, EPA Victoria					
Measure(s):	Number of contaminated and potentially contaminated land locations					

Why this indicator?

Like other economies with a significant history of settlement and industrial activity, Victoria has a legacy of waste and pollution.

Contaminated sites range from landfills and industrial sites to sites requiring active management to reduce the risk to human health and the environment.

Why this assessment in 2023?

The basis of the status assessment of fair is that several sites in Victoria are known to be contaminated or are the location of current activity involving a relatively high risk of contamination. The subjective interpretation is that contaminated sites are exerting moderate pressure on environmental condition and human health.

The trend is unclear because information is generally 'point-in-time' spatial data.

Although the quality of datasets is good, the confidence for this assessment is low because there are no thresholds available to guide the status assessment. Furthermore, most data presented in this indicator are maintained by EPA Victoria and collected to help regulate and manage contamination; in their current format they are not suited for the broadscale assessment of status or trend in contaminated land.

Summary of State of the Environment 2018 Report assessment

- No overall status assessment was provided for this indicator due to the lack of information about contaminated sites across the state. The knowledge at the time only pertained to a subset of contaminated sites. The trend was unclear because, even though there was evidence of environmental audits taking place that were leading to improved land use, it was unclear how many sites had become contaminated during the reporting period and what the overall change in the number of contaminated sites had been.
- There were 603 53X environmental audits completed in the state from 2013 to 2017, with a peak of 142 audits in 2015. The number of audits dropped during the two years prior to the SoE 2018 Report.
- The number of sites on EPA Victoria's Priority Site Register (PSR) had remained reasonably stable from June 2013 to June 2018, with the number of sites on the register at the end of each financial year holding steady between 230 and 300.
- Some chemicals were emerging as threats for site contamination, including per- and poly-fluoroalkyl substances.

Critical data used for the 2023 assessment

- EPA Victoria's PSR
- EPA Victoria's contaminated land notifications
- EPA Victoria's Groundwater Quality Restricted Use Zones (GQRUZs)
- EPA Victoria's licenced sites
- EPA Victoria's environmental audits

Land

2023 assessment

No complete database of contaminated sites exists for Victoria, although DELWP and EPA Victoria partnered to produce Victoria Unearthed, which is an online mapping tool that brings together relevant information on potential land and groundwater contamination.[1180]

Despite this, EPA Victoria estimated as part of the development of the Environment Protection Regulations 2021 (the Regulations) that there were upwards of 30,000 contaminated sites during 2019 with varying levels of risk to human health and the environment across Victoria. [1181] The estimates categorised the contaminated sites as follows:

- 1,400 high-risk (non-aqueous phase liquids) sites
- 3,300 high-risk (vapours) sites
- 1,800 high-risk (groundwater contamination offsite) sites
- 9,400 high-risk (groundwater contamination on-site) sites
- 7,400 medium-risk (unsafe for current use, high contaminant levels) sites
- 1,500 medium-risk (unsafe for current use) sites
- 4,100 low-risk (safe for current use) sites
- 1,200 low-risk (below thresholds) sites.

These estimates highlight the potential value of maintaining an active database on contaminated sites. If this information was updated periodically (e.g. annually), and included the area of contamination, then it would be the primary resource for assessing the environmental status and trend of contaminated sites in Victoria.

Priority sites

EPA Victoria's PSR is one of the best available data sources to inform the extent of currently known land contamination. A priority site is either a site issued with a current clean up notice or pollution abatement notice, or it is a site issued with a current environmental action notice or other notice to manage contamination. [1182]

The contamination at priority sites may pose a risk to human health or the environment, and the sites are no longer fit for their approved land uses without management or clean-up.[1183]

The number of sites on EPA Victoria's PSR remained reasonably stable between 230 and 300 from June 2013 to June 2018. Since then, the number of sites on the register has steadily climbed to be above 400 as of June 2021, before a slight dip to 371 in January 2023.[1184]

The location of contaminated sites is heavily weighted towards Victorian regions with greater industrial activity and people: areas with more industrial facilities and people are, on balance, more likely to have more pollution reports. This is shown by heatmaps of PSR sites for Victoria (Figure L6) and Melbourne (Figure L7), with the distinct hotspots being industrial areas in Melbourne's western and south-eastern suburbs.

1180. Department of Environment Land, Water and Planning (DELWP), 'Victoria unearthed' https://www.environment.vic.gov.au/sustainability/victoria-unearthed Accessed 26 April 2022.
1181. Department of Environment Land, Water and Planning (DELWP), Environment Protection Authority (EPA) 2019, 'Regulatory Impact Statement: proposed environment protection regulations', prepared by Deloitte Access Economics for the purpose of assessing the impact of draft Environment Protection Regulations 2019, https://engage.vic.gov.au/download/document/8219 Accessed 15 September 2022.
1182. Environment Protection Authority (EPA), 'Priority Sites Register' https://www.epa.vic.gov.au/for-community/environmental-information/land-groundwater-pollution/priority-sites-register Accessed 30 January 2023.
1183. Ibid.
1184. State Government of Victoria, 'EPA Victoria priority sites register (PSR) - location points' https://discover.data.vic.gov.au/dataset/epa-victoria-priority-sites-register-psr-location-points2 Accessed 30 January 2023.

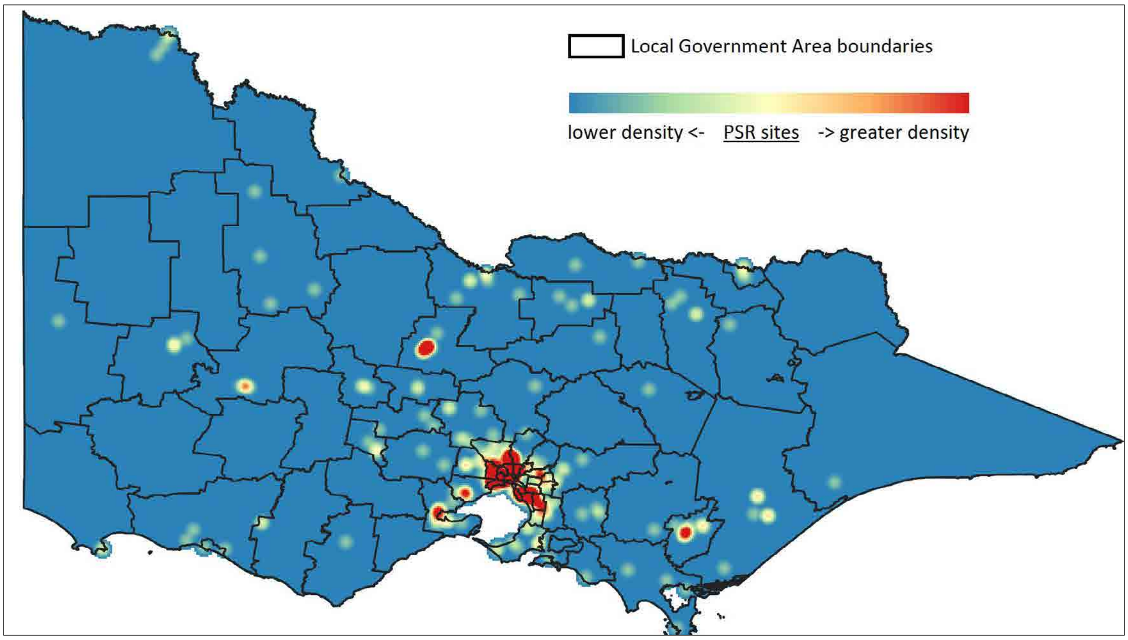


Figure L6: Heatmap of sites across Victoria on EPA Victoria's Priority Sites Register in January 2023.[1185]

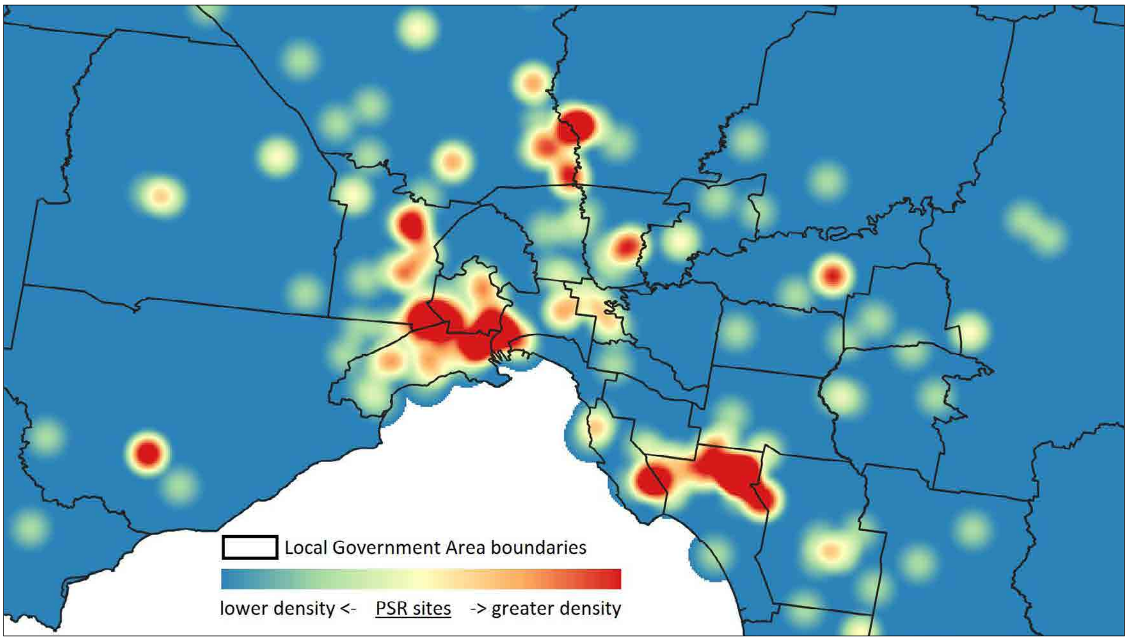


Figure L7: Heatmap of sites across Melbourne on EPA Victoria's Priority Sites Register in January 2023.[1186]

The total number of PSR sites for each local government area (LGA) is provided in Table L10, which shows the top 10 LGAs for priority sites and includes all of the five LGAs with the greatest proportion of land zoned for industrial use. Of the top 10 LGAs having the greatest number of PSR sites, four are in Melbourne's west, three are in regional Victoria, two are in Melbourne's south-east and one is in Melbourne's north.

1185. State Government of Victoria, 'EPA Victoria priority sites register (PSR) - location points' https://discover.data.vic.gov.au/dataset/epa-victoria-priority-sites-register-psr-location-points2 Accessed 30 January 2023.
1186. Ibid.

Table L10: Top 10 LGAs for number of sites on EPA Victoria's Priority Sites Register in January 2023.[1187, 1188]

LGA	Number of sites on EPA Victoria's Priority Sites Register	Ranking of proportion of LGA with land zoned for industrial land (1 = LGA with the greatest proportion of land zoned for industrial use)
Kingston	29	4
Hume	26	11
Brimbank	23	2
Hobsons Bay	22	5
Greater Bendigo	17	30
Maribyrnong	16	3
Greater Geelong	15	20
Latrobe	13	24
Greater Dandenong	11	1
Wyndham	11	12

Contaminated land notifications

As part of the *EP Act*, there have been requirements which commenced July 2021 for land duty holders to notify EPA Victoria of confirmed contamination above thresholds that indicate potential risks to human health and the environment.[1189] EPA Victoria has provided monthly data for contaminated land notifications, which shows 471 contaminated land notifications were made to EPA Victoria in the first 11 months of the Regulations, from July 2021 to May 2022. More than three quarters of these notifications were received in the first five months (an average of 74 notifications per month), compared to an average of 17 notifications per month for the most recent 6 months of data (December 2021 to May 2022).

EPA Victoria categorises the con taminated land notification data by type of contamination (e.g. non-aqueous phase liquid, groundwater contamination and onsite soil contamination) and cause of contamination (e.g. industry or activity). These breakdowns will be particularly useful to incorporate in this indicator assessment in the next SoE report, when more than five years of data will have been collected and enable a comprehensive analysis.

Groundwater Quality Restricted Use Zones

GQRUZ are areas where there has been historic groundwater pollution due to previous industrial or other activities, and where groundwater contamination remains after all reasonably practicable efforts have been made to clean up the pollution as a part of an environmental audit.[1190]

In January 2023, there were 485 GQRUZs in Victoria, with more than 90% of the GQRUZs located in Melbourne, indicating the scale of groundwater pollution and restrictions impacting metropolitan LGAs. [1191] The trend in the number of GQRUZs in Victoria is unclear, with only current data available.

The Melbourne LGAs of Brimbank, Greater Dandenong, Melbourne and Moreland are the only LGAs in Victoria that are ranked in the top 10 for cumulative GQRUZ area and have GQRUZs covering more than 1% of the LGAs land area. All four of these LGAs are ranked in the top 10 for the greatest proportion of LGAs with land zoned for industrial land, which highlights the link between industrial activity and groundwater pollution.

1187. State Government of Victoria, 'EPA Victoria priority sites register (PSR) - location points' https://discover.data.vic.gov.au/dataset/epa-victoria-priority-sites-register-psr-location-points2 Accessed 30 January 2023.
1188. State Government of Victoria, 'Vicmap planning - Planning scheme zone polygon', https://discover.data.vic.gov.au/dataset/vicmap-planning-planning-scheme-zone-polygon Accessed 31 January 2023.
1189. State Government of Victoria, '*Environment Protection Act 2017*', Authorised version 009, https://content.legislation.vic.gov.au/sites/default/files/2022-09/17-51aa009%20authorised_0.pdf Accessed 31 January 2023.
1190. Environment Protection Authority (EPA), 'About groundwater' https://www.epa.vic.gov.au/for-community/environmental-information/land-groundwater-pollution/about-groundwater Accessed 31 January 2023.
1191. State Government of Victoria, 'EPA Victoria Groundwater Quality Restriction Use Zones (GQRUZ) - Location Polygons' https://discover.data.vic.gov.au/dataset/epa-victoria-groundwater-quality-restriction-use-zones-gqruz-location-polygons Accessed 30 January 2023.

Land

EPA Victoria Licenced Sites

EPA Victoria licenced sites are a category of regulation within the regulations addressing complex activities that justify the highest level of regulatory control due to the significant risk of harm to human health and the environment, or a high potential for mismanagement.[1192]

In April 2022, there were 643 sites licenced by EPA Victoria. [1193] Similar to the location of PSR sites, EPA Victoria's licenced sites are generally located in LGAs with a greater proportion of land zoned for an industrial use. More than one third of all EPA Victoria's licenced sites are located within 10 LGAs (Hume, Greater Dandenong, Latrobe, Wyndham, Greater Geelong, Brimbank, Campaspe, Yarra Ranges, South Gippsland and Murrindindi). This highlights the disproportionate risk of contaminated land across Victoria, as these licenced sites are premises with the potential for significant environmental impact.

Environmental audits

An environmental audit provides advice on risks of harm to human health or the environment from contaminated land, waste and pollution, and may consider the suitability of site uses. Environmental audits can also be used to provide recommended measures to manage the risk of harm to human health or the environment. Only environmental auditors appointed by EPA Victoria can conduct environmental audits.[1194]

Under the *Environment Protection Act 1970*, audits could be in two forms. A 53X (condition of the environment) audit verified whether potentially contaminated land may be used for a specific use (industrial, commercial or residential). A 53V (risk of harm) audit was most commonly used by EPA Victoria to understand the risk to the environment posed by an industrial activity, or to validate that clean-up of contaminated land or groundwater had occurred.[1195]

The current *EP Act* removed the distinction between 53X and 53V audits. All audits are now completed under Section 208, and there are three kinds of audits:

- suitability of land use
- risk of harm from an activity
- risk of harm from contaminated land, waste, or pollution. [1196]

Section 204 of the *EP Act* introduced a new measure, known as a preliminary risk screen assessment (PRSA).[1197] Rather than replacing an environmental audit, a PRSA determines if an audit is required. As with audits, only an environmental auditor appointed by EPA Victoria can perform a PRSA.[1198]

Data on environmental audits completed under Section 208 of the current *EP Act* are only available as a searchable register, therefore, no consolidated data were available to be analysed as part of the status and trend assessments for this indicator. [1199] Data on environmental audits completed under the *Environment Protection Act 1970* are available from DataVic — Victoria's open data platform. [1200]Based on advice from EPA Victoria, data on 53X environmental audits have been deemed as the most suitable environmental audit data to be used for this indicator. Generally, a 53X audit (condition of the environment) verifies that potentially contaminated land may be used for a specific use, while a 53V audit (risk of harm) has most commonly been used by EPA Victoria to understand the risk the environment posed by a specific activity (e.g. industrial), or to validate that clean-up of contaminated land or groundwater has occurred. For the most recent five years of data (2016-17 to 2020-21), an average of 100 53X environmental audits have been competed each financial year. This is a 6% increase from the previous 5-year period (2011-12 to 2015-16) when an average of 94 properties per year were issued with a certificate. These numbers can't be used to determine whether an increasing amount of land remediation has been taking place in Victoria, however, they can be used as a proxy to see trends in contaminated land works. This is shown in Figure L8, which displays the number of 53X environmental audits completed by financial year.

1192. Environment Protection Authority (EPA) 2021, 'Permissions scheme policy', publication 1799.2, Carlton, Victoria.
1193. State Government of Victoria, 'EPA Victoria Licence - Location Points' https://discover.data.vic.gov.au/dataset/epa-victoria-licence-location-points1 Accessed 31 January 2023.
1194. Environment Protection Authority (EPA), 'Environmental audit system' https://www.epa.vic.gov.au/for-business/find-a-topic/environmental-audit-system Accessed 31 January 2023.
1195. State Government of Victoria 2021, '*Environment Protection Act 1970*, Version 216 https://content.legislation.vic.gov.au/sites/default/files/2021-03/70-8056aa216%20authorised.pdf Accessed 31 January 2023
1196. State Government of Victoria, '*Environment Protection Act 2017*', Authorised version 009 https://content.legislation.vic.gov.au/sites/default/files/2022-09/17-51aa009%20authorised_0.pdf Accessed 31 January 2023.
1197. Ibid.
1198. Environment Protection Authority (EPA), 'Preliminary risk screen assessments' https://www.epa.vic.gov.au/for-business/find-a-topic/environmental-audit-system/preliminary-risk-screen-assessments Accessed 31 January 2023.
1199. Environment Protection Authority (EPA), 'Register of environmental audits' https://www.epa.vic.gov.au/about-epa/public-registers/environmental-audits Accessed 31 January 2023.
1200. State Government of Victoria, 'EPA Victoria Environmental Audit Reports - Location Polygons', https://discover.data.vic.gov.au/dataset/epa-victoria-environmental-audit-reports-location-polygons2 Accessed 31 January 2023.

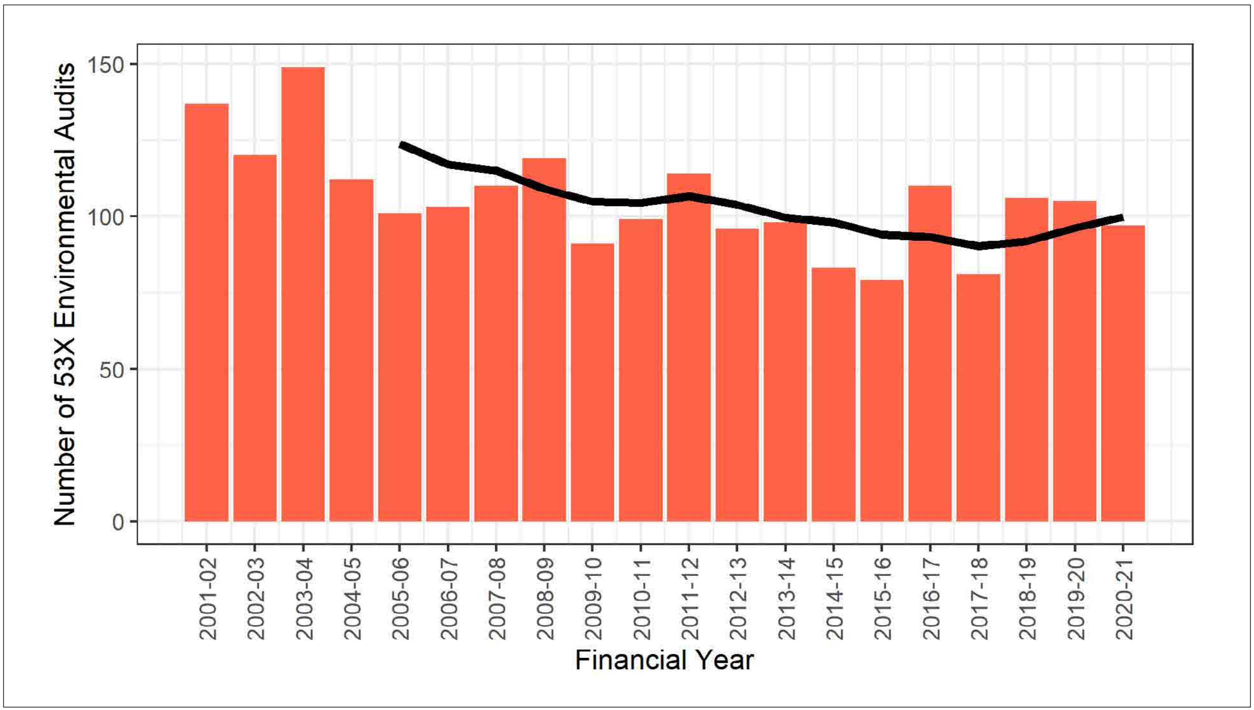


Figure L8: Number of 53X environmental audits completed by financial year in Victoria from 2001-02 to 2020-21.[1201]

Meeniyan-Mirboo North Road, Gippsland 2017.
Credit: Josie Withers. © Visit Victoria.

1201. State Government of Victoria, 'EPA Victoria Environmental Audit Reports - Location Polygons', https://discover.data.vic.gov.au/dataset/epa-victoria-environmental-audit-reports-location-polygons2 Accessed 31 January 2023.

Indicator L:10 Participation in natural resource management activities

L:10 Participation in natural resource management activities						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide	Good	Improving	High	Good	Improving	Good
Data source(s):	CMAs, Landcare, PV					
Measure(s):	Number of volunteers within government- and community-based programs Number of volunteer hours with government- and community-based programs CMA targets and actual figures for participation					

Why this indicator?

Individual and community participation can improve environmental stewardship, connect people to nature, and improve physical, mental and emotional health and wellbeing.

NB: This modified SoE 2023 indicator was formed by merging the SoE 2018 indicators 'L:10 Land management activities' and 'L:11 Participation in natural resource management activities'.

Criteria used for status assessment

Good: ≥7 of Victoria's 10 CMA regions meeting their targets for participation in NRM activities

Fair: 3 to 6 of Victoria's 10 CMA regions meeting their targets for participation in NRM activities

Poor: <3 of Victoria's 10 CMA regions meeting their targets for participation in NRM activities

Why this assessment in 2023?

All CMAs met, or exceeded, their targets for event participation across the five years, except for one CMA, which did not meet its target during one of the years. The 2019–20 bushfires briefly affected participation in eastern Victoria and COVID-19 impacted levels of participation in NRM activities. However, the general trend is improving.

Summary of State of the Environment 2018 Report assessment

- Parks Victoria's community network provided 281,776 volunteering hours, with 37,200 volunteer attendees across 167 parks and included 234 volunteer (or volunteer-involving) organisations.
- The Victorian Catchment Management Council estimated that Victorian communities co-contributed approximately $116 million in 2015–16 to catchment management across all Victorian CMA regions.
- There were approximately 600 Landcare groups and 64 Landcare networks in Victoria that were reported as having contributed 375,000 hours in 2016–17 to land, water and biodiversity protection across Victoria, providing a value of $11.2 million.

Critical data used for the 2023 assessment

- Victorian CMA Action and Achievements Reports from 2017-18 to 2020-21.

2023 assessment

Victoria has a strong history of environmental volunteering, with volunteers contributing enormously to improving the environment, local communities and the economy. Environmental volunteering encompasses a diverse range of environmental and sustainability activities carried out by individuals and community groups. This includes stewardship, physical work and on-the-ground activities to protect and enhance the natural environment. These activities can occur in parks, in coastal areas and on private and public land. Key groups include Traditional Owners, Friends groups, Landcare, Coastcare, Parks Victoria volunteers, committees of management, community nurseries and environment groups.

There are approximately 600 Landcare and environmental volunteering groups and 64 Landcare networks across Victoria, supported by the Victorian Landcare Facilitator program. They contribute to the almost 2,000 groups and organisations volunteering for nature across Victoria. These networks have been involved in the delivery of several government-funded bushfire recovery projects.

The Australia State of the Environment 2021 Report noted that a 2021 KPMG survey of 1,000 volunteers and coordinators in 2021 found that:

- overall mental health had moderately or significantly improved for 49% of survey participants
- feelings of empowerment, belonging and purpose increased
- most mental health benefits arise for those who contribute 20–40 hours per month
- additional savings of $191 million per year were estimated to arise due to improved productivity and resilience to natural disasters.[1202]

Multiple opportunities exist for landholders to participate in private land conservation in Victoria, with the Trust for Nature covenanting program (additional detail in B:36) and the Land for Wildlife program having the greatest longevity. Land for Wildlife is a Victorian government program that began in 1981 and encourages landowners to create or protect habitat on their properties. Over 12,000 people, with 5,000 properties covering more than 530,000 hectares, have joined the program which provides 'the ability for landholders with a range of habitat values on their land to be recognised for the contribution they (and their properties) are making to conservation.[1203, 1204]

CMAs engage their communities in NRM activities. In 2020-21, there were 56,959 people attending authority events (Table L11).[1205] Each authority is also working with local groups on projects to restore habitat and help recover threatened species in their regions.

Improving the management of biodiversity on private land is also the focus of the 10-year management agreements entered into between CMAs and landholders. Such agreements can include vegetation management and changes in grazing regimes. In 2019–20 and 2020-2021, there were 1,078 management agreements in place, with livestock grazing control covering 8,403 hectares.[1206, 1207]

The Commonwealth Government allocated $57 million over five years (2018–2023) to support biodiversity conservation projects through Regional Land Partnerships. These collaborative projects between CMAs and Landcare groups work to control herbivore, pest predator and weeds, conduct revegetation, and establish permanent protection of private land and land management agreements.

In State of the Parks 2018, Parks Victoria reported that volunteer engagement in land management activities, such as planting, habitat restoration, wildlife monitoring, environmental research, conservation of historic heritage sites and maintenance of tracks, grew from 219,000 to 281,776 hours in 2017-18 and to more than 300,000 hours in 2018-19. [1208] More than 80% of parks reported that volunteers were essential, or contributed to, achieving park objectives.[1209]

In the Coastcare program, community organisations and volunteer groups help to maintain marine and coastal environments through activities such as revegetating coastal areas, building boardwalks, fencing, building tracks, monitoring native shorebirds and other animals, presenting education and awareness-raising sessions, plantings, landscaping coastal areas and protecting cultural sites.

Launched in 2018, the Victorians Volunteering for Nature: Environmental Volunteering Plan has provided a revitalised approach to the sector, including a comprehensive annual snapshot of the state of volunteering for nature. [1210] The snapshot, Volunteering Naturally, collects the annual hours volunteered and number of volunteers across Victorian environmental volunteer organisations and groups (Table L12).

Volunteering Naturally recognises the variety of types and modes of environmental volunteering. This includes regular volunteering activity, large annual volunteering events, community-based models of volunteering in nature, and more recent interest in living sustainably. Data were not extrapolated from groups that did not respond and, therefore, it is likely that the numbers in Table L12 are underestimated. A lower level of reported hours of active volunteerism was evident due to COVID-19 restrictions during the reporting period.

1202. Commonwealth of Australia 2021, 'Australian state of the environment', Canberra, Australian Capital Territory https://soe.dcceew.gov.au/ Accessed 7 June 2023.
1203. Department of Energy, Environment and Climate Change (DEECA), 'Land for Wildlife', Melbourne, Victoria, https://www.wildlife.vic.gov.au/protecting-wildlife/land-for-wildlife Accessed 20 January 2023.
1204. Prado J, Puszka H, Forman A, Cooke B, Fitzsimons J 2018, 'Trends and values of "Land for Wildlife" programs for private land conservation', *Ecological Management & Restoration*, 19, pp. 136-146.
1205. Victorian Catchment Management Authorities (CMAs) 2021, 'Actions and achievements report 2020-21', Melbourne, Victoria.
1206. Victorian Catchment Management Authorities (CMAs) 2020, 'Actions and achievements report 2019–20', Melbourne, Victoria.
1207. Victorian Catchment Management Authorities (CMAs) 2021, 'Actions and achievements report 2020–21', Melbourne, Victoria.
1208. Parks Victoria (PV) 2020, 'State of the parks 2018', Melbourne, Victoria.
1209. Ibid.
1210. Department of Environment, Land, Water and Planning (DELWP) 2018, 'Victorians volunteering for nature: environmental volunteering plan', Melbourne, Victoria.

Table L11: Volunteering event participation and targets by CMA from 2017-18 to 2020-21.[1211, 1212, 1213, 1214]

CMA	2017-18 # of participants (target)	2018-19 # of participants (target)	2019-20 # of participants (target)	2020-21 # of participants (target)
Corangamite	11,751 (6,826)	10,450 (6,721)	9,559 (4,768)	7,749 (970)
East Gippsland	4364 (2,037)	1,676 (876)	1,736 (1,416)	699 (941)
Glenelg Hopkins	5285 (2,456)	6,241 (3,444)	4,689 (2,388)	7,565 (4,000)
Goulburn Broken	30,111 (11,147)	17,778 (10,537)	15,298 (10,277)	3,594 (246)
Mallee	8,905 (6,332)	7,695 (5,016	6,004 (4,794)	6,275 (3,971)
North Central	7,088 (3,792)	5,993 (5,524)	5,421 (2,079)	4,503 (2,549)
North East	11,602 (3,031)	8,645 (2,155)	7,385 (2,189)	4,199 (2,200)
Port Phillip and Westernport	8,837 (1,877)	6,179 (970)	6,953 (1,332)	16,010 (95)
West Gippsland	3,641 (1,041)	5,929 (1,705)	3,639 (1,307)	2,750 (2,750)
Wimmera	5,372 (2,340)	6,273 (4,900)	6,597 (655)	2,931 (422)

Table L12: Number of hours contributed by volunteers in Volunteering Naturally from 2019 to 2022.[1215]

	2019	2020	2021	2022
Volunteer hours	1,506,617	2,429,484	1,299,169	1,481,823
Volunteer numbers	134,244	186,508	160,970	173,629

1211. Victorian Catchment Management Authorities (CMAs) 2018, 'Actions and achievements report 2017-18', Melbourne, Victoria.
1212. Victorian Catchment Management Authorities (CMAs) 2019, 'Actions and achievements report 2018-19', Melbourne, Victoria.
1213. Victorian Catchment Management Authorities (CMAs) 2020, 'Actions and achievements report 2019–20', Melbourne, Victoria
1214. Victorian Catchment Management Authorities (CMAs) 2021, 'Actions and achievements report 2020-21', Melbourne, Victoria.
1215. Department of Environment, Land, Water and Planning (DELWP), 'Unpublished data', Melbourne, Victoria, Accessed 2022.

Land

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

L:11 Use of best practice for sustainability outcomes on agricultural lands						
Regions(s)	**2023 status**	**2023 trend**	**2023 confidence**	**2018 status**	**2018 trend**	**2018 data quality**
Statewide		↗			?	
Data source(s):	DELWP					
Measure(s):	Area of land with improved and sustainable agricultural practices in Victoria					

Why this indicator?

Land managed using best-practice techniques can maintain and improve land and ecosystem health. This indicator arises from UN SDG Target 2.4, which aims to ensure sustainable food production systems and the implementation of resilient agricultural practices by 2030.

NB: This modified SoE 2023 indicator was formed by merging the SoE 2018 indicators 'L:12 Use of best practice on agricultural lands' and 'L:13 Proportion of agricultural land area under productive and sustainable agriculture'. The 2018 assessment provided above is for 'L:12 Use of best practice on agricultural lands' as its measure is most comparable to that of the modified 2023 indicator.

Criteria used for status assessment

Good: ≥7 of Victoria's 10 CMA regions meet or exceed their targets for improved agricultural practices

Fair: 3 to 7 of Victoria's 10 CMA regions meet or exceed their targets for improved agricultural practices

Poor: <3 of Victoria's 10 CMA regions meet or exceed their targets for improved agricultural practices

Why this assessment in 2023?

There are no clear official targets for the use of best practice on agricultural land, whether it be number of farmers using best-practice techniques or spatial extent of land improved. The above criteria are based on agricultural improvements reported by CMAs, which is a limited data set. The data presented in the indicator assessment narrative suggest that there is an improving trend in best-practice in agriculture.

Summary of State of the Environment 2018 Report assessment

- From 2014–15 to 2016–17, the area of land with improved agricultural practices increased each year.
- Agriculture Victoria's Land Health Program influenced and improved management practices on land used for stock and crops from 2013-14 to 2015-16.
- Agricultural industries were undertaking a range of processes to improve their sustainability.

Critical data used for the 2023 assessment

- Victorian CMA Action and Achievements Reports from 2017-18 to 2021-22
- Australian Agricultural Sustainability Framework
- Department of Agriculture, Water and the Environment website
- Drivers of practice change in land management in Australian agriculture
- GRDC Farm Practices Survey Report 2021

2023 assessment

CMAs work with landholders to improve agricultural practices, which are 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.

Table L13 presents the results of these efforts for the years 2017-18 to 2020-21 and reveals that the improvement target was well exceeded in each year except for 2020-21. The total area of improvements across the four years was 96,971 hectares.

Table L13: Area of improved agricultural practices from 2017-18 to 2020-21.[1216, 1217, 1218, 1219]

Year	Improvement target (ha)	Actual improvement (ha)
2017-18	30,032	54,787
2018-19	2,805	6,208
2019-20	20,125	27,084
2020-21	19,211	8,892
Total	72,173	96,971

The Commonwealth Government's Agriculture Stewardship Package aims to develop arrangements to reward farmers for protecting biodiversity and identify other sustainability opportunities. Current opportunities include:

- Carbon + Biodiversity Pilot to develop a market-based mechanism to reward farmers who replant areas to increase biodiversity on their property and maintain those areas for at least 25 years. In return, farmers will receive payments and could become eligible for carbon credits. In Victoria, the pilot is being trialled in the North Central and Broken Goulburn regions.[1220]
- Enhanced Remnant Vegetation Pilot where farmers could receive payments by protecting biodiversity using fencing, weed and pest control, and replanting.
- Australian Farm Biodiversity Certification Scheme which enables consumers to identify produce from farms where land stewardship and biodiversity conservation are occurring.
- Agriculture Biodiversity Policy Statement that sets out agriculture's role in protecting biodiversity.[1221]

Land Health, which is a program delivered by Agriculture Victoria, works with dryland farmers across Victoria to improve the productivity, quality and health of their land and adjacent waterways. Partners include CMAs, Landcare networks, the Commonwealth Government, industry organisations and agricultural education institutions. The Land Health program offers training, advice and information to dryland farmers and rural service providers in the areas of farm planning, productive soils, farm water, grazing and pasture management, sustainable cropping and soil conservation.

1216. Victorian Catchment Management Authorities (CMAs) 2018, 'Actions and achievements report 2017-18', Melbourne, Victoria.
1217. Victorian Catchment Management Authorities (CMAs) 2019, 'Actions and achievements report 2018-19', Melbourne, Victoria.
1218. Victorian Catchment Management Authorities (CMAs) 2020, 'Actions and achievements report 2019-20', Melbourne, Victoria.
1219. Victorian Catchment Management Authorities (CMAs) 20210, 'Actions and achievements report 2020-21', Melbourne, Victoria.
1220. Department of Climate Change, Energy, the Environment and Water (DCCEEW), 'Carbon + biodiversity pilot', https://www.dcceew.gov.au/environment/environmental-markets/agriculture-stewardship/c-b-pilot Accessed 3 August 2023.
1221. Department of Agriculture, Water and the Environment (DAWE), 'Agriculture stewardship package' https://www.agriculture.gov.au/ag-farm-food/natural-resources/landcare/sustaining-future-australian-farming Accessed 14 May 2021.

Land

Theme	Categories	V3 Principles (desired outcome or IDEAL STATE)	V3 Criteria (conditions to be met to comply with a Principle)
Environmental Stewardship	GREENHOUSE GASES & AIR	*P1. Net anthropogenic GHG emissions are limited to minimise climate change*	C1. GHG emissions are reduced throughout lifecycle C2. Carbon emissions are sequestered throughout lifecycle C3. Where necessary (i.e. if C1 & C2 are impractical), GHG emissions are offset throughout lifecycle by purchasing recognised credits or participating in recognised projects C4. Plant, equipment and machinery are appropriately maintained and operated to maximise efficiency
		P2. Adverse impacts to air quality are avoided or minimised	C5. Activities which generate particulate matter are conducted within regulatory guidelines
	SOIL & LANDSCAPES	*P3. Soil health and functionality are protected and enhanced* *P4. Landscape degradation is avoided or minimised*	C6. Soils are managed to provide ecosystem services, including sustainable agricultural production C7. Land under productive agricultural management delivers beneficial environmental services C8. Natural waterways are preserved and improved
	BIODIVERSITY	*P5. Biodiverse ecological communities are protected and enhanced*	C9. Farms support a diverse range of beneficial flora and fauna species C10. Farm-related ecosystems are functioning and thriving
	WATER	*P6. Water resources are used responsibly and equitably*	C11. Water is used efficiently in agricultural systems C12. Adverse impacts to surface water and groundwater quality are prevented
	MATERIALS & RESOURCES	*P7. Finite resources are safeguarded in circular economic systems*	C13. The use of inputs and resources that cannot be reused or recycled is minimised C14. Renewable sources of inputs are prioritised C15. Residues and waste are reused or recycled
People, Animals & Community	HUMAN HEALTH, SAFETY & WELLBEING	*P9. Safe agricultural outputs are produced for public consumption*	C16. Food and fibre is produced, packaged and distributed to world-leading standards of safety C17. Food produced by the industry is healthy and nutritional C18. Producers practice good antimicrobial stewardship
		P9. Safe working environments are provided for employees	C19. Occupational health and safety are upheld in the working environment C20. Labour rights are respected and compliance with relevant legislation is demonstrated C21. Physical health and mental wellbeing are valued and actively supported
	LIVELIHOODS	*P10. Fair access to a decent livelihood is provided within the industry*	C22. Profitability and competitiveness are encouraged C23. A rewarding and enriching work environment is provided
	RIGHTS, EQUITY & DIVERSITY	*P11. Discrimination is not tolerated in an inclusive industry*	C24. Human rights are respected unequivocally C25. Workplace diversity is valued and actively supported
	ANIMAL WELLBEING	*P12. Farmed animals are given the best care for whole of life*	C26. Best practice on-farm husbandry is demonstrated C27. Safe transportation of animals is demonstrated C28. Humane end of life for farmed animals is ensured
	SOCIAL CONTRIBUTION	*P13. Society benefits from the agricultural industry's positive contribution*	C29. Industry contributes to local community economic growth and social capital C30. Indigenous culture is recognised, valued and actively supported C31. Community trust in the industry is upheld
Economic Resilience	GOOD GOVERNANCE	*P14. All industry participants behave ethically and lawfully*	C32. Compliance with applicable laws and regulations is demonstrated C33. Fair access to participate equally in markets is ensured C34. Zero tolerance for bribery or corruption is demonstrated
		P15. Reslience is protected and enhanced by assessment, mitigation and management of risks	C35. Government and industry develop and extend overarching national scenario planning for industry risks C36. Industry participants develop, implement and regularly review risk management plans C37. Innovation and infrastructure are well-resourced and supported by government and industry, and can be equitably accessed by industry participants
	FAIR TRADING	*P16. Unconscionable conduct is eliminated from the supply chain via demonstrated transparency and accountability*	C38. Product provenance information is readily available (i.e. traceability) C39. Information asymmetry in the supply chain is eliminated where perverse outcomes are a risk C40. Carbon footprint accounting is harmonised
	BIOSECURITY	*P17. Biosecurity threats are assessed, mitigated and effectively managed in systems of continuous improvement*	C41. Farms have systems in place to monitor risk, prevent and mitigate adverse impacts from biosecurity threats C42. Industry has systems in place to monitor risk, prevent and mitigate adverse impacts from biosecurity threats C43. Government has systems in place to monitor risk, prevent and mitigate adverse impacts from biosecurity threats

Figure L9: Key elements of the Australian Agricultural Sustainability Framework V3 (April 2022).[1222]

1222. Australian Farm Institute 2022, 'AASF: Australian agricultural sustainability framework' https://www.farminstitute.org.au/product/aasf-australian-agricultural-sustainability-framework/ Accessed 28 August 2022.

Land

Part of the Australian Government's $34-million Agriculture Stewardship Package (2018–19 to 2022–23) is the development and trial over 2019 to 2022 of the Australian Agricultural Sustainability Framework (Figure L9). The two objectives of the framework are to:

- integrate productivity, sustainability and biodiversity on Australian farms to provide lasting benefits to farmers and the community
- ensure Australian farmers can showcase best-practice sustainability and biodiversity management of natural resources and ensure these actions are recognisable by supply chains, markets, investors, the community and other farmers.[1223]

After extensive consultation, the Australian Farm Institute released the third iteration of the Australian Agricultural Sustainability Framework in April 2022. The framework contains three themes — 'Environmental stewardship', 'People, animals and communities' and 'Economic resilience' — and 17 principles and 43 criteria.[1224]

Although now 10 years old, a survey of Australian farmers in the broadacre sector (1,228 respondents) and dairy sector (265 respondents) revealed the levels of adoption of land management practices. [1225] Table L14 summarises the results of the survey. A similar survey of 179 land managers in the horticulture sector was also conducted in 2014 (Table L15).

Grazing and crop management had higher adoption rates than native vegetation management and weed management, and generally the level of adoption was higher in the broadacre sector. For horticultural practices, soil management had higher adoption rates than vegetation management, although horticultural properties are generally smaller and may not have the same opportunities to improve or maintain native vegetation as the broadacre and dairy sectors.

Motives for adoption of best-practice management were divided into financial and environmental benefits and personal motivations (Table L16). The surveys also identified that the main barriers to adoption were available time and workload, lack of funds, age and industry outlook.

The Australian State of the Environment 2021 Report noted that:

> 'Some studies demonstrate that regenerative agriculture directly impacts mental health... One study found that a group of regenerative graziers were not only more profitable, but also had significantly higher wellbeing and general health relative to comparative farmers in their state who contributed to the Australian Bureau of Agricultural and Resource Economics and Sciences Farm Survey.' [1226]

A 2021 national survey conducted for the Grain Research and Development Corporation found that grain producers, including those in Victoria, were increasingly using technology to improve productivity that also helped reduce soil compaction and manage weeds (controlled traffic technology) and provide greater precision in the application of fertiliser (variable rate technology).[1227] The survey also found that an increasing percentage of Victorian grain farmers had vegetation plans.[1228] For 90% of farms having a plan, the main purpose of these plans was to conserve an area of vegetation for biodiversity.[1229]

1223. National Farmer's Federation, 'Australian agricultural sustainability framework' https://nff.org.au/programs/australian-agricultural-sustainability-framework/ Accessed 14 May 2021.
1224. Australian Farm Institute 2022, 'AASF: Australian agricultural sustainability framework' https://www.farminstitute.org.au/product/aasf-australian-agricultural-sustainability-framework/ Accessed 28 August 2022.
1225. Australian Bureau of Agricultural and Resource Economics (ABARES) 2014, 'Drivers of practice change in land management in Australian agriculture, synthesis report', Canberra, Australia.
1226. Commonwealth of Australia 2021, 'Australian state of the environment', Canberra, Australian Capital Territory https://soe.dcceew.gov.au/ Accessed 7 June 2023.
1227. Umbers A, Watson D 2021, 'GRDC farm practices survey report 2021', report prepared for the Grain Research and Development Corporation (GRDC), Barton, Australian Capital Territory.
1228. Ibid
1229. Ibid.

Table L14: Proportion of farms adopting land management practices within the broadacre and dairy sectors based on a 2014 survey (1228 respondents).[1230]

Category	Management practice	Broadacre adoption (%)	Dairy adoption (%)
Crop management	No-till, reduced tillage or direct drilling	83	44
	Periods of fallow in crop rotation	58	29
	Retained stubble	82	19
Grazing management	Cell or strip grazing	60	99
	Set minimum groundcover targets for long term	90	91
	Planted or maintained deep rooted perennial pastures	53	45
Native vegetation management	Planted native pasture or encouraged regrowth	34	13
	Planted native vegetation or encouraged regrowth	41	42
	Fenced native vegetation to control stock access	50	53
Weed management	Management of Weeds of National Significance	46	53

Table L15: Proportion of farms adopting land management practices within the horticulture sector based on the results of a 2014 survey (179 respondents).[1231]

Category	Management practice	Horticulture adoption (%)
Soil management	Minimum tillage or cultivation (e.g. permanent beds and direct planting)	66
	Controlled trafficking [of vehicle movements]	49
	Incorporation of organic matter	82
	Cover crops, inter-row crops, mulching	55
	Optimisation of pesticide/fertiliser use and reduced reliance	90
Vegetation management	Planted or encouraged regrowth of native vegetation in riparian areas	23
	Planted or encouraged regrowth of native vegetation (non-riparian)	26
	Fenced native vegetation to prevent degradation	19
Weed management	Management of Weeds of National Significance	48

Table L16: Motives for adopting land management practices among the broadacre, dairy and horticulture sectors.[1232]

Financial benefits	Environmental benefits	Personal motivations
Increased returns or income Reduced financial risk Reduced costs Improved year-round feed availability Cost of not acting would be too high Reduced livestock losses Provides shelter for stock and crops Increased land productivity	Improves soil condition Reduces soil loss through wind and water erosion Aligns with my environmental goals/beliefs Provide habitat for native fauna Corporate social and environmental responsibility	Desire to protect natural resources for the long term Reduction in workload—provides time for other activities Liked the technologies involved Desire to improve amenity of the landscape Family considerations Recognition by neighbours and community Prepared to risk short-term production losses

1230. Australian Bureau of Agricultural and Resource Economics (ABARES) 2014, 'Drivers of practice change in land management in Australian agriculture, synthesis report', Canberra, Australia.
1231. Ibid.
1232. Ibid.

Abbreviations

AANP .... Australian Alps National Parks
AAP .... adaptation action plan
ABARES .... Australian Bureau of Agricultural and Resource Economics and Sciences
ABC .... Australian Broadcasting Corporation
ABS .... Australian Bureau of Statistics
ACCU .... Australian Carbon Credit Unit
ACORN-SAT .... Australian Climate Observations Reference Network – Surface Air Temperature
ACU .... Australian Catholic University
AgVic .... Agriculture Victoria
ANCHORS .... Australian National Collection of Homogenized Observations of Relative Sea Level
APACs .... Air pollution assessment criteria
ARI .... Arthur Rylah Institute
ARV .... Alpine Resorts Victoria
AWA .... Aboriginal Waterway Assessments
BBRR .... Bushfire Biodiversity Response and Recovery
BOM .... Australian Bureau of Meteorology
BSUD .... biodiversity-sensitive urban design
C&D .... construction and demolition
C&I .... commercial and industrial
CaLP Act .... *Catchment and Land Protection Act 1994*
CAPAD .... Collaborative Australian Protected Areas Database
CAR .... comprehensive, adequate and representative
CC Act .... *Climate Change Act 2017*
CES .... Commissioner for Environmental Sustainability Victoria
CEWH .... Commonwealth Environmental Water Holder
CEWO .... Commonwealth Environmental Water Office
CFA .... Victorian Country Fire Authority
CFC .... chlorofluorocarbon
CGRSWS .... Central and Gippsland Region Sustainable Water Strategy
CIP .... Coupe Inspection Program
CMA .... Victorian Catchment Management Authority
CO2-e .... carbon dioxide equivalent
COP26 .... Conference of the Parties 26
CR .... Conservation Regulator
CRC .... Cooperative Research Centre

Abbreviations

CSIRO .... Commonwealth Scientific and Industrial Research Organisation

dB .... decibel

DCCEEW .... Commonwealth Department of Climate Change, Energy, the Environment and Water

DEECA .... Victorian Department of Energy, Environment and Climate Action (formerly DELWP prior to 1 January 2023)

DELWP .... Victorian Department of Environment, Land, Water and Planning (now DEECA as of 1 January 2023)

DEPI .... Victorian Department of Environment and Primary Industries

DHHS .... Victorian Department of Health and Human Services

DJCS .... Victorian Department of Justice and Community Safety

DJPR .... Victorian Department of Jobs, Precincts and Regions (now DJSIR as of 1 January 2023)

DPC .... Victorian Department of Premier and Cabinet

DSE .... Victorian Department of Sustainability and Environment

DTP .... Victorian Department of Transport and Planning

EBA .... ecosystem-based adaptation

EC .... electrical conductivity

EFG .... ecological fire groups

EIA .... environmental impact assessment

EMV .... Emergency Management Victoria

EP Act .... *Environment Protection Act 2017*

EPA Victoria .... Environment Protection Authority Victoria

EPBC Act .... *Environment Protection and Biodiversity Conservation Act 1999*

EPCE .... Eminent Panel for Community Engagement

ERF .... Emission Reduction Fund

ERS .... Environment Reference Standard

EVC .... ecological vegetation class

EWAP .... Environmental Water Action Plan

EWR .... Environmental Water Reserve

FAP .... Forest Audit Program

FFDI .... forest fire danger index

FFG Act .... *Flora and Fauna Guarantee Act 1988*

FMP .... forest management plan

FOGO .... food organics and garden organics

FRD .... Financial Reporting Directive

FRV .... Fire Rescue Victoria

FT .... full-time equivalent

g CO2/km .... grams CO2 per kilometre

Abbreviations

G20 ... Group of Twenty
GDE ... groundwater-dependent ecosystem
GHG ... greenhouse gas
GIS ... geographic information system
GL ... gigalitre
GM2030 ... Groundwater Management 2030
GMA ... groundwater management area
GMU ... groundwater management unit
GMZ ... general management zone
GORCP ... Great Ocean Road Coast and Parks
GQRUZ ... groundwater quality restricted use zone
GSP ... gross state product
GSS ... growth stage structure
GW ... gigawatt
ha ... hectare
ICAO ... International Civil Aviation Organization
IEA ... International Energy Agency
IFER ... Integrated Forest and Ecosystem Research
IHD ... ischemic heart disease
IMOS ... Integrated Marine Observing System
IPA ... immediate protection area
IPAF ... Invasive Plants and Animals Policy Framework
IPCC ... Intergovernmental Panel on Climate Change
IPPU ... Industrial Processes and Product Use
IV ... Infrastructure Victoria
IWH ... instream woody habitat
IUCN ... International Union for the Conservation of Nature
IWM ... Integrated Water Management
JFMP ... Joint Fuel Management Program
KAB ... Keep Australia Beautiful
kg ... kilogram
km ... kilometre
Kt ... kilo-tonne
LAC ... limit of acceptable change
LED ... light emitting diode

Abbreviations

LGA .... local government area
LGWSR .... Local Government Waste Services Report
LTWRA .... Long Term Water Resource Assessment
LULUCF .... land use, land-use change and forestry
m3 .... cubic metre
MACKF .... Marine and Coastal Knowledge Framework
MDBA .... Murray-Darling Basin Authority
MER .... monitoring, evaluating and reporting
MERF .... monitoring, evaluation and reporting framework
MERI .... monitoring , evaluation, reporting and improvement
ML .... megalitre
MSW .... municipal solid waste
Mt .... mega-tonne
MtC .... million tonnes of carbon
MW .... megawatt
MWh .... megawatt hour
µg .... microgram
µS/cm .... microseimens per centimetre
NCIS .... National Coronial Information System
NEM .... National Electricity Market
NEPM AAQ .... National Environment Protection (Ambient Air Quality) Measure
NFI .... National Forestry Index
NHRA .... Natural Hazards Research Australia
NOAA .... National Oceanic and Atmospheric Administration
NRM .... natural resource management
NTU .... nephelometric turbidity unit
OECD .... Organisation for Economic Co-operation and Development
P&E Act .... *Planning and Environment Act 1987*
PCV .... permissible consumptive volume
PFAS .... per- and poly-fluoroalkyl substance
PJ .... petajoule
PM_{10} .... particles less than 10 micrometres in diameter
$PM_{2.5}$ .... particles less than 2.5 micrometres in diameter
ppm .... parts per million
PRSA .... preliminary risk screen assessment

Abbreviations

PSR .... Priority Sites Register
PV .... Parks Victoria
QUT .... Queensland University of Technology
RAS .... Regional Adaptation Strategy
RCP .... representative concentration pathway
RECP .... Regional Circular Economy PlanREZ
.... Renewable Energy Zone
RFA .... Regional Forest Agreement
RIWR .... Recycling Industry Waste Report
RLP .... regional land partnerships
RMIT .... Royal Melbourne Institute of Technology
RO .... resource outlook
RV .... Recycling Victoria
RWMP .... Regional Water Monitoring Partnerships
SA2 .... Statistical Area 2
SA4 .... Statistical Area 4
SDG .... sustainable development goal
SEC .... State Electricity Commission
SEPP .... State Environment Protection Policy
SES .... Victorian State Emergency Service
SMP .... Strategic Management Prospects
SMZ .... special management zone
SNA .... System of National Accounts
SOC .... soil organic carbon
SoE .... State of the Environment
SPZ .... special protection zone
SV .... Sustainability Victoria
SWRRIP .... Statewide Waste and Resource Recovery Infrastructure Plan
t .... tonne
TCFD .... Taskforce on Climate-related Financial Disclosures
TFI .... tolerable fire interval
TLM .... The Living Murray
TRP .... Timber Release Plan
TSCRA .... Threatened Species and Communities Risk Assessment
TVC .... total vegetation cover
UHI .... urban heat island

Abbreviations

UNESCO .... United Nations Educational, Scientific and Cultural Organization
UNFCCC .... United Nations Framework Convention on Climate Change
UV .... ultraviolet radiation
UWS .... Urban Water Strategies
VAGO .... Victorian Auditor-General's Office
VEAC .... Victorian Environmental Assessment Council
VEFMAP .... Victorian Environmental Flows Monitoring and Assessment Program
VEWH .... Victorian Environmental Water Holder
VFMP .... Victorian Forest Monitoring Program
VFP .... Victorian Forestry Plan
VicWaCI .... Victorian Water and Climate Initiative
VIIRS .... visible infrared imaging radiometer suite
VNI .... Victoria-New South Wales Interconnector
VOC .... volatile organic compound
VPC .... Victorian Plantations Corporation
WetMAP .... Wetland Monitoring and Assessment Program
WMIS .... Water Measurement Information System
WQI .... water quality index
WSPA .... water supply protection area
YSP .... Yarra Strategic Plan
YLL .... years of life lost
ZEV .... zero emissions vehicle

Authorised by the Commissioner for Environmental Sustainability

Level 36, 2 Lonsdale Street
Melbourne, Victoria 3000

Accessibility

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Disclaimer

For further information contact:

Commissioner for Environmental Sustainability
Level 36, 2 Lonsdale Street
Melbourne Victoria 3000

Email: info.ces@ces.vic.gov.au
www.ces.vic.gov.au

ISBN (print): 978-0-6458456-0-0

ISBN (online): 978-0-6458456-1-7

Published by the Commissioner
for Environmental Sustainability,
Victoria, 2023

Level 36, 2 Lonsdale Street
Melbourne Victoria 3000

info.ces@ces.vic.gov.au
www.ces.vic.gov.au

Commissioner *for* Environmental Sustainability Victoria

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