BIODIVERSITY (B)

SCIENTIFIC ASSESSMENTS Part III

Commissioner *for* Environmental Sustainability Victoria

Biodiversity

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

Background

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

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

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

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

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

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

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

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

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

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

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

10 Ibid

Current Victorian Government Settings: Legislation, Policy, Programs

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Indicator Assessments

Biodiversity Themes

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

Legend

Status

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

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

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

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

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

Trend

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

Unclear

Deteriorating

Stable

Improving

Data quality

Poor
Evidence and consensus too low to make an assessment

Fair
Limited evidence or limited consensus

Good
Adequate high-quality evidence and high level of consensus

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

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

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

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

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

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

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

Summary		Status (UNKNOWN / POOR / FAIR / GOOD)	Trend
Indicator **B:06C** Invertebrates **Region** Victoria **Measures** Conservation status of terrestrial threatened species, which measures changes in the status of threatened terrestrial species Trends in population and distribution of selected threatened terrestrial species over time Threatening processes impacting and affecting native terrestrial threatened species **Data custodian** DELWP		DATA QUALITY Fair	
Indicator **B:07** Private Land Conservation **Region** Victoria **Measures** Conservation on private land which assesses the area of private land under conservation agreements Management of biodiversity on private land which assesses activities taken to conserve species, conserve communities and maintain, improve or restore habitat on private land **Data custodian** Trust for Nature	Trust for Nature has assisted with the permanent protection of more than 100,000 hectares of native habitat on private land using a range of conservation tools, including conservation covenants, land acquisition, donations of land and its Revolving Fund. There are 1416 voluntary conservation covenants and 43 Trust for Nature properties and/or reserves.	DATA QUALITY Good	

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

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

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

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

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

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

Invasive Plants and Animals

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

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

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:01 Invasive freshwater plants and animals Data custodian DELWP, DEDJTR		?	DATA QUALITY Poor

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

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

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

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

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

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

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

18 Dugdale TM, Hunt TD, Clements D 2013, 'Aquatic weeds in Victoria: where and why are they a problem, and how are they being controlled?' *Plant Protection Quarterly*, 28(2), pp. 35-40.
19 Ibid
20 Ibid
21 Ibid
22 DEPI 2013, 'Improving our waterways. Victorian waterway management strategy', Melbourne, Victoria.
23 DEPI 2013, 'Improving our waterways, Victorian waterway management strategy', Melbourne, Victoria.
24 Ibid

25 Ibid
26 Ibid
27 DELWP 2017, 'Victorian environmental flows monitoring and assessment program (VEFMAP) stage 6. Project update – 2017 pilot monitoring of aquatic and river bank vegetation', Melbourne, Victoria.

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:01A Trend in Carp *(Cyprinus carpio)* Distribution Data custodian DELWP, DEDJTR		↘	DATA QUALITY Good

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

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

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

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

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

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

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

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

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

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

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

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

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

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

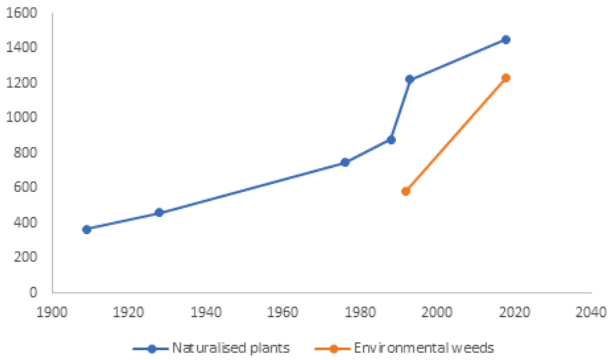


Figure B.1 Number of naturalised plants and environmental weeds in Victoria, 1909–2018

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

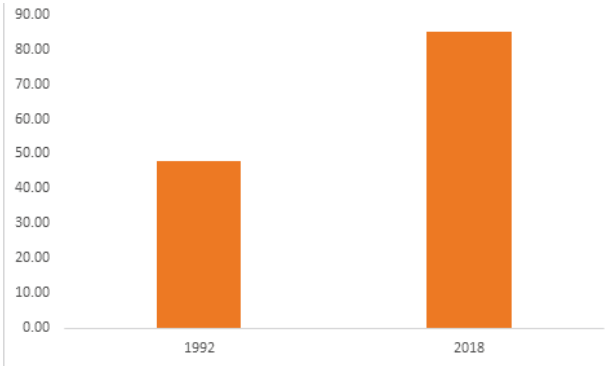


Figure B.2 Increase in percentage of naturalised plants considered to be environmental weeds, 1992–2018 [45]

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

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

45 Ibid

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

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

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

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

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

46 Environment, Natural Resources and Regional Development Committee 2017, 'Inquiry into the control of invasive animals on Crown land', Parliament of Victoria, Melbourne, Victoria.
47 Ibid

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

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

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

Sambar Deer

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

Fallow Deer

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

Red Deer

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

Hog Deer

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

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

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

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

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

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

60 Hobbs RJ, Hinds LA 2018, 'Could current fertility control methods be effective for landscape-scale management of populations of wild horses (*Equus caballus*) in Australia?', *Wildlife Research*, 45, pp. 195-207.
61 Hobbs RJ, Hinds LA 2017, 'Review of the feasibility of current fertility control methods for management of wild horse populations (Equus caballus) in Kosciuszko National Park', Summary report to the Science Division, Office of Environment and Heritage, New South Wales.

Threatened Species

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

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

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

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

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

62 Clemann N 2015, 'Cold-blooded indifference: a case study of the worsening status of threatened reptiles from Victoria, Australia', *Pacific Conservation Biology*, 21, pp.15-26.
63 Ibid
64 Skerratt LF, Berger l, Clemann N, Hunter DA, Marantelli G, Newell DA, Philips A, McFadden M, Hines HB, Scheele BC, Brannelly LA, Speare R, Versteegen S, Cashins SD, West M 2016, 'Priorities for management of chytridiomycosis in Australia: saving frogs from extinction', *Wildlife Research*, 43(2), pp.105-120.

65 Arthur Rylah Institute 2018, 'Threatened plants and animals', Heidelberg, Victoria https://www.ari.vic.gov.au/research/threatened-plants-and-animals Accessed 27 September 2018.
66 Ibid
67 Intergovernmental Memorandum of Understanding 2017, 'Agreement on a common assessment method for listing of threatened species and threatened ecological communities' https://www.environment.gov.au/system/files/resources/36ece4ab-82dc-4de9-aac6-9cc54bd7a820/files/mou-cam.docx Accessed 27 September 2018.

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

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

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

Data custodian: None

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

Data custodian DELWP

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

75 Ibid

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

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

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

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

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

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

78 Hunter DA, Smith MJ, Scroggie MP, Gilligan D 2011, 'Experimental examination of the potential for three introduced fish species to prey on tadpoles of the endangered Booroolong frog, *Litoria booroolongensis*', *Journal of Herpetology*, 45(2), pp.181-185.
79 DEE 2016, 'Threat abatement plan for infection of amphibians with chytrid fungus resulting in chytridiomycosis', Australian Government, Commonwealth of Australia.

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

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

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

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

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

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

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

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

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

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

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

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

Data custodian DELWP

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Protecting Victoria's Biodiversity

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

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

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

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

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

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

Results from on-ground management actions include:

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

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

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

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

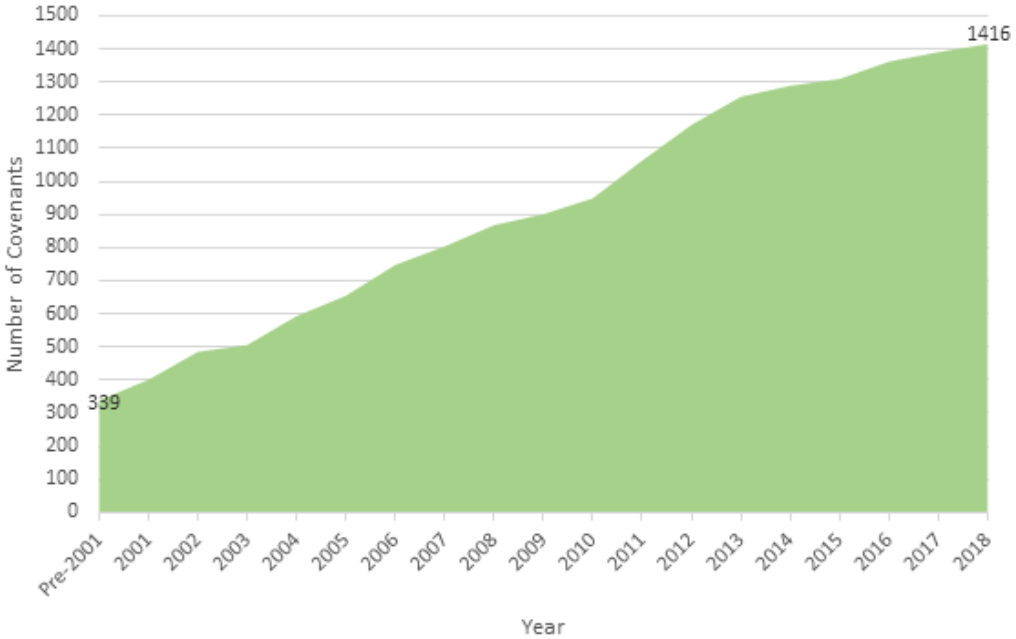


Figure B.3 Growth in the total number of private land covenants, 2001–18

(Data source: TfN, 2018)

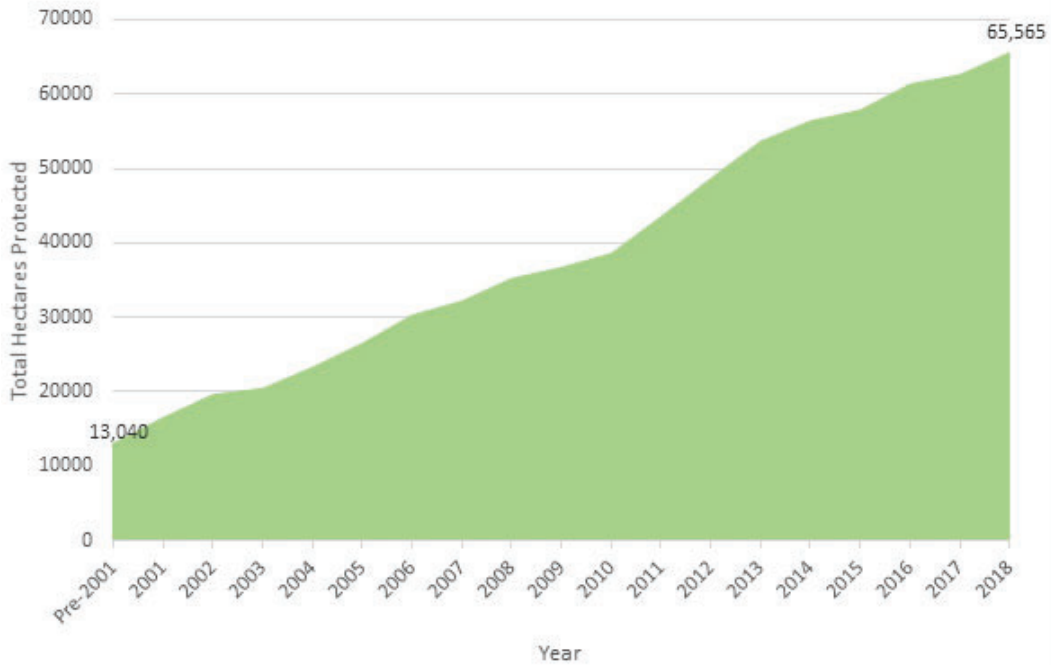


Figure B.4 Growth in total hectares of private land under covenant, 2001–18

(Data source: TfN 2018)

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

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

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

These are illustrated in Table B.7.

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

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

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

(Data source: VicGrid94)

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

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

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

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

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

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

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

91 Note: Parks Estate conservation areas applying VicGrid94 spatial delineation.
92 Ibid
93 High altitude alpine sphagnum bogs and associated fens are referred to as high altitude wetlands in Figure B.5.

94 VEAC 2017, 'Statewide assessment of public land final report', Melbourne, Victoria.
95 VEAC 2017, 'Statewide assessment of public land supplement to the discussion paper. Melbourne, Victoria. Note: an extensive list of under-represented EVCs can be found in Table 4.1 on page 23.
96 Ibid
97 VEAC 2011, 'Remnant native vegetation investigation final report', Melbourne, Victoria.

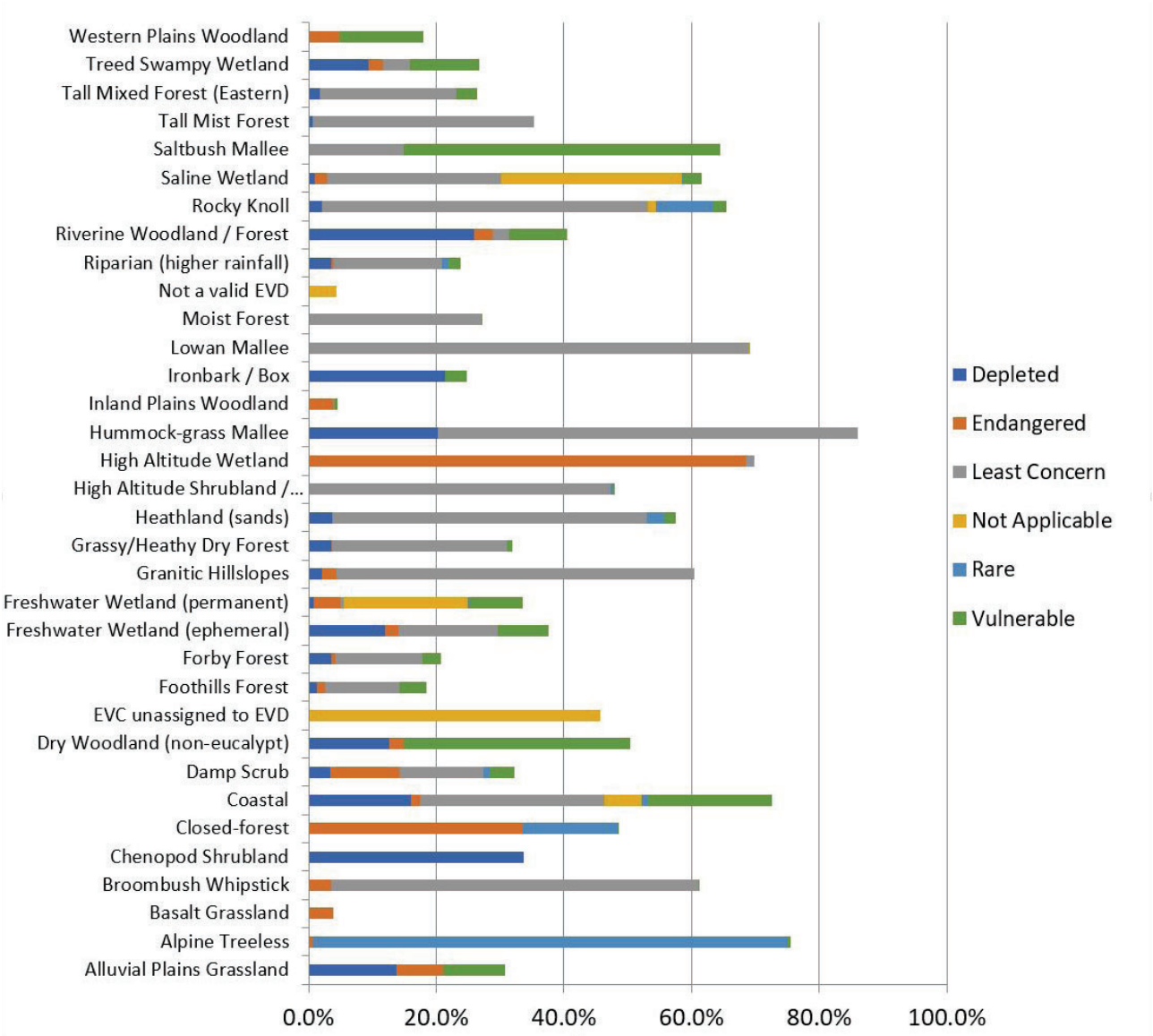


Figure B.5 Current state of EVDs for Parks Estate defined by bioregional threat status

(Data source: Parks Victoria 2018)

Freshwater Biodiversity

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:11 Area of functional floodplain		?	DATA QUALITY Poor
Data custodian DELWP			

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:13 Distribution and abundance of fish		↘	DATA QUALITY Good
Data custodian DELWP			

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

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

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

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

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

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

VEFMAP Stage 5

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

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

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

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

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

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

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

145 Ibid

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

  Glenelg – estuary perch and tupong

  Thomson–Macalister and Yarra – Australian grayling and tupong.

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

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

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

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

146 Ibid
147 Ibid
148 Ibid

VEFMAP Stage 6

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

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

Coastal Rivers

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

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

149 Ibid

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

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

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

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

Northern Rivers

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

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

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

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

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

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

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

Population demography surveys revealed the following:[157]

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

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

154 Ibid
155 Ibid
156 Ibid
157 Ibid

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:14 Distribution and abundance of waterbirds in the Murray Darling Basin Data custodian DELWP		↘	DATA QUALITY Fair

The Eastern Australian Waterbird Survey has collected and analysed waterbird data annually since 1983, with the latest available report dated 2017.[158] This large-scale biodiversity dataset monitors change in the distribution and abundance of 50 waterbird species, including threatened species, and the health of rivers and wetlands. Waterbird abundances are strongly related to river flows and rainfall. Within Victoria, this survey is limited to the Murray–Darling Basin and coastal Ramsar sites (the latter is discussed in the Marine and Coastal Environments chapter).

There have been ecological impacts to the Murray–Darling Basin's rivers and floodplains due to reductions in cumulative annual flows extracted by water resource development.[159] Although waterbird abundances were highly variable over the 35-year survey period, a reduction in water flow has contributed to a long-term decline in the total abundance, as well as in functional response groups (ducks, grebes, herbivores, large wading birds and piscivores (fish-eaters)) and in individual species of waterbird at the basin, river and wetland scales. Ecosystem level change has impacted three Ramsar-listed sites including Lower Lakes, Coorong and Murray Mouth.[160]

The 2012 Wetland Connectivity study[161] recorded 145 waterbird species across Victorian wetlands. This figure excludes pelagic (ocean-going) seabirds and a small number of land birds associated with saltmarsh habitats. Of the 145 species, 83 breed in Victoria and the remainder are regular migrants (29 species) or rare vagrants which are seen far outside their expected breeding, wintering or migrating range (29 species). Some of the migrants breed in New Zealand, but most of them travel longer distances to breed in arctic or subarctic regions of northern Asia or Alaska.[162] As this study focused on wetland connectivity for birds, rather than being a pure bird population survey, there is no trend analysis to identify how bird numbers are influenced by international drivers or how wetland water availability across Victoria and Australia governs where birds choose to feed and breed.

Populations of waterbirds utilise multiple habitats over varying spatial scales (including wetlands, rivers and estuaries) to moult, roost, breed and forage.[163] Wetland water regimes strongly influence waterbird populations. Floods trigger breeding in many species, and wetland systems that are flooded after a dry period support large numbers of waterbirds compared to permanently flooded sites.[164]

Some waterbirds that occur in Victoria are common, occupying a range of habitats. Other species have more specialised requirements and only occupy habitats with certain levels of aquatic vegetation cover and salinity. Some of the less common species tend to be associated with large and complex wetlands that provide a range of habitat resources.[165]

158 Kingsford RT, Bino G, Porter JL 2017, 'Continental impacts of water development on waterbirds, contrasting two Australian river basins: global implications for sustainable water use', *Global Change Biology*, pp.1-12.
159 There are 240 large dams and annual diversions of approximately 6,800GL due to water resource use in the Murray–Darling Basin system.
160 Kingsford RT, Bino G, Porter JL 2017, 'Continental impacts of water development on waterbirds, contrasting two Australian river basins: global implications for sustainable water use', *Global Change Biology*, pp.1-12.
161 Morris K 2012, 'Wetland connectivity: understanding the dispersal of organisms that occur in Victoria's wetlands', Arthur Rylah Institute for Environmental Research Technical Report Series No.225, Heidelberg, Victoria.

162 Ibid
163 Ibid
164 Ibid
165 Ibid

The geographical arrangement of wetlands in the landscape and the dispersal capacity of waterbirds influence the dynamics of waterbird populations. Although there is some information about the dispersal capacity of waterbirds over large scales, there is little information on the frequencies or patterns of waterbird movements between wetlands over small spatial and temporal scales. Knowledge of these finer-scale movements, particularly during critical life stages, is needed to identify the landscapes elements required to sustain waterbird populations.[166]

166 Ibid

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:15 Distribution and abundance of macroinvertebrates Data custodian EPA Victoria		→	DATA QUALITY Fair

Inland aquatic macroinvertebrates are widely used in Australian assessments of ecosystem condition. The RiverMAP Long Term Sites (LTS) Project provides trends in aquatic macroinvertebrate biodiversity across 66 sampling sites. Sampling of inland aquatic macroinvertebrates has taken place since 1990. Between 1990 and 2012, the number of sampled sites, years sampled and total samples have varied. Therefore, trends reported here are heavily weighted towards more frequently sampled sites.

EPA Victoria and DELWP selected and agreed on 66 sites on initiation of the RiverMAP program. Of the 66 LTS, 39 are in DELWP's high priority locations and 15 are from EPA Victoria's long-term monitoring sites (sites that have been sampled since the 1990s), which simultaneously maximises coverage across SEPP defined bioregions (Table B.11). The remaining 12 sites were included to add analytical strength to detect change in macroinvertebrate condition at both statewide and SEPP region scales. While reasonably representative of conditions within a bioregion, the LTS do not represent the full range of environmental variability within a bioregion and therefore trends presented here are not indicative of long-term conditions for all stream types within a bioregion.

Table B.11 A description of the 5 SEPP WoV bioregions applied to the LTS Project[167]

SEPP Bioregion	Description
Highlands (B1)	This region is in the high country of Victoria, with streams often on steep slopes, generally above 1,000 m and subject to high rainfall. The vegetation tends to be native forest, woodland and grassland. Riparian shading varies from moderate to low cover, depending on the course of streams through forested or grassland areas, respectively.
Forests A (B2)	Six separate areas form this region, comprising upland reaches in the Upper Murray, Mitta Mitta, Kiewa, Goulburn, Yarra, Latrobe and Thomson catchments, and rivers and streams in the Grampians, Strzeleki Ranges, Wilsons Promontory and far East Gippsland. Although not all are geographically connected, they share similar environmental and biological characteristics. The streams are generally located on moderately steep slopes at much lower altitudes than the Highlands Region, but at moderately high altitudes relative to the remaining regions. The region receives moderate to high rainfall. Tall forests and woodlands are the typical vegetation cover, with some forestry and grazing activities. Streams generally have considerable shading from the riparian zone, and tend to be further from their source with a greater upstream catchment area than the Highlands Region. Cool waters with very low alkalinity, turbidity and salinity characterise the region, except in the Grampians where there is low to moderate salinity. Streams typically have both riffle and edge habitat with moderately coarse substrate, and very low macrophyte cover and diversity.
Forests B (B3)	The Forests B Region incorporates the upland reaches in the Ovens, Broken, Goulburn, Macalister, Mitchell, Tambo and Snowy catchments, and rivers and streams in the Otway Ranges. This discontiguous region generally covers an area similar in altitude to the Forests A Region, but stream slopes are less steep. Rainfall is slightly less in this region than in Forests A Region, and supports tall open forests. A greater degree of clearing for forestry, grazing and some intensive agriculture occurs in this region compared with the Highlands Region and Forests A Region. This results in a lower level of riparian shading. Streams are further from their source, with more than double the catchment area of streams in Forests A Region. Alkalinity of the cool waters typical of this region is slightly elevated relative to the Highlands Region and Forests A Region, but still remains low compared to the rest of the state along with turbidity and salinity. Stream habitat is characterised by the presence of riffles and edges, with very coarse substrate and high macrophyte diversity and cover.

167 EPA Victoria 2004, 'Information bulletin biological objectives for rivers and streams – ecosystem protection', Melbourne, Victoria.

SEPP Bioregion	Description
Cleared Hills and Coastal Plains (B4)	The urban area of Melbourne divides this region, which is characterised by coastal plains in the south and inland plains and low foothills in the north and east. This region includes upper reaches in the Campaspe, Loddon, Avoca, Wimmera and Hopkins catchments, midreaches in the Ovens, Broken and Goulburn catchments, lowland reaches in the Barwon, Yarra, Latrobe, Thomson, Macalister, Mitchell, Tambo and Snowy catchments, all reaches in the Curdies, Moorabool, Werribee, Maribyrnong and Western Port catchments, and river and stream reaches in South Gippsland. Streams flow through an undulating landscape of low altitude with little gradient and relatively low rainfall. The region has been substantially cleared for intensive agriculture including dryland pasture and some irrigated pasture, resulting in poor riparian shading. Warm stream waters with high alkalinity and low to moderate turbidity and salinity characterise the region. The edge habitat is more developed and extensive, and riffles are less common. The substrate tends to be composed of moderate to fine particles, and there is a very high diversity and moderate cover of macrophytes.
Murray and Western Plains Region (B5)	This region incorporates the west and north of the state and covers an area of low altitude plains with very little topographical relief and low rainfall. This region includes lowland reaches in the Kiewa, Ovens, Broken, Goulburn, Campaspe, Loddon, Avoca, Wimmera, Glenelg, and Hopkins catchments, the entire Corangamite catchment and the Portland and Millicent Coast basins. The region has been generally cleared for dryland and irrigated pasture, and broad-acre cropping. It also includes some patches of Mallee woodland. Riparian shading is, therefore, typically very poor. The waters are warm and slow, often seasonally intermittent, tending towards pond-like waterways with high alkalinity, and moderate to high turbidity and salinity. The very fine substrate of the streams means that the principal habitat is along edges, with the high diversity and cover of macrophytes and woody debris being the dominant habitat for invertebrates. Riffles are uncommon.
North-west Victoria	Because of insufficient data in the north-west area of Victoria, and a very different aquatic environment, no specific biological objectives have been set for water bodies in this region. If required, the objectives from the Murray and Western Plains Region (B5) can be used as interim objectives where streams are present.

The analysis explored relationships between trends and environmental variables and applied four macroinvertebrate metrics:[168]

- total number of different macroinvertebrate groups (total richness)
- total number of specific macroinvertebrate family groups, specifically Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa
- stream invertebrate grade number average level (SIGNAL2) which is a grading system ranging between 1 and 10 that represents water-quality sensitivities[169] of macroinvertebrates
- an indicator of community composition, Australian River Assessment System observed/expected index (AUSRIVAS O/E).[170]

At the statewide scale, the overall condition of inland aquatic macroinvertebrates across Victoria's 66 long-term monitoring sites is stable.[171,172] Forest and riparian cover were all strongly positively correlated with the condition of macroinvertebrates,[173] whereas rainfall, streamflow and land use all influenced the differences found in macroinvertebrate assemblages across all SEPP bioregions.[174]

Macroinvertebrate trends varied at the SEPP bioregional scale. The Cleared Hills and Coastal Plains and Murray and Western Plains bioregions (Figure B.6) had low numbers of sensitive taxonomic macroinvertebrate groups (EPT taxa) and low SIGNAL2 scores indicating poor stream health compared to Highlands and Forests A and B. Cleared Hills and Coastal Plains had comparatively low SIGNAL2 scores which is partially attributed to streamflow and potentially other variables such as higher proportions of land use.

168 EPA Victoria 2016, 'RiverMAP long term sites project final report', Melbourne, Victoria.
169 Note: water-quality sensitivities includes: water temperatures, turbidity, electrical conductivity, alkalinity, pH, dissolved oxygen, total nitrogen and total phosphorus, in: Chessman B 2003, 'New sensitivity grades for Australian river macroinvertebrates', *Marine and Freshwater Research*, 54, pp.95-103.
170 Note: the AUSRIVAS O/E is a standardised protocol for the assessment of river physical and chemical condition incorporating in-stream physical habitat, catchment geomorphology, riparian condition and water quality, in: Parsons M, Ransom G, Thoms M, Norris R, 2002, 'Australian river assessment system: AusRivAS physical and chemical assessment Module', Monitoring River Heath Initiative Technical Report no 23, Commonwealth of Australia and University of Canberra, Canberra.
171 Ibid
172 EPA 2016, 'River monitoring and assessment program (RiverMAP): river health modelling project technical report', Melbourne, Victoria.
173 Ibid
174 EPA Victoria 2016, 'RiverMAP long term sites project final report', Melbourne, Victoria.

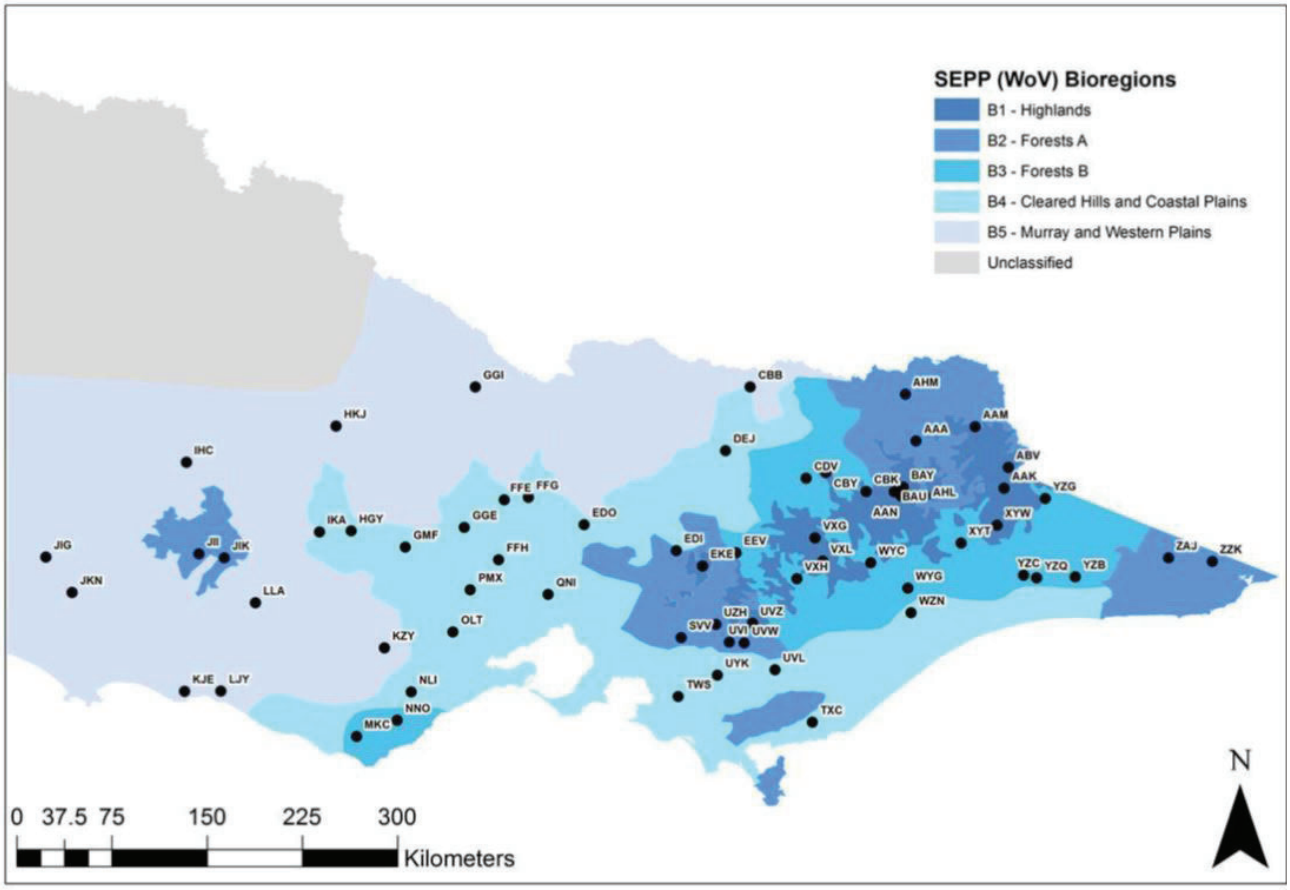


Figure B.6 The 66 sampled sites across SEPP bioregions for the RiverMAP long-term sites monitoring project[175]

175 Ibid

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:16 Wetland extent and condition		?	DATA QUALITY
Data custodian DELWP			Poor

Wetlands are defined as natural, modified or artificial areas subject to permanent or temporary inundation that hold static or very slow-moving water and develop – or have the potential to develop – biota adapted to inundation and the aquatic environment.[176] The naming convention for inland (freshwater) wetland types was revised in the *Victorian Wetland Classification Framework 2014*.[177] There are two types of freshwater wetlands:

- lacustrine wetlands categorised by less than 30% vegetation cover such as lakes
- palustrine wetlands categorised by greater than 30% vegetation cover and divided into the following types:
  - swamps (wetlands dominated by woody vegetation)
  - marshes/meadows (wetland dominated by non-woody emergent vegetation)
  - high country peatlands.

Water sources for lacustrine and palustrine wetlands can include groundwater, river or those that are artificially filled and have permanent or periodically inundated water regimes, for example seasonal, intermittent or episodic water availability.[178] Marine and estuarine wetlands are assessed in the Marine and Coastal Environments chapter.

The 2014 inventory of Victoria's wetlands recorded 23,739 natural wetlands covering 604,322 hectares and 11,060 artificial wetlands covering 170,613 hectares.[179] More than a quarter of Victoria's wetlands have been lost since European settlement.[180] Of the 149 wetland EVCs, nearly all are threatened in at least one Victorian bioregion and over 75% of all wetland EVCs across Gippsland Plains, Glenelg Plain, Otway Plain, Victorian Riverina, Victorian Volcanic Plain and Warrnambool Plan are considered endangered and vulnerable.[181] There have been no further statewide assessments on wetland condition using the Index of Wetland Condition[182] since the release of the SoE 2013 report.[183]

DELWP is currently developing a statewide wetland monitoring and assessment program for environmental watering (WetMAP). WetMAP represents a short-to-medium term intervention approach and will monitor a subset of Victoria's wetlands, from each CMA region, before and after environmental water delivery. This long-term program aims to evaluate the effectiveness of wetland management by monitoring and assessing responses to different management approaches.[184]

176 DELWP 2018, 'Wetlands', https://www.water.vic.gov.au/waterways-and-catchments/rivers-estuaries-and-waterways/wetlands Accessed 9 September 2018.
177 DELWP 2016, 'The Victorian wetland classification framework 2014', Melbourne, Victoria.
178 Ibid
179 Ibid
180 Ibid
181 VEAC 2017, 'Statewide assessment of public land supplementary paper', Melbroune, Victoria.
182 Papas P, Moloney P 2012, 'Victoria's wetlands 2009–2011: statewide assessments and condition modelling', Arthur Rylah Institute for Environmental Research Technical Report Series No. 229, Heidelberg, Victoria.
183 CES 2013, 'Victoria: State of the Environment Report Science Policy People', Melbourne, Victoria.
184 DELWP 2017, 'VEFMAP Stage 6 Part A: program context and rationale', Arthur Rylah Institute for Environmental Research, Heidelberg, Victoria.

Cropping in Wetlands

The last Index of Wetland Condition found that cropping occurred in 7.5% of the 8,489 wetlands assessed (Figure B.7). An examination of key attributes for wetlands where cropping was recorded found that cropping appears most likely to occur in palustrine, fresh, periodically inundated wetlands with an episodic or seasonal water regime. The nationally, critically endangered ecological community of Seasonal Herbaceous Wetlands (Freshwater) of the Temperate Lowland Plains is an example of a wetland community that occurs in Victoria in wetlands with these attributes. This data indicates that cropping in wetlands is reasonably common and that certain types of wetlands are more vulnerable than others to the impacts of cropping.

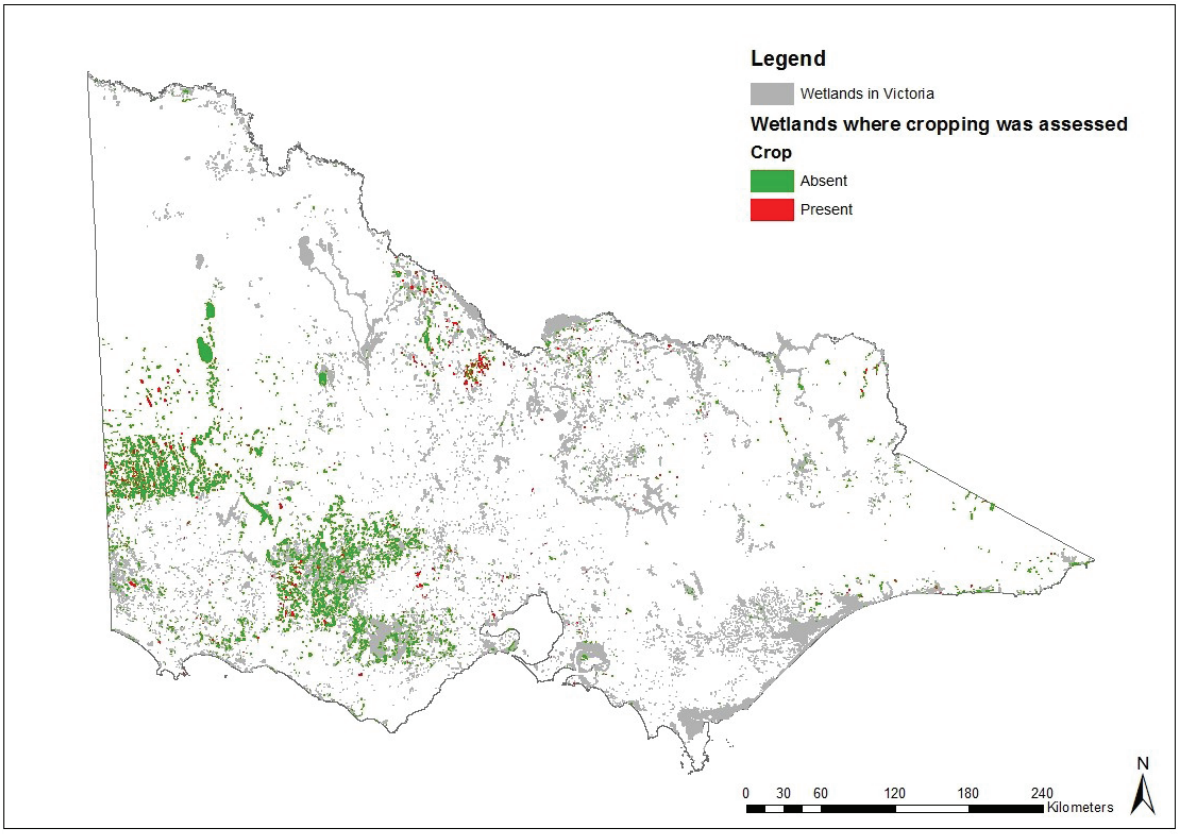


Figure B.7 Locations where wetland cropping occurs, based on results from the last Index of Wetland Condition.

Note: Cropping is marked in red.

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:17 Health and status of Ramsar wetlands in Victoria		?	DATA QUALITY Poor

Data custodian DELWP

Victoria has 11 Ramsar sites, of which 6 are inland and cover 98,623 hectares (Table B.12).[185] As part of the Ramsar Convention, management agencies are to maintain the ecological character description for each site. The 2016 Victorian Auditor-General's Office report *Meeting Obligations to Protect Ramsar Wetlands* found limited evidence that ecological character descriptions for each site were being maintained. The status of the ecological character of some sites cannot be fully determined due to limitations such as a lack of data. Therefore, trends in ecological health and status cannot be reported here. Where information is available, it shows that some Ramsar sites are not being effectively managed and protected from ecological decline. These declines are attributed to changed water regimes, water quality, recreational use, agricultural use, invasive species and climate change.[186]

Biodiversity 2037 Indicators

This theme will report on indicators that have been developed for *Biodiversity 2037*. These indicators include: Change in suitable habitat, Landscape scale change and Net gain in extent and condition of native vegetation. These indicators are assessed through new methodologies and will provide baselines for future status and trend analysis. Due to these new methodologies, it is not possible to continue previous trend analysis provided in SoE 2008 and 2013 reports. Trend analysis reported for *Biodiversity 2037* indicators are based on time-period data provided by the Data custodian, which varies across each indicator.

Table B.12 Inland aquatic Ramsar sites in Victoria[187]

Ramsar site	Area (ha)	Ramsar primary manager
Barmah Forest	29,305	Parks Victoria
Gunbower Forest	20,218	Parks Victoria and DELWP
Hatta-Kulkyne Lakes	977	Parks Victoria
Lake Albacutya	5,659	Parks Victoria
Kerang Wetlands	9,793	Parks Victoria and Goulburn–Murray Water
Western District Lakes	32,671	Parks Victoria

185 VAGO 2016, 'Meeting obligations to protect Ramsar wetlands', Melbourne, Victoria.
186 Ibid
187 Ibid

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:18 Net Gain in Extent and Condition of Native Vegetation Data custodian DELWP		↘	DATA QUALITY Good

This indicator combines the following biodiversity indicators from previous Victorian SoE reports:

- Habitat Condition – measured as change in the extent and quality of vegetation by EVC categories
- Habitat Extent – measured as fragmentation of native vegetation
- Native Vegetation Extent – assessed as change in the extent of vegetation by EVCs
- Quality, Condition and Fragmentation of Victoria's native vegetation – provided as overall condition of native vegetation using modelled quality assessments.

These historical indicators are now reported here under the new *Biodiversity 2037* key performance indicator, 'Net gain in extent and condition of native vegetation'. This measure provides estimates of the overall rate of change in extent and quality of native vegetation on public and private land in Victoria. It should be noted that DELWP is currently designing a 'net gain' key performance indicator for freshwater and marine habitats.

Previous 'net gain' results, reported in 2008, were based on a once-off modelled overall rate of change in extent and quality of native vegetation on Victorian public and private land in 2007.[188] These results were based on a range of assumptions regarding specific transactions (such as investment, permitted clearing, management actions and offsets) and broad changes (based on imagery and data taken at regular intervals for comparison over time). Results were subject to high variability and poorly quantified levels of uncertainty.

188 DSE 2008, 'Native vegetation net gain accounting. First approximation report', Melbourne, Victoria.

The updated 'net gain' methodological approach applied to this indicator keeps the core modelling change categories, but adjusts the assumptions based on collated evidence. Change categories include:

- gain activities – government investment, general management, voluntary actions, improved security
- loss activities – entitled uses, exemptions, controlled management regimes on public land
- neutral activities – permits and offsetting, wildfire, forest harvesting and regeneration.

The impact of controlled management regimes is included as a loss where recent planned burns have resulted in native vegetation being below the tolerable fire interval.[189] While planned burns may provide some benefits for native vegetation extent and condition, this relationship needs further investigation and is not included in this report's calculations. Controlled management decisions on public land are made in the context of many factors including community health and safety. These decisions and their trade-offs are not within the scope of any 'net gain' calculations.

There has been a loss in native vegetation on public and private land between 2008 and 2014 (Table B.13). The largest contributors to net loss in native vegetation on private and freehold land are entitled uses (for example, grazing and removal of trees and fallen logs for personal use), unmanaged threats beyond legislative obligations (for example, environmental weeds) and clearing that is exempt from requiring a permit (such as fences and fire

189 Tolerable fire interval is defined as the minimum or maximum recommended time intervals between successive fire disturbance events at a site or defined area for a particular vegetation community. It guides how frequent fires should be in the future to allow the persistence of all species at the site or defined area, in: Cheal D 2010, 'Growth stages and tolerable fire intervals for Victoria's native vegetation data sets', Fire and Adaptive Management Report No.84, Melbourne, Victoria.

protection)[190] (Figure B.8). There is also limited data available on some native vegetation losses, such as permitted clearing through local government approvals, exemptions and illegal clearing.[191] It should be noted that native vegetation removal regulations and offsets for the removal of native vegetation will also influence future 'net gain' results and should be carefully assessed in all calculations.

Table B.13 Six-year trend in 'net gain' calculations on Victorian public and private land

	Public Land (habitat ha/yr)		Private Land (habitat ha/yr)	
	2008	**2014** (a)	**2008**	**2014**
Gains subtotal	+ 8,760	+10,500	+ 4,560	+3,100
Losses subtotal	- 2,860	- 8,400	- 14,550	- 13,400
'Net gain' outcome (b)	+ 5,900	+ 2,100	- 9,990	-10,300

(a) The 2014 calculations contain information that was not included in the 2008 Net Gain First Approximation Report.

(b) Due to significant uncertainties associated with underlying assumptions and availability of site specific data, these figures may be under or over estimates, possibly up to 20%.

(Data source: DELWP, 2018)

There has been no acquisition of new imagery for vegetation condition data since 2008. Updated data provided by DELWP (see B:19) will apply Landsat imagery together with resources required to resample previous monitoring sites across the state to model vegetation condition.[192] This will inform new monitoring sites that sample the native vegetation 'space' based on type, extent and other factors. DELWP has developed a framework and standards for monitoring native vegetation to inform management effectiveness studies and to help test assumptions.[193]

190 DELWP 2015,' 2015 qualitative update of the 2008 net gain accounting first approximation report', Melbourne, Victoria.
191 Ibid

192 Ibid
193 Ibid

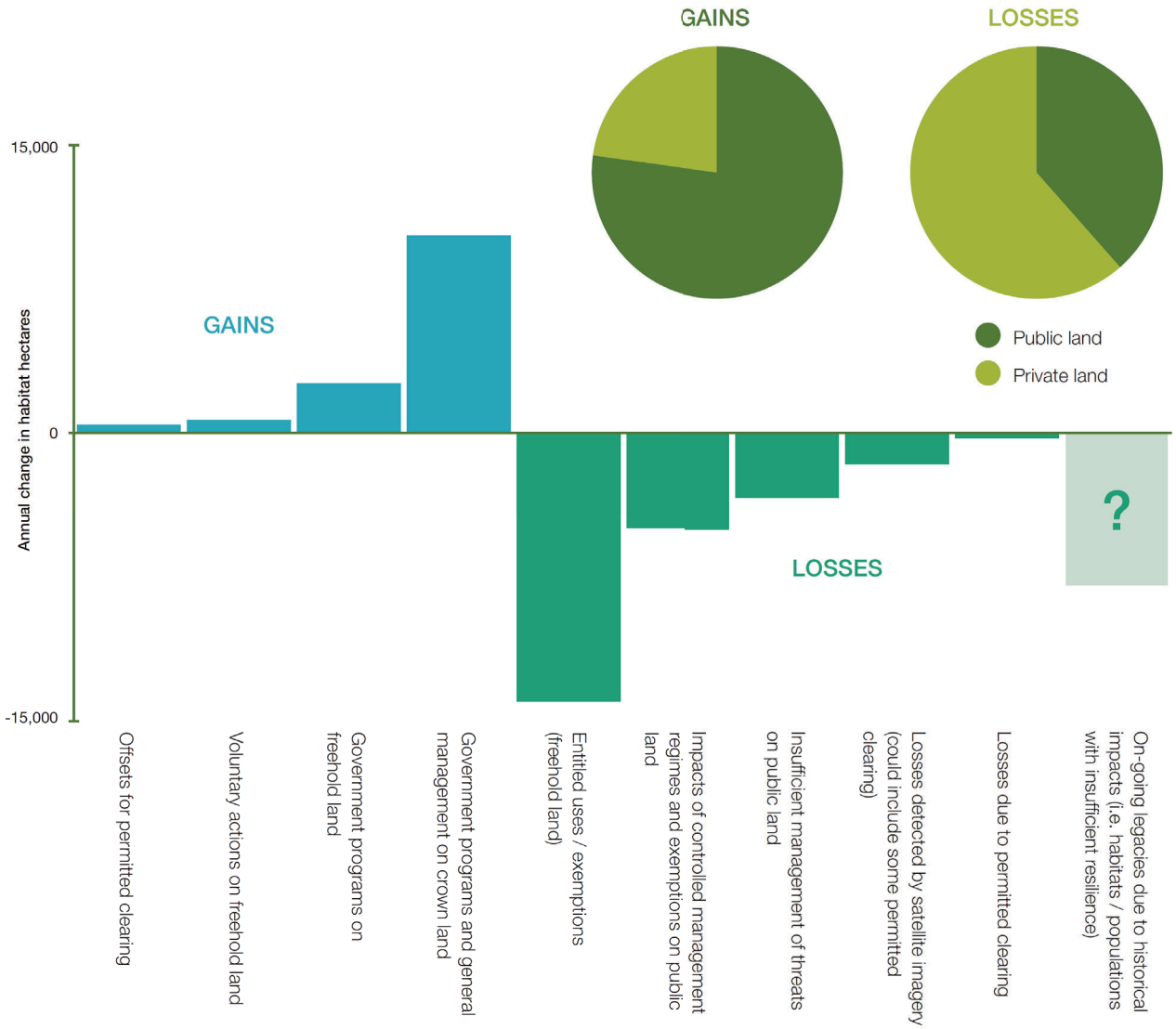


Figure B.8 Relative changes in native vegetation in 2014 estimated using the 'net gain' accounting approach[194]

194 DELWP 2016, 'Draft protecting Victoria's environment – Biodiversity 2036', Melbourne, Victoria.

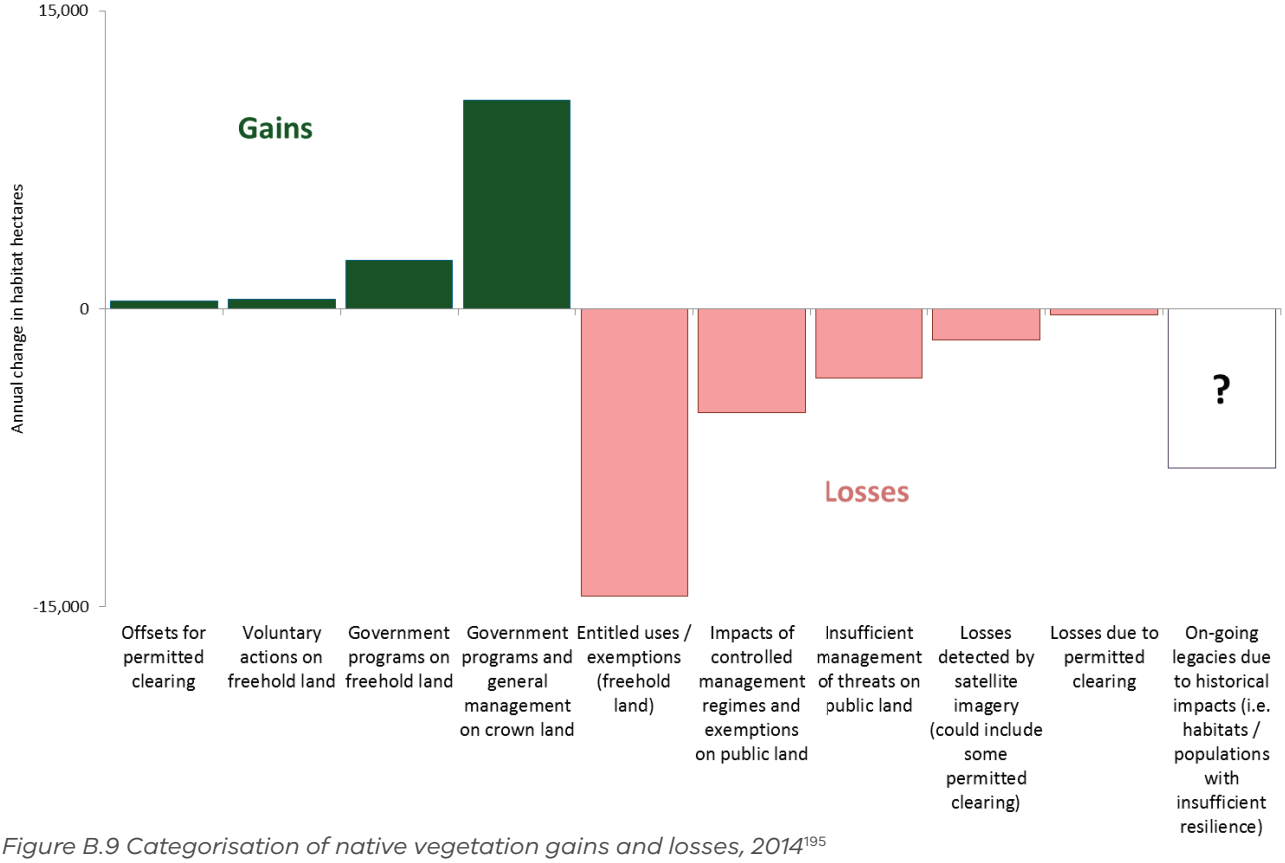


Figure B.9 Categorisation of native vegetation gains and losses, 2014[195]

Please note, the question mark in this figure denotes a lack of data to accurately measure on-going legacies.

195 DELWP 2015, '2015 qualitative update of the 2008 net gain accounting first approximation report', Melbroune, Victoria..

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:19 Landscape Scale Change Data custodian DELWP		↘	DATA QUALITY Fair

Landscape scale change is a new *Biodiversity 2037* indicator. Results provide new information on trends in native vegetation extent and land use from 1987 to 2015. Broken into six time epochs, Landscape scale change will be assessed on five-year groupings. The acquisition of Landsat (satellite) imagery, together with existing (and a small amount of new) training data, will provide a basis for modelling the distribution of native vegetation from a range of variables derived from satellite datasets. Training data is used to predict the relationship between the satellite imagery and native vegetation extent. This methodology will enable the quantification of how vegetation extent (measured as hectares) has changed across Victoria since 1987.

Analysis of landscape scale change shows an increase in landscapes associated with human-based activities and an overall decrease in native vegetation and intermittent and seasonal wetlands not of a marine water source.[196] The urban landscape, most notably in Melbourne's western suburbs and some regional areas such as Bendigo, has increased from 193,200 hectares in 1990 to 270,547 hectares in 2015, representing a 40% increase (Table B.14 and Figure B.10). This urban expansion has resulted in a loss of native grasslands and increased pressures on surrounding native vegetation in terms of asset protection from fire.[197] The built-up landscape, often associated with urban expansion, has also increased from 10,180 hectares to 13,089 hectares (29% increase) for the same time period. Additional landscape type increases between the years 1990 and 2015 include:

- hardwood plantations from 51,084 hectares to 243,609 hectares (377% increase) dryland cropping from 4,382,138 hectares to 5,145,877 hectares (17% increase) – specifically around the vicinity of Lake Bolac, Mallee, Mooroopna and Melbourne's western suburbs[198]
- native grasslands and herblands specifically in Kerang, most likely attributed to climate change due to variable rainfall resulting in drought and wet years[199]
- irrigated horticulture from 460,525 hectares in 1990 to 585,312 hectares in 2015 (27% increase) – specifically expansions in Robinvale[200]
- exotic woodlands from 77,137 hectares in 1990 to 109,837 hectares in 2015 (42% increase) – most notably around Lake Eppalock.

There have been decreases for the following landscape types between the years 1990 and 2015:

- native grasslands and herblands from 2,282,992 hectares to 1,820,093 hectares (20% decrease) – most notably around the vicinity of Lake Bolac, due to the expansion of dryland cropping and non-native pastures. This is also causing pressure on intermittent and seasonal wetlands and in Melbourne's western suburbs due to urban expansion and dryland cropping.
- native scattered trees from 542,201 hectares to 393,147 hectares (27% decrease)
- native shrubs from 165,262 hectares to 116,620 hectares (29% decrease)
- intermittent and seasonal wetlands, 47,286 hectares to 42,133 hectares 2015 (11% decrease) and 418,611 hectares to 342,955 hectares (18% decrease) respectively.

196 Note: definition of wetlands in the biodiversity chapter applies the Victorian wetland classification framework 2014. DELWP 2016, 'The Victorian wetland classification framework 2014', Melbourne, Victoria.
197 DELWP 2018, Data Analysis.

198 Ibid
199 Ibid
200 Ibid

Table B.14 Landscape scale change disaggregated to landscape type across 6 time epochs, 1990–2015[201]

Landscape name	1990		1995		2000		2005		2010		2015	
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
Built-up	10,180	100	10,975	108	11,562	114	12,336	121	13,452	132	13,089	129
Disturbed Ground	25,555	100	25,756	101	23,558	92	25,900	101	28,381	111	25,353	99
Dryland Cropping	4,382,138	100	4,673,019	107	4,793,679	109	4,978,979	114	5,035,536	115	5,145,877	117
Exotic Woody	77,317	100	74,668	97	95,930	124	91,825	119	88,649	115	109,837	142
Hardwood Plantation	51,084	100	66,513	130	73,400	144	164,109	321	201,594	395	243,609	477
Irrigated Horticulture	460,525	100	574,821	125	463,421	101	444,881	97	405,604	88	585,312	127
Mangrove	5,887	100	6,217	106	6,291	107	6,325	107	6,386	108	6,706	114
Native Grass Herb	2,282,992	100	2,083,245	91	1,944,463	85	2,124,330	93	2,222,795	97	1,820,093	80
Native Scattered Trees	542,210	100	454,371	84	492,556	91	467,682	86	446,289	82	393,147	73
Native Trees	7,822,316	100	7,935,448	101	7,912,706	101	7,916,538	101	7,917,106	101	8,000,382	102
Native Shrub	165,262	100	138,990	84	156,291	95	135,752	82	118,125	71	116,620	71
Natural Low Cover	101,448	100	92,462	91	90,162	89	98,925	98	97,689	96	96,063	95
Pasture Not Native	5,954,067	100	5,727,331	96	5,848,345	98	5,429,390	91	5,334,092	90	5,324,753	89
Pine Plantation	207,713	100	217,611	105	223,771	108	227,169	109	227,853	110	232,058	112
Saltmarsh	11,327	100	11,863	105	11,388	101	11,427	101	11,756	104	12,055	106
Urban	193,200	100	221,729	115	227,292	118	245,303	127	253,738	131	270,547	140
Water	1,527,070	100	1,526,788	100	1,509,181	99	1,504,251	99	1,500,232	98	1,506,213	99
Wetland Intermittent	47,286	100	47,869	101	40,191	85	41,851	89	34,265	72	42,133	89
Wetland Seasonal	418,611	100	397,106	95	361,999	86	359,225	86	342,651	82	342,955	82

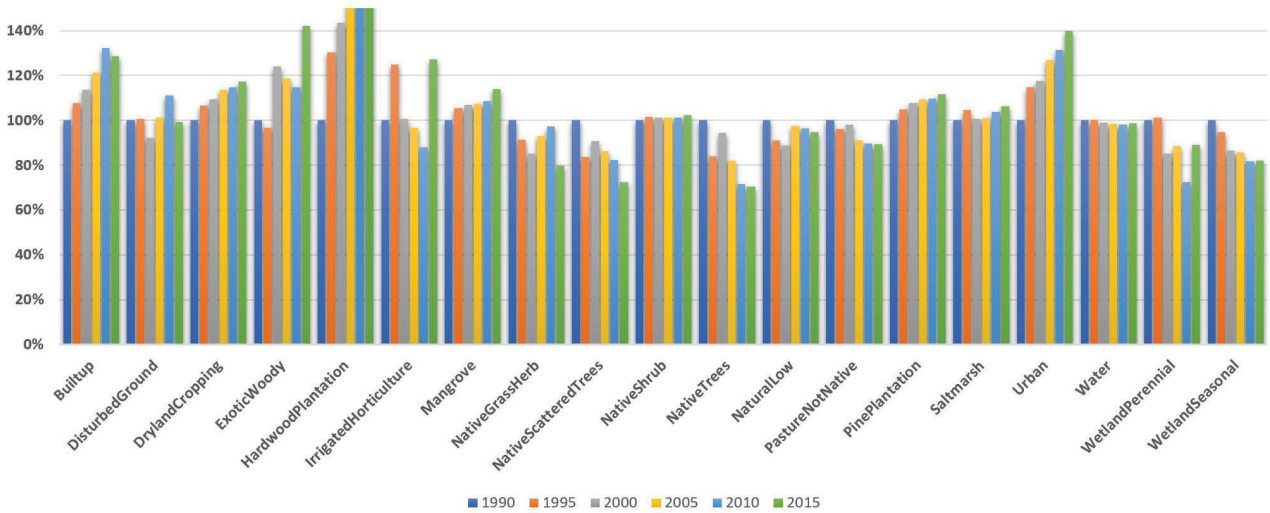


Figure B.10 Landscape Scale Change for each landscape type across 6 time epochs, 1990–2015[202]

201 DELWP 2018, Data Analysis.
202 Ibid

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:20 Change in Suitable Habitat		→	DATA QUALITY Good
Data custodian DELWP			

The previous Victorian SoE biodiversity indicator, Biodiversity Information, which assesses the comprehensiveness of biodiversity information required for effective management, is reported here under the new indicator title, Change in suitable habitat (CSH), which will be included in future SoE reporting.

CSH is the Victorian Government's new key performance indicator (KPI) through which it will measure progress towards the targets in *Biodiversity 2037*. This indicator's aim is to provide a practical measure for estimating net improvement in suitable habitat and the most effective options for improving the future of native species across the state under climate change.[203] The indicator's target is a 100% net positive change (on average) in suitable habitat for threatened species in 50 years.

The methodology considers the type, extent and configuration of habitat for a species and the factors that influence how much a species can make use of this habitat. This measure allows comparisons to be made between species, places and actions and is a shift from considering threatened species individually to securing the greatest overall benefit for all threatened and native species, taking account of cost-effectiveness. It compares the relative benefits that can be expected for different species from diverse management interventions. CSH can be calculated for one species and can be combined across many species.

Biodiversity 2037 states that achieving the 100% change (on average) in suitable habitat target will require the establishment and maintenance of management actions and associated targets identified in the Strategic Management Prospects (SMP) tool. The contributing management actions and targets identify priority areas that need to achieve the CSH, as soon as possible, and its maintenance over the life of the management plan. If effort slows or stops, for even a short time, the gains made over the preceding years of management effort could be lost. The faster the management actions are implemented and sustained to deliver their contributing targets, the more likely the statewide target, 100% net positive change (on average) in suitable habitat for threatened species in 50 years, can be achieved. The contributing management actions and targets will be reviewed every five years to ensure they are contributing to the statewide target.

To track and identify each management plan's actions and efforts in meeting this indicator's statewide target, DELWP has established five-yearly milestone targets for each management plan. Milestone targets identify whether the expected management actions and efforts in priority locations, from existing and proposed activities, align with the management plan's target and the statewide target. Milestone targets will also consider that some management actions and efforts, such as deer control, are still subject to adaptive management approaches.

For each management plan, CSH measures the increase in the likelihood that a species will persist at a priority location at a future time (for example, in 50 years) in response to sustained management of relevant threats. It is expressed as the proportional increase (percentage) in hectares of suitable habitat a species has received under a sustained management regime, compared with no management.

203 DELWP 2017, 'Protecting Victoria's Environment – Biodiversity 2037', Melbourne, Victoria.

The calculation for CSH is:

$$\text{CSH (for a species)} = (\text{action}^1 - \text{action}^0) \div \text{action}^0$$

where:

action^0 is the likelihood of persistence of the species with no action in the analysis

action^1 is the likelihood of persistence of the species with actions, adjusted based on the standard of work applied.

Management actions at sites included in the analysis are based on the activity data (DELWP standard outputs) reported by organisations delivering on-ground works to control terrestrial pest plants and animals (Figure B.11). The current analysis includes on-ground management actions from 2015–16 and 2017–18, in addition to any permanent protection agreements.

Results found that the average percentage CSH in 50 years for all native species is 5.24% (Table B.15). For threatened species, the average percentage CSH in 50 years is 5.3%, based on the on-ground management actions taken. For some species, the percentage CSH was much higher than the average. For example:

- 6 species had CSH greater than 100%
- 89 species had a CSH greater than 20%
- 431 species had a CSH greater than 10%.

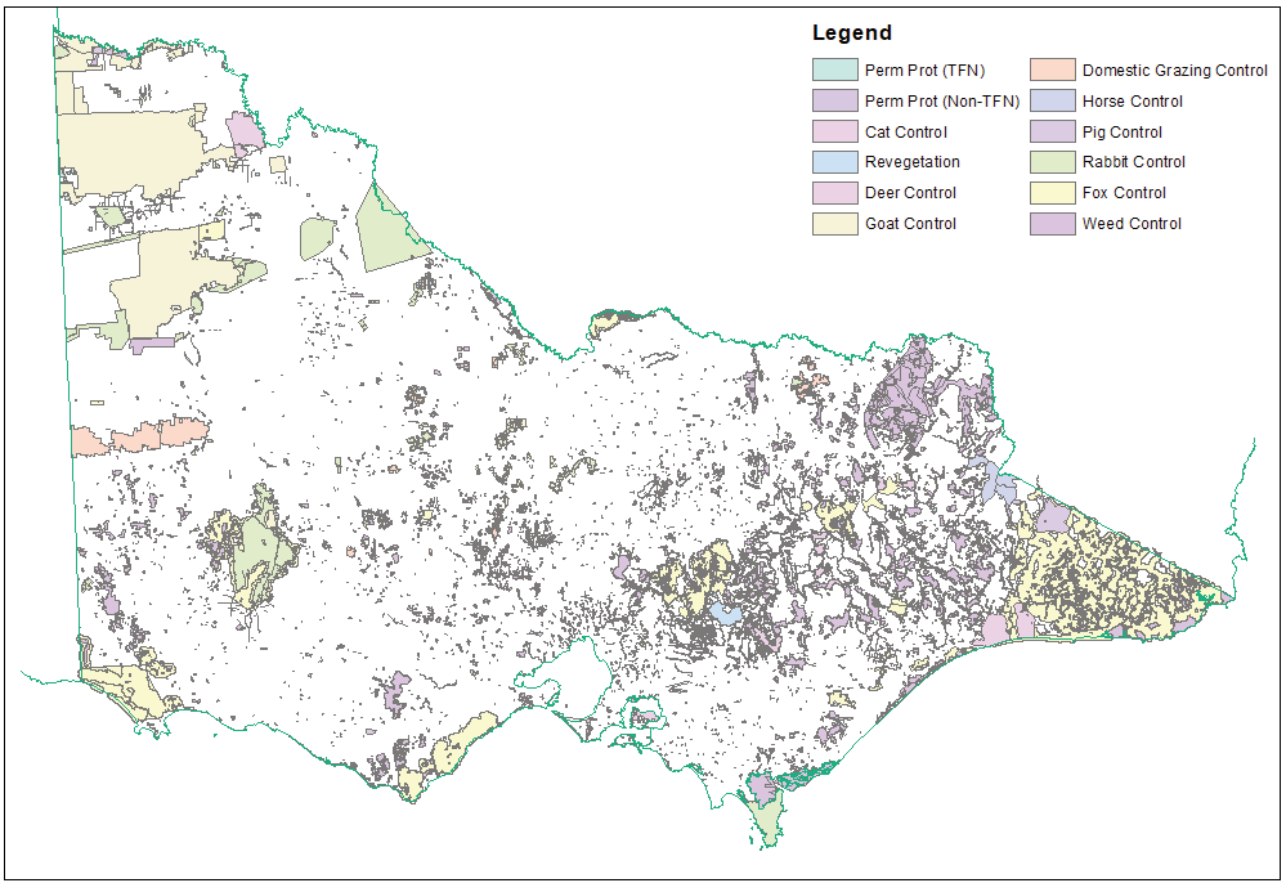


Figure B.11 Map of reported on-ground management actions across Victoria and applied to assess CSH assessment

(Source: DELWP 2018)

Table B.15 CSH for all native species in 50 years

Parameter	Target net positive CSH in 50 years for all species (%)	(on average) % net CSH in 50 years (%)
All species	(on average) 100	5.24
Birds		2.56
Frogs		3.45
Mammals		27.11
Plants		4.33
Reptiles		19.02
Threatened species	n/a	(on average) 5.3

(Data source: DELWP 2018)

A key assumption of these calculations is that the actions are continued for the next 50 years at the best practice standard. The relatively low predicted percentage net change (on average) in suitable habitat in 50 years may be due to the following factors:

- the short time frame over which reporting and recording of key management actions has occurred
- a lack of alignment of key management actions with priority locations
- evidence of only partial control of the threat due to the lack of a fully integrated management plan or implementation of partial treatments of a particular threat (Figure B.11). For example, management actions such as pest predator and herbivore controls in priority locations require an integrated approach to fully manage these threats. All pest herbivore species must be adequately controlled in a location for a beneficial management outcome. In practice, controlling all pest herbivore species is rarely done, and in many cases, only one or two species are targeted for control at a management location. While there is a large amount of pest herbivore control occurring in priority management locations across Victoria (Table B.16), analysis of management actions indicate that the benefits are not being fully realised in terms of percentage increase in suitable habitat as not all pest herbivore species are being adequately controlled in those priority locations (for example, there is a need for integrated feral horse, deer and pig control in the Victorian Alps).
- a relatively large number (over 100) of flora species that received negative benefits from predator control management actions, due to the increase of herbivore species (such as rabbits) from reductions in predation without the corresponding pest herbivore control, therefore increasing total grazing pressure. Such negative benefits could be avoided by an increase in integrated ecosystem management, such as considering the potential flow-on effects of predator control by restoring or mirroring the function of predators through other management.
- the need for further management action through increased investment
- missing spatial data for management actions completed or being undertaken that may impact on CSH, particularly for threatened species (for example, species-specific actions) or actions implemented by community groups, volunteers, conservation efforts on private land and gaps for individual CMAs and other organisations who manage environmental assets that have not been recorded and reported to DELWP.

Caveats and assumptions for implementing and measuring CSH include:

- The values provided here assume that the reported management actions were done to best practice, and that they will be sustained for 50 years. Any estimated benefits do not apply if a management action is not sustained for the 50-year time horizon. Therefore, when calculating benefits, management actions will be counted for a location if they are current (either newly established or continuing from previous years).
- The location across which management actions were implemented for each individual species targeted contributes to the overall management target, even when the location of the management action or the management action itself overlaps.
- he benefit and area data are calculated on the assumption that a management action is implemented across the full extent of the polygons reported, and therefore may be overestimated in some cases. Efforts were applied to refine polygons where better information was available, however, data for some actions (such as weed control) may still be an overestimate due to spatial data that overvalues the actual area of management action. Future reporting against these targets requires refinement of reporting data to reduce this uncertainty and associated overestimates.
- In instances, some polygons of reported management action did not intersect with action benefit models in the SMP tool. This was due to some threat models underestimating the true distribution of a threat, and therefore, locations where management action is required. This results in an optimistic CSH value.
- The figures detailed here apply to the information provided by the current (v1.2) SMP analysis. As the SMP develops and improves over time, and includes accurate data for effective treatment area and standard of works, the CSH values will vary. It will be possible in the future to back cast the SMP models and data to provide trend information through time.

Case Studies

Potoroos

The Long-footed Potoroo (*Potorous longipes*) and Long-nosed Potoroos (*Potorous tridactylus*) are both expected to have a net positive CSH of 127% and 98.6%, respectively, over the next 50 years under their reported management regimes. This is largely due to large-scale predator control programs (e.g. Southern Ark) operating in East Gippsland.

Anglesea Grevillea

The Anglesea Grevillea (*Grevillea infecunda*) will experience a positive CSH by approximately 4.1% over the next 50 years under the reported management plans. This positive change is due to weed control efforts across its distribution range. Important threats to the Anglesea Grevillea include: physical disturbance by humans and inappropriate fire regimes. Management of these threats are not captured in this assessment. Future inclusion of these management actions, and others, in this assessment might result in an increase in the expected positive CSH for Anglesea Grevillea.

Button Wrinklewort

The Button Wrinklewort (*Rutidosis leptorhyncoides*) is expected to have roughly a 1.3% positive CSH over the next 50 years under the reported management plans, due to weed control efforts. Other key management actions for this species including management of fire regimes and species' genetic diversity management across its distribution range, are not captured in this assessment. Increasing the coverage and inclusion of management actions specific to this endangered species, such as genetic rescue, might result in an increase in the expected positive CSH for Button Wrinklewort.

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:21 Area of Management in Priority Locations Data custodian DELWP		→	DATA QUALITY Fair

This indicator sets out targets for hectares of management in priority locations, including restoration of habitat, which includes:

- 4 million hectares of herbivore control in priority locations by 2037
- 1.5 million hectares of pest predator control by 2037
- 1.5 million hectares of weed control in priority locations by 2037
- 200,000 hectares of revegetation in priority areas for connectivity between habitats by 2037
- 200,000 hectares of new protected areas on private land by 2037

A priority location refers to areas identified within the top 20% cost-effective actions in the SMP. SMP helps to integrate and compare information on the expected benefits and indicative costs of conservation actions across species and locations. It allows us to compare management options, or the effectiveness of individual management actions in different places.

SMPs will help conservation managers make decisions across Victoria, including both investment in actions to strengthen biodiversity, and guidance in the application of statutory responsibilities and regulatory controls. SMP helps to integrate and compare information on the expected benefits and indicative costs of conservation actions across species and locations. It allows us to compare management options, or the effectiveness of individual management actions in different places.[204]

The SMP focuses on the benefit of action (representing best options for gains) and so contains a mix of values, noting some high-value areas may not be included because they may not have a relevant action in the analysis, the actions are not particularly cost-effective, or the needs of that species have been met by other actions in other places. Increasing the alignment of these actions to sit in the top 20% cost-effective actions, as indicated in the SMP analysis outputs,[205] could yield greater biodiversity benefit per unit cost.

On-ground management works are progressing towards Victorian priority location *Biodiversity 2037* targets (Table B.16 and Figure B.12). Caveats and assumptions for implementing and measuring change in area of management in priority locations include:

- Measures include the effective treatment area over which the management action was undertaken. For example, herbivore control in an area with introduced herbivores such as, deer, rabbits, goats, horses and stock. Pigs were controlled by culling, other animals were removed or restricted, shot, trapped, excluded (seasonal or permanent) or a changed grazing regime was introduced. It recognises the area where the target species is located and treatment is applied. It does not include the search area.

204 DELWP 2018, 'Strategic Management Prospectus', Melbourne, Victoria http://delwp.maps.arcgis.com/apps/MapJournal/index.html?appid=e0289e3fe12f436490ef63d4444a05df# Accessed 2 October 2018.

205 Ibid

- This assessment assumes on-ground management actions were completed to an appropriate standard (such as DELWP's *Biodiversity 2037* Monitoring, Evaluation and Reporting Framework, DELWP Output Delivery Standards and Output Data Standard).[206] A discount rate was applied where a lower level of standard has been applied to the work, where only a portion of the area has been treated or where there is insufficient information provided on the delivery standard. Given this dataset is preliminary in nature, any of these discount rate scenarios are likely to have occurred. Discount rates were 50% of the estimated total biodiversity benefit for the actions where the discount was applied. Weed control and revegetation had a 50% discount applied to each as both actions are rarely done to the standard that is the basis of the benefit estimate in SMP. The spatial data provided for weed control appeared to overestimate the area controlled (in areas such as Murray-Sunset, Grampians and East Gippsland). Weed control, for example, assumes that all high threat weeds are controlled in an area, not just a single or subset of species. Revegetation assumes that it is done to the ecological vegetation class standards, rather than just selected overstorey and understorey species.
- Priority locations in the SMP contain a mix of area values, where some high value areas may not be included due to the following:

  - They lack a relevant management action in the analysis.

  - The management actions are not particularly cost-effective.

  or

  - The needs of that species have been met by management actions in other locations.

Increasing the alignment of these management actions to the top 20% cost-effective management actions in the SMP could yield greater biodiversity benefit per unit cost.

206 Note: see Biodiversity 2037 Monitoring, Evaluation and Reporting Framework, DELWP Output Delivery Standards, DELWP Standard Outputs.

Table B.16 Measuring progress from on-ground management actions in achieving *Biodiversity 2037* targets for priority locations across Victoria applying DELWP's Standard Output Data

	Contribution of actions to Biodiversity 2037 targets		Actions across the State
Management action	**Hectares of action in priority locations (ha)**	**Target hectares of actions in priority locations by 2037 (ha)**	**Total hectares of action in priority and other locations across the state (ha)**
Herbivore control	1,572,725	4,000,000	6,979,935
Pest predator control	705,590	1,500,000	2,475,713
Weed control	1,916,350	1,500,000	4,223,328
Restoration	359	200,000	65,217
Hectares of newly protected area on private land	2,204 (a)	200,000	137,270 (b)

(a) Priority location does not apply to this management action.

(b) Total area of permanently protected area on private land in Victoria

(Data source: DELWP 2018)

Some management plans and projects may occur in locations where it would be beneficial to conduct a particular management action. However, each management action is competing with all other management actions across Victoria in the SMP Analysis. This means that not all locations where it is beneficial to conduct a particular management action will be in a 'priority location' within the SMP analysis or where that management action is the most cost-effective. Further progress towards targets could be made by increased alignment of management actions in priority locations (including a combination of actions) through increased funding.

Further progress towards targets could be made by increased alignment of management actions in priority locations (including a combination of management actions). An audit of management sites is planned to determine how management and data standards are being interpreted and applied in DELWP's Standard Output Data. This will feed into a review of the standards to ensure reporting accurately reflects on-ground management action and progress towards priority location targets.

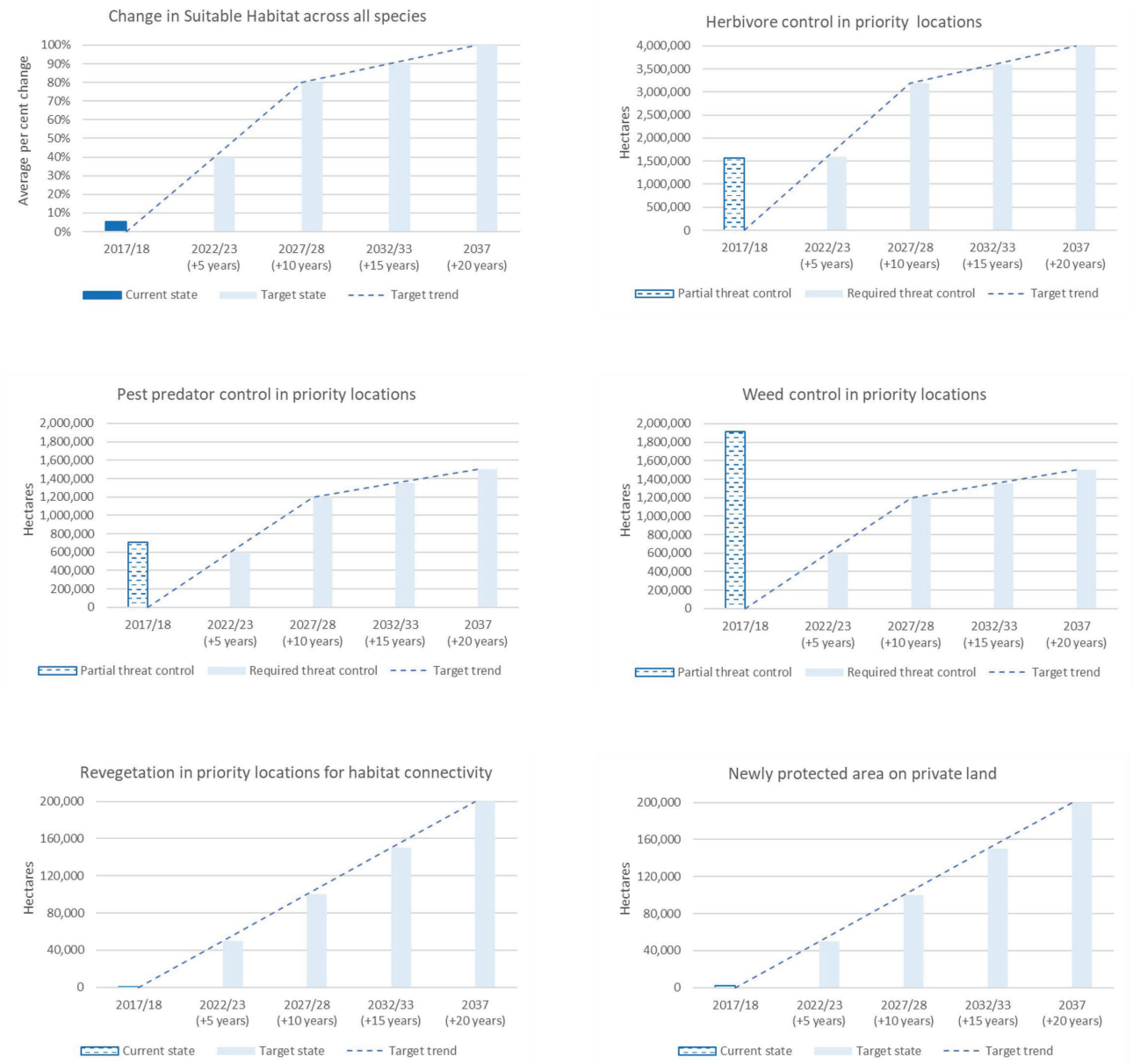


Figure B.12 Measuring progress from on-ground management actions in achieving Biodiversity 2037 targets for priority locations across Victoria

(Data source: DELWP 2018)

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
B:22 Victorians value nature		?	DATA QUALITY Poor
Data custodian DELWP, Parks Victoria, CMAs			

There is an estimated number of 100,000 Victorians participating in environmental volunteering each year across diverse volunteer groups and mostly structured programs.[207] These include citizen science programs, marine and coastal volunteers, water programs, Landcare, friends groups, parks volunteers, outdoor enthusiasts groups, Zoos Victoria, climate change and sustainability networks, gardening, wildlife programs, corporate volunteering, not-for-profits, and local government and government agency programs. The majority of environmental volunteer groups are based in regional and rural Victoria.[208] There is a lack of culturally and linguistically diverse communities involved in environmental volunteering.[209]

'Victorians value nature' (VVN) is a key objective for the Victorian Government's *Biodiversity 2037*. This objective aims to understand and assess how Victorians are connecting with the natural environment, how this improves their health and wellbeing and how people are protecting Victoria's natural environment for current and future generations.[210] An underlying assumption here is that an increased connection with nature will lead to greater value placed on the environment and more Victorians acting to support biodiversity. This indicator describes the relationship between people's interaction with nature (how they value it and act to protect or enhance biodiversity) and the ways they use it to improve their health and wellbeing. Targets for VVN include:

- all Victorians connecting with nature
- five million Victorians acting to protect the natural environment
- all Victorian Government organisations that manage environmental assets contributing to achieving the above two targets.

To meet these targets, DELWP has developed the Victorians Volunteering for Nature – Environmental Volunteering Plan. This plan has four key foci areas:

- sustain – to sustain existing environmental volunteering programs and networks
- expand – to regenerate environmental volunteering and encourage more Victorians to act for nature
- value – to value and recognise the contributions of environmental volunteers
- understand – to understand the diverse needs of the environmental volunteering sector.

To implement this plan, DELWP is currently developing the Victorians Valuing Nature Conceptual Framework, which includes the Victorians Valuing Nature Foundations Survey and Structured Decision Making Process for Victorians Valuing Nature. The Victorians Valuing Nature Conceptual Framework will assist in conceptualising the work and creating measures to meet the above targets to be included in the next iteration of the *Biodiversity 2037* Monitoring, Evaluation and Reporting Framework in mid-2019. This will include the development of KPIs and related outcomes for the VVN goal, together with a description of the outputs and the types of standard outputs data required for reporting. As a new *Biodiversity 2037* indicator, baseline figures to assess and inform future state and trend of how Victorians value nature and their experience with nature is currently being collated by DELWP.

207 DELWP 2018, 'Victorians volunteering for nature environmental volunteering plan', Melbourne, Victoria.
208 Ibid
209 Ibid
210 DELWP 2017, 'Protecting Victoria's Environment – Biodiversity 2037', Melbourne, Victoria.

Parks Victoria visitor data can also contribute to understanding how Victorians value nature through visitor numbers. In 2013–14, approximately 4.3million day trips were taken to natural areas by Victorian domestic nature-based visitors.[211] During 2016–17, there were 449 licensed tour operators which increased to 494 licensed tour operators in 2017–18 with active licences working across Parks Estate, highlighting visitor interest.[212] It is estimated that visits to parks saves Victoria between $80 to $200 million per year from avoidance of disease, mortality and lost productivity.[213] Aboriginal cultural tourism is also expanding to meet the growing demand for Aboriginal cultural experiences and products.[214] ParkConnect is Park Victoria's online volunteer management system. The largest demographic registering to volunteer on ParkConnect is the 18 to 35-year old age group with the highest percentage indicating their employment status as 'full-time'. The largest proportion of volunteer activities are focused on habitat restoration followed by environmental research, historic heritage conservation then gardening. Since the implementation of ParkConnect there has been a significant shift in demographics of new volunteers with the highest percentage of volunteers previously over 65.[215]

Citizen Science Contribution to Understanding and Managing Victoria's Biodiversity

Under VVN there is an opportunity for citizen science data to complement science research data for evidence-based biodiversity planning and management decisions. The following indicators can be considered for future reporting of citizen science data:

- the actual data, and its quality, that contribute to management decisions
- the number and types of citizen science programs contributing data for informing real-time on-ground management decisions
- the number of volunteers involved in citizen science programs and the economic value of volunteers' time
- social benefits – for example social cohesion, level of environmental stewardship and health and wellbeing benefits – as outcomes from volunteers engaging in citizen science.

211 DELWP 2016, 'Protecting Victoria's Environment – Biodiversity 2036. Supporting technical supplement', Melbourne, Victoria.
212 PV Data 2018.
213 PV 2015, 'Valuing Victoria's Parks. Accounting for ecosystems and valuing their benefits: Report of first phase findings', Melbourne, Victoria http://parkweb.vic.gov.au/about-us/news/valuing-victorias-parks Accessed 27 July 2018.
214 Tourism Victoria 2014, 'Aboriginal tourism: market profile year ending June 2014', Melbourne, Victoria. http://www.tourism.vic.gov.au/research/domestic-and-regional-research/product-segment-market-profiles.html Accessed 27 July 2018.
215 PV Data 2018.

Indicator	Status UNKNOWN POOR FAIR GOOD	Trend	Data Quality
B:23 Number of Victorian Government organisations that manage environmental assets that contribute to DELWP Standard Output Data Data custodian DELWP		?	DATA QUALITY Poor

This indicator's target is to have 100% of Victorian Government organisations that manage environmental assets contributing to DELWP Standard Output Data.

To date, 12% of Victorian Government organisations who manage Victoria's natural assets have contributed some data. In most cases this data is not complete and does not reflect all on-ground works those organisations have delivered or funded. Further work, funding and resourcing is needed to support all Victorian Government organisations who manage natural assets to contribute activity data, and ensure they include as requirement for programs including any grant agreements.

Future Focus

Improve Victoria's biodiversity outcomes on public land

As this report demonstrates, the data and science available to answer many of the critical questions about biodiversity condition and extent in Victoria, is inadequate. This fragmented evidence base is an impediment to adaptive management and improving biodiversity outcomes. This fragmentation has three overarching causes.

Firstly, various investment programs across multiple land management groups have created different and inconsistent data sources and terminologies for reporting on the state of biodiversity, land and forest assets in Victoria. These inefficiencies impact on the ability to present a coherent and integrated evidence base to improve management interventions and ultimately, biodiversity outcomes. Streamlining its approach to land-management to reduce inefficiencies will assist DELWP to deliver a well-coordinated and coherent approach.

Secondly, these measures will require complementary investment in improving data capability to routinely monitor progress towards biodiversity outcomes. This will result in improved accessibility and utility of data in more meaningful timeframes for biodiversity, land and water decision-making. Improved data capability has been recognised as an 'enabler' in DELWP's Science Statement for increasing connectivity and discoverability of science across the department, with partners, stakeholders and the community.

Finally, Victoria's biodiversity science and data capability, although underpinned by world-class scientists and research institutions (including DELWP's Arthur Rylah Institute), is diminished by a lack of coordination and strategy in approach to investing in critical research to enable better and more timely decision-making and policy interventions. This is a critical theme that links many of the recommendations presented in this report – and the broader narrative of addressing knowledge gaps and improving the evidence base for environmental management.

This report highlights the need for improved functionality of biodiversity science across the Victorian Government environment portfolio to improve the collection, coordination, curation and interpretation of biodiversity science. Perhaps most critical is the need to integrate biodiversity science to inform solutions to complex problems, cumulative threats (climate change, fire, drought, flood, heatwave, invasive pests, development) and cumulative challenges (forests, water, marine and coastal management).

A chief biodiversity scientist for Victoria would provide the leadership that is missing in Victoria to improve investment and coordination in biodiversity science and research. The chief biodiversity scientist would report directly to the Secretary of DELWP, complement the current roles of EPA Victoria's Chief Environmental Scientist, Parks Victoria's Chief Conservation Scientist and Victoria's Lead Scientist, and provide the DELWP Secretary and the Minister for Environment with esteemed counsel on biodiversity, threatened species and the impacts of climate change, invasive pests and extreme events on biodiversity values and assets. This science leadership role would also extend to advising on the development of the biodiversity targets that the Victorian Government has committed to establishing in *Biodiversity 2037*. A key function of this role would be to ensure that biodiversity research investment by the Victorian Government is targeted to management and policy priorities across the portfolio, and that the science is better curated, coordinated and tailored to improve the collective research impact of the investment on adaptive management.

The chief biodiversity scientist would be equipped with the authority to provide esteemed counsel on the Victorian Government's collective biodiversity research effort and on enhancing biodiversity outcomes consistent with the objectives of *Biodiversity 2037*.

Recommendation 5: That DELWP streamline the governance and coordination of investment in the science and data capability of all government biodiversity programs and improve the coherence and impact of the publicly-funded, scientific endeavour. Further, that DELWP establish the position of the chief biodiversity scientist to oversee this coordinated effort and provide esteemed counsel to the DELWP Secretary and the Minister for Environment to improve the impact of investment in biodiversity research across the Victorian environment portfolio.

Improve Victoria's biodiversity outcomes on private land

The rate of biodiversity loss on private land requires greater focus and effort by government. Victoria has nearly 23 million hectares of land: public land accounts for 37% and private land 63%.[216] Private land conservation through permanent protection has been increasing across the state. However, it occurs at a slower rate than biodiversity loss and needs to be addressed as a priority over the next decade.

The recommended chief biodiversity scientist would, in consultation with stakeholders across the portfolio, provide esteemed counsel to the DELWP Secretary and the Minister for Environment on the science that underpins private land conservation and on enhancing biodiversity outcomes on private land consistent with the objectives of *Biodiversity 2037*.

Recommendation 6: That DELWP improve biodiversity outcomes on private land by accelerating private land conservation. This will require resourcing permanent protection measures that focus on high-priority ecosystems and landscapes, and investing in local government capability to enforce the existing *Guidelines for the Removal, Destruction or Lopping of Native Vegetation and the Invasive Plants and Animals Policy Framework*.

216 VEAC, 2016. Statewide Assessment of Public Land Discussion Paper. Victorian Environmental Assessment Council, East Melbourne, Victoria.

Accounting for the Environment

Biodiversity plays an essential role in supporting economic and social wellbeing through maintaining functioning ecosystems that produce ecosystem services. Environmental–economic accounting provides a framework to measure and link biodiversity and the ecosystem services it supports that underpin economic activity and wellbeing.

The impact of healthy or degraded biodiversity already appears to some extent in Victoria's traditional economic accounts (the System of National Accounts (SNA)) that record goods and services such as tourism and agricultural production, which are often supported by biodiversity. However, traditional accounts do not identify the proportion of economic activity that can be attributed to biodiverse ecosystems. The System of Environmental–Economic Accounting (SEEA) extends the SNA by including environmental and ecosystem assets. For example, in 2015, Victorian parks were found to support $1.4 billion per year in visitor expenditure and generate $1 billion gross value added for the Victorian economy.[217] Biodiversity is a key part of the visitor experience attraction of parks.

Biodiversity accounts can help illustrate the relationship between biodiversity and economic activity and wellbeing by reporting data in a spatially explicit and consistent and comparable manner. By comparing trends in biodiversity against measures such as land use, energy use, or residual pollutants such as carbon emissions or nitrogen loads it may be possible to link key drivers and pressures contributing to biodiversity loss. Biodiversity accounts have the potential to play an important role in evaluating the efficiency and effectiveness of government and community management actions to protect and enhance Victoria's biodiversity.

In experimental ecosystem accounting, biodiversity is typically considered as a characteristic of ecosystems which can be strongly linked to the ecosystem services they provide. In this context, falling biodiversity (as measured, for example, by reductions in the number of species in a given area) will generally correspond to declining ecosystem condition. A measure of biodiversity could be a relevant condition metric for ecosystem assets discussed in other chapters of the SoE 2018, such as forests or marine and coastal environment.

Biodiversity accounting is a complex and evolving area of environmental–economic accounting. Its measurement is a specialist field, and different methods for assessing biodiversity provide varying levels of accuracy and precision. Biodiversity accounting is advancing but remains less defined than other areas of environmental–economic accounting such as land, water or carbon accounting.

Species Accounts

As a component of biodiversity, species form the biotic elements of ecosystems and have an important role in how ecosystems function and deliver ecosystem services that support economic activity and human wellbeing.

Specific species can also contribute directly to economic activity and wellbeing. For instance, some species are important for providing food or medicines used by local communities and in commercial activities. Others may contribute to wellbeing due to their charismatic and iconic nature – valued on the basis of aesthetics, characteristics and behaviour – or because of the cultural status given to them.

Species accounts may support the following analytical uses:

comparing trends in species status with information on economic activities and other drivers of species loss

- organising the information required to support trend analysis – for instance, via interpolation (new data points in an existing set) or forecasting

217 Varcoe T, Betts O'Shea H, Contretas Z 2015, 'Valuing Victoria's parks: Accounting for ecosystems and valuing their benefits', Melbourne, Victoria.

- organising information on species for aggregation and communication across all scales
- communicating the relationships between species, ecosystems and the supply of ecosystem services
- providing objective statistics to report on policies related to species and ecosystems
- exploring future trade-offs by organising species information required to support scenario modelling
- informing cost–benefit or ecological return on investment analyses
- supporting expert judgement on species status and trends by organising available information on the observations of species.

Australian Capital Territory Butterfly Accounts

Due to the complexities of biodiversity measurement, the focus is often placed on selected indicators of biodiversity rather than accounting for all aspects of biodiversity.

Butterflies can be used as indicators of environmental condition and change. The Australian Capital Territory (ACT) has recently prepared a set of novel SEEA butterfly accounts[218] aiming to use accounting for butterflies as a metric of ecosystem condition to identify problems and guide management of ecosystems. The ACT butterfly accounts include:

1. number of butterfly species at different scales (ACT, Australia and global) at one point in time
2. snapshot of species by family with breakdown by breeding category (endemic or introduced) and specialisation (generalists able to survive in a wide range of conditions or specialists that are more localised with specific needs for survival)
3. snapshot of species focusing in classifying in a way to enable links between species and ecosystem condition and climate change (by identifying those which rely on habitats in the ACT to breed)
4. account bringing together the information in points two and three above over two periods of time, showing 9 species added over 40 years.

Lessons learned from the butterfly accounts include that, while conservation status is important, a number of other classifications are useful for understanding the management needs of species, or strategies for conservation of species. In particular, classifications of species as specialists or generalists in terms of habitat needs as well as by area of distribution and movement is important. Having these classifications standardised in future will be useful. The ACT is also planning to compare measures of ecosystem condition from remote sensing data with the butterfly accounts.

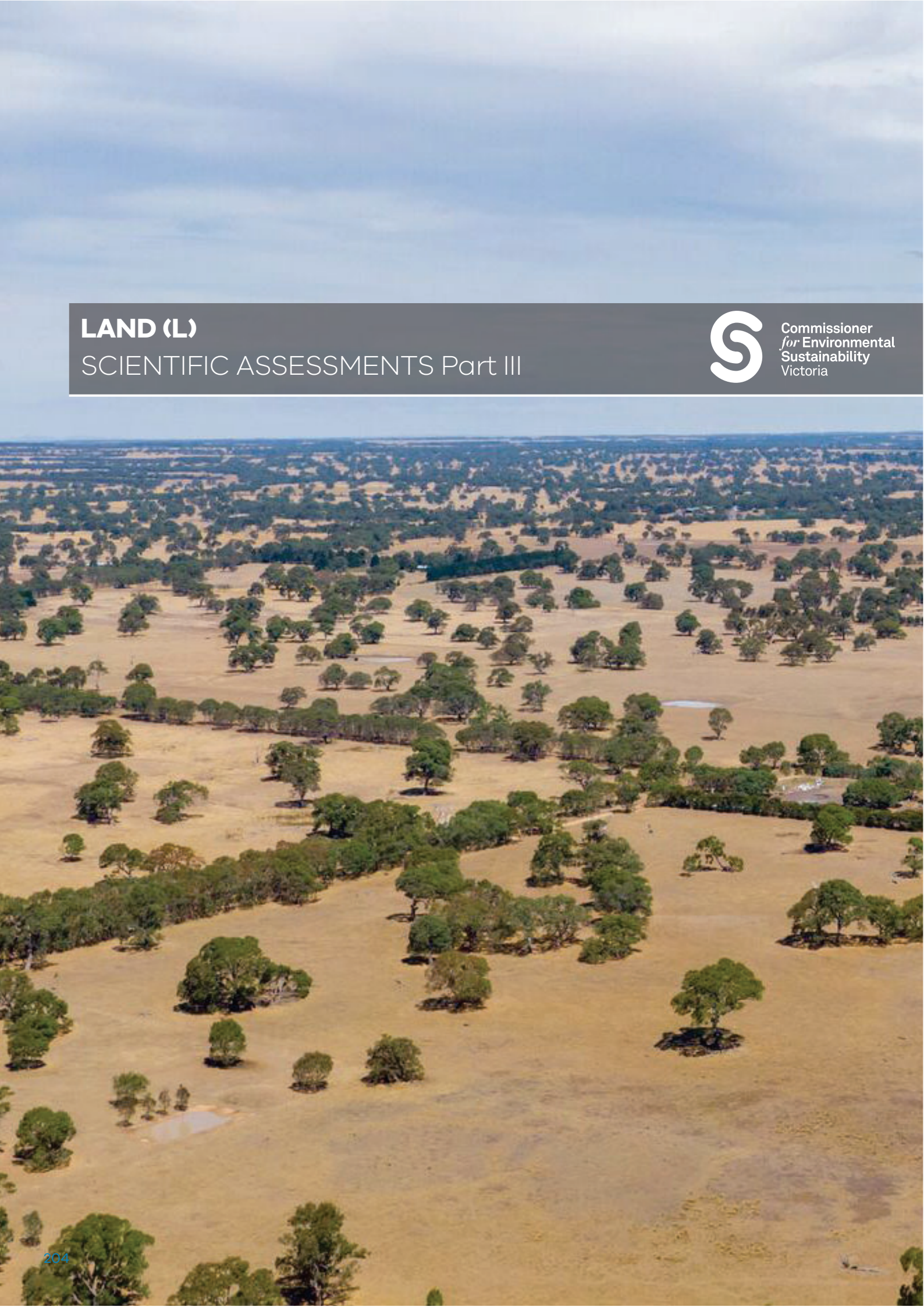
The ACT is aiming to eventually use butterfly accounts covering species presence and abundance by habitat type and season each year and between two points in time, species area of distribution by habitat and a land cover account.

218 Bond S, Vardon M 2018, 'Moonlight Jewels to Common Browns: Butterfly Accounts for the ACT, Canberra', Australian Bureau of Statistics and Australian National University. https://seea.un.org/sites/seea.un.org/files/lg_24_d_16b.pdf Accessed September 2018.

LAND (L)

SCIENTIFIC ASSESSMENTS Part III

Commissioner *for* Environmental Sustainability Victoria



Land

This chapter includes assessments of Victoria's land health across four key themes: land use, soil health, contaminated sites and land management. The land use theme looks at current land use and land-use changes over time as well as greenfield versus infill development. The soil health theme incorporates soil carbon content, salinity, acidification and erosion. The contaminated sites theme contains a single indicator on that topic, while the land management theme includes assessments of land-management activities, participation in natural resource management activities, use of best practice on agricultural land and the proportion of the agricultural area under productive and sustainable agriculture.

Background

Victoria's land is used for a variety of purposes, including residential and business use, agricultural lands for production of food and fibre, and conservation areas to protect biodiversity. Maintaining the viability of the agricultural sector while also protecting and enhancing biodiversity is a key challenge for land managers.

The SoE 2013 reported that land development for urban and agricultural uses has resulted in declines in the condition of land, water and biodiversity. Many of the environmental challenges facing Victoria are the result of decisions about land use and land management. Land-use change is driven by a range of social, economic and environmental pressures. Preference for living in coastal or rural areas close to Melbourne has an impact on natural ecosystems and agricultural land, and threat to biodiversity. However, the main drivers of agricultural land-use change are climate (for example, water availability), commodity prices, supporting infrastructure and land capability (for example, soil type, terrain, susceptibility to flooding and inundation). These factors determine the type of farming that can be carried out, as well as those types that will maximise returns.[1]

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

Few long-term datasets exist to inform our knowledge of Victoria's statewide land health, and those datasets that do exist are often limited in extent, impairing our ability to comprehensively understand environmental condition. This lack of land-health data was a key observation of the Victorian Catchment Management Council's (VCMC) *Catchment Condition and Management Report 2017*.[2]

New and emerging technology is helping to improve the data capture and understanding of Victoria's land health. Remote sensing is one example, with satellite and aerial imagery capable of identifying areas subject to climate stress. However, remote sensing only has a limited ability to identify specific land-management types. Despite this limitation, remote sensing is rapidly improving with more investment in the sector (including by Digital Earth Australia and the Australian National University).[3,4]

More frequent drought and fires will reduce vegetation cover, and more severe storms and extreme rainfall events are also likely.[5] These conditions will create great potential for severe erosion and reductions in soil nutrients and carbon.[6]

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

- ensuring on-ground monitoring is undertaken to understand changing land-management practices
- enhancing the ability of technology such as remote sensing to identify land areas subject to climate stress
- mitigating the effect of climate change on soil degradation

2. Victorian Catchment Management Council 2017, 'Catchment Condition and Management Report 2017', East Melbourne, Victoria, http://www.vcmc.vic.gov.au/pdf/CCMR_Report_2017.pdf Accessed 3 December 2018.
3. Geosciences Australia 2017, 'Digital Earth Australia', Canberra, Australia http://www.ga.gov.au/__data/assets/pdf_file/0008/49490/Prospectus.pdf Accessed 3 December 2018.
4. Australian National University, 'Projects', Canberra, Australia http://wald.anu.edu.au/ Accessed 3 December 2018.
5. Commissioner for Environmental Sustainability 2012, 'Climate Change Victoria: the science, our people and our state of play', Melbourne, Victoria.
6. Ibid

- increasing, and then maintaining, soil carbon. Decomposing organic matter is the most useful soil carbon for farming and is very susceptible to deterioration during drought.
- proactively identifying and remediating legacy land contamination
- ensuring that environmental implications are a primary consideration in land-use decision-making, including providing land users and managers with timely information on land condition.

Current Victorian Government Settings: Legislation, Policy, Programs

In May 2016, a Ministerial Advisory Committee (MAC) completed its inquiry into Environment Protection Authority Victoria (EPA Victoria). One of the MAC's recommendations was for Department of Environment, Land, Water and Planning (DELWP) to 'develop a comprehensive database of contaminated sites'.[7] The Victorian Government supported this recommendation and asserted that 'a public database providing consistent and easily accessible, statewide site history information will be developed to assist with the identification of potentially contaminated sites'.[8] More information on the progress of this database is provided in indicator L:09 (Contaminated sites).

Relevant audits within the land-health sector have been completed during the past decade by the Victorian Auditor-General's Office. The audit topics were Soil Health Management (October 2010) and Enhancing Food and Fibre Productivity (August 2016).[9,10] The 2010 audit recommended the development of agreed soil-health indicators and monitoring programs to assess soil-health status and trends. The Soil Health Strategy released by DELWP in July 2012 responded to the 2010 audit. This strategy included an action to identify key performance indicators that effectively and pragmatically measure the impact against departmental and regional priority environmental assets, using monitoring programs to collect the data required.[11]

7. MAC 2016, 'Independent inquiry into the Environment Protection Authority', http://www.epa-inquiry.vic.gov.au/__data/assets/file/0008/336698/Inquiry-report-EPA_June.pdf Accessed 3 December 2018.
8. DELWP 2017, 'Andrews Labor Government Response to the Independent Inquiry into the Environment Protection Authority', East Melbourne, Victoria https://www.environment.vic.gov.au/__data/assets/pdf_file/0025/49741/Andrews-Labor-Government-Response-to-the-Independent-Inquiry-into-the-Environment-Protection-Aut.pdf Accessed 3 December 2018.
9. VAGO 2010, 'Soil Health Management', Melbourne, Victoria https://www.parliament.vic.gov.au/papers/govpub/VPARL2006-10No378.pdf Accessed 3 December 2018.
10. VAGO, 'Enhancing Food and Fibre Productivity', Melbourne, Victoria https://www.audit.vic.gov.au/report/enhancing-food-and-fibre-productivity Accessed 3 December 2018.
11. Department of Sustainability & Environment 2012, 'Soil Health Strategy 2012', Melbourne, Victoria https://teamspace.cenitex.vic.gov.au/LotusQuickr/landhealthprogram2013-2017/Main.nsf/h_Toc/1B9120B62D5E6597CA257BDB0017203D/%24FILE/DSE-Soil-Health-Strategy.doc Accessed 3 December 2018.

The 2016 audit recommended that the Department of Economic Development, Jobs, Transport and Resources (DEDJTR) develop or utilise external performance measures to provide assurance that changes in agricultural practices and productivity are not affecting the long-term sustainability of the natural resources base. In its response to the audit, DEDJTR agreed to seek to incorporate indicators of the long-term sustainability of the state's natural resource base as part of the agriculture-industry component of the DEDJTR-wide Outcomes Framework.

To address the challenges associated with measuring statewide changes to soil health, Agriculture Victoria is working with the Cooperative Research Centre for High Performing Soils to ascertain key soil properties that could form the basis for soil performance indicators.[12] In alignment with this, Agriculture Victoria has recently completed work to update its data systems for improved data sharing and accessibility. Another project designed to improve access to both public and private data includes the Soil and Landscape Grid of Australia (funded by the Terrestrial Ecosystem Research Network and the National Research Infrastructure for Australia).[13]

The Australian Government has invested $1 billion in the National Landcare Program over four years from 2014–15 to 2017–18. The program is designed to address problems such as loss of vegetation, soil degradation, the introduction of pest weeds and animals, changes in water quality and flows, and changes in fire regimes. Over the coming five years, from 2018–19 to 2022–23, the Australian Government will invest more than $1 billion in a second phase of the National Landcare Program.[14]

In 2017, Agriculture Victoria released the *Agriculture Victoria Strategy*. The strategy noted the agriculture sector was continuing to make a major contribution to Victoria's economic and employment growth, even though the nature of farming has changed dramatically in recent decades.[15] This strategy is a reform framework, articulating Agriculture Victoria's priorities to enhance the global competitiveness, innovation and resilience of the state's agriculture.[16]

Parks Victoria works with Traditional Owners to manage parks and reserves. The Managing Country Together framework provides both practical and symbolic recognition of Traditional Owner rights, underpins enduring partnerships with Traditional Owners and strengthens sector capacity in joint protected area and cultural heritage management.[17]

12. Soil CRC, 'Current Projects', https://www.soilcrc.com.au/projects/ Accessed 3 December 2018.
13. Terrestrial Ecosystem Research Network, 'Soil and Landscape Grid of Australia', http://www.clw.csiro.au/aclep/soilandlandscapegrid/index.html Accessed 3 December 2018.
14. National Landcare Program, 'National Landcare Program Phase Two', Canberra, Australia http://www.nrm.gov.au/national-landcare-program Accessed 3 December 2018.
15. DEDJTR 2017, 'Agriculture Victoria Strategy', Melbourne, Victoria http://agriculture.vic.gov.au/__data/assets/pdf_file/0011/385949/Agriculture-Victoria-Strategy_FINAL.pdf Accessed 3 December 2018.
16. Parks Victoria, 'Managing Country together', http://parkweb.vic.gov.au/park-management/aboriginal-joint-management Accessed 3 December 2018.
17. Ibid

Indicator Assessment

Legend

Status

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

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

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

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

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

Trend

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

Unclear

Deteriorating

Stable

Improving

Data quality

Poor
Evidence and consensus too low to make an assessment

Fair
Limited evidence or limited consensus

Good
Adequate high-quality evidence and high level of consensus

LAND

	Summary	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend
Indicator **L:01** Land use types in Victoria **Region** Victoria **Measures** Percentage of Victoria's area classified by each type of land use class **Data custodian** AV, DELWP	Slightly more than half of Victoria's land is used for primary production. The overall mix of land use across Victoria is viewed as having a limited and variable impact on environmental health across Victoria. *For trend refer to L:02 and text explanation	DATA QUALITY Good	N/A
Indicator **L:02** Changes in major land uses in Victoria **Region** Victoria **Measures** Changes in Victoria's land use over time **Data custodian** AV, DELWP	There were no significant shifts in Victorian land use from 2012-17. *For status refer to L:01 and text explanation	N/A DATA QUALITY Good	→
Indicator **L:03** Changes in land tenure **Region** Victoria **Measures** Percentage of Victoria's area classified as public or private land **Data custodian** AV, DELWP	There were no significant shifts in Victorian land tenure from 2012-17.	DATA QUALITY Good	→

	Summary	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend
Indicator **L:04** Greenfield versus infill development **Region** Victoria **Measures** (i) Housing development and greenfield development in Melbourne (ii) Population change in growth LGAs (iii) Urban area of Melbourne **Data custodian** DELWP	Melbourne's population is growing more than twice as quickly in growth areas on the urban fringes than it is in established areas.	DATA QUALITY Good	→
Indicator **L:05** Soil carbon content **Region** Victoria **Measures** Victorian Soil Total Organic Carbon at various depths **Data custodian** AV	There is an extremely wide range of soil organic carbon stocks across Victorian cropping and pasture soils, with most of the variation attributable to climate.	DATA QUALITY Fair (detailed baseline data for all private land except the north east of Victoria – however unable to assess changes in soil carbon and statewide raster (grid) data)	?
Indicator **L:06** Area affected by salinity **Region** Victoria **Measures** Percentage of Victoria's area classified as public or private land **Data custodian** AV, DELWP	Fewer bores are being found with an increasing salinity threat in the catchments that drain to the Murray River.	Improving for the river catchments that drain to the Murray River and Unclear elsewhere DATA QUALITY Fair (for the river catchments that drain to the Murray River and Poor elsewhere (monitoring has largely ceased beyond the river catchments that drain to the Murray River))	↗ ?

	Summary	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend
Indicator **L:07** Soil acidification **Region** Victoria **Measures** Victorian soil pH ($CaCl^2$) at various depths **Data custodian** AV	Soil acidity and acidification is an issue for the high rainfall agriculture regions in the south west and east of Victoria.	DATA QUALITY Fair (there is baseline statewide soil pH data but no suitable data to assess the pH change (acidification))	?
Indicator **L:08** Soil erosion **Region** Victoria **Measures** Dryland area with 30-100% bare soils **Data custodian** AV	Victoria's dryland area at risk of erosion has steadily increased to 37% in 2016 from a low of 13% in 2011.	DATA QUALITY Poor (only case study data and no current statewide information)	↘
Indicator **L:09** Contaminated sites **Region** Victoria **Measures** (i) Number of environmental audits completed in Victoria (ii) Number of sites on EPA's Priority Sites Register **Data custodian** EPA Victoria, DELWP	More than 600 contaminated sites have been improved between 2013-17 to be suitable for more sensitive land use. However, it is unclear how many sites have become contaminated during that time.	DATA QUALITY Fair (the current knowledge only pertains to a subset of contaminated sites, databases and regions)	?

	Summary	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend
Indicator **L:10** Land management activities **Region** Victoria **Measures** The area of land managed for conservation **Data custodian** CMAs	The six CMAs reporting on the area of land managed for conservation reported a slight increase in the hectares of land covered by Trust for Nature covenants in 2016-17.	FAIR DATA QUALITY Fair (Corangamite, Glenelg Hopkins, North Central, North East, West Gippsland and Wimmera CMAs) Poor (no data available for Port Phillip & Westernport, East Gippsland, Mallee, Goulbourn Broken CMAs)	↗
Indicator **L:11** Participation in natural resource management activities **Region** Victoria **Measures** (i) Number of volunteers (ii) Amount of volunteer hours (iii) Community co-contribution in economic terms **Data custodian** CMAs, Landcare, PV	Parks Victoria's volunteer network has provided over $10 million of in-kind support in 2017-18, the highest ever recorded for Parks Victoria. Participation at CMA natural resource management engagement events has increased each year since data was first reported in 2013-14.	GOOD DATA QUALITY Good	↗
Indicator **L:12** Use of best practice on agricultural lands **Region** Victoria **Measures** Area of land with improved agricultural practices in Victoria **Data custodian** CMAs	Data is showing an increasing amount of land being used with improved agricultural practices. However, there is no statewide data on the total area of land with suitable agricultural practices.	UNKNOWN DATA QUALITY Poor (no statewide comprehensive data; data isn't granular)	?

	Summary	Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **L:13** Proportion of agricultural area under productive and sustainable agriculture **Region** Victoria **Measures** Proportion of agricultural area under productive and sustainable agriculture **Data custodian** AV, CMAs	Evidence of improved management practices on more than 120,000 hectares of land used for stock and more than 50,000 hectares of land used for crops has been recorded from 2013-14 to 2015-16. There is no statewide data on sustainable agriculture.	DATA QUALITY Poor (limited examples from two CMAs)	?

Land Use

	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
L:01 Land use types in Victoria		N/A	DATA QUALITY Good
Data custodian AV, DELWP			

Land use across Victoria is shown in Figure L.1 and Table L.1, with data sourced from the Victorian Land Use Information System (VLUIS). The most up-to-date version of VLUIS contains data for 2016–17. The data in VLUIS has been categorised according to the Australian Valuation Property Classification Codes, which categorise land use into nine broad categories and many more subcategories.[18]

51.8% of Victoria's land use is defined as primary production, with most of that area used for mixed farming and grazing (23.2% of the state). Agriculture cropping (16.5%) and livestock grazing (8.4%) are other primary production land uses that take up significant portions of the state.[19] Another 39.8% of the state comprises national parks, conservation areas and forest reserves.[20,21] Urban areas – such as residential and commercial properties, industrial facilities and built-up areas – and roads make up 7% of Victoria's land.

18. Australian Bureau of Agricultural and Resource Economics and Sciences 2011,' Guidelines for land use mapping in Australia: principles, procedures and definitions 4th edition', Canberra, Australia.
19. DEDJTR, 'Victorian Land Use Information System 2016/17', Melbourne, Victoria https://www.data.vic.gov.au/data/dataset/victorian-land-use-information-system-2016-2017 Accessed 3 December 2018.
20. Ibid
21. Note that the terminology in the Australian Valuation Property Classification Codes for the categorisation of 'National Parks, conservation areas, forest reserves and natural water reserves' should be considered in the Victorian context to include national parks, conservation areas and State forest.

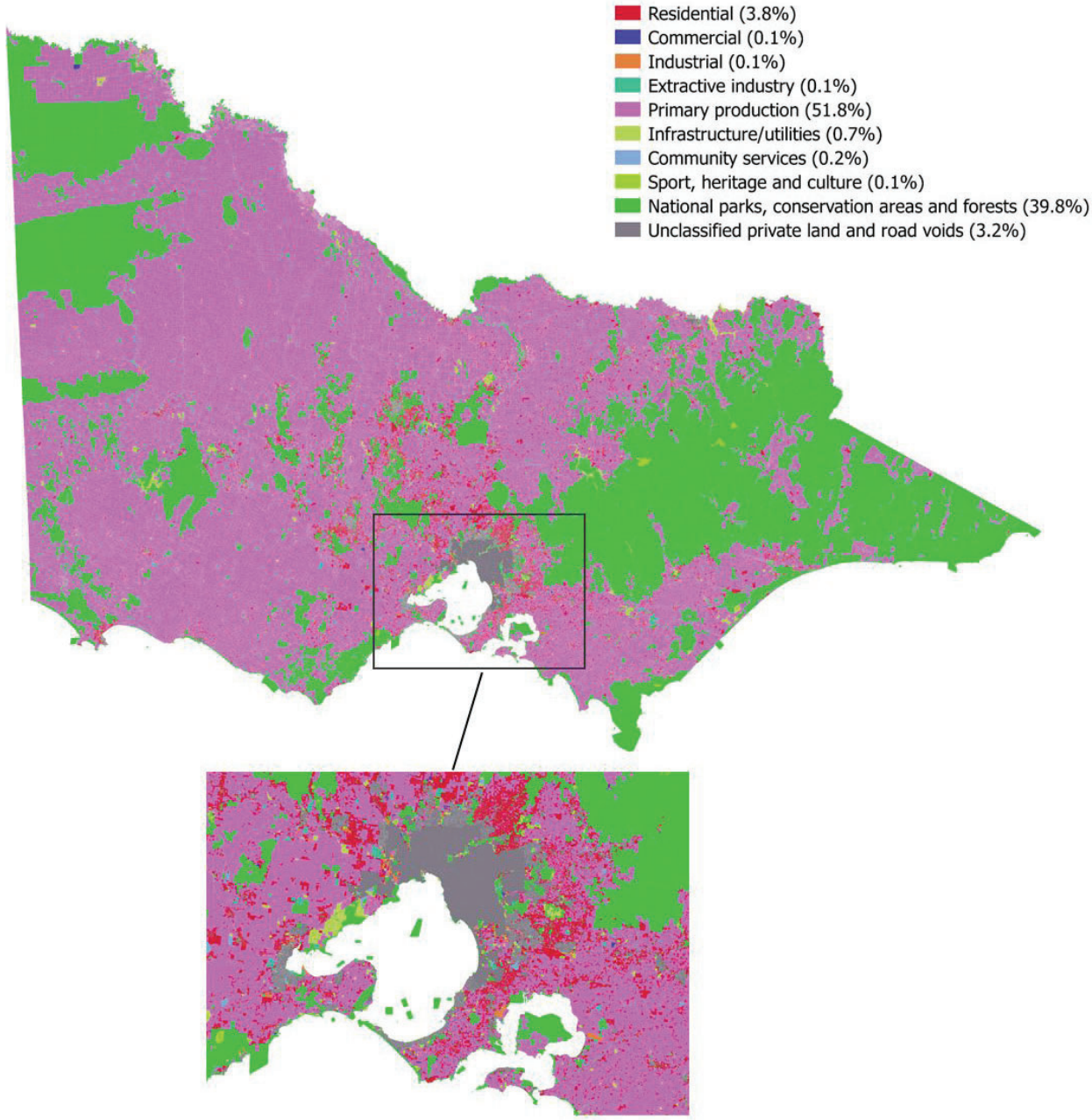


Figure L.1 Major land-use classes in Victoria

(Data source: VLUIS 2016–17)

Table L.1 Major land-use classes in Victoria, with selected subcategories included

Land-use type	Proportion of Victoria's area %
Primary production	
Mixed farming and grazing	23.2
Agriculture cropping	16.5
Livestock grazing and production	8.4
Softwood and hardwood plantations	2.1
Other	1.6
Total primary production	51.8
National parks, conservation areas and forest reserves	39.8
State forest	12.7
National park - land	11.5
Nature reserves	9.8
Other	5.7
Total national parks, conservation areas and forest reserves	39.8
Residential	3.8
Unclassified Private land and road voids	3.2
Infrastructure and utilities	0.7
Community services	0.2
Sport, heritage and culture	0.1
Extractive industries	0.1
Industrial	0.1
Commercial	0.1

(Data source: VLUIS 2016–17)[22,23]

22. DEDJTR, 'Victorian Land Use Information System 2016/17', Melbourne, Victoria https://www.data.vic.gov.au/data/dataset/victorian-land-use-information-system-2016-2017 Accessed 3 December 2018.
23. Total area of Victoria in VLUIS 2016/17 is 25.5 million hectares.

At a regional level, land use varies significantly between catchments. Approximately three-quarters of the land in the western catchments of Glenelg Hopkins, Wimmera and North Central is used for primary production. These areas in western Victoria are typically flatter and more accessible for agricultural production than other parts of Victoria. Conversely, the eastern and north-eastern catchments predominantly comprise national parks, conservation areas and forests. More than 20% of land in the Port Phillip and Westernport catchment is residentialThis is a much greater percentage of residential land than any other catchment and demonstrates the specific environmental pressures of the region.

Irrigated agriculture can require large volumes of water and needs careful management to ensure water quality and water resources are not adversely impacted. Even though it accounts for just over 1 million hectares (less than 5% of Victoria's land), irrigated agriculture is responsible for 78% of the state's surface-water consumption (see indicator WR:07 (Percentage of waterways and groundwater areas, subject to water extraction, exceeding sustainable yields)) and contributes $4.2 billion (30%) of Victoria's total gross value of $14 billion of agricultural production.[24] Because of its heavy water usage, irrigated agriculture is impacting flow regimes by reversing the seasonality of natural flows, with large volumes of water released for irrigation during the dry season (see indicator WR:03 (Condition of flow regimes)). As detailed in indicator WR:09 (Percentage of agricultural land with improved irrigation), some improvements have been made to irrigation efficiency in Victoria.

The status of this indicator has been assessed as Fair because the overall mix of land use across Victoria is viewed as having a limited and variable impact on environmental health across Victoria.

24. Australian Bureau of Statistics 2018, '4610.0.55.008 - Gross Value of Irrigated Agricultural Production, 2016-17', Canberra, Australia http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/4610.0.55.008Main+Features12016-17?OpenDocument Accessed 3 December 2018.

	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
L:02 Changes in major land uses in Victoria Data custodian AV, DELWP	N/A				→	DATA QUALITY Good

Land-use change is driven by a range of social, economic and environmental pressures. For example, population growth is a key driver of urban land-use change, leading to urban expansion in Melbourne's fringe areas and parts of regional Victoria (see indicator L:04 (Greenfield versus infill development)). As stated in the SoE 2013, urban land use is also strongly affected by social pressures through the property market, which drives land use towards the highest values (for example, housing in fringe areas).[25] In addition, preference for living in coastal or rural areas close to Melbourne is resulting in the loss of natural ecosystems and agricultural land. Such losses threaten biodiversity and promote more intensive agriculture to compensate for reductions in the availability of productive land.[26]

The agricultural landscape in northern Victoria has changed markedly in recent years with the introduction of a water market. The ability to trade and move water has provided increased opportunities for certain subsectors, including high-value horticulture.

The data for this indicator is sourced from the VLUIS dataset for 2012–13, which aligns with the release of the previous SoE report, and the most recent VLUIS dataset (2016–17).[27, 28] There were no significant shifts in Victorian land use from 2012–13 to 2016–17.

25. Commissioner for Environmental Sustainability 2013, 'State of the Environment report 2013', Melbourne, Victoria https://www.ces.vic.gov.au/sites/default/files/publication-documents/2013%20SoE%20report%20full.pdf Accessed 3 December 2018.
26. Ibid
27. DEDJTR, 'Victorian Land Use Information System 2012/13', Melbourne, Victoria https://www.data.vic.gov.au/data/dataset/victorian-land-use-information-system-2012-2013 Accessed 3 December 2018.
28. DEDJTR, 'Victorian Land Use Information System 2016/17', Melbourne, Victoria https://www.data.vic.gov.au/data/dataset/victorian-land-use-information-system-2016-2017 Accessed 3 December 2018.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
L:03 Changes in Land Tenure	○	○	●	○	→	DATA QUALITY Good

Data custodian AV, DELWP

Public land is mainly divided between parks and reserves, managed under the *National Parks Act 1975*, and state forests, managed under the *Forests Act 1958*. State forests are managed for multiple purposes, including timber harvesting, conservation, recreation and water production.

Similarly to indicator L:02 (Changes in major land uses in Victoria), the data for this indicator is sourced from the VLUIS dataset for 2012–13, which aligns with the release of the previous SoE report and the most recent VLUIS dataset (2016–17).[29,30]

For 2016–17, 57.6% of Victoria's land was privately owned (Figure L.2), which remained stable from 2012–13 when 57.3% of the state's land was recorded as privately owned. Private land can exert more pressure on the environment; however, the effect of changing land tenure does not necessarily mean a change in environmental pressure – the effect of land-use management is the driving force. Consequently, more information on land-use management associated with land tenure is required to determine if the move of private land to public land is resulting in more secure management. Private land is predominantly used for primary production, which accounts for half of Victoria's total area. Residential areas are another form of private land use, making up 3.8% of the state's total area. Melbourne occupies less than 5% of Victoria's land area but is home to more than 75% of Victoria's population, illustrating the land-health pressures that exist in the state's capital.[31,32]

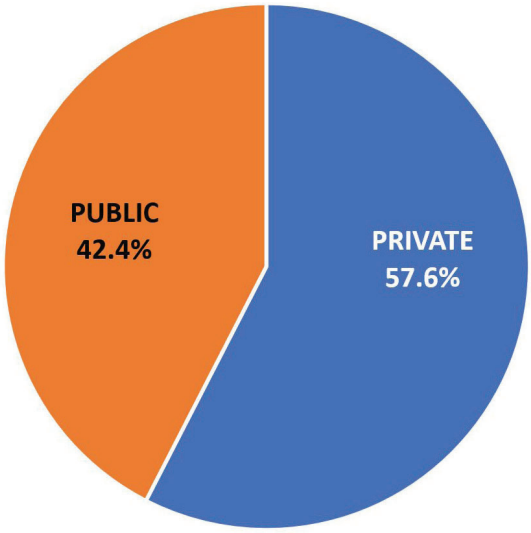


Figure L.2 Land tenure in Victoria, 2016–17

(Data source: VLUIS 2016–17)[33]

29. DEDJTR, 'Victorian Land Use Information System 2012/13', Melbourne, Victoria https://www.data.vic.gov.au/data/dataset/victorian-land-use-information-system-2012-2013 Accessed 3 December 2018.
30. DEDJTR, 'Victorian Land Use Information System 2016/17', Melbourne, Victoria https://www.data.vic.gov.au/data/dataset/victorian-land-use-information-system-2016-2017 Accessed 3 December 2018.
31. Australian Bureau of Statistics , 'Greater Melbourne (GCCSA) (2GMEL)', Canberra, Australia http://stat.abs.gov.au/itt/r.jsp?RegionSummary&region=2GMEL&dataset=ABS_REGIONAL_ASGS2016&geoconcept=ASGS_2016&datasetASGS=ABS_REGIONAL_ASGS2016&datasetLGA=ABS_REGIONAL_LGA2017&regionLGA=LGA_2017&regionASGS=ASGS_2016 Accessed 3 December 2018.
32. Australian Bureau of Statistics , 'Victoria (STE) (2)', Canberra, Australia http://stat.abs.gov.au/itt/r.jsp?RegionSummary&region=2&dataset=ABS_REGIONAL_ASGS2016&geoconcept=ASGS_2016&datasetASGS=ABS_REGIONAL_ASGS2016&datasetLGA=ABS_REGIONAL_LGA2017&regionLGA=LGA_2017&regionASGS=ASGS_2016 Accessed 3 December 2018.
33. DEDJTR, 'Victorian Land Use Information System 2016/17', Melbourne, Victoria https://www.data.vic.gov.au/data/dataset/victorian-land-use-information-system-2016-2017 Accessed 3 December 2018.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
L:04 Greenfield versus infill development	○	○	●	○	→	DATA QUALITY Good

Data custodian DELWP

As Victoria's population continues to grow, so will construction of residential, commercial and industrial properties to meet demand. The construction increase comes in the form of two types of development: the utilisation of previously developed land for urban and other development (infill), and previously undeveloped land (greenfield). The data included in this indicator provides background information on land-use pressures for a range of issues, including biodiversity.

Housing development increased at record levels across Melbourne in the five years to 2016. In established areas of Melbourne, 10,000 more dwellings were constructed in 2016 than 2012 – the majority being apartment developments.[34] As these are most commonly intensifying existing residential uses or urban-renewal projects, this has not increased the urban area of Melbourne. The City of Melbourne has seen a population increase of nearly 50,000, with its urban land intensified or existing urban uses transformed.[35]

Greenfield development has also been at record levels and has delivered approximately 30% of housing development across the five years.[36] Greenfield development and associated infrastructure increased the urban area of Melbourne by approximately 7,400 hectares from 2012 to 2016.[37]

The local government areas (LGAs) of Wyndham and Casey have seen the most growth over the five years, with increases in population of 60,000 and 50,000 respectively.[38] The urban areas of both LGAs has increased by approximately 1,500 hectares between 2012 and 2016.[39]

Figure L.3 shows that Melbourne's population is growing more than twice as quickly in growth areas on the urban fringes than it is in established areas.[40] This increases the pressure on biodiversity in Melbourne's urban fringes. Figure L.4 shows that Melbourne's urban area has increased by at least 1,000 hectares each year since 2012.[41] Melbourne's urban fringes also contain areas known as 'green wedges' that host a mix of agriculture and low-density activities such as:

- major infrastructure that supports urban areas, including Melbourne and Moorabbin airports
- the western and eastern water treatment facilities
- major quarries used in the building industry
- cultural heritage sites
- biodiversity conservation areas
- water catchments.[42]

With the expanding populations in green wedge LGAs, the importance of green wedges to protect environmental values is increasing.

34. Australian Bureau of Statistics 2018, '8731.0 - Building Approvals, Australia, May 2018', Canberra, Australia http://www.abs.gov.au/ausstats/abs@.nsf/mf/8731.0 Accessed 3 December 2018.
35. Australian Bureau of Statistics 2018, '3218.0 - Regional Population Growth, Australia, 2016-17', Canberra, Australia http://www.abs.gov.au/ausstats/abs@.nsf/mf/3218.0 Accessed 3 December 2018.
36. Australian Bureau of Statistics 2018, '8731.0 - Building Approvals, Australia, May 2018', Canberra, Australia http://www.abs.gov.au/ausstats/abs@.nsf/mf/8731.0 Accessed 3 December 2018.
37. DELWP, 'Rural urban fringe GIS layer', East Melbourne, Victoria.
38. Australian Bureau of Statistics 2018, '3218.0 - Regional Population Growth, Australia, 2016-17', Canberra, Australia http://www.abs.gov.au/ausstats/abs@.nsf/mf/3218.0.
39. DELWP, 'Rural urban fringe GIS layer', East Melbourne, Victoria.
40. Ibid
41. Ibid
42. DELWP, 'Green wedges', East Melbourne, Victoria https://www.planning.vic.gov.au/policy-and-strategy/green-wedges Accessed 3 December 2018.

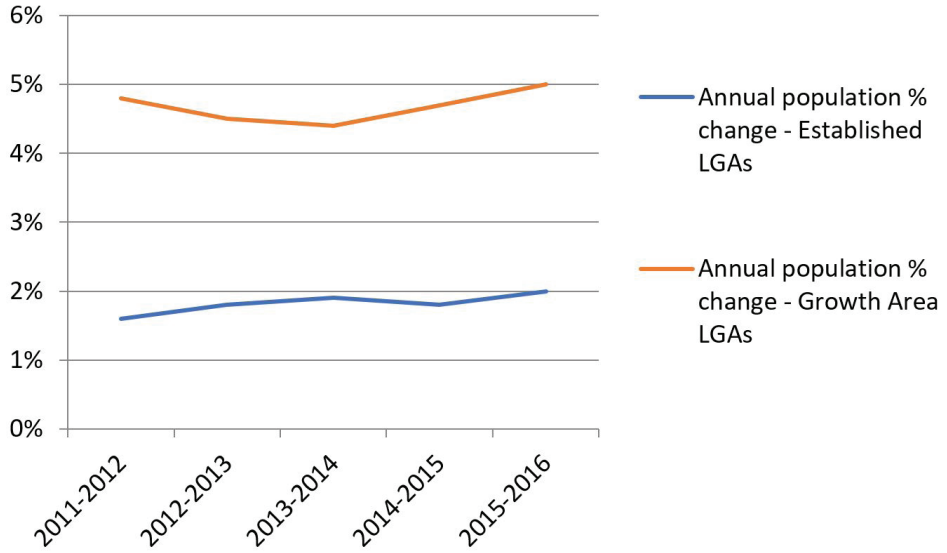


Figure L.3 Annual percentage change in population for LGAs in Melbourne, 2011–12 to 2015–16

Note: Growth area LGAs are Cardinia, Casey, Hume, Melton, Whittlesea and Wyndham

(Data source: ABS, 2016)[43]

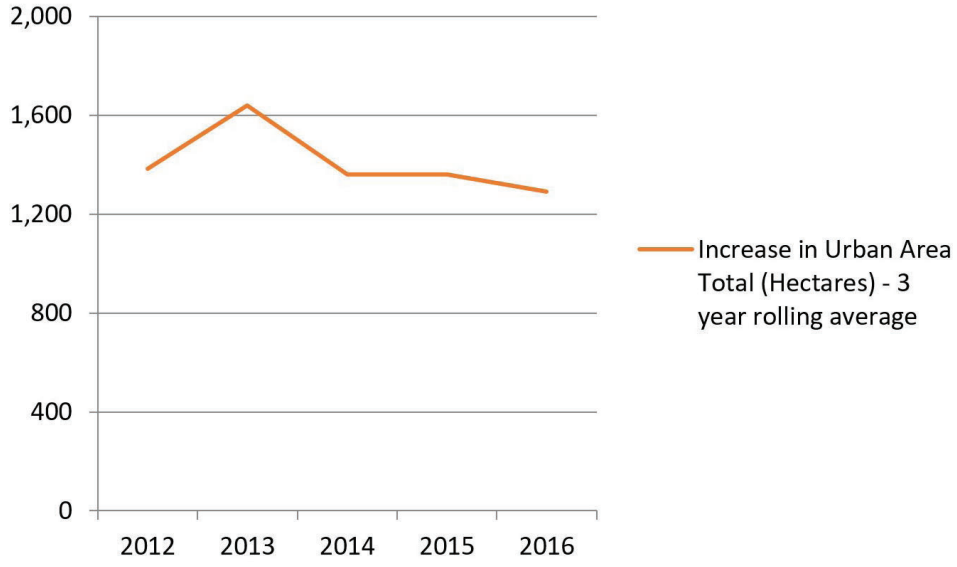


Figure L.4 The increase in urban area land (hectares) shown as a three-year rolling average, 2012–2016

(Data source: DELWP)[44]

43. Australian Bureau of Statistics 2018, '3218.0 - Regional Population Growth, Australia, 2016-17', Canberra, Australia http://www.abs.gov.au/ausstats/abs@.nsf/mf/3218.0 Accessed 3 December 2018.
44. DELWP, 'Rural urban fringe GIS layer', East Melbourne, Victoria.

Soil Health

	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
L:05 Soil carbon content		?	DATA QUALITY Fair

Data custodian AV

Increasing the organic carbon content in soils may help to mitigate rising greenhouse gas emissions, while sustaining agricultural productivity and environmental conditions.[45, 46] A benchmarking study undertaken between 2010 and 2012 at 615 sites on farms across western and south-eastern Victoria determined how much soil organic carbon (SOC) was present in Victoria's agricultural lands (Figure L.5).[47] The results of the study were published in 2016 and have been used as part of the assessment for this indicator. Data has also been sourced from the Soil Grids of Victoria that were published in 2017.[48] The methodology used to develop the Soil Grids of Victoria is based on the Australian Soil and Landscape Grid, and the new maps are most appropriately used for assessments of regional to statewide trends of soil properties.

The amount of carbon stored in soil is the balance between inputs (mainly from plants) and losses (decomposition, erosion or removal at harvest).[49] These processes are influenced by environmental factors such as climate and topography, as well as by physical, chemical and biological soil properties. Inputs of carbon could also be manure or compost on a minority of farms.

45. Lal R, Follett RF 2009, 'Soil carbon sequestration and the greenhouse effect', Soil Science Society of America, Madison, WI, USA.
46. Swift RS 2001, 'Sequestration of carbon by soil', *Soil Science*, 166, 858–871.
47. Robertson F et al 2016, 'Soil organic carbon in cropping and pasture systems of Victoria, Australia', *Soil Research*, 54(1), pp. 64-77.
48. DEDJTR, 'SOIL_TOTAL_ORGANIC_CARBON', Melbourne, Victoria http://services.land.vic.gov.au/SpatialDatamart/dataSearchViewMetadata.html?anzlicId=ANZVI0803005804&extractionProviderId=2 Accessed 3 December 2018.
49. Robertson F et al 2016, 'Soil organic carbon in cropping and pasture systems of Victoria, Australia', *Soil Research*, 54(1), pp. 64-77.

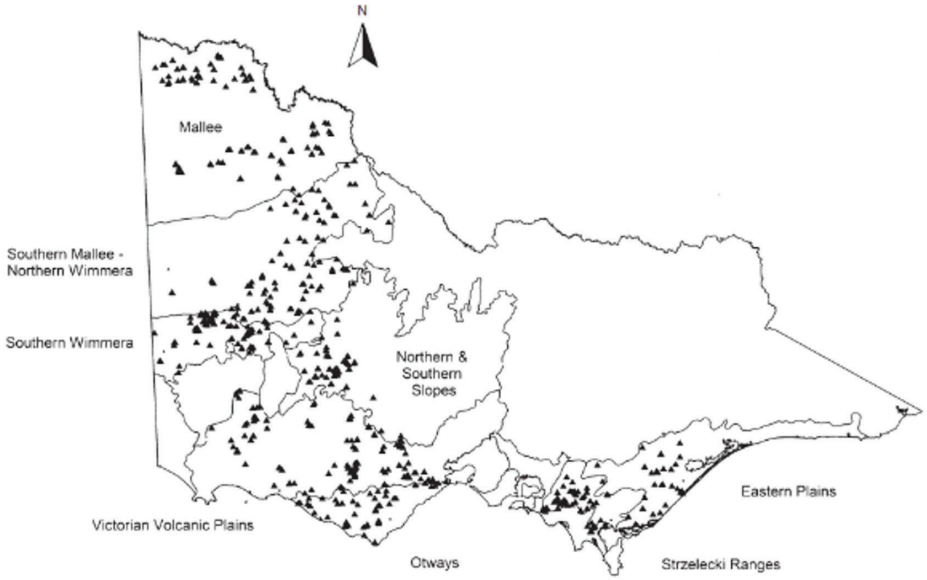


Figure L.5 Map of Victoria showing approximate location of sampled sites within each region[50]

Note: The regions are the primary production landscape of Victoria.[51]

The results of the study found an extremely wide range in SOC stocks across Victorian cropping and pasture soils.[52] Results from the study outlined four key factors assessed for their impact on soil carbon content:

- **Climate** – Most of the variation in SOC was attributable to climate, with nearly 80% of the differences in SOC stocks across the state explained by local patterns of annual rainfall or vapour pressure deficit.[53]
- **Texture-related soil properties** – Silicon and clay explained a further small amount of variation in SOC.[54]
- **Management classes (continuous cropping, crop-pasture rotation, sheep or beef pasture, and dairy pasture)** – After accounting for climate and soil properties, differences in SOC between management classes were small and often not significant.[55]
- **Management practices (stubble retention, minimum cultivation, perennial pasture species, rotational grazing and fertiliser inputs)** – These were also not significantly related to SOC stock.[56] These results were consistent with a 2013 study that concluded the potential to increase carbon through changes to management practices is quite limited.[57]

SOC stocks were generally greatest in the Strzelecki Ranges, Eastern Plains, Victorian Volcanic Plains and the Otways, while SOC was less abundant in the Mallee and Wimmera (areas of less rainfall).

Data from the Soil Grids of Victoria supports these findings, with Figure L.6 showing the raster maps of SOC as taken from the Spatial Datamart Victoria and displayed on the Australian Digital Soil Mapping website OzDSM.[58,59]

50. Ibid
51. MacEwan R, Robinson N, Imhof M, Rees D, Sposito V 2008, 'Primary Production Landscapes of Victoria', Paper presented at the 14th Agronomy Conference, Adelaide, South Australia, 21–25 September 2008.
52. Robertson F et al 2016, 'Soil organic carbon in cropping and pasture systems of Victoria, Australia', *Soil Research*, 54(1), pp. 64-77.
53. Ibid
54. Ibid
55. Ibid
56. Ibid
57. Robertson F, Nash D 2013, 'Limited potential for soil carbon accumulation using current cropping practices in Victoria, Australia', Agriculture, Ecosystems & Environment, 165, pp. 130-140.
58. DEDJTR, 'SOIL_TOTAL_ORGANIC_CARBON', Melbourne, Victoria http://services.land.vic.gov.au/SpatialDatamart/dataSearchViewMetadata.html?anzlicId=ANZVI0803005804&extractionProviderId=2 Accessed 3 December 2018.
59. OzDSM, 'Australian digital soil mapping', Ballarat, Victoria http://www.ozdsm.com.au/ozdsm_map.php Accessed 3 December 2018.

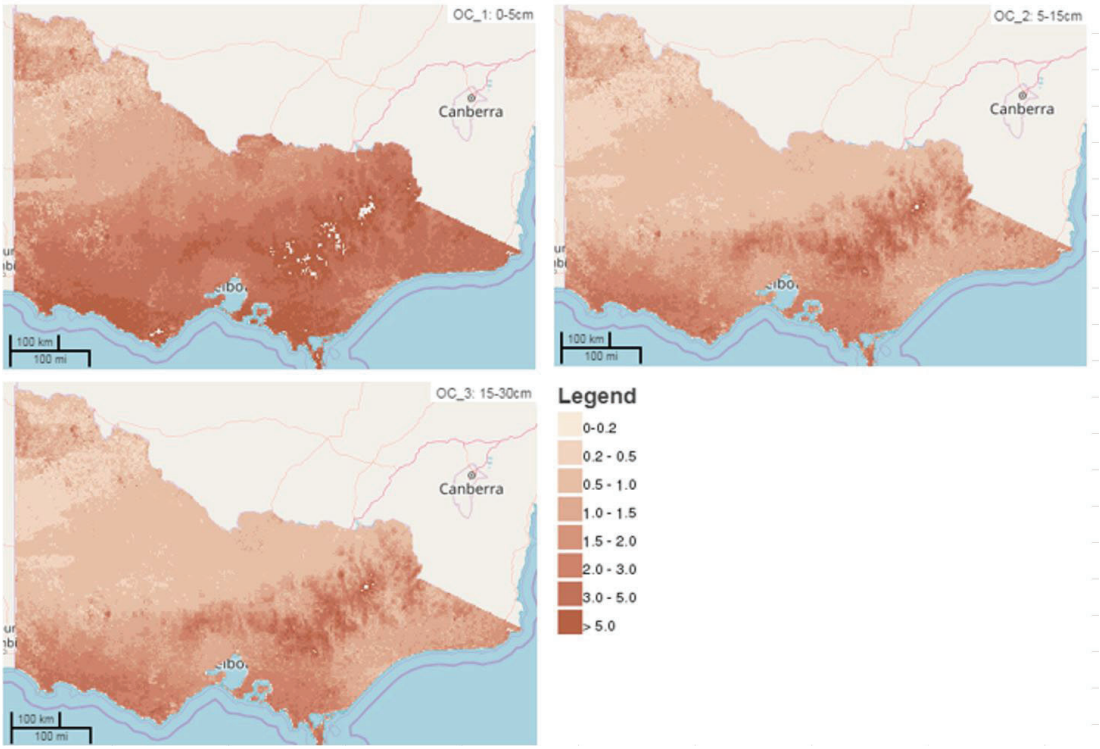


Figure L.6 Victorian Soil Total Organic Carbon (%) at various depths.[60,61]

The status of this indicator has been assessed as Unknown due to the absence of available standards to determine suitable SOC stocks.

60. DEDJTR, 'SOIL_TOTAL_ORGANIC_CARBON', Melbourne, Victoria http://services.land.vic.gov.au/SpatialDatamart/dataSearchViewMetadata.html?anzlicId=ANZVI0803005804&extractionProviderId=2 Accessed 3 December 2018.
61. OzDSM, Ballarat Victoria http://www.ozdsm.com.au/ozdsm_map.php Accessed 3 December 2018.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
L:06 Area affected by salinity					↗ ?	DATA QUALITY
			Improving for the river catchments that drain to the Murray River and Unclear elsewhere			Fair
Data custodian AV, DELWP						

A statewide update on the area of land affected by salinity cannot be provided due to the absence of current data. Dryland salinity occurrence has not been systematically remapped since the millennium drought. In SoE 2013, it was estimated that 2% of the total area of dryland agriculture in Victoria was affected by dryland salinity.[62] Some small areas of soil salinity occurrence were remapped in research areas after the drought, and this work showed that a contraction of discharge areas occurred after 2010. On top of the salinity mitigation benefits of the lower rainfall years, improved land-management practices reduced salinity severity in many landscapes by lowering groundwater recharge and protecting groundwater discharge areas from further damage. These improved practices arose out of community, state and federal salinity management programs that commenced in the late 1980s. The effects of irrigation-induced salinity tend to be more seasonal than for dryland areas and are defined by the extent of high water tables associated with each irrigation area.

Salinity remains a threatening process in many parts of Victoria. One means by which this threat is now monitored is looking at trends in groundwater level in observation bores. For the five river catchments that drain to the Murray River, the Basin Salinity Management 2030 strategy requires a review of groundwater levels every five to ten years to identify trends.[63] Recently completed reviews in three of these catchments (the Campaspe, Ovens and Kiewa Rivers) provide an indication of the salinity threat relative to earlier decades. The analysis found fewer bores with a rising trend across all landscape positions monitored.[64, 65, 66] Most bores had declining or flat trends, and for those few bores still rising, the trends were smaller than those seen in previous reviews. Figure L.7 provides an illustration of the trends seen from 57 bores in the Campaspe catchment. In the Below Mount Camel Ranges subset, groundwater levels are still rising, albeit at a slower rate than prior to 2000.[67]

62. Commissioner for Environmental Sustainability 2013, 'State of the Environment report 2013', Melbourne, Victoria https://www.ces.vic.gov.au/sites/default/files/publication-documents/2013%20SoE%20report%20full.pdf Accessed 3 December 2018.
63. Murray-Darling Basin Ministerial Council 2015, 'Basin Salinity Management 2030 (BSM2030)', Canberra, Australia https://www.mdba.gov.au/sites/default/files/pubs/D16-34851-basin_salinity_management_strategy_BSM2030.pdf Accessed 3 December 2018.
64. Cheng X 2017, 'Draft Technical Report - 2017 Campaspe Catchment Register B Five-year Review', prepared for DEDJTR, Melbourne, Australia.
65. Ibid
66. Ibid
67. Ibid

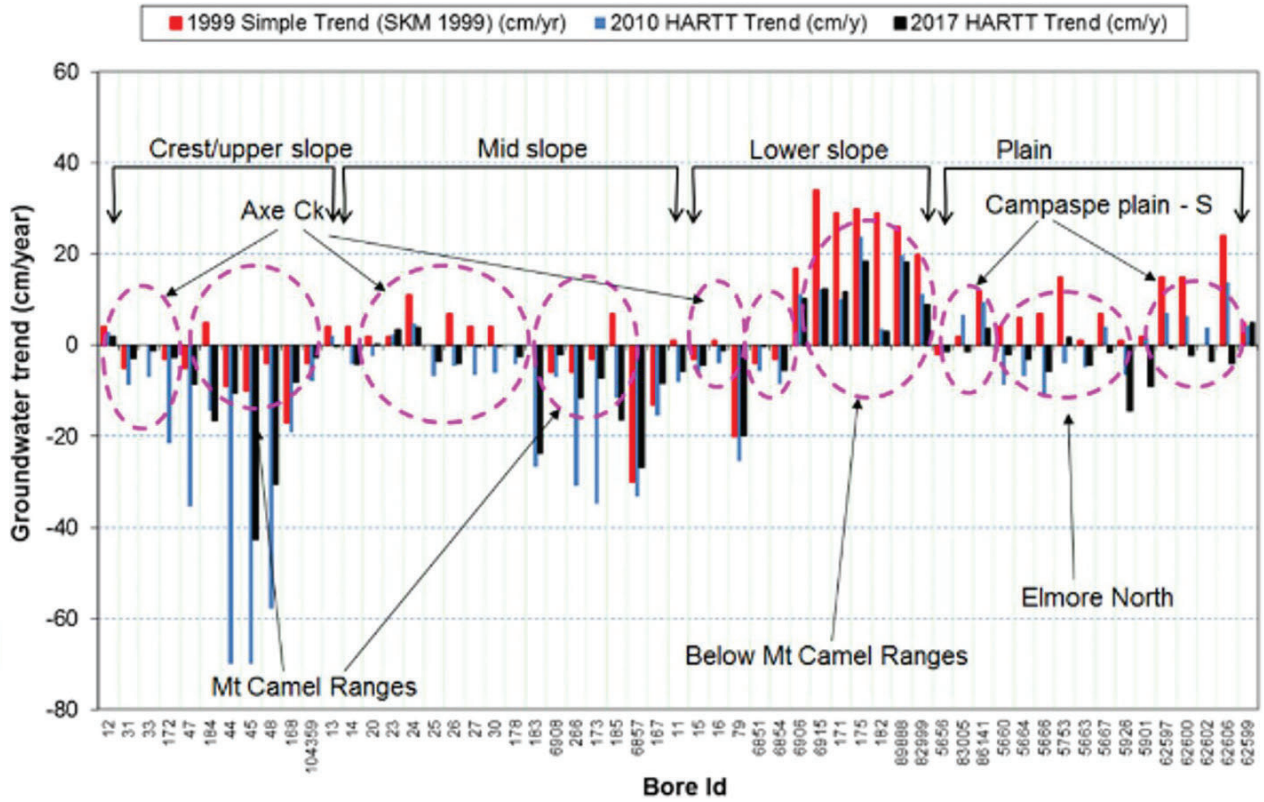


Figure L.7 Dryland salinity observation bore trends from the 2017 review[68]

Note: The bars above the line shows bores with a rising level; bars below show a falling trend.

For parts of the state outside the five northern river basins that flow into the Murray River, monitoring of salinity has largely ceased (except for the Macalister Irrigation District in Gippsland). However, salinity can be a threatening process to parts of all Victorian landscapes, including in areas where water trade is moving to support new irrigation developments, and land-use change compromises past salinity management work, or in land close to sea level where the water table is permanently close to the surface. Dryland salinity data in southern Victoria is currently well understood; however, our knowledge will decrease in the absence of data collection.

While not a direct measure of the area affected by salinity, the depth to shallow groundwater is a close proxy for area threatened by salinity. This is particularly the case in irrigated areas where there is ongoing monitoring and annual production of groundwater maps. DELWP maintains a statewide layer showing the depth to the watertable and (Figure L.8). Further detail on groundwater salinity, indicator WR:11 (Groundwater quality).

68. Ibid

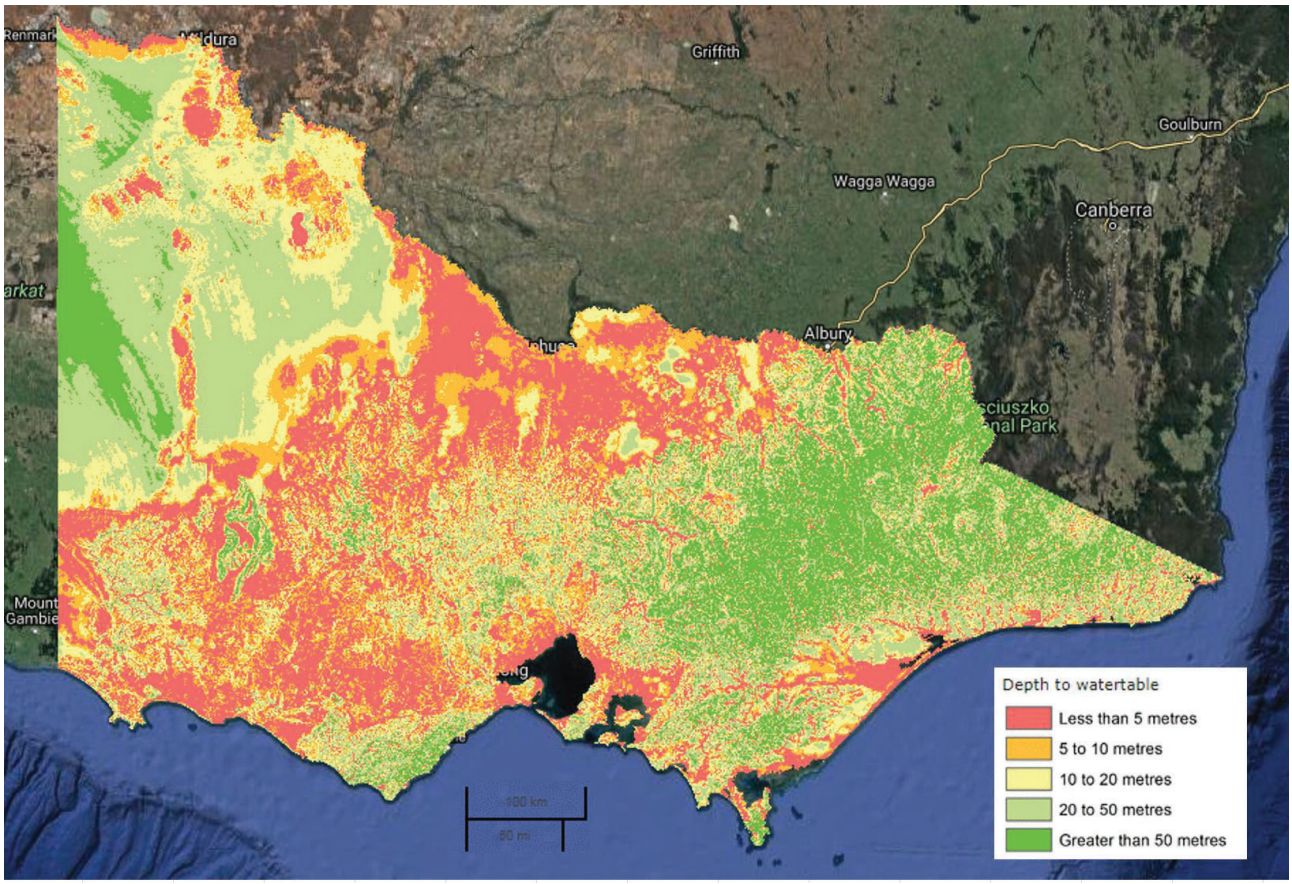


Figure L.8 Depth to watertable in Victoria [69, 70]

69. Visualising Victoria's Groundwater, 'Visualising Victoria's Groundwater', Ballarat, Victoria http://maps.cerdi.com.au/vvg.php Accessed 3 December 2018.
70. DELWP, 'Victorian Aquifer Framework (VAF) 3D Surfaces', East Melbourne, Victoria https://www.data.vic.gov.au/data/dataset/victorian-aquifer-framework-vaf-3d-surfaces Accessed 3 December 2018.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
L:07 Soil acidification					?	DATA QUALITY Fair
Data custodian AV						

Soil acidification refers to a decrease in soil pH over time, while soil alkalinisation describes the process of soil pH increasing over time. Soils that are too acidic or too alkaline present problems for many crops and pastures. In acidic soils, the availability of several nutrients is generally reduced and the solubility of elements toxic to plants is greater. Soil acidification impacts farming when the acidity of surface soil and/or subsurface soil limits crop or pasture choices, or detrimentally affects productivity and ground cover. In turn, this can increase the risk of soil erosion and the potential of losing nutrients to groundwater and/or surface waters. In 2014, the cost of lost productivity due to soil acidity and acidification in Victoria was estimated at $470 million per year.[71]

The most comprehensive dataset on Victorian soil pH was collated from farming paddocks between 1973 and 1994.[72] The study found that the pH of Victoria's soils ranged from extremely acidic to extremely alkaline, although such extremes in soil pH were rare and only occurred in a minority of Victoria's agricultural land. Spatial modelling of this data indicated that 29% of Victoria's agriculturally productive soils were affected by soil acidity and were expected to have a pH of less than 4.8, which was an increase from 23% of soils in the 1970s. These results show that areas of Victoria acidified from the 1970s to the 1990s.

The Soil Grids of Victoria published in 2017 and used as part of the assessment for indicator L:05 (Soil carbon content) have also been used for the assessment of this indicator. Soil acidity and acidification is an issue for the higher rainfall agriculture regions in the south-west and east of Victoria, whereas soil alkalinity is an issue for agriculture in the lower rainfall north-western region of the state. Figure L.9 shows soil pH across Victoria as taken from Spatial Datamart Victoria and displayed on the Australian Digital Soil Mapping website OzDSM.[73,74]

71. Parliament of Victoria Environment and Natural Resources Committee 2004, 'Inquiry on the impact and trends in soil acidity', Melbourne, Victoria https://www.parliament.vic.gov.au/images/stories/FINAL_REPORT_Inquiry_into_Impacts_and_Trends_in_Soil_Acidity.pdf Accessed 3 December 2018.
72. Marchant BP, Crawford DM, Robinson NJ 2014, 'What can legacy datasets tell us about soil quality trends? Soil acidity in Victoria', *IOP Conference Series: Earth and Environmental Sciences*, 25, pp. 1–15.
73. DEDJTR, 'SOIL_pHcacl2', Melbourne, Victoria http://services.land.vic.gov.au/SpatialDatamart/dataSearchViewMetadata.html?anzlicId=ANZVI0803005795&extractionProviderId=2 Accessed 3 December 2018.
74. OzDSM, http://www.ozdsm.com.au/ozdsm_map.php Accessed 3 December 2018.

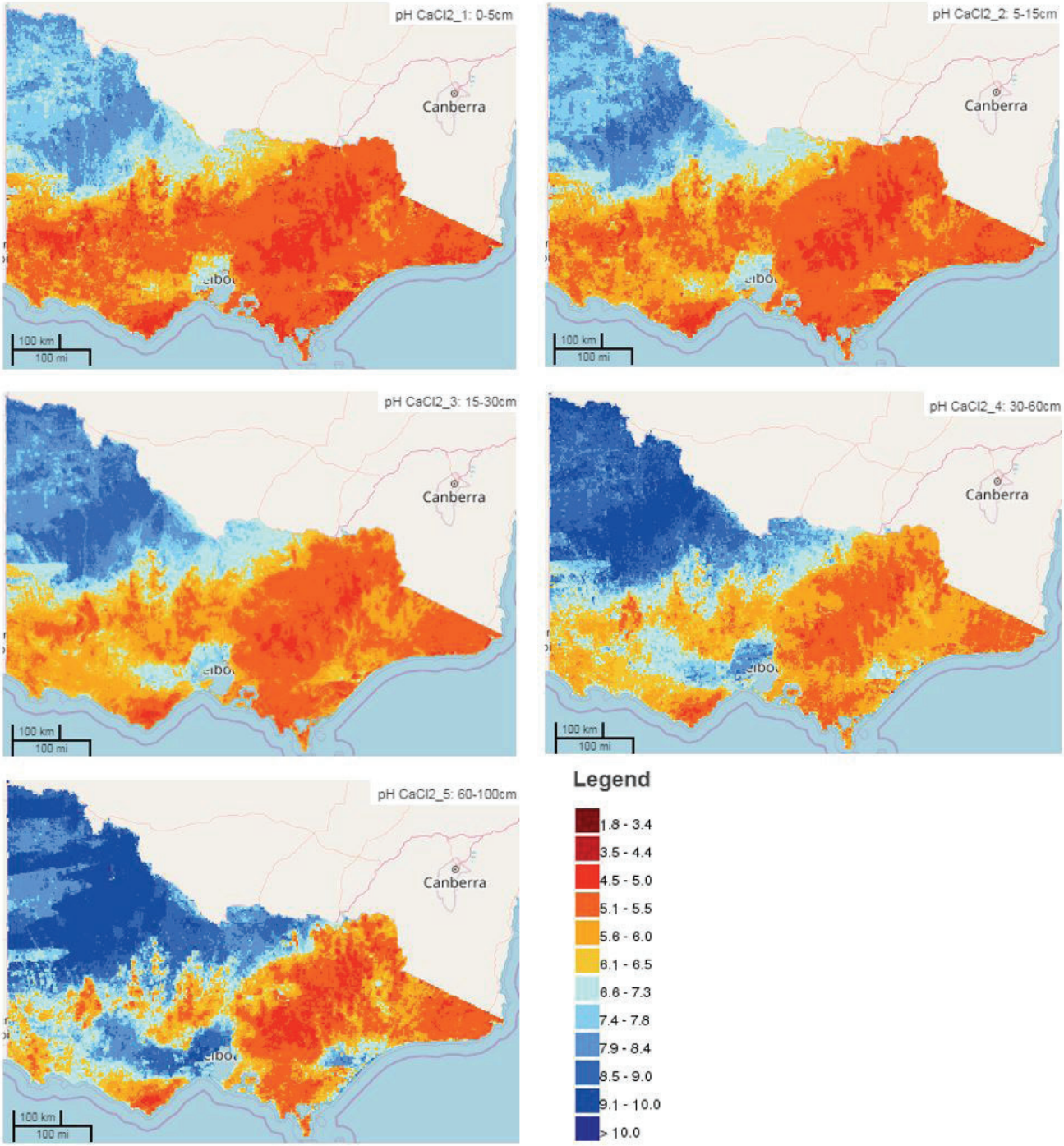


Figure L.9 Victorian Soil pH ($CaCl^2$) at various depths [75, 76]

75. DEDJTR, 'SOIL_pHcacl2', Melbourne, Victoria http://services.land.vic.gov.au/SpatialDatamart/dataSearchViewMetadata.html?anzlicId=ANZVI0803005795&extractionProviderId=2 Accessed 3 December 2018.
76. OzDSM, http://www.ozdsm.com.au/ozdsm_map.php Accessed 3 December 2018.

Soil pH naturally changes as soil weathers and forms, both decreasing in pH (acidification) and increasing pH (alkalinisation). Changes take place very gradually in undisturbed ecosystems and occur in both surface soil and subsoil. These changes can be accelerated by agriculture, particularly in surface soil. Importantly for Victoria, it has been found that many surface soils that were once slightly or moderately acidic are now more acidic since the land has been cleared and used for agriculture. In some soils, subsurface acidification has occurred but much less data is available on this soil degradation issue.

In the past, detailed analysis was undertaken to look at soil acidification under both pastures and crops, with faster acidification rates under crops, particularly those where nitrogen fertilisers are applied and where legumes are included in the rotation. However, this research was conducted in association with a range of farming systems that are not used as prevalently today (such as conventional cultivation, ley farming). There is little data available to understand soil acidification under current farming systems, while there has been almost no research on the extent and severity of soil acidification in horticulture or irrigated broad-acre agriculture.

The use of nitrogen-based fertilisers is recognised as a profitable management practice in horticulture, dairying and cropping. The risk of soil acidification increases in areas where land use changes from low nitrogen-use pastures (usually under meat and wool production) to high nitrogen-use cropping or other more intensive farming systems.

Limited data exists to understand current practices for managing soil acidity. Up until 2012–13, the Australian Bureau of Statistics (ABS) regularly surveyed farm businesses on a range of issues, including soil testing. From 2013–14, the question on soil testing was no longer asked. The 2012–13 data showed soil pH testing was infrequent, with only 16% of agricultural businesses testing their soil in the previous 12 months.[77]

Precision agriculture tools, such as variable-rate liming and digital mapping of soil pH, are now available to more efficiently manage soil pH. Adoption of variable-rate fertiliser application is mainly being taken up in cropping, although the uptake has been limited with just over 10% of the area under crop being applied with variable rates of fertiliser.[78]

A significant number of landholders are managing acidification using lime, although there is great potential to increase lime application in Victoria. In 2016–17, published ABS data showed lime was only applied to 4% of land used for agricultural production.[79] The ABS data also displayed the average rate of lime application at 1.7 tonnes per hectare, which is below the general minimum recommendations of 2.5–7.5 tonnes per hectare.[80]

No overall status assessment has been provided for this indicator due to the lack of current information on soil acidification across the state. The current knowledge is mostly based on data that is now more than a decade old.

77. Australian Bureau of Statistics 2014, '4267.0 - Land Management and Farming in Australia, 2012-13, 'Rural Environment and Agricultural Commodities Survey', Canberra, Australia http://www.abs.gov.au/ausstats/abs@.nsf/ProductsbyReleaseDate/59575E628C99F1ECCA257E-92001B14A1?OpenDocument Accessed 3 December 2018.

78. Australian Bureau of Statistics 2016, '4627.0 - Land Management and Farming in Australia, 2014-15, 'Rural Environment and Agricultural Commodities Survey', Canberra, Australia http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/4627.0Main+Features102014-15?OpenDocument Accessed 3 December 2018.

79. Australian Bureau of Statistics 2018, '4267.0 - Land Management and Farming in Australia, 2016-17', Canberra, Australia http://www.abs.gov.au/ausstats/abs@.nsf/mf/4627.0 Accessed 3 December 2018.

80. Tasmanian Department of Primary Industries, Parks, Water and Environment 2014, 'Soil pH & Liming', https://dpipwe.tas.gov.au/agriculture/land-management-and-soils/soil-management/soil-ph-liming Accessed 3 December 2018.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
L:08 Soil erosion	○	○	●	○	↘	DATA QUALITY
Data custodian AV						Poor

Soil erosion and structure decline is a natural process, determined by factors such as soil type and slope. However, it can be accelerated by human activities, including vegetation clearing, some cropping activities (for example, cultivation, sowing, harvesting, burning of crop residues), soil compaction from farm traffic and livestock, forestry activities (such as heavy vehicle compaction), mining, and the development of land for residential and other purposes.[81]

Ground-cover management can be used as a surrogate for soil health, but particularly for soil erosion. Ground cover assists in: protecting the soil from wind and water erosion, slowing and reducing runoff, improving water retention and infiltration into the soil, maintaining soil structure and preserving soil carbon. Improvements in ground-cover management have occurred through the provision of government funds to enable farmers to set up stock containment areas that protect soil and pasture resources during adverse seasons. In 2017, Agriculture Victoria announced that 550 stock containment areas would be built in Victoria.

The best available Victorian data on soil erosion was published in the VCMC's *Catchment Condition and Management Report 2017*.[82] The report contained information on Victoria's dryland area with 30–100% bare soils (i.e. the area at higher risk of erosion). Victoria's dryland area at risk of erosion is greatest during prolonged periods of dry weather, which is shown in Figure L.10 by the higher erosion risk during the end period of the millennium drought (2007–09). The dryland area at risk of erosion has steadily increased to 37% in 2016 from a low of 13% in 2011. This low was associated with increased rainfall after the millennium drought.

81. Commissioner for Environmental Sustainability 2013, 'State of the Environment report 2013', Melbourne, Victoria https://www.ces.vic.gov.au/sites/default/files/publication-documents/2013%20SoE%20report%20full.pdf Accessed 3 December 2018.
82. Victorian Catchment Management Council 2017, 'Catchment Condition and Management Report 2017', East Melbourne, Victoria, http://www.vcmc.vic.gov.au/pdf/CCMR_Report_2017.pdf Accessed 3 December 2018.

The spatial pattern of erosion risk is linked with annual average rainfall. Relatively wet catchments, such as West and East Gippsland, have the lowest dryland erosion risk in the state, while more arid regions (such as Mallee) have a much greater erosion risk.

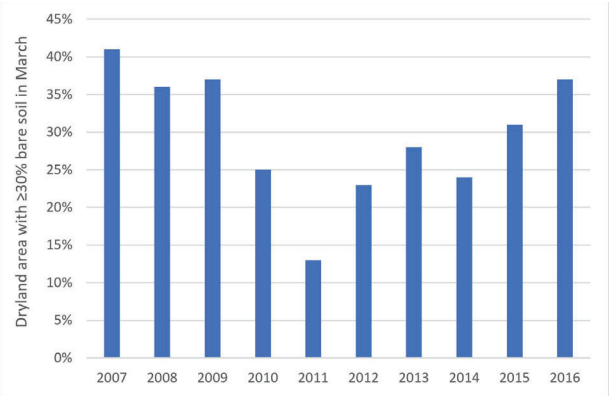


Figure L.10 Dryland area with 30–100% bare soils (higher risk of erosion) in March, 2007–16[83]

Advances in remote sensing to create seasonal Fractional Ground Cover (FGC) estimates offer the opportunity to improve data supporting grazing management and cropping practices that protect soil resources. However, the practical application of FGC data in the Victorian agricultural-management context indicates that FGC data must be combined with contextual information on land management and landscape condition. There are important differences in the management of agricultural systems that influence the ground cover across regions and throughout seasons. Future reporting will require the development of a method that uses a range of features to contextualise the measured FGC and then monitor soil protection.

83. Ibid

Contaminated Sites

	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
L:09 Contaminated sites		?	DATA QUALITY: Fair

Data custodian EPA Victoria, DELWP

Like other economies with a significant history of settlement and industrial activity, Victoria has a legacy of waste and pollution. Contaminated sites range from old mines and industrial sites to petrol stations and dry-cleaning operations.[84]

No complete database of contaminated sites exists for Victoria, although DELWP and EPA Victoria are partnering to develop an online mapping system. This system will bring together relevant information on potential land and groundwater contamination (for example, groundwater quality restricted-use zones, environmental audits, Victorian Landfills Register and historical business listings). When completed, the availability of this data will improve access to information that will strengthen management and awareness of legacy contamination. As this mapping system develops, it will be easier to report on the extent and trend of site contamination in Victoria.

As part of the assessment of the indicator in this report, data on contaminated sites was sourced from EPA Victoria's 53X audits and Priority Sites Register.

A 53X audit is an environmental audit that verifies that potentially contaminated land can be used for a specific purpose (industrial, commercial or residential).[85] The number of completed 53X audits shows how many contaminated sites have been improved to be suitable for a more sensitive land use, and can be used to show the scale of land quality improvement at contaminated sites across Victoria. There were 603 53X audits completed in the state from 2013 to 2017, with a peak of 142 audits in 2015. The number of audits has dropped during the past two years.

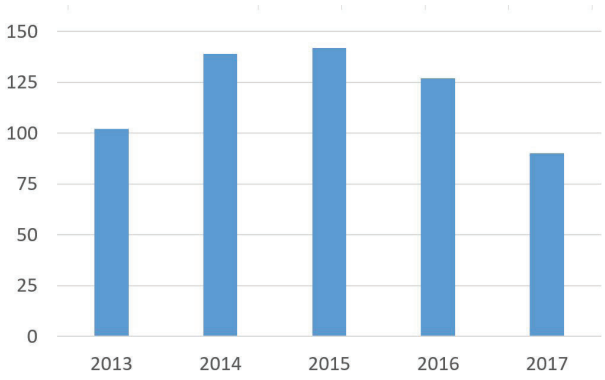


Figure L.11 53X Audits completed in Victoria, 2013–2017

(Data source: EPA Victoria, 2018)

Priority sites are sites for which EPA Victoria has issued a clean-up notice or pollution abatement notice due to land and/or groundwater pollution. The condition of these sites is not compatible with the current or approved use of the site without active management to reduce the risk to human health and the environment. Such management can include clean-up, monitoring and/or institutional controls.[86] The number of sites on EPA Victoria's Priority Sites Register has remained reasonably stable from June 2013 to June 2018, at 230 and 300 respectively (Figure L.12).[87]

84. MAC 2016, 'Independent inquiry into the Environment Protection Authority', http://www.epa-inquiry.vic.gov.au/__data/assets/file/0008/336698/Inquiry-report-EPA_June.pdf Accessed 3 December 2018.
85. EPA, 'Types of environmental audit', Carlton, Victoria https://www.epa.vic.gov.au/our-work/environmental-auditing/types-of-environmental-audit Accessed 3 December 2018.
86. EPA, 'Priority Sites Register', Carlton, Victoria https://www.epa.vic.gov.au/your-environment/land-and-groundwater/priority-sites-register Accessed 3 December 2018.
87. EPA, communication dated 04/10/2018 ("PSR_summary_delwp.xlsx").

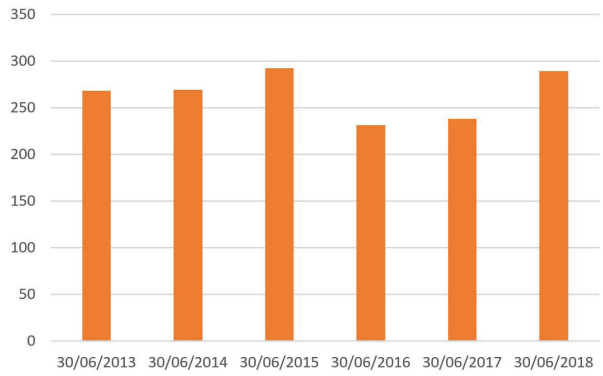


Figure L.12 Number of sites on EPA Victoria's Priority Sites Register as at the end of June, 2013–2018

(Data source: EPA Victoria, 2018)

Some chemicals are emerging as threats for site contamination, including per-and poly-fluoroalkyl substances (PFAS). An example of the increasing focus on PFAS is the investigation EPA Victoria is coordinating into potential environmental contamination, including soil, surface water and groundwater pollution, from the historical use of PFAS in firefighting foam by the Country Fire Authority (CFA).[88] In addition to the investigation of PFAS pollution at CFA sites, EPA Victoria has collaborated with industrial groups to identify the likely major industries in Victoria that would use PFAS.

The major industrial sources of PFAS were found to be:

- the oil and gas industry
- firefighting
- bulk storage facilities for flammable products
- chemical manufacturing
- metal plating.[89]

In 2018, RMIT University released a publicly available database and interactive map of ambient background soil concentrations and other soil characteristics for four Victorian regions (Ballarat, Greater Geelong, Greater Melbourne and Mitchell).[90] The key factors that influenced ambient background variability of As, Cu, Cr, Ni, Pb and Zn in the surveyed soils of those Victorian regions are summarised below by Mikkonen et al.[91]:

- Arsenic enrichment was attributed to erosion and landscape transfer of mineralised (gold bearing) soils, including alluvial and aeolian deposition and accumulation of As with Fe during lateritic weathering.
- Nickel enrichment occurred in soils overlying basalt and was associated with the weathering of olivine, and influence of illuviation, resulting in Ni enrichment in B horizon soils.
- Chromium enrichment occurred in highly weathered soils and was likely to have developed during lateritic weathering, due to immobilisation with Fe.
- Copper concentrations were negatively correlated with weathering and precipitation and likely to be influenced by clay content.
- Lead concentrations in soil were found to be influenced by multiple factors including co-accumulation with Fe in the highly weathered environments, topography and possibly diffuse contamination from urban areas.
- Zinc concentrations were negatively correlated with weathering and precipitation, but were indicated to be influenced by biological cycling, resulting in enrichment in surface soils compared to subsurface soils.

No overall status assessment has been provided for this indicator due to the lack of information of contaminated sites across the state. The current knowledge only pertains to a subset of contaminated sites. The trend is unclear, because even though there is evidence of environmental audits taking place that lead to improved land use, it is unclear how many sites have become contaminated during that time and what the overall change in the number of contaminated sites has been.

88. EPA, 'CFA regional training centres', Carlton, Victoria http://www.epa.vic.gov.au/our-work/current-issues/water-quality/cfa-regional-training-centres Accessed 3 December 2018.
89. EPA, 'Interim position statement on PFAS', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1669%202.pdf Accessed 3 December 2018.
90. Mikkonen HG, Bentley PD, Barker AO, Dasika R, Wallis CJ, Clarke BO, Reichman SM 2018, 'Victorian Background Soil Database, Version 1.0', RMIT University, Melbourne, Australia https://soilexplorer.eres.rmit.edu.au/soil-explorer/ Accessed 3 December 2018.
91. Mikkonen HG, Dasika R, Drake JA, Wallis CJ, Clarke BO, Reichman SM 2018, 'Evaluation of environmental and anthropogenic influences on ambient background metal and metalloid concentrations in soil', *Science of The Total Environment*, 624, pp. 599-610.

Land Management

	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
L:10 Land management activities	FAIR	↗	DATA QUALITY: Fair

Data custodian CMAs

Most Catchment Management Authorities (CMAs) are now reporting on the area of land managed for conservation in their annual reports. The Corangamite, Glenelg Hopkins, North Central, North East, West Gippsland and Wimmera CMAs all reported this data in their 2016–17 annual reports.[92,93,94,95,96,97]

The six CMAs reporting on the area of land managed for conservation had a combined total of approximately 43,000 hectares of land covered by Trust for Nature covenants, which increased by nearly 1,500 hectares from the previous year. The purpose of these covenants is to permanently conserve and protect the natural, cultural or scientific values of the land. The reporting CMAs also entered into management agreements with landholders to improve and conserve a further 8,000 hectares of land, increasing the total area of landholder agreements by nearly 10% on the previous year. The Glenelg Hopkins CMA was responsible for the greatest additional areas of land managed for conservation in 2016–17 across both landholder agreements and Trust for Nature covenants (Figure L.13). There were no additions to the public reserve system in any of the reporting CMAs.

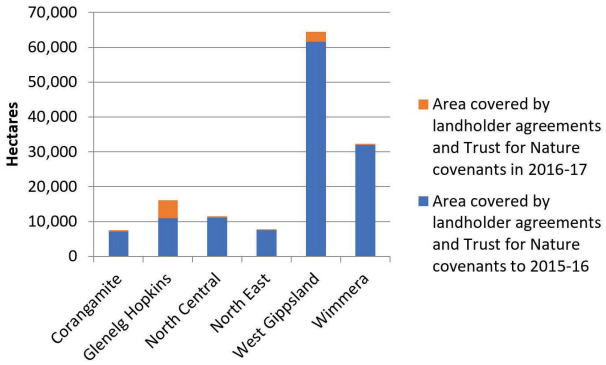


Figure L.13 Area of land covered by landholder agreements and Trust for Nature covenants

Note: Area is shown in hectares.

(Data source: 2016–17 CMA annual reports)

This indicator would ideally include statewide data and a detailed trend analysis, and be complemented with a more comprehensive quantitative analysis of the outputs and benefits associated with land-management activities; however, this type of data is not collated or published.

In addition to the work at the CMA level, the *Traditional Owner Settlement Act 2010* provides for certain Crown land sites to be granted to the Traditional Owner corporation in Aboriginal title, and then for that land to be jointly managed with the state. Joint management recognises the ongoing connection of Traditional Owners to their land and enables the knowledge and culture of the Traditional Owner group to be incorporated in the management of that land. Traditional Owners and the state work together in equal partnership to manage the natural and cultural values of parks and reserves under Aboriginal title.

92. Corangamite Catchment Management Authority 2017, 'Annual Report 2016-2017', Colac, Victoria.
93. Glenelg Hopkins Catchment Management Authority 2017, 'Annual Report 2016-2017', Hamilton, Victoria.
94. North Central Catchment Management Authority 2017, 'Annual Report 2016-2017', Huntly, Victoria.
95. North East Catchment Management Authority 2017, 'Annual Report 2016-2017', Wodonga, Victoria.
96. West Gippsland Catchment Management Authority 2017, 'Annual Report 2016-2017', Traralgon, Victoria.
97. Wimmera Catchment Management Authority 2017, 'Annual Report 2016-2017', Horsham, Victoria.

Aboriginal title is a highly modified freehold grant to the Traditional Owners. Under Aboriginal title, the right to occupy, use, control and manage the land is transferred back to the state, including the authority to issue leases and licences. Transfer of parks or reserves to Aboriginal title does not affect existing use and access, which will continue to be managed under the relevant land act. Table L.2 shows current Traditional Owner organisations and corporation(s) with native title and settlement negotiations, while Table L.3 shows the current Traditional Owner corporation(s) in settlement negotiations with the state under the *Traditional Owner Settlement Amendment Act 2016*.

Table L.2 Current Traditional Owner Corporations with native title and settlement determinations

Current Traditional Owner Corporations	Region
Dja Dja Wurrung Clans Aboriginal Corporation	North Central Region
Gunaikurnai Land and Waters Aboriginal Corporation	Gippsland Region
Gunditj Mirring Traditional Owners Aboriginal Corporation	Barwon South West Region
Yorta Yorta Nation Aboriginal Corporation	Hume Region
Barengi Gadjin Land Council	Grampians Region

Table L.3 Current Traditional Owner Corporations in settlement negotiations with the State of Victoria under the *Traditional Owner Settlement Amendment Act 2016*

Current Traditional Owner Corporations	Region
Taungurung Clans Aboriginal Corporation	Hume Region
Eastern Maar Aboriginal Corporation	Barwon South West Region
Barengi Gadjin Land Council	Grampians Region
Gunditj Mirring Traditional Owners Aboriginal Corporation	Barwon South West Region

	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
L:11 Participation in natural resource management activities	GOOD	↗	DATA QUALITY: Good

Data custodian CMAs, Parks Victoria, Landcare

This indicator assesses community participation in natural resource management (NRM) activities, which includes volunteers who are involved in 'Friends of' and community groups, Landcare and citizen science programs across terrestrial, inland aquatic, coastal and marine ecosystems. Community participation can improve environmental stewardship, connect people to nature and improve physical, mental and emotional health and wellbeing. In the future, this indicator can potentially be used to assess the progress of Priority 5, 'Increase opportunities for all Victorians to act to protect biodiversity' in the new plan, *Biodiversity 2037 – Protecting Victoria's Environment*. An assessment of citizen science programs by DELWP found 34 active programs across Victoria.[98] These programs run across all Victorian ecosystem types, including terrestrial, rivers, estuaries, wetlands, coasts and marine waters, and are led by government, non-government and academic organisations.

Parks Victoria engages an extensive community network that provides 281,776 volunteering hours with 37,200 volunteer attendees across 167 parks. This network includes 234 volunteer (or volunteer-involving) organisations that partner with Parks Victoria to engage and facilitate practical volunteering outcomes. Parks Victoria's volunteer network has provided over $10 million of in-kind support in 2017–18. This is the highest ever recorded figure for Parks Victoria.

Parks Victoria has continued to implement the first online volunteer management system for a state park agency. ParkConnect enables staff and volunteer groups to collaboratively plan, manage and report on volunteer activities. It makes volunteering more accessible and promotes volunteer opportunities broadly across Victoria. There have been over 1,500 new volunteer registrations with over 65% attending one or more of the 573 activities planned within the system. The largest demographic registering to volunteer has been 18 to 35-year-olds in full-time employment. The largest proportion of volunteer activities are focused on habitat restoration, followed by environmental research, historic heritage conservation and gardening.

The VCMC estimated that Victorian communities co-contributed approximately $116 million in 2015–16 to catchment management across all Victorian CMA regions.[99] Although this estimate was based on a simple calculation, and therefore should be treated with caution, this value is potentially equivalent to both national and state government investment in NRM, as well as investment from other sources.[100] This figure does not take into account the intangible benefits to the community of participation in catchment management, including: physical and mental wellbeing, social capital, and engaged and resilient communities.[101] Two essential components of the work coordinated by CMAs to successfully manage natural resources in their regions are: actively engaging the many stakeholders (such as private landholders, community groups and local councils), and understanding their local issues.

Participation at CMA natural resource management engagement events has increased each year since data was first reported in 2013–14 (Figure L.14).[102,103] Engagement events have included field days, seminars and farm

98. Data supplied by DELWP in 2018.

99. Victorian Catchment Management Council 2017, 'Catchment Condition and Management Report 2017', East Melbourne, Victoria, http://www.vcmc.vic.gov.au/pdf/CCMR_Report_2017.pdf Accessed 3 December 2018..
100. Ibid
101. Ibid
102. Victorian Catchment Management Authorities 2017, 'Actions & Achievements Report 2016-17', Corangamite CMA, East Gippsland CMA, Glenelg Hopkins CMA, Goulburn Broken CMA, Mallee CMA, North Central CMA, North East CMA, Port Phillip and Westernport CMA, West Gippsland CMA, Wimmera CMA, Colac, Bairnsdale, Hamilton, Shepparton, Irymple, Huntly, Wodonga, Frankston, Traralgon, Horsham, Victoria.
103. Victorian Catchment Management Authorities, 2017, 'Actions & Achievements Report 2015-16', Corangamite CMA, East Gippsland CMA, Glenelg Hopkins CMA, Goulburn Broken CMA, Mallee CMA, North Central CMA, North East CMA, Port Phillip and Westernport CMA, West Gippsland CMA, Wimmera CMA, Colac, Bairnsdale, Hamilton, Shepparton, Irymple, Huntly, Wodonga, Frankston, Traralgon, Horsham, Victoria.

inspections. There were nearly 35,000 participants at engagement events in 2013–14, which has grown to more than 93,000 participants in 2016–17, although it should be noted that the 2013–14 report captured only state-funded outputs.[104] The data from 2014–15 onwards provides a better comparison as it consistently contains State and Commonwealth funding sources. Participation at engagement events has increased by nearly 70% since 2014–15, indicating a more engaged and informed stakeholder cohort.

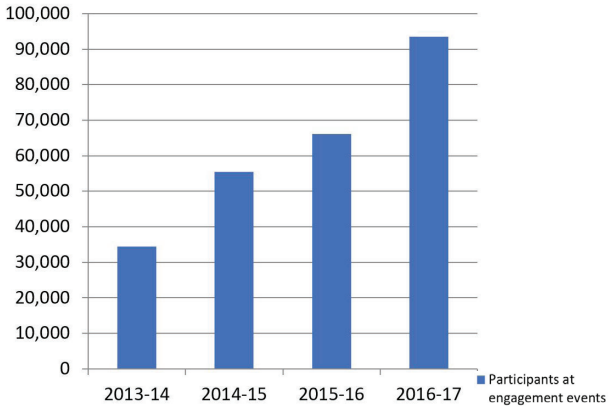


Figure L.14 Participation at CMA organised natural resource management engagement events

(Data source: CMA Actions and Achievements report, 2015-16 and 2016-17) [105,106]

The Goulburn Broken CMA recorded the greatest participation at engagement events in 2015–16 and then doubled this in 2016–17. This is reflective of a regional area with local communities, Traditional Owners, partner organisations, farmers and other individuals that are an active presence in decision-making and take actions to improve their local environments.[107]

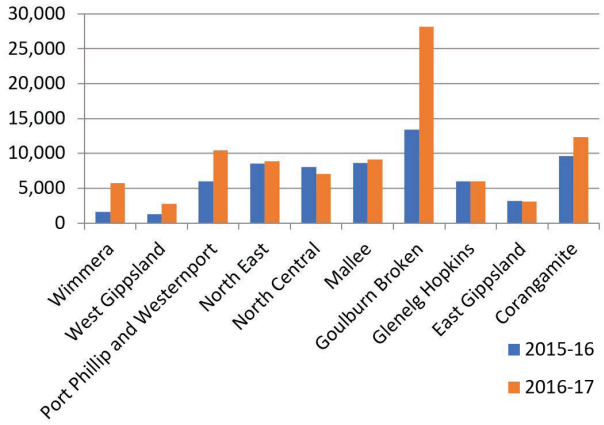


Figure L.15 Participation at organised natural resource management engagement events by CMA, 2015–16 and 2016–17

(Data source: CMA Actions and Achievements reports, 2015–16 and 2016–17).[108,109]

Landcare is a vital community-based volunteer movement that facilitates and coordinates actions to care for the environment. Among the wide variety of on-ground activities undertaken by Landcare are: rejuvenation and repair of habitats, restoration of waterways, improvements to farmland, and addressing of land-management issues such as erosion and pest plants and animals.[110] There are around 600 Landcare groups and 64 networks in Victoria that cover 65% of the state (82% of private land and 32% of public land).[111,112] Landcare volunteers reported

104. Ibid
105. Victorian Catchment Management Authorities 2017, 'Actions & Achievements Report 2016-17', Corangamite CMA, East Gippsland CMA, Glenelg Hopkins CMA, Goulburn Broken CMA, Mallee CMA, North Central CMA, North East CMA, Port Phillip and Westernport CMA, West Gippsland CMA, Wimmera CMA, Colac, Bairnsdale, Hamilton, Shepparton, Irymple, Huntly, Wodonga, Frankston, Traralgon, Horsham, Victoria.
106. Victorian Catchment Management Authorities, 2017, 'Actions & Achievements Report 2015-16', Corangamite CMA, East Gippsland CMA, Glenelg Hopkins CMA, Goulburn Broken CMA, Mallee CMA, North Central CMA, North East CMA, Port Phillip and Westernport CMA, West Gippsland CMA, Wimmera CMA, Colac, Bairnsdale, Hamilton, Shepparton, Irymple, Huntly, Wodonga, Frankston, Traralgon, Horsham, Victoria.
107. Goulburn Broken Catchment Management Authority 2017, 'Annual Report 2016-2017', Shepparton, Victoria.
108. Victorian Catchment Management Authorities 2017, 'Actions & Achievements Report 2016-17', Corangamite CMA, East Gippsland CMA, Glenelg Hopkins CMA, Goulburn Broken CMA, Mallee CMA, North Central CMA, North East CMA, Port Phillip and Westernport CMA, West Gippsland CMA, Wimmera CMA, Colac, Bairnsdale, Hamilton, Shepparton, Irymple, Huntly, Wodonga, Frankston, Traralgon, Horsham, Victoria.
109. Victorian Catchment Management Authorities 2017, 'Actions & Achievements Report 2015-16', Corangamite CMA, East Gippsland CMA, Glenelg Hopkins CMA, Goulburn Broken CMA, Mallee CMA, North Central CMA, North East CMA, Port Phillip and Westernport CMA, West Gippsland CMA, Wimmera CMA, Colac, Bairnsdale, Hamilton, Shepparton, Irymple, Huntly, Wodonga, Frankston, Traralgon, Horsham, Victoria.
110. DELWP, 'Landcare', East Melbourne, Victoria https://www.environment.vic.gov.au/landcare Accessed 3 December 2018.
111. Ibid
112. Landcare, communication dated 02/10/2018 ("Landcare Total Coverage – Groups & Networks.pdf").

contributing 375,000 hours in 2016–17 to land, water and biodiversity protection across Victoria, providing a value of $11.2 million.[113] The reported Landcare contributions in 2016–17 varied from 2015–16, when the Victorian Landcare Program estimated that volunteers contributed $20 million worth of hours.[114]

Traditional Owner participation is another vital component of NRM. Traditional Owners have strategies for their participation in NRM detailed within a Natural Resource Agreement (as part of their Recognition & Settlement Agreements). For more information refer, to indicator L:10 (Land-management activities).

Research from 2015 shows the importance of combining social and environmental values in NRM.[115] The research develops a Valued Attributes of Landscape Scale to help bridge the divide between theoretical understandings of value in psychology, which have largely focused on the core values held by people, and values as understood by NRM professionals, which have largely focused n valuing the environment.[116]

113. Victorian Catchment Management Authorities 2017, 'Actions & Achievements Report 2016-17', Corangamite CMA, East Gippsland CMA, Glenelg Hopkins CMA, Goulburn Broken CMA, Mallee CMA, North Central CMA, North East CMA, Port Phillip and Westernport CMA, West Gippsland CMA, Wimmera CMA, Colac, Bairnsdale, Hamilton, Shepparton, Irymple, Huntly, Wodonga, Frankston, Traralgon, Horsham, Victoria.
114. Victorian Catchment Management Authorities, 2017, 'Actions & Achievements Report 2015-16', Corangamite CMA, East Gippsland CMA, Glenelg Hopkins CMA, Goulburn Broken CMA, Mallee CMA, North Central CMA, North East CMA, Port Phillip and Westernport CMA, West Gippsland CMA, Wimmera CMA, Colac, Bairnsdale, Hamilton, Shepparton, Irymple, Huntly, Wodonga, Frankston, Traralgon, Horsham, Victoria.
115. Kendal D, Ford RM, Anderson NM, Farrar A 2015, 'The VALS: a new tool to measure people's general valued attributes of landscapes', *Journal of Environmental Management*, 163, pp. 224-233.
116. Ibid

	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
L:12 Use of best practice on agricultural lands		?	DATA QUALITY
Data custodian CMAs			Poor

As discussed in indicator L:01 (Land use types in Victoria), half of Victoria's land use is defined as primary production. Therefore, it is critical that agricultural land is managed well for multiple outcomes. This indicator is designed to assess the area of land managed using best-practice techniques that maintain and improve land and ecosystem health.

No data currently exists to determine whether each parcel of agricultural land is operated under best practice. The available statewide data that most closely relates to this indicator is the area of land with improved agricultural practices – defined as the area over which agricultural practices have been established, modified, maintained or removed (this may include retaining ground cover, changes in cropping practices or nutrient management).[117] This has been annually reported by CMAs for the three years from 2014–15 to 2016–17. During that three-year period, the area of land with improved agricultural practices has increased each year, with an extra 335,325 hectares of agricultural land operating under improved management.[118]

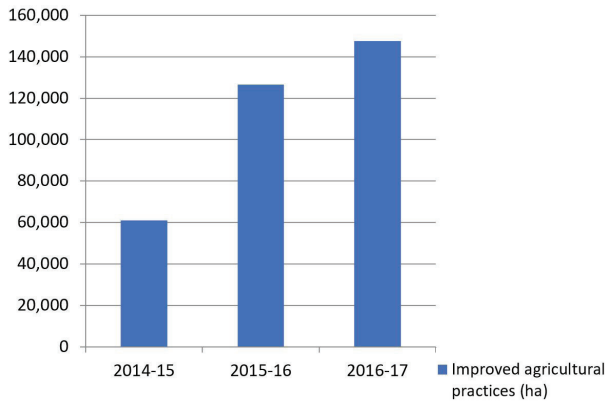


Figure L.16 Area (hectares) of improved agricultural practices in Victoria, 2014–15 to 2016–17

Note: Area is shown in hectares

(Data source: CMA Actions and Achievements reports for 2016–17)

More than 93,000 hectares of improved agricultural practices during 2016–17 were federally funded through the National Landcare Program. These improved practices were focused on the grains and grazing industries, and included work coordinated by the West Gippsland CMA that saw landholders develop: 60 nutrient and effluent management plans; 21 irrigation plans; 14 grazing, soil and nutrient management plans; and 5 soil erosion management plans.[119]

The current data does not enable statewide status or trend assessments. There is information to suggest best practice on agricultural land is becoming more prevalent in Victoria; however, a trend cannot be determined without baseline data on the use of best practice on agricultural land.

117. DELWP 2015, 'DELWP Output data standards', East Melbourne, Victoria https://www.water.vic.gov.au/__data/assets/pdf_file/0016/120463/DEL-WP-OutputDataStandard-web-V4.0.pdf Accessed 3 December 2018.

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

119. Victorian Catchment Management Authorities, 2017, 'Actions & Achievements Report 2015-16', Corangamite CMA, East Gippsland CMA, Glenelg Hopkins CMA, Goulburn Broken CMA, Mallee CMA, North Central CMA, North East CMA, Port Phillip and Westernport CMA, West Gippsland CMA, Wimmera CMA, Colac, Bairnsdale, Hamilton, Shepparton, Irymple, Huntly, Wodonga, Frankston, Traralgon, Horsham, Victoria.

	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
L:13 Proportion of agricultural area under productive and sustainable agriculture Data custodian AV, CMAs		?	DATA QUALITY Poor

This indicator arises from the United Nations Sustainable Development Goals (SDGs), specifically Target 2.4 that aims to ensure sustainable food production systems and implement resilient agricultural practices by 2030. Achievement of this aim will: increase productivity and production; help maintain ecosystems and strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters; and progressively improve land and soil quality.[120]

The definition of sustainable agriculture used for this indicator is based on the definition provided by the Food and Agriculture Organization of the United Nations in 1988: 'the management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such development conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable.'[121]

Agriculture Victoria coordinates a Land Health Program that delivers a range of activities including whole-farm planning, grazing management workshops and general soil extension. These activities assist farmers to improve their skills in assessing land capability and land class, empowering them to modify management practices to increase long-term sustainability. This program influenced and improved management practices on more than 120,000 hectares of land used for stock, and more than 50,000 hectares of land used for crops, from 2013–14 to 2015–16.

Qualitative information relating to this indicator is also captured as part of the two transect surveys Agriculture Victoria conduct each year with the CMAs in the Glenelg Hopkins and Wimmera catchments. The transect surveys monitor land-management practices and ground cover in autumn and spring across the Wimmera and South West regions. The surveys cover approximately 83,000 hectares across the two catchments, with a much larger area covered in the Wimmera catchment, which is split into a northern and southern region.[122,123,124] The most recent available transects were conducted in autumn 2018, following a dry summer that appears to have had a significant impact on land practices and increased the risk of soil loss through erosion in southern Wimmera.

The transect surveys have found that northern Wimmera farmers have increasingly adopted conservation farming practices that minimise the risk of topsoil erosion, rather than the more traditional farming methods that were prevalent during the first survey observations from 1996. Less promisingly, recent surveys have observed more variable stubble retention practices in the northern Wimmera that can cause an increase in chemical fallow and legume stubbles, which increase the risk of soil erosion in the lead-up to crop establishment, or if dry conditions continue.

In the Glenelg Hopkins catchment, it was found that nearly all livestock were being fed supplementary hay and grain. It was evident that there was insufficient pasture available to sustain them. The common observation was that the livestock grazing those paddocks were in predominantly barer paddocks than usual.[125]

120. United Nations, 'SDG Indicator 2.4.1 - Agricultural sustainability', http://www.fao.org/sustainable-development-goals/indicators/241/en/ Accessed 3 December 2018.
121. Food and Agriculture Organization of the United Nations 1988, 'Report of the Council of FAO', Ninety-fourth Session, Rome, 15-26 November 1988. http://www.fao.org/docrep/meeting/011/t0087e/t0087e00.htm Accessed 3 December 2018.
122. Agriculture Victoria, 'Northern Wimmera Cropland Management Transect Survey – Autumn 2018'.
123. Agriculture Victoria, 'Southern Wimmera Cropland Management Transect Survey – Autumn 2018'.
124. Agriculture Victoria, 'Glenelg Hopkins Catchment Land Use and Land Management Transect – Land cover Autumn 2018'.
125. Ibid

Agricultural industries are undertaking a range of processes to improve their sustainability. An example is the dairy industry, with Dairy Australia establishing its own sustainability framework in 2012.[126] The framework includes four environmental goals to be achieved by 2020:

- Improve nutrient, land and water management
- Reduce consumptive water intensity of dairy manufacturers by 20%
- Reduce greenhouse gas emissions intensity by 30%
- Reduce waste to landfill by 40%.

To meet each of these goals, the framework contains targets that need to be achieved. In the 2016 report, most of the measured targets showed environmental improvements from 2012 to 2016.[127]

The information from the Land Health Program, the transect surveys and the information on improved practices on agricultural land tell a story of an agricultural sector that appears to be becoming more productive and sustainable.

However, overall status and trend assessments could not be provided at the time of this report due to the absence of baseline data on where sustainable agriculture is being operated in Victoria. It is anticipated that the SDGs will become increasingly central to Victorian environment reporting, therefore it is intended this indicator will be reported in future SoEs and drive the collection of more suitable data for future assessments.

126. Dairy Australia Limited 2013, 'Australian Dairy Industry Sustainability Framework Progress Report 2013', Melbourne, Victoria.
127. Dairy Australia Limited 2017, 'Australian Dairy Industry Sustainability Report 2016', Melbourne, Victoria.

Future Focus

Improve understanding of soil and land conditions and threats

To manage Victoria's land health during a time of climate change, it is essential that a long-term plan is created for the collection, consolidation, reporting and assessment of land data across the state. It may be a decade before the benefits of this plan are realised, but it is critical that responsible agencies commence work now so that adequate assessments of land health can be used to drive statewide improvements in land-health condition across Victoria.

The main challenges to soil monitoring are the inherently high variability of soils (the changes are minor and occur over decades), and that measuring soil characteristics can be expensive. These are national issues. New collaboration and funding models linking public and private databases and federated data could provide greater opportunity for soil-health monitoring. Alignment of these new models with the work undertaken by the Cooperative Research Centre for High Performing Soils to develop and measure soil-health indicators for the future could be the foundation for a state soil and land condition monitoring program.

Further analyses of the threats and impacts of land use and land-use change would also improve policy development and decision-making across a variety of sectors, including agriculture, planning and water management. An analysis of the tools that support ongoing land-use assessments, including the Victorian Land Use Information System, and the optimum frequency for updating land-use datasets and maps would be required.

Recommendation 7: That Agriculture Victoria lead the design and delivery of a state soil and land condition monitoring program, that includes analysis of the threats and impacts of land use and land-use change, to improve decision-making across a variety of sectors including agriculture, planning and water management.

Note: This recommendation complements recommendation 6: Improve biodiversity outcomes on private land. The investigation of the threats and impacts of land use and land-use change would determine the impact of private land on Victoria's ecosystems and inform actions to maintain and improve biodiversity on private land.

Accounting for the Environment

Land accounts are at the core of environmental–economic accounting. Land accounts can be used to assess changes in tenure, impacts of urbanisation, intensity of crop and animal production, deforestation and other direct and indirect uses. Land accounts are also very relevant to many levels of governance including local, regional, catchment and state. While broad assessment of the changing shares of different land use and land cover within the state may provide useful indicators of change, increasingly the power of the land accounts is reflected in the use of mapping technologies that can pinpoint areas of change. The UN SEEA describes land as:

A unique environmental asset that delineates the space in which economic activities and environmental processes take place and within which environmental assets and economic assets are located.[128]

The use of any given parcel of land determines the suite of ecosystem services it may provide. For instance, a native forest provides water purification, carbon sequestration and habitat services. By contrast land used for farming, such as wheat production, is generally limited to providing provisioning services in the form of wheat for feed. There are many other instances where a unit of land can provide multiple ecosystem services, and it is government policy and economic activity that determine land use and in turn the suite of ecosystem services.

A key feature of land accounts is the ability to disaggregate them for specific and targeted spatial analysis and decision-making. For instance, biodiversity-related services are highly dependent on specific types of land or ecosystem assets, including Ecological Vegetation Classes (EVCs), wetlands and rivers. Further, many species require specific types of ecosystem assets in a condition that allows for them to exist and breed.

Land accounts alone are not sufficient and there is generally a need to have them connected to accounts that can report on ecosystem services and benefits. The decision to use land should include an analysis of the potential changes in both services and benefits, noting that some benefits may not be monetary and so not all land-use decisions are driven or motivated by economic returns.

For example, forests are a type of land account. Forest asset accounts can be linked to the natural inputs and ecosystem services they produce which have benefits for the economy and society. (This is discussed further in the Forests chapter).

Land accounts are linked to soil resources. Soil is an important environmental asset that provides services and benefits, but it can be degraded. The services provided by soil are linked to land accounts, as the way land is used and managed impacts on the condition of soil, and the condition of soil affects land-use decisions. Soil assets can be managed to improve or maintain their condition. For example, soil acidification can be reversed with the application of lime, and soil erosion can be managed by maintaining ground cover that protects soil from wind and water erosion.

Land also has an important role to play in climate change. For instance, land may be inundated in coastal areas or contain ecosystem assets that will be impacted by changing climatic conditions. Changes are already being observed in the allocation of land to different agricultural enterprises in response to changes in climate and weather patterns. Land accounts could be used to forecast potential impacts on land and how that may impact on economic and social wellbeing for planning and government policies and programs.

128. United Nations 2014, 'System of Environmental-Economic Accounting 2012: Central Framework'.

Victorian Land Accounts

The ABS provided land accounts for Victoria showing the rateable value of land (see Figure L.17), and the distribution of the native vegetation from 1750 that was remaining in 2006 (see Figure L.18 and Figure L.19).

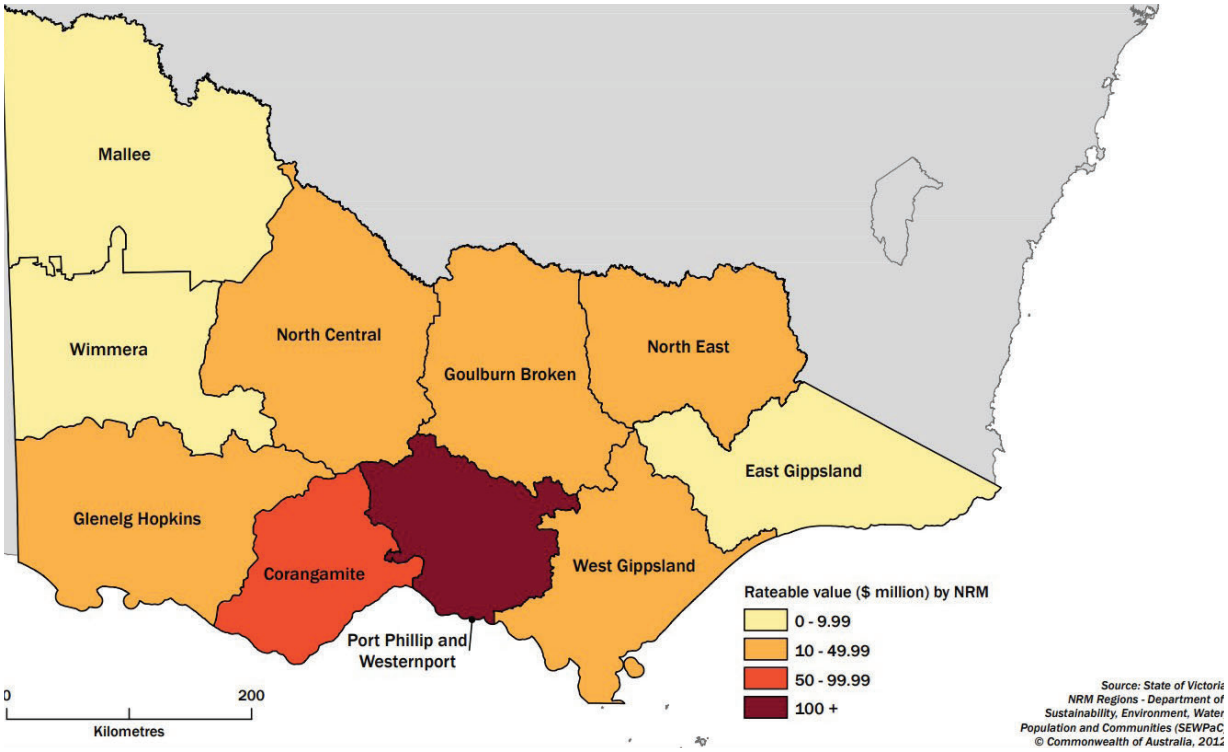


Figure L.17 Total rateable value of land by natural resource management area, 2012

(Data source: 4609.0.55.002 - Land Account: Victoria, Experimental Estimates, 2012)

A particular feature of land accounts is that they can be tailored to analyse of specific areas in the state. For example, Figure L.18 shows the distribution of native vegetation by NRM area whereas Figure L.19 reports the same information but for Interim Biogeographic Regionalisation for Australia (IBRA) regions. Further specific analysis can be done to show the links between economic activity and the state of the environment for any area of interest.

Ecosystem accounts as a special case of land accounts are important because they can be used to show the change in extent of EVCs, and can be linked to economic activity and investments by government to improve or maintain the condition of the ecosystems (spatial condition accounts). Both extent and condition accounts can then be linked to Habitat Distribution Models (HDMs) to demonstrate how the maintenance and improvement of key ecosystems can contribute to species preservation (see the Forests chapter for an example of links to HDMs and rare and threatened species).

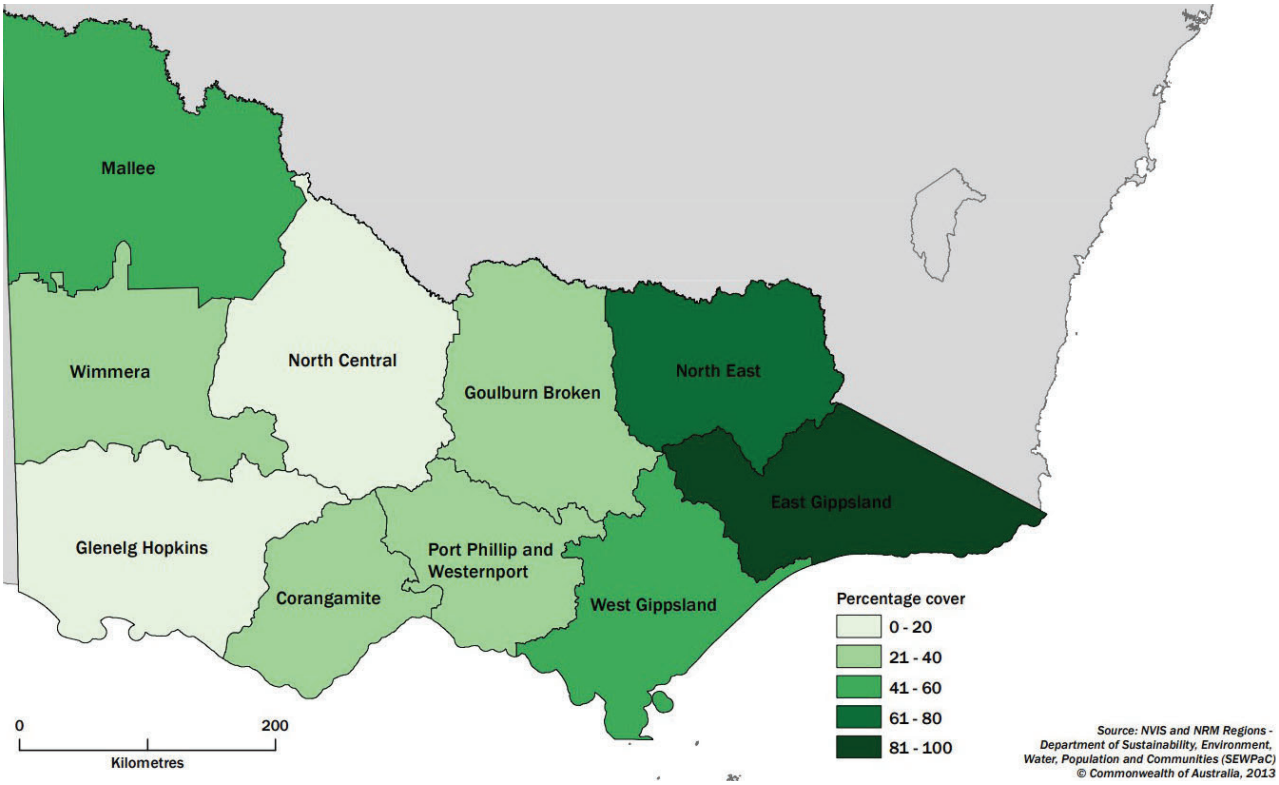
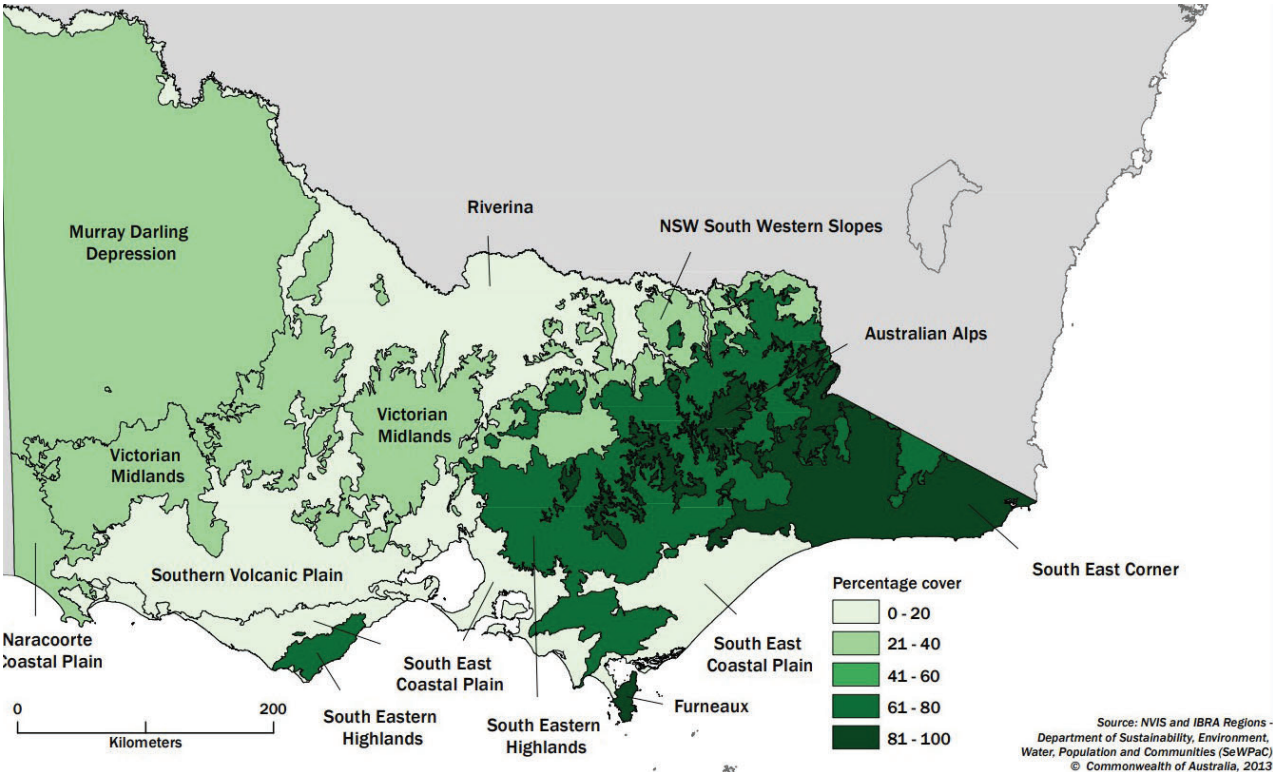


Figure L.18 Percentage of 1750 native vegetation cover remaining in 2006 by NRM area

(Data source: 4609.0.55.002 - Land Account: Victoria, Experimental Estimates, 2012)



zzFigure L.19 Percentage of 1750 native vegetation cover remaining in 2006, by IBRA

(Data source: 4609.0.55.002 - Land Account: Victoria, Experimental Estimates, 2012)

There are several measurement and reporting requirements for the regular production of land accounts. These requirements include:

- regular and ongoing collection of land use and land cover data, rather than ad hoc project-based work
- spatial standards for the collection and collation of spatial data to ensure government agencies can aggregate the data to undertake integrated analysis
- clarity on the classification of land for different purposes and consistent use across government agencies for integrated decision-making
- systems in place to report on changes in land condition and the services the land is providing
- systematic reporting on the spatial location of land and its contribution to economic and social wellbeing.

FORESTS (Fo)

SCIENTIFIC ASSESSMENTS Part III

Commissioner *for* Environmental Sustainability Victoria

Forests

The Forests chapter has 21 indicators divided across eight themes: 1) Ecosystem Diversity, 2) Genetic Diversity, 3) Species Diversity, 4) Ecosystem Health, 5) Carbon Cycles, 6) Productive Capacity, 7) Legal, Institutional and Economic and 8) Socio-economic Benefits.

In terms of biodiversity, the Genetic Diversity and Species Diversity themes discuss forest-dependent species using the limited available information. Several threatened species are discussed in relation to their risks and potential consequences of timber production activities. This chapter does not discuss soil and water resources in Victorian forests and several socio-economic aspects, which will be included in the State of the Forests (SoF) 2018 report. This chapter does not provide comprehensive discussions about climate change and fire, as these are discussed in the respective chapters.

Background

Forests and the services they provide are essential for the health and wellbeing of all Victorians. Forests maintain Victoria's water quality, purify the air and store carbon, stabilise and nourish soil, assist agriculture, and support economies vital for regional communities and businesses. Forests have also been an essential part of history and culture for Victoria's Traditional Owners and Aboriginal Victorians. The definition of 'forest' used by Australia's National Forest Inventory, established in 1988, is:

> an area, incorporating all living and non-living components, that is dominated by trees having usually a single stem and a mature or potentially mature stand height exceeding 2 metres and with existing or potential crown cover of overstorey strata about equal to or greater than 20 per cent. This includes Australia's diverse native forests and plantations, regardless of age. It is also sufficiently broad to encompass areas of trees that are sometimes described as woodlands.[1]

Victoria has 7.9 million hectares of public land (excluding marine and coastal areas). Parks and Reserves, and State Forest, account for 3.7 million and 3.2 million hectares of land respectively and both have approximately 3 million hectares of forest cover. Other crown land, which accounts for the remaining 1 million hectares of public land, has 0.4 million hectares of forest cover, bringing the total area of forest across the public land estate to 6.4 million hectares (Figure Fo.1)[2]. Since European settlement, more than 14 million hectares (60%) have been cleared, mainly for agriculture and settlements.[3] Victoria's population growth and subsequent urban expansion will increase the pressure on Victorian forests through elevated water demand from forest catchments and timber harvesting.[4] In managing these forests, a range of actions are identified to achieve the principles of sustainable forest management.

This was defined in 1993 at the Ministerial Conference on the Protection of Forests in Europe as:

> the stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems.[5]

1. Australian Department of Agriculture and Water Resources ABARES, 'Australia's forests', Canberra, Australia http://www.agriculture.gov.au/abares/forestsaustralia/australias-forests Accessed 3 December 2018.
2. Forest and land area statistics are provided by DELWP in 10 January 2019, using public land management datasets (PLM25)..
3. Commissioner for Environmental Sustainability 2013, 'State of the Environment report 2013', Melbourne, Victoria http://www.ces.vic.gov.au/sites/default/files/publication-documents/2013%20SoE%20report%20full.pdf Accessed 3 December 2018.
4. Lindenmayer DB, Sato C 2018, 'Hidden collapse is driven by fire and logging in a socioecological forest ecosystem', *Proceedings of the National Academy of Sciences*, 115, pp. 5181-5186.
5. Second Ministerial Conference on the Protection of Forests in Europe 1993, 'Resolution H1: general guidelines for the sustainable management of forest in Europe', Helsinki, Finland https://www.foresteurope.org/docs/MC/MC_helsinki_resolutionH1.pdf Accessed 3 December 2018.

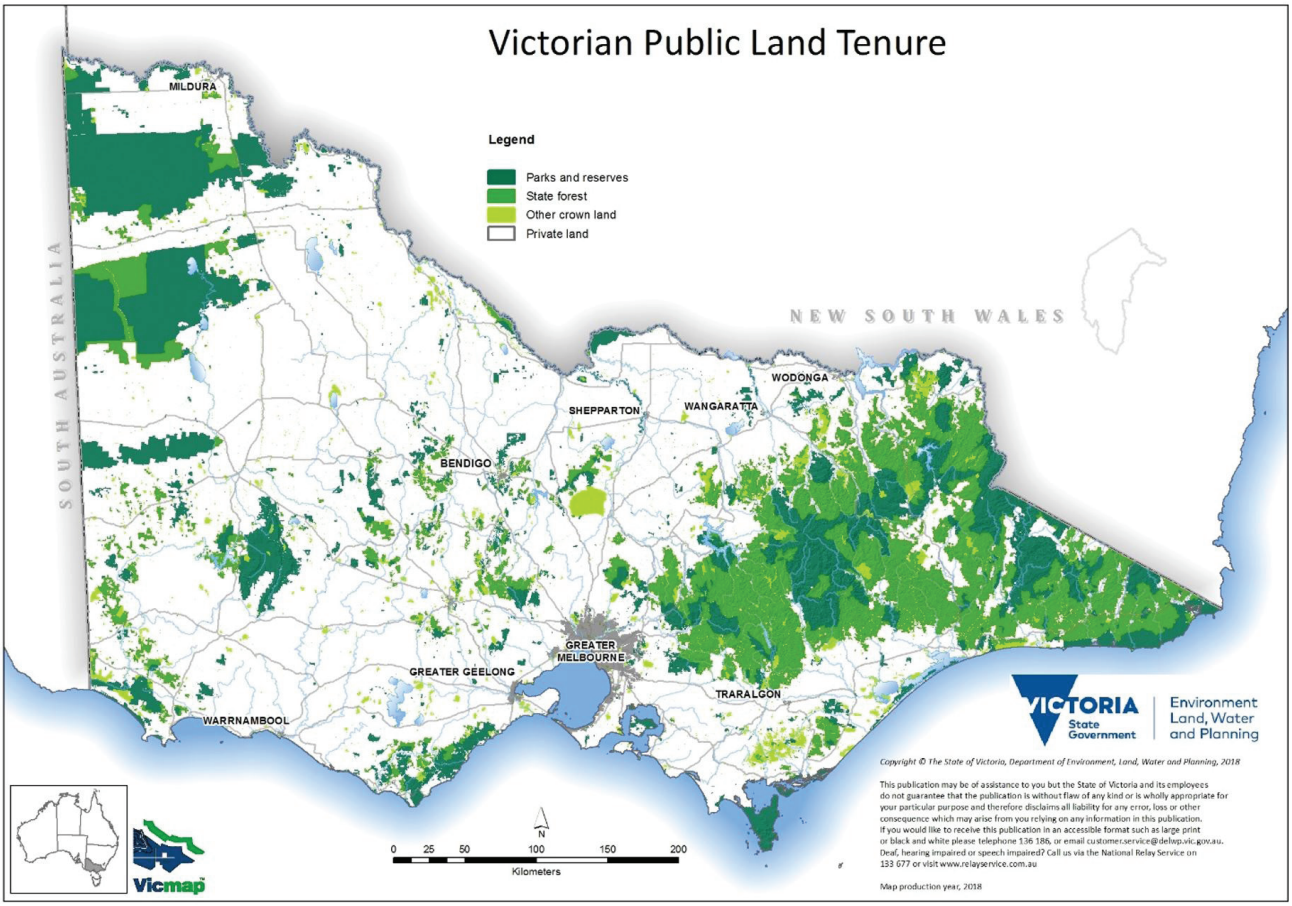


Figure Fo.1 Victorian state forest, and parks and reserves

(Data source: DELWP, 2018)

The current literature identifies several major issues for long-term sustainable forest management in Victoria:

- Climate change – There is considerable scientific evidence predicting damage to the vitality and health of Australia's forests due to climate change.[6,7,8,9] Forests are an important element of the global carbon cycle; therefore, monitoring carbon stocks in forests is an essential part of sustainable forest management.
- Changing fire regimes – more frequent and severe fires as a result of changing climate are expected to cause tree mortality, regeneration and seed viability in the fire-sensitive forest types,[10] including eucalypt forests (such as *Eucalyptus pauciflora*[11] and *Eucalyptus delegatensis subsp. Delegatensis*[12]).
- Biodiversity – In Victoria, nearly 250 fauna species are listed as 'threatened' in the *Flora and Fauna Guarantee Act 1988 (FFG Act)*. Of these, approximately 20% are forest-dependent species. While disturbance and regeneration are fundamental to

6. Madsen T, Ujvari B, Shine R, Olsson M 2006, 'Rain, rats and pythons: climate-driven population dynamics of predators and prey in tropical Australia', *Austral Ecology*, 31(1), pp. 30-37.
7. Donohue RJ, McVicar TR, Roderick L 2009, 'Climate-related trends in Australian vegetation cover as inferred from satellite observations, 1981-2006'.*Global Change Biology*, 15(4), pp. 1025-1039.
8. Johnson BJ, Miller GH, Fogel ML, Magee JW, Gagan MK, Chivas AR 1999, '65,000 years of vegetation change in central Australia and the Australian summer monsoon'. *Science*, 284(5417), pp. 1150-1152.
9. Hughes L 2003, 'Climate changes and Australia: trends, projections and impacts'. *Austral Ecology*, 28(4), pp. 423-443.
10. Fairman T, Nitschke CR, Bennett LT 2016, 'Too much, too soon? A review of the effects of increasing wildfire frequency on tree mortality and regeneration in temperate eucalypt forests'. *International Journal of Wildland Fire*, 25(8), pp. 831-848.
11. Fairman, TA, Bennett LT, Tupper S, Nitschke CR 2017, 'Frequent wildfires erode tree persistence and alter stand structure and initial composition in a fire-tolerant sub-alpine forest'. *Journal of Vegetation Science*, 28(6), pp. 1151-1165.
12. Doherty MD, Gill AM, Cary GJ, Austin MP 2017, 'Seed viability of early maturing alpine ash (Eucalyptus delegatensis subsp. delegatensis) in the Australian Alps, south-eastern Australia, and its implications for management under changing fire regimes'. *Australian Journal of Botany*, 65, pp. 517-523.

forest maintenance, significant shifts in the frequency, scale and intensity of these processes can disrupt the health of forests.[13]

- Fragmentation – Forest-dwelling fauna species, including endangered species, are impacted by the fragmentation of native forests.[14] This loss of forest connectivity eventually leads to the geographic isolation of a species' population and impacts on the species' genetic diversity. This has significant implications for the survival of many iconic and forest-dependent species.
- Economy – Forests provide a resource for several economically significant industries in Victoria. These include forest products, agriculture (agroforestry) and tourism. The forest products industry alone provides an estimated 15,696 jobs, of which 14,475 are directly related[15] to forests. Victoria has the largest total area of plantations in Australia, compared to other states and territories, with 433,000 hectares of commercial hardwood and softwood plantations in 2013–14, up 13% from 2003–04.[16] Successful management of Victoria's forest/timber resources is vital to the state's economy.
- Legal framework – Management of Victoria's forests is delivered within a complex legal and policy framework. Relevant legislation includes the *Sustainable Forests (Timber) Act 2004*, *National Parks Act 1975* and *Forests Act 1958*.[17]

Critical challenges for sustainable forest management in Victoria, now and in the future, include:

- establishing long-term monitoring of key aspects of forest conditions, such as loss of species population and genetic diversity due to fragmentation of native forests
- understanding the changes in patterns of natural disturbances including fire, flood and drought, and any increase in variability and intensity of these disturbances due to climate change
- understanding the impacts of altered disturbance patterns on forest productivity and forest-related biophysical and social values
- understanding Victoria's forest carbon cycle and increasing the carbon storage capacity of forests
- improving complex and outdated forest management legislation that cause inconsistencies, overlaps and gaps, and lead to confusion for land managers and communities
- managing forests for a range of social, cultural, economic and ecological values and uses
- enhancing the protection and management of forests with attributes important to ecological conservation and carbon storage[18]
- characterising the optimal restoration targets (location, maturity stages) in post-fire and/or logged regrowth forests to reduce fire proneness[19]
- achieving sustainable native-timber production while protecting threatened species such as Leadbeater's possum
- defining forest-logging to fire-severity relationships as mediated by regrowth stage, tree abundance and density
- being consistent, multi-tiered and multi-valued in monitoring approaches and data acquisition strategies for sustainable forest management.

13. Keenan R J and Nitschke C 2016, 'Forest management options for adaptation to climate chance: a case study of tall, wet eucalypt forests in Victoria's Central Highlands region'. *Australian Forestry*, 79(2), pp. 96-107.
14. Riitters KH, Wickham JD, O'Neill R, Jones B, Smith E 2000, 'Global-scale patterns of forest fragmentation'. *Conservation Ecology*, 4(2), pp. 3.
15. Schirmer J, Mylek M, Magnusson A, Yabsley B, Morison J 2018, 'Socio-economic impacts of the forest industry Victoria (exc. The Green Triangle)'. *Forest & Wood Products Australia*, Melbourne, Victoria https://www.fwpa.com.au/resources/reports/other/1631-socio-economic-impacts-of-the-forest-industry-victoria-exc-the-green-triangle.html Accessed 3 December 2018.
16. VAFI 2015, 'Industry review 2015', Melbourne, Victoria, http://www.vafi.org.au/wp-content/uploads/2015/12/VAFI015-Victorian-Forest-Industry-Review-2015-FINAL.pdf Accessed 3 December 2018.
17. VEAC 2017, 'Conservation values of state forests: assessment report', Melbourne, Victoria http://www.veac.vic.gov.au/documents/Complete%20report%20for%20web%20page.pdf Accessed 3 December 2018.
18. Lindenmayer DB, Blair D, McBurney L, Banks S 2015, 'Mountain Ash: fire, logging and the future of Victoria's giant forests', CSIRO Publishing, Melbourne, Victoria.
19. Ibid

Current Victorian Government Settings: Legislation, Policy, Programs

Victoria's forests are managed in accordance with Victorian legislation, including the *National Parks Act 1975*, *Forests Act 1958*, *Conservation, Forests and Land Act 1987*, *Flora and Fauna Guarantee Act 1988*, *Crown Land (Reserves) Act 1978*, *Land Act 1958*, and *Sustainable Forests (Timber) Act 2004*, along with related regulations, codes of practice, management plans and policy initiatives.[20] The system undertakes to balance management of the multiple values of Victoria's forests, including environmental values.

Recent policy measures that address or overlap with the issues above include:

- *Protecting Victoria's Environment – Biodiversity 2037 (Biodiversity 2037)* which sets out a 20-year vision and goals for biodiversity in Victoria
- review of the *Flora and Fauna Guarantee Act 1988* (FFG Act), so that it can more effectively protect Victoria's biodiversity in the face of existing and emerging threats
- amendments to regulation of native vegetation with the aim of providing for better consideration of biodiversity elements in decision-making, including habitat for rare or threatened species, large trees, endangered ecological vegetation classes (EVCs), sensitive wetlands and coastal areas.

In 2017, the Victorian Environmental Assessment Council (VEAC) recommended the following be undertaken within five years:

- state forests be administered under one Act
- the *National Parks Act 1975* be expanded to include revised categories of national parks, conservation parks, nature reserves, marine protected areas, and other categories and overlays classified as protected areas, to become the 'National Parks and Conservation Reserves Act'
- a new public land Act be developed to replace the current *Land Act 1958, Crown Land (Reserves) Act 1978* and *Forests Act 1958*.

The Victorian Government has accepted these recommendations.

Elements of Victoria's forest management framework are accredited by the Commonwealth under five Regional Forest Agreements (RFAs).[21] The RFAs were a key outcome of the *National Forest Policy Statement (1992)* through which the federal, state and territory governments committed to the sustainable management of all Australian forests.

RFAs endeavour to maintain a comprehensive, adequate and representative reserve system, to manage forests on an ecologically sustainable basis, and provide for the long-term stability of forests and forest industries. All five Victorian RFAs are due to expire in March 2020.

The Victorian Government endorsed a program to modernise Victoria's RFAs. Over the next two years, the Department of Environment, Land, Water and Planning (DELWP) has committed to engaging with Victorian communities on how they value Victoria's forests. DELWP will also complete assessments of forest values, including environmental values, indigenous heritage values, economic values, social values and principles of ecologically sustainable management.

It is anticipated that the outcomes of the engagement and assessments processes will inform the modernisation of Victoria's RFAs and the planning and regulatory frameworks they accredit.

20. Turner J, Flinn D, Lambert M, Wareing K, Murphy S 2011, 'Management of Victoria's Publicly-owned Native Forest for Wood Production', *Forest & Wood Products Australia*, Melbourne, Victoria. http://www.fwpa.com.au/images/resources/PRC174-0910_Research_Report_Native_forest_project.pdf Accessed 3 December 2018.

21. DELWP 2018, 'Modernising Victoria's regional forest agreements', Melbourne, Victoria https://www.forestsandreserves.vic.gov.au/forest-management/regional-forest-agreements Accessed 3 December 2018.

Indicator Assessments

The Montreal Process

The Montreal Process is a voluntary agreement between nations to monitor and report on agreed criteria and indicators for the conservation and sustainable management of forests. Australia has accepted the criteria and developed indicators that best represent Australia's unique forest conditions in the *Framework of Regional (Sub-National) Level Criteria and Indicators of Sustainable Forest Management in Australia* (the framework).

Victoria has developed 45 indicators under the framework for reporting on Victoria's forest management.[22] To ensure accurate and consistent performance reporting against the criteria, since 2003, DELWP has produced three iterations of Victoria's SoF report every five years. Through the reporting process, a range of key challenges have been identified that are necessary to achieve sustainable forest management. Through discussions with relevant stakeholders, the Office of the Commissioner for Environmental Sustainability (OCES) has selected 20 indicators from six criteria relevant for the Montreal Process to be discussed in this chapter. A complete version of the OCES analysis, including all 45 framework indicators, will be presented in SoF 2018.

Victorian Forest Monitoring Program

The main data source for the Forests chapter is the Victorian Forest Monitoring Program (VFMP), which has informed 9 of the 21 forest-related indicators in this report.

DELWP's Victorian Forest Monitoring Program (VFMP) was stablished in 2011. It measures and monitors landscape-level trends in forest ecosystems in the Victorian public land estate, and is the only broad-scale forest-monitoring process operating in Australia.[23] It aims to provide relevant information for the Montreal Process, and contribute to policy development and decision-making related to carbon, biomass and ecosystem-service accounting, water-yield modelling, habitat structure, forest health and productivity, and the impacts of disturbances such as fire.

The VFMP comprises a network of 786 permanent ground plots, which are stratified (or grouped) into 21 distinct regions, according to Victoria's 11 bioregions (Table Fo.1 and Figure Fo.3)[24] and by public tenure ('state forests' and 'parks and conservation reserves'). The field measurement process achieved 84% (662 plots) of the 786 ground plots, with the remaining plots not measured due to various constraints such as accessibility or other hazards (Table Fo.1).

The results of the VFMP's first full cycle of measurements, completed in November 2015, are reported here. The second measurement cycle is to be completed in 2020.

22. Department of Sustainability and Environment 2007, 'Criteria and indicators for sustainable forest management in Victoria: guidance document', Melbourne, Victoria https://www.forestsandreserves.vic.gov.au/__data/assets/pdf_file/0022/30865/Vic_Indicators_for_SFM_Guidance.pdf Accessed 3 December 2018.

23. Haywood A, Thrum K, Mellor A, Stone C 2017, 'Monitoring Victoria's public forests: implementation of the Victorian Forest Monitoring Program'. *Southern Forests*, 2620, pp. 1–10.

24. Australian Department of the Environment and Energy, 'Australia's bioregions (IBRA)', Canberra, Australia http://www.environment.gov.au/land/nrs/science/ibra Accessed 3 December 2018.

Note that comparison of results between this report and SoF 2013 is limited due to changes to data collection, and improvements in data quality. For example, when SoF 2013 was prepared, only 337 plots (or approximately 50%) had been measured (Table Fo.1). While important, increased sample sizes and improved accuracy have introduced analytical 'noise'. More accurate trend analysis for all VFMP metrics will be possible from 2020 onwards, once two full measurement cycles have been completed.

VFMP evaluates its performance against a quality assurance and quality control (QA/QC) protocol.[25] The protocol involves a training and audit program that assesses a minimum 15% of plots per year – an increase of 7 percentage points from the previous report.[26] The QA/QC program is important to avoid any bias from data interpretation for evaluating natural and human-induced disturbance and the efficacy of management actions and policy decisions about public forests.

SoF reports prior to 2013 were produced based on data sources with varying spatial and temporal scales and a bias towards commercial state forests in eastern Victoria.[27] The VFMP is intended to help DELWP improve its forest monitoring activities with a more consistent and comprehensive monitoring approach across tenure (state forest/national park). However, the program has limitations, which have been acknowledged by its design team.[28] A relatively low sample size (786 at the time of the evaluation), determined by the available budget, means the program must leverage a three-tiered remote-sensing approach to improve its forest-area estimates. Consequently, the program's application to finer-scale or discrete metrics is not recommended. Rather, the program is designed to observe broad-scale, long-term trends in forest health and condition. It could be improved by investments in separate but complementary monitoring activities specific to important/relevant sites.

Note that DELWP has increased the sample size by 73 plots (from 786 to 859) since the evaluation was conducted, as a result of tenure change in the Riverina and improvements to spatial data accuracy.

Continuous improvement is necessary for the program to remain a useful tool to assist public land managers to observe the influence of tenure-specific management interventions (across national parks and state forests) at the bioregion level.

25. DELWP 2017, 'Standard operating procedures field guide (v2.1.0): Victorian Forest Monitoring Program', Melbourne, Victoria.
26. Haywood A, Thrum K, Mellor A, Stone C 2017, 'Monitoring Victoria's public forests: implementation of the Victorian Forest Monitoring Program'. *Southern Forests: Journal of Forest Science*, 80(2), pp. 185-194.
27. Ibid
28. Ibid

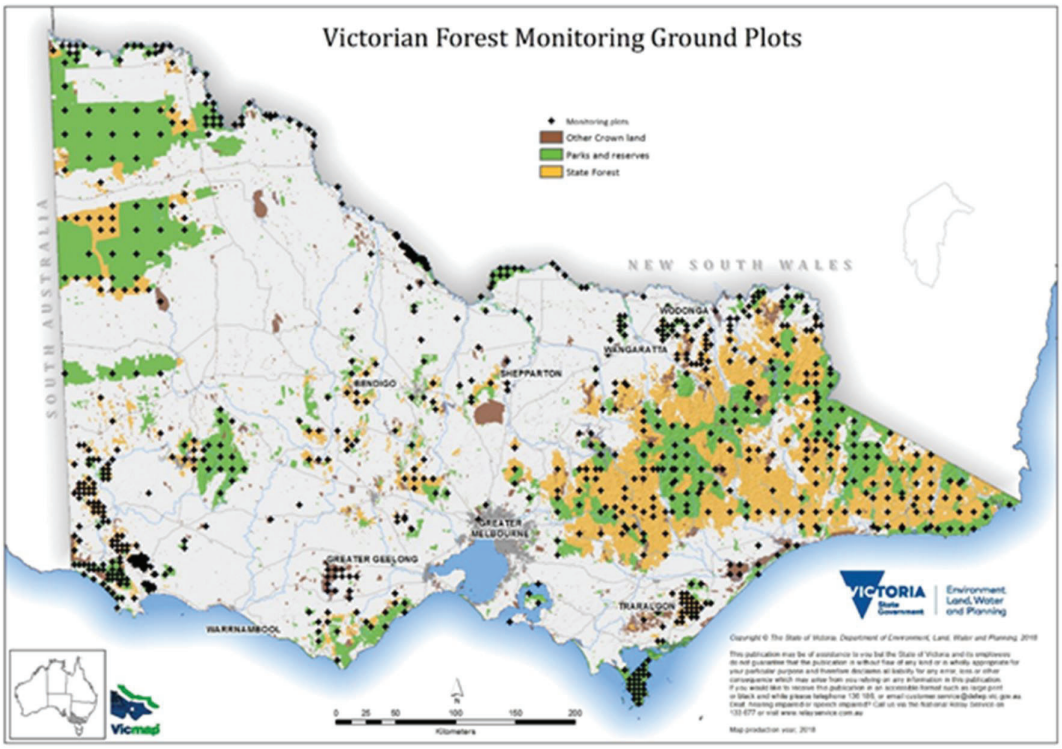


Figure Fo.2 Location of sampling units for VFMP

(Data source: DELWP, 2018)

Table Fo.1 Number of VFMP permanent sample plots per bioregion

Bioregion	2013 VFMP plots	2018 VFMP plots
Australian Alps	61	76
Flinders	9	19
Murray–Darling Depression	21	58
Naracoorte Coastal Plain	32	79
NSW South Western Slopes	27	65
Riverina	27	69
South East Coastal Plain	24	40
South East Corner	29	66
South Eastern Highlands	50	74
Victorian Midlands	36	66
Victorian Volcanic Plain	21	50
Total	**337**	**662**

(Data source: DELWP 2018)

Indicator Assessment

Legend

Status

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

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

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

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

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

Trend

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

? **Unclear**

↘ **Deteriorating**

→ **Stable**

↗ **Improving**

Data quality

Poor
Evidence and consensus too low to make an assessment

Fair
Limited evidence or limited consensus

Good
Adequate high-quality evidence and high level of consensus

FORESTS

	Summary	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend
Indicator **Fo:01A** Area of forest by type and tenure-forest canopy cover **Region** Victoria **Measures** Forest canopy cover **Data custodian** DELWP	Maps of forest cover in Victoria are based on satellite data. Although the 2008–13 data can provide the change in forest cover, the trends have not been demonstrated for this report, but will be included in future reports.	DATA QUALITY Poor	?

	Summary	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend
Fo:01B Area of forest by type and tenure-forest type **Region** Victoria **Measures** Forest area on public lands **Data custodian** DELWP	Forest extent in Victoria was heavily affected by the 2009 'Black Saturday' bushfires. But a decrease in the areas where classified as 'Forest unclassified (burnt)' demonstrates tree regrowth from previously burnt forest, largely concentrated in the Mallee.	DATA QUALITY Good	↗
Indicator **Fo:01C** Area of forest by type and tenure-plantation forest **Region** Victoria **Measures** Plantation area (hectare) New plantation establishment per year **Data custodian** ABS	Plantation area in private land had little change since 2009-10. This is due to a significant decline in new plantation establishment in Victoria (none since 2012-13).	DATA QUALITY Good	→
Indicator **Fo:02** Area of forest type by growth stage **Region** Victoria **Measures** Forest area by growth stage **Data custodian** DELWP	This indicator reports the growth stage by broad forest type which provides an indication of diversity and balance of growth stages across Victoria's forest estate. Comparison of two datasets captured in different years indicates that forest area in different types increased both in State forest, parks and reserves but it is still difficult to determine current status.	DATA QUALITY Good	↗

	Summary	Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **Fo:03** Area of forest type by growth stage distribution in protected zones **Region** Victoria **Measures** IUCN and PV protected area Implications of changes in IUCN and PV protected area for threatened species **Data custodian** DELWP, PV	Overall IUCN protected area increased between 2004 - 2016, and PV managed formal protected area (parks and reserves) also increased between 1956 - 2016. While this is anecdotally a positive outcome for conservation of forest systems, there is limited evaluation of the effectiveness of the protected area network in providing better protection of biodiversity assets such as threatened species.	DATA QUALITY Fair	↗
Indicator **Fo:04** Fragmentation of native forest cover **Region** Victoria and regional locations **Measures** Forest fragmentation: edge, interior, patch, perforated and transitional area by bioregion **Data custodian** DELWP	The presented data demonstrates a map of forest fragmentation in Victoria. As this is a snapshot of forest fragmentation in 2018, no trend analysis is available. Peer-reviewed journal papers have found that several threatened species are at risk due to forest fragmentation.	DATA QUALITY Fair	?

	Summary	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend
Indicator **Fo:05** Number of in-situ and ex-situ conservation efforts for forest dependent species **Region** Victoria **Measures** in-situ and ex-situ conservation activities on forest dependent threatened species Quantifiable conservation efforts **Data custodian** DELWP	In 2013, a method change occurred, making it difficult to determine benefits from management activities, and making trend analysis unachievable. The data presented has been provided by on-ground managers.	DATA QUALITY Poor	?
Indicator **Fo:06** The status of forest dependent species at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment **Region** Victoria **Measures** Conservation status: numbers of rare or threatened forest dependent species **Data custodian** DELWP	Since 2013, the only species group to be updated is vascular plants, in 2014. However, assessing changes in DELWP's advisory list related to plants can be misleading due to the frequent changes in botanical nomenclature. Except for the 36 species that were added, the status of the other 461 species has not been changed. Vascular plants represent by far the greatest proportion of these species. This might be due to greater knowledge and awareness of vascular plants within the scientific community, and their relative ease of detection. Since 2007–08, no changes have been observed in the number of rare or threatened amphibians.	DATA QUALITY Good	↘

	Summary	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend
Indicator **Fo:07** Degree of disturbance to native forest species caused by invasive species **Region** Victoria **Measures** Scale and impact of invasive species on native forests, plantation and urban/farm forests **Data custodian** DELWP	For most identified pathogens and insect agents in Victoria, damage during the reporting period has stabilised or decreased. But a few species, including Red Gum basket lerp, *Dothistroma* needle blight, Mycosphaerella leaf disease, Cypress canker and *Phytophthora cinnamomi* have expanded their distribution and impact.	FAIR DATA QUALITY Good	↘
Indicator **Fo:08A** Scale and impact of agents and processes affecting forest health and vitality – mortality, dieback, canopy health sub-section **Region** Victoria **Measures** Degree of leaf damage based on mortality, crown dieback, crown defoliation **Data custodian** DELWP, BoM	Robustness of previous datasets is weaker than current dataset, preventing comparison of current and past data. Across all Victorian bioregions, the average percentage of areas showing mortality, crown dieback and canopy health impacted are 14.3%, 20.3% and 23.3 % respectively.	FAIR DATA QUALITY Fair	?

	Summary	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend
Indicator **Fo:08B** Scale and impact of agents and processes affecting forest health and vitality – bushfire affected area and climate sub-section **Region** Victoria **Measures** Bushfire affected area (hectare) Annual mean temperature by year Number of unusually warm days by year **Data custodian** DELWP, BoM	Between 2013 and 2018, The most damaging bushfire on record is the Wye River-Jamieson Track fire, instigated by lightning on 19 December 2015. The fire exceeded control lines on Christmas Day under extreme weather conditions, burning 2,520 hectares of national park and private properties, with an estimated 160 houses. Between 2013 and 2014, Victoria experienced its most significant fire season since 2008, which challenged emergency services and Victorian communities. Across the season, Victoria had 19 days of Extreme and Severe Fire Danger Rating, and 16 days of Total Fire Ban. More than 463,000 hectares of public and private land was burnt, and 80 residences destroyed. Bushfire-affected area has been decreasing since 2003. Annual mean temperature and number of unusually warm days are increasing. This could reverse this trend in the future.	DATA QUALITY Good	↘
Indicator **Fo:09A** Area and type of human-induced disturbance – Planned burns **Region** Victoria **Measures** Annual planned burn area **Data custodian** DELWP	Following the 2010 final report by the 2009 Victorian Bushfires Royal Commission, the Victorian Government committed to expand its planned-burning approach by aiming to reduce fuel hazards and protect human life. But in 2016, based on recommendations by the Inspector-General for Emergency Management, the government began to shift from a hectare-based approach to a risk-based approach to bushfire management. This focuses on areas where the likelihood of a bushfire starting, spreading and impacting on people, property and the environment is greatest, based on fire-modelling results. The government is developing a system of bushfire management strategies to reduce risk, to be delivered by 2020. A strategic change in planned-burning targets prevents trend analysis.	DATA QUALITY Good	?
Indicator **Fo:09B** Area and type of human-induced disturbance – grazing **Region** Victoria **Measures** Number of licences issued for grazing activities **Data custodian** DELWP	License numbers and payments for rent or other activities on Crown land in the reporting period were stable. However, it is difficult to assess status, as the relationship between license numbers and environmental impact is unknown. No information on the size of grazing area has been identified.	DATA QUALITY Poor	→

	Summary	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend
Indicator **Fo:10** Total forest ecosystem biomass and carbon pool by forest type, age class and succession all stages **Region** Victoria **Measures** Total carbon distribution per bioregion, tenure and type **Data custodian** DELWP	The amount of carbon mass is presented by bioregion, tenure and type. Relevant information for a single period is presented as provided from the VFMP. Trend analysis will be possible from 2020, once the five-year panel system is fully implemented.	DATA QUALITY Fair	?
Indicator **Fo:11** Contribution of forest ecosystems to the global greenhouse gas balance **Region** Victoria **Measures** Carbon dioxide emissions by sector **Data custodian** DELWP	Since 2011, there has been an increase in sequestration from forest management activities, driven by 20 vegetation projects funded by the Emissions Reduction Fund over the last 5 years. This trend is observed through an upsurge in the Kyoto Australian carbon credit unit (KACCU), representing abatement from activities that contribute to the nation's emission targets under the Kyoto protocol. Estimated net contribution of the Fund to the sequestration in LULUCF is minimal. Compared to other sectors, including waste and agriculture, proportional contribution of forest related activities to state-scale greenhouse gas balance is minimal.	DATA QUALITY Good	↗
Indicator **Fo:12** Area and percentage of forest and net area of forest available and suitable for wood production **Region** Victoria **Measures** Area and percentage of forest and net area of forest available and suitable for wood production **Data custodian** VicForests, DELWP	The Resource Outlook from VicForests has reduced the available timber production area in State forests. The Resource Outlook defines the volume of hardwood timber products from native forests made available to the market, separating the species groups of timber supply into two groups: ash and mixed-species. The reduction in availability of sawlog resource in areas such as the Central Highlands of Victoria can be attributed to the effects of fire in estimates of sustained yield. The trend indicates that less timber production in state forests will occur in the future and more emphasis will be on other values including species conservation and carbon sequestration issues.	DATA QUALITY Good	↘

	Summary	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend
Indicator **Fo:13** Area of native forest harvested **Region** Victoria **Measures** Area available for native timber harvesting **Data custodian** VicForests, DELWP	Allocation Order shows that the area available to harvest for ash timber will decrease dramatically, whereas that for mixed species will increase. The overall area available for timber harvesting is stable.	DATA QUALITY Good	
Indicator **Fo:14** Annual production of wood products from State forests compared to sustainable harvest levels **Region** Victoria **Measures** Annual production of wood products from State forest **Data custodian** VicForests, DELWP	Total timber annual production from state forests has been gradually decreasing. Decreasing sawlog production, seen over the past 20 years, has continued. Production fell by more than 50% between 1996-97 and 2016-17. Pulpwood has followed a similar trend. This will deteriorate further, as age class distribution of ash forests are highly imbalanced.	DATA QUALITY Good	
Indicator **Fo:15** Proportion of timber harvest area successfully regenerated by forest type **Region** East Victoria **Measures** Net native forest area regenerated **Data custodian** VicForests	Between 2011–17, 2,059 hectares more have been harvested than regenerated. This does not indicate that sustainable harvest has not been achieved, according to DEDJTR. The figures show the area harvested in a specified five-year period, and the area regenerated in the same five-year period. This needs to be carefully monitored to ensure successful post-harvest timber harvest is fully achieved. A VAGO 2013 audit report found that the harvest manager, VicForests, was meeting the required regeneration standards, but recommended better alignment of harvesting and regeneration reports. .	DATA QUALITY Good	

	Summary	Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **Fo:16** Extent to which the legal framework (laws, regulations, guidelines) supports the conservation and sustainable management of forests **Region** Victoria **Measures** Impact of legislations on conservation and sustainable management of forests **Data custodian** DELWP	There are currently 33 legislations that regulate forest management in Victoria. VEAC provided its *Statewide Assessment of Public Land Final Report* to government in May 2017, including several recommendations to reform the complex public land legislative framework. The Victorian Government has accepted, or accepted in principle or in part, all recommendations made by VEAC, including committing to rewriting the Crown land legislation over the next four years.	DATA QUALITY Fair	
Indicator **Fo:17** Extent to which the institutional framework supports the conservation and sustainable management of forests **Region** Victoria **Measures** The overall assessment result of compliant and non-compliant audit **Data custodian** DELWP	Audits since 2014 have targeted elements of the regulatory framework that have been assessed as having a 'high risk' of causing environmental harm. While the 'high risk' elements have been targeted, VicForests have indicated a high level of compliance with lower risk prescriptions for timber production harvesting and coupe closure activities throughout the reporting period. The major environmental impact of timber production harvesting and coupe completion operations has been increasing.	DATA QUALITY Fair	

	Summary	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend
Indicator **Fo:18** Extent to which the economic framework supports the conservation and sustainable management of forests **Region** Victoria **Measures** Description of economic framework in Victoria to quantify and evaluate all relevant aspects for the conservation and sustainable management of forests **Data custodian** DELWP	The overall assessment result of compliant and non-compliant audit elements by different environmental impact categories since 2014 for native timber harvesting activities is described in this indicator. VicForests has indicated a high level of compliance with lower risk prescriptions for timber production harvesting and coupe closure activities throughout the reporting period. Some coupes that were harvested between 2014-15 and 2015-16 were assessed to have major environmental risk. A number of these coupes have been increasing which must be identified and investigated in the future.	DATA QUALITY Fair	?
Indicator **Fo:19** Capacity to conduct and apply research and development aimed at improving forest management, including development of scientific understanding of forest ecosystem characteristics and functions **Region** Victoria **Measures** Number of full-time equivalent employees by research activity for government agencies, private companies and academia **Data custodian** DELWP	Although the overall number of Full-time equivalent (FTE) employees remained unchanged, FTE employees in academia increased by around 4 FTE in fire behaviour and forest hydrology when comparing 2011-17. Conversely, the FTEs in government agencies decreased the same amount in fire and flora ecology. For both years, topics related to fire, ecology and hydrology accounted for 80% of overall FTE employees. DELWP indicates that current budget allocation for R&D is based on identification and prioritisation of research directions. The organisation also explained that the expected impact of the research activities on management actions or policy change has been documented.	DATA QUALITY Good	→

	Summary	Status UNKNOWN POOR FAIR GOOD	Trend
Indicator **Fo:20** Investment and expenditure in forest management **Region** Victoria **Measures** Expenditure on forest management **Data custodian** DELWP	Expenditure for forest fire management was reduced to $269.9 million in 2016–17. Prior to this, it fluctuated, including up to $396.5 million in 2015–16. Reported expenditure on conservation and recreation increased significantly between 2014-15 and 2016-17 to $369.8 million. This may reflect increased Victorian Government focus on conservation and recreational values in state forests, parks and reserves.	DATA QUALITY Good	
Indicator **Fo:21** Value ($) of forest derived ecosystem services **Region** Victoria **Measures** ($) Value of forest derived ecosystem services **Data custodian** DELWP	Forest ecosystems provide a suite of ecosystem services, including climate regulation, water supply, and filtration and habitat services. There is no state-scale approach that quantifies the value ($) of forest-derived ecosystem services in Victoria. Existing regional-scale approaches could be expanded to work on a state-scale.	DATA QUALITY Fair	?

Ecosystem Diversity

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:01 Area of forest by type and tenure	●	○	○	○	?	DATA QUALITY Poor

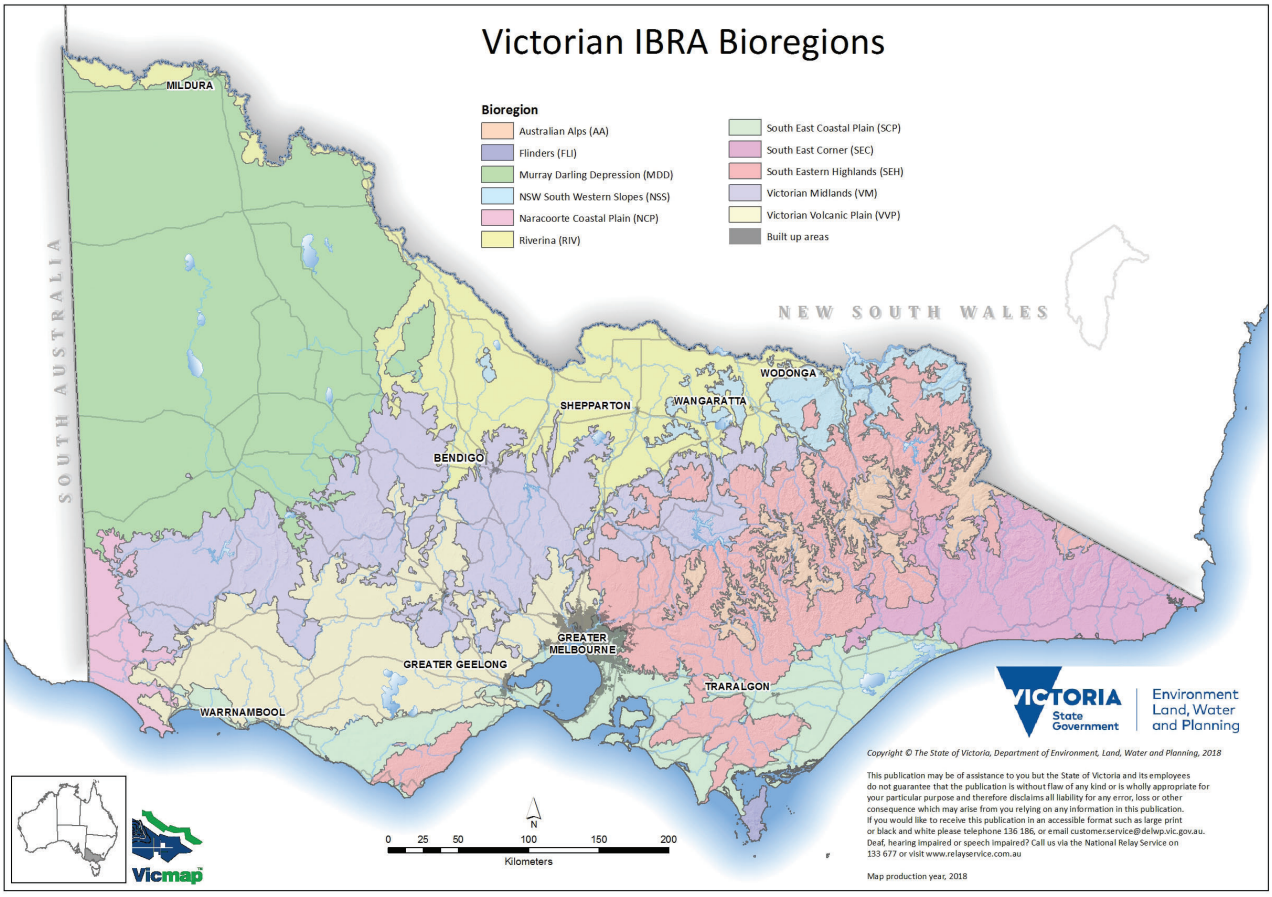


Figure Fo.3 Interim Biogeographic Regionalisation for Australia bioregions in Victoria

(Data source: DELWP, 2018)

To effectively manage Victorian forests, it is necessary to understand forest area by type, as it provides a broad measure of forest ecosystem and biodiversity maintenance. Changes in forest area and structure over time also provide an indicator for the impact of environmental disturbances and extreme events on forest ecosystems (such as bushfires).

Bioregions are the major geographic stratification unit for the VFMP, with 11 bioregions located within Victoria (Figure Fo.3). Within each bioregion, further divisions are made based on public land tenure. In Victoria, state forests and parks and reserves are the two major tenures of interest for this report.[29] State forests are primarily managed for conservation and recreation, with small portions of areas for native-timber harvesting. Parks and conservation reserves are managed for conservation outcomes as well as recreation and tourism. Intensive recreation takes place in some areas, such as alpine parks.

This indicator provides information on the area of forest by broad forest type and tenure, as well as change in forest extent (forest cover) over time. Forest types, including height and canopy-cover classes, are defined according to Australia's National Forest Inventory (NFI) definitions. Information about area of forest by forest type and tenure is reported for public forests and plantations on private land.

29. Department of State Development, Business and Innovation, 'Public land management (PLM25)', Melbourne, Victoria https://www.data.vic.gov.au/data/dataset/public-land-management-plm25 Accessed 3 December 2018.

	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
Fo:01A Area of forest by type and tenure- forest canopy cover Data custodian DELWP		?	DATA QUALITY Poor

Forest canopy cover is derived from the freely available Landsat archive, with a baseline year of 2013. (This is consistent with the five-year interval used in SoF 2013, which presented a 2008 baseline year.) A binary (forest/non-forest) classification is applied. The identified forest area is used as the extent for the direct expansion method, from which the aspatial forest type estimates described above are derived (Figure Fo.4).

Comparison of this product to national and global forest-cover products[30] suggests this process is relatively accurate for state-level reporting, with a global error of +/– 15% variable across the state. It is even more accurate for public land, which provided the source of validated, ground-truthed data.

Analysis demonstrates that forest-cover confidence is lowest in the Mallee and some coastal regions, particularly in national and global forest-cover products. Although the 2008–13 data can provide the change in forest cover, the trends have not been analysed for this report due to time constraints, but will be included in future reports.

Figure Fo.4 Victorian forest cover, 2018

(Data source: DELWP, 2018)

30. Soto-Berelov M, Jones SD, Haywood A 2018, 'Assessing large area forest cover products derived from the same imaging source across Victoria, Australia', *Ecological Management & Restoration*, 19(1), pp. 66-75.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:01B Area of forest by type and tenure-forest type	○	○	●	○	↗	DATA QUALITY Good
Data custodian DELWP						

'Forest' is defined by Australia's National Forest Inventory as an area greater than 0.5 hectares of native forest, with a dominant vegetation height of greater than 2 m and canopy cover greater than 20%. Areas that meet this definition are assigned a land cover classification based on the species they are home to, dominant height and canopy cover, as well as the level of disturbance experienced. Forest types are based on the relative abundance of eucalypt species (eucalypt, mallee or mixed) and divided into height classes: low (2–10 m), medium (11–30 m) and tall (>30 m).

Forest-area estimates are derived from a network of 2 km x 2 km high-resolution aerial photographs taken above each VFMP plot. The photographs have been interpreted by trained practitioners and provide information describing the boundaries of different forest and land regions using the classifications of broad forest type, canopy cover and height, as described above.

A direct expansion method[31] was used to inform area and uncertainty estimates. This method has been found to be practical for land-cover-type mapping.[32] It incorporates digitised representative sample units through mathematical functions, enabling unbiased, landscape-scale land-cover interpretation of estimates with minimal sampling size.[33] (Information about forest type on private land is not reported under this methodology; however, some estimates are provided in the section on Forest Canopy Cover.[34]

The VFMP estimates forest extent with the help of remote-sensing technology. In 2013, the forest area estimates were derived from imagery from a five-year period (2003–07) and modelled to a baseline year of 2008. The forest-area estimates in this report were derived from a 5-year period (2008–12) and modelled to 2013.

The forest-area estimates report the land-cover types of Victoria's major vegetation types based on predominant height.[35]

The area of most forest types has increased. A notable exception is the 'forest unclassified (burnt)' type. This increased dramatically after the February 2009 'Black Saturday' fires (Table Fo.2 and Table Fo.3), but has decreased as forest areas recover (Figure Fo.5 and Figure Fo.6).

Note that methodological uncertainty may contribute to observed variation. For example, the dataset from 2018 is more comprehensive, with 15 additional Aerial Photo Interpretation (API) plots. Another potential source of error is the improved resolution of DELWP's corporate public land management spatial layer, which has improved from 100 m resolution in 2008 to 25 m resolution in 2013. Manual interpreters, with the aid of higher-resolution images, may make different decisions about forest types.

31. Deppe F 1998, 'Forest Area Estimation Using Sample Surveys and Landsat MSS and TM Data', *Photogrammetric Engineering and Remote Sensing*, 64(4), pp. 285-292.
32. Kamaruzaman JHj, Hasmadi IM 2008, 'Mapping and quantification of land area and cover types with Landsat TM in Carey Island, Selangor, Malaysia', *Modern Applied Science*, 3(1), pp. 42.
33. Ibid
34. Farmer E, Jones S, Clarke C, Buxton L, Soto-Berelov M, Page S, Mellor A, Haywood A 2013, 'Creating a large area landcover dataset for public land monitoring and reporting', In C. Arrowsmith, C. Bellman, W. Cartwright, S. Jones, & M. Shortis (Eds.), Progress in Geospatial Science Research (pp. 85–98). Publishing Solutions, Melbourne, Victoria.
35. Farmer E, Jones S, Clarke M, Soto-Berelov M, Mellor A, Haywood A 2011, 'Semi-Automated API for Large Area Public Land Monitoring and Reporting'. *Proceedings of the GSR_1 Research Symposium*, Melbourne, Australia, 12-14 December 2011, pp. 1–12.

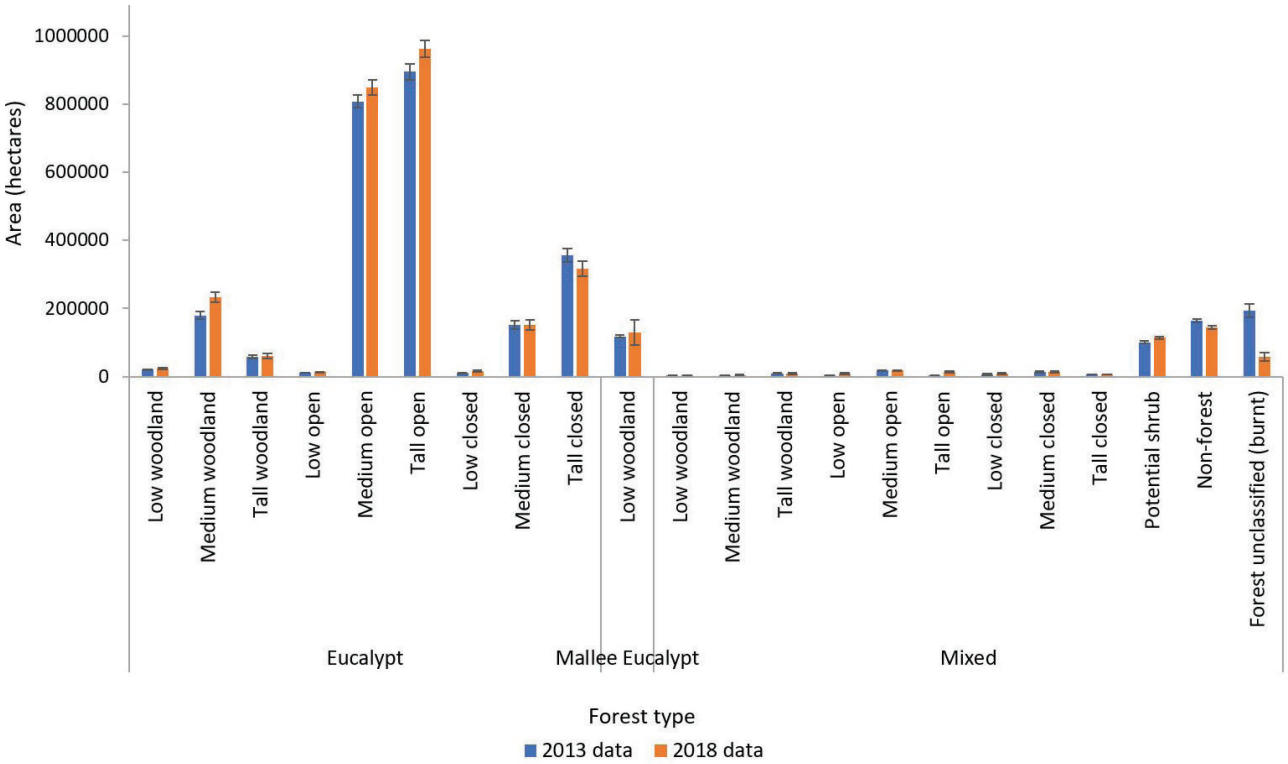


Figure Fo.5 Area of forest by broad forest type, height and canopy cover in state forest

(Data source: DELWP, 2018)

Table Fo.2 State forest area estimates

Forest type/land cover	Cover	2013		2018	
		Area (ha)	C.I. (95%)	Area (ha)	C.I. (95%)
Eucalypt	Low woodland	19,895	8.3	23,313	12.5
	Medium woodland	179,929	6.5	233,037	6.2
	Tall woodland	58,281	7.9	60,647	10.6
	Low open	11,492	6.5	12,559	6.2
	Medium open	808,105	2.4	849,327	2.7
	Tall open	895,140	2.6	962,058	2.6
	Low closed	10,301	15.2	16,805	15.7
	Medium closed	151,501	8.2	152,784	9.7
	Tall closed	356,340	5.3	317,722	7.0
Mallee Eucalypt	Low woodland	117,872	2.8	128,802	28.5
Mixed	Low woodland	3,683	4.0	3,381	6.7
	Medium woodland	4,601	5.5	4,766	6.3
	Tall woodland	9,637	17	9,531	28.3
	Low open	3,582	13.7	8,504	19.9
	Medium open	17,859	7.4	17,592	9.4
	Tall open	3,750	30.5	13,802	18.7
	Low closed	6,266	29.5	7,756	28.6
	Medium closed	14,055	16.3	14,027	20.7
	Tall closed	6,533	10.6	6,429	15.3
Potential shrub		100,658	3.8	113,566	3.6
Non-forest		163,719	2.5	143,794	3.1
Forest unclassified (burnt)		194,257	10.1	57,935	21.5

Note: C.I. = confidence interval

(Data source: DELWP, 2018)

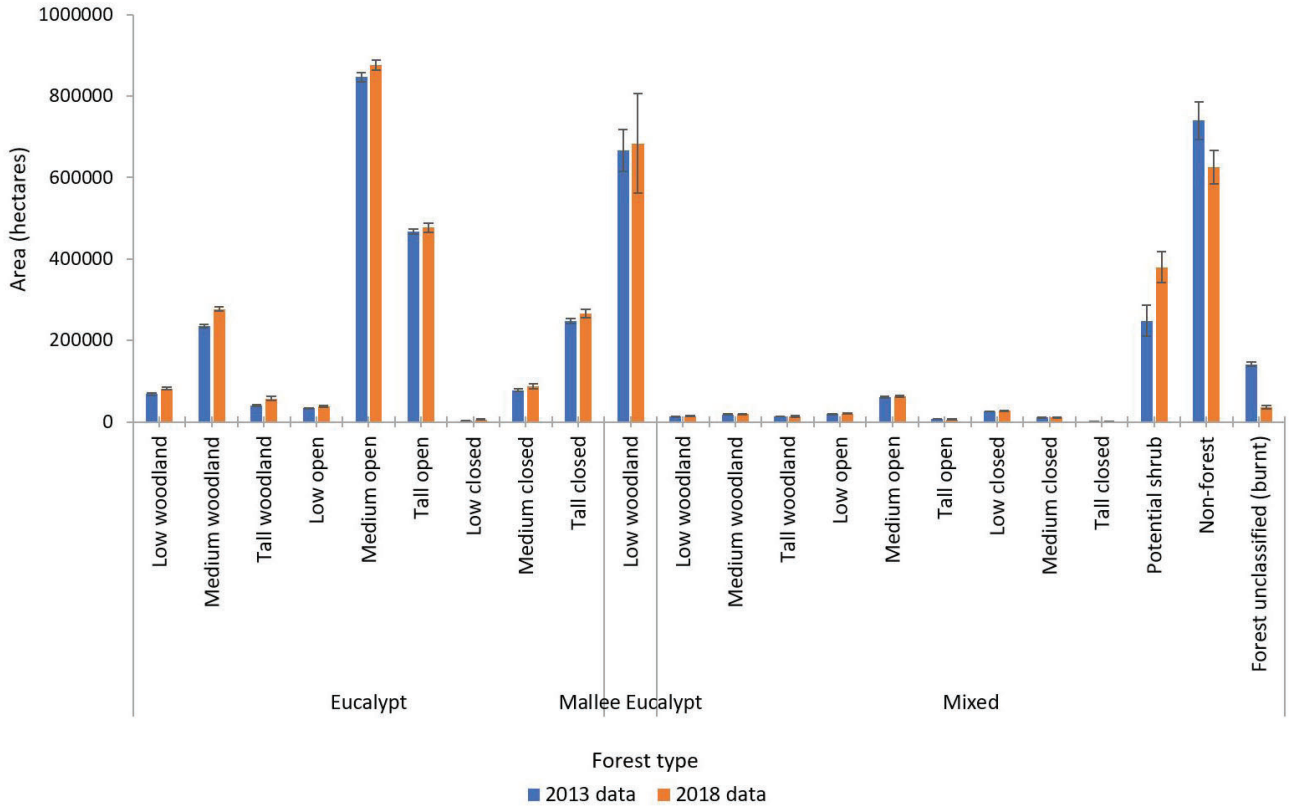


Figure Fo.6 Area of forest by broad forest type, height and canopy cover in parks and reserves

(Data source: DELWP, 2018)

Table Fo.3 Parks and reserves area estimates

Forest type/land cover	Cover	2013		2018	
		Area (ha)	C.I. (95%)	Area (ha)	C.I. (95%)
Eucalypt	Low woodland	68,001	4.8	81,773	4.1
	Medium woodland	234,369	1.7	277,013	2.0
	Tall woodland	39,830	5.4	57,193	9.4
	Low open	33,105	5.4	38,337	5.2
	Medium open	846,636	1.4	875,429	1.4
	Tall open	467,166	1.4	476,742	2.2
	Low closed	2,877	8.5	5,933	9.1
	Medium closed	77,993	3.1	87,878	6.8
	Tall closed	246,887	2.4	265,896	3.7
Mallee Eucalypt	Low woodland	665,686	7.7	683,707	17.8
Mixed	Low woodland	12,399	4.9	13,734	7.3
	Medium woodland	18,410	5.0	18,711	7.6
	Tall woodland	13,131	5.8	13,165	16.1
	Low open	19,418	5.3	20,478	5.3
	Medium open	60,099	2.7	62,466	2.6
	Tall open	6,784	8.3	6,069	23.7
	Low closed	25,599	1.9	27,210	3.4
	Medium closed	10,520	2.2	10,336	5.1
	Tall closed	241	12.8	241	39.3
Potential shrub		247,927	15.3	379,715	9.9
Non forest		739,807	6.3	625,948	6.6
Forest unclassified (burnt)		141,083	3.9	35,814	9.2

Note: C.I. = confidence interval

(Data source: DELWP, 2018)

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:01C Area of forest by type and tenure-plantation forest					→	DATA QUALITY Good
Data custodian ABS						

Victoria's plantation forests provide export and domestic timber products, including both hardwood and softwood. Plantation forests are almost all privately owned (99%).

The most recent statistics, from 2015to 2016, show Victoria has the largest total area of plantations in Australia.[36] Victorian plantations account for approximately one-fifth of Australia's total plantation forest estate. Each year, plantation areas are harvested extensively, and some are not replanted and possibly left fallow. (Note that in this report, 'plantation' describes land use: both planted and fallow land may be referred to as 'plantation').

In 2016–17, there were 421,700 hectares of industrial hardwood and softwood plantations in Victoria (Figure Fo.7). Over the past 18 years, commercial softwood plantation areas have been stable at between 212,000 and 226,000 hectares. By contrast, commercial hardwood plantation areas doubled in the 10 years since the 1999–2000 financial year, from 101,500 to 203,000 hectares. (This increase was mainly due to managed investment schemes, popular in the early 2000s. A number of high-profile agri-business managed investment schemes collapsed, resulting in substantial losses for many investors).

Since the 2010–11 financial year, plantation areas have gradually decreased by approximately 11,200 hectares (Figure Fo.7). This is due to a decrease in the rate of new plantation establishments since 2000.

Newly established plantation areas in Victoria have decreased sharply from a peak of approximately 38,000 hectares in 1999–2000 (Figure Fo.8). No new plantation areas have been established since the 2012–13 financial year. Victoria pledged $110 million in the 2017–18 budget to assist plantation establishment in the Latrobe Valley, to support the long-term sustainability of Victoria's timber-harvesting industry.[39]

36. Australian Department of Agriculture and Water Resources ABARES, 'Australian plantation statistics 2017 update', Canberra, Australia https://data.gov.au/dataset/pb_aplnsd9abfe20170503/resource/477323a0-11dd-4276-a765-dc8e19fdeb49 Accessed 3 December 2018.

39. Victorian Department of Treasury and Finance 2017, 'Getting on with the job: Victorian Budget 17/18 overview', Melbourne, Victoria https://www.dtf.vic.gov.au/sites/default/files/2018-02/state-budget-overview-2017-18.pdf Accessed 4 December 2018.

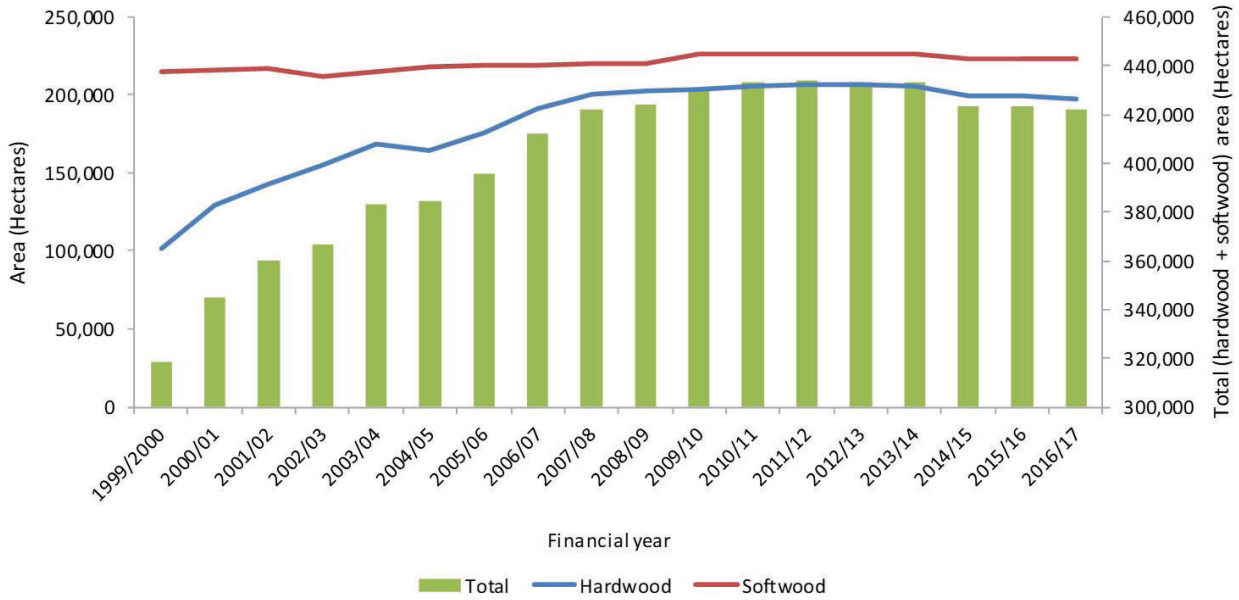


Figure Fo.7 Plantation areas in Victoria, 1999–2000 to 2016–17 [37, 38]

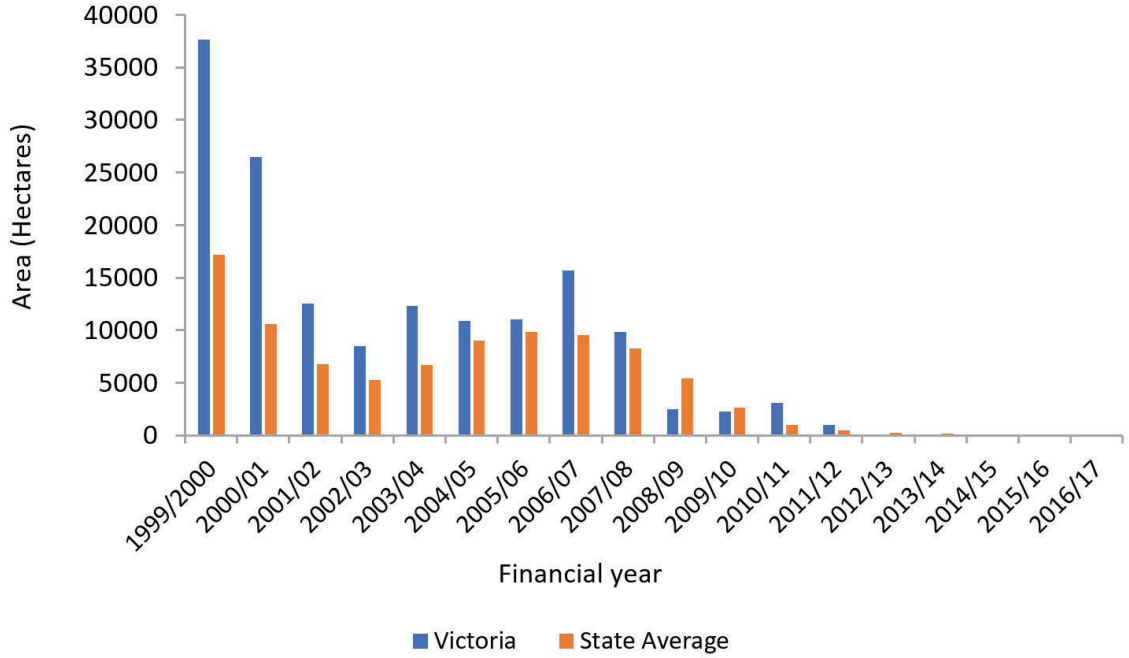


Figure Fo.8 Area of new plantation establishment in Victoria, 1999–2000 to 2016–17[40]

37. Australian Department of Agriculture and Water Resources ABARES 2018, 'Australian forest and wood products statistics: September and December quarters 2017', Canberra, Australia http://data.daff.gov.au/data/warehouse/9aaf/afwpsd9abfe/afwpsd9abfe20180524/AFWPSOverview_Sep-Dec_2017_v1.0.0.pdf Accessed 4 December 2018.
38. Australian Department of Agriculture and Water Resources ABARES 2007, 'Australian forest and wood products statistics: September and December quarters 2006', Canberra, Australia http://data.daff.gov.au/data/warehouse/pe_abare99001363/afwps06.2_sept__dec06.pdf Accessed 4 December 2018.
40. Australian Department of Agriculture and Water Resources ABARES 2018, 'Australian forest and wood products statistics: September and December quarters 2017', Canberra, Australia http://data.daff.gov.au/data/warehouse/9aaf/afwpsd9abfe/afwpsd9abfe20180524/AFWPSOverview_Sep-Dec_2017_v1.0.0.pdf Accessed 4 December 2018.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:02 Area of forest type by growth stage					↗	DATA QUALITY Good
Data custodian DELWP						

Understanding the previous and current growth stages of forests in Victoria is important for sustainable forest management. Forest dynamics, and particularly species succession, can be drastically altered by natural and human-induced disturbances, which are increasing. Knowledge of growth stages, and subsequent forest-recovery conditions, is thus critical for decision-making by land managers to mitigate any ecological losses.[41]

This indicator provides information on the area and extent of forest ecosystem types, including successional stage, age class and the nature of tenure or ownership. Reporting the growth stage by broad forest type provides an indication of the diversity and balance of growth stages across Victoria's forest estate.

In this report, forest area is classified by height, which is considered a growth-stage indicator. Height is classified according to the NFI[42] forest definition into three types, depending on stand height:

- low: 2–10 m
- medium: 11–30 m
- tall: > 30 m

The total area of all forest types, except 'non-forest' (describing a traditional forest area that currently has no trees due to disturbances including fire damage), increased between the two assessments.

Recovery of forests following the 2009 Black Saturday bushfires explains the large reduction in 'non-forest' areas compared with SoF 2013, which has a baseline year of 2008. Fire-affected areas that regrew post-2008 are likely to have been reclassified from 'non-forest' to 'forest' or 'forest potential shrub'.

Medium and tall eucalypt forests make up 63% of the native forests across Victoria's state forests, parks and conservation reserves, covering an area of 4.6 million hectares. While the total area of medium and tall forest has increased since 2013, the relative proportion of these types has declined by approximately 15% due to an increase in low eucalypt, low mixed/other forest and forest potential shrub with a decrease of non-forest area. This is predominately due to residual mallee regrowth from fires that occurred during the 2002-03 summer bushfire season. For a description of the method used to calculate areas and associated uncertainty estimates indicator Fo:01 (Area of forest by type and tenure)

41. Franklin JF, Lindenmayer DB, MacMahon JA, McKee A, Magnusson J, Perry DA, Waide R, Foster DR 2000, 'Threads of continuity: ecosystem disturbances, biological legacies and ecosystem recovery', *Conservation Biology in Practice*, 1, pp. 8-16.
42. Australian Department of Agriculture and Water Resources ABARES, 'Australia's national forest inventory', Canberra, Australia http://www.agriculture.gov.au/abares/forestsaustralia/australias-national-forest-inventory Accessed 3 December 2018.

Table Fo.4 Broad forest types by estimated area in State forest and Parks and conservation reserves

Forest type and height class	State forests				Parks and conservation reserves			
	2013		2018		2013		2018	
	Area (ha)	C.I.	Area (ha)	C.I.	Area (ha)	C.I.	Area (ha)	C.I.
Low Eucalypt	41,688	6.1	52,677	7.4	103,983	3.6	126,042	3.1
Medium Eucalypt	1,139,535	1.8	1,235,148	1.9	1,158,997	1.1	1,240,319	1.1
Tall Eucalypt	1,309,761	1.8	1,340,426	1.8	753,883	1.0	799,832	1.7
Mallee Eucalypt	117,872	2.8	128,802	28.5	665,686	7.7	683,707	17.8
Low mixed/other* forest	13,530	15.6	19,641	15.7	57,416	2.6	61,421	2.5
Medium mixed/other forest	36,514	7.6	36,385	9.5	89,029	2.7	91,513	2.6
Tall mixed/other forest	19,920	11.9	29,762	11.6	20,156	6.1	19,475	15
Forest potential shrub†	100,658	3.8	113,566	3.6	247,927	15.3	379,715	9.9
Non-forest	359,003	5.5	203,421	5.6	881,388	5.4	662,277	6.2

C.I. = Confidence Interval (95%)

†Forest potential shrub: previously forested land cover which has undergone significant disturbance (such as short-interval bushfire) or clearance (such as by clearfell logging), but which is known to be regenerating as 'forest' (according to NFI definition).

** Mixed/other forest types include casuarina, callitris, acacia, melaleuca, rainforest and mangrove. Eucalypt forests comprise the vast majority of Victoria's public forests. As a result, other forest types are underrepresented in the land cover map ecause sampling and obtaining reliable area estimates is difficult. For this analysis, these forest types are aggregated into a 'mixed and other forest types' class. Based on data presented in SoF 2008, other forest types make up less than 10% of Victoria's total native forest area.*

(Data source: DELWP, 2018)

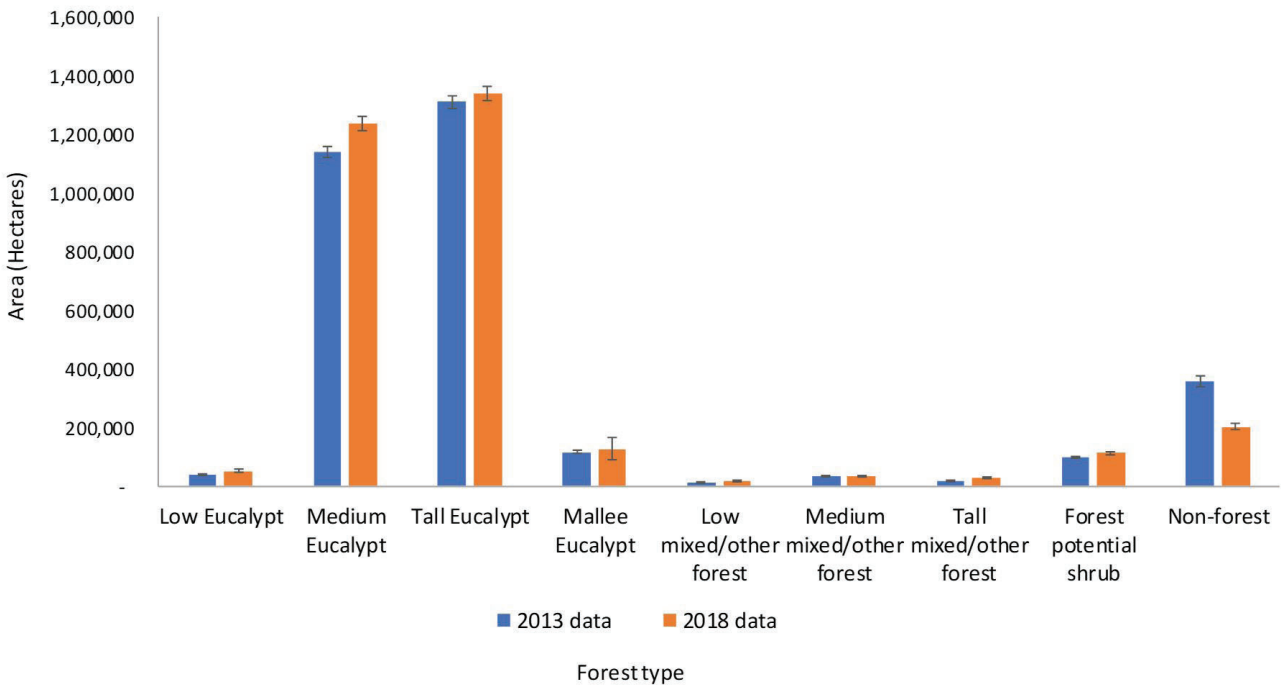


Figure Fo.9 Area of state forest by forest type, 2013 and 2018

(Data source: DELWP, 2018)

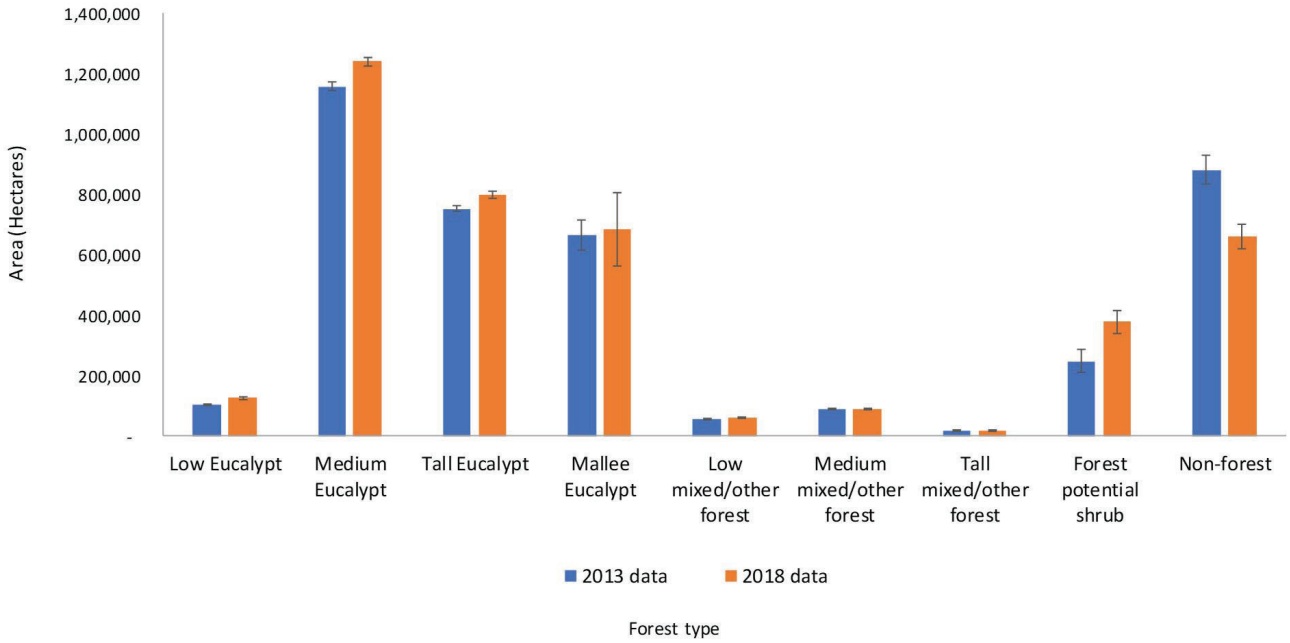


Figure Fo.10 Area of parks and reserves by forest type, 2013 and 2018

(Data source: DELWP, 2018)

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:03 Area of forest type by growth stage distribution in protected zones	○	○	●	○	↗	DATA QUALITY Fair

Data custodian DELWP, Parks Victoria

The protection of biodiversity to sustain forest ecosystems and the species that inhabit them is fundamental to Victoria's approach to forest conservation. It is also a key objective of sustainable forest management.

The management of forests in Australia is guided by the 1992 *National Forest Policy Statement* (NFPS): a set of broad goals agreed to by Commonwealth, state and territory governments. The goals undertake to embed the concept of ecologically sustainable development. The aim is to manage Australia's native forests to conserve biological diversity, heritage, and cultural values, while at the same time developing an internationally competitive forest products industry based on native forests that are managed sustainably.

Major elements of the NFPS include a commitment to the development of a comprehensive, adequate and representative (CAR) reserve system, and implementation of strategies to protect old-growth forests and wilderness as part of the reserve system. The CAR reserve system is based on three principles:

- including the full range of vegetation communities (comprehensive)
- ensuring the level of reservation is large enough to maintain species diversity (adequate)
- conserving the diversity within each vegetation community, including genetic diversity (representative).

The system identifies the forested areas based on 'JANIS'[43] criteria to protect nature conservation reserves.[44]

43. Australian Department of Agriculture and Water Resources, 'Protecting our forest environment', Canberra, Australia http://www.agriculture.gov.au/forestry/policies/rfa/about/protecting-environment Accessed 3 December 2018.
44. Australian Department of Agriculture and Water Resources, 'Conservation of Australia's forests', Canberra, Australia http://www.agriculture.gov.au/forestry/australias-forests/forest-mgnt/conservation Accessed 3 December 2018.

The CAR reserve system contains two categories, formal and informal reserves, defined as follows:

- formal reserve: including Crown land formally reserved where environmental protection that provides legislated prohibition on timber harvesting is required – such as forest parks, national parks, state parks, nature conservation reserve and other conservation reserve
- informal reserve: including public land where public authorities are assigned to achieve conservation values while excluding timber harvesting.

The proportion of Victorian land assigned formal protection status has risen from less than 1% in the 1950s to 17% in 2016 (Figure Fo.11). Between the late 1970s and early 1990s, the addition of more than 3,000 protected areas significantly increased the total formal protected area. Much of this increase was due to changes to the *National Parks Act 1975* and *Crown Land (Reserves) Act 1978*.

Between 2000 and 2014, the total area of parks and conservation reserves increased by around 400,000 hectares. Since 2014, additional land parcels have been added as a result of improvements and clarifications to Crown land records, changes of the on-ground manager (for example, land has moved from Parks Victoria to Water Authority/VicTrack[45]) and the purchasing and reserving of land.

45. VicTrack is a state-owned enterprise which owns all railway and tram lines.

Details of significant additions to reserves are described in Table Fo.5. (Note that the addition of land to Great Otway National Park was not captured in the 'land assigned formal protection status' prior to its surrender to the Crown. The assignment of 6,367 hectares in 2017 was not included in the Parks Victoria (PV) managed estate reported in annual reports and budget papers tabled in Victorian Parliament.)

There was a net addition of approximately 5,800 hectares to the area that PV manages between July 2014 and July 2017.

Table Fo.5 Significant additions to formal protection area, July 2014 to July 2017

Significant additions	Area (ha)
Belfast Coastal Reserve – addition of tidal areas	34
Red Gum Swamp, Jallumba Wildlife Reserve – previously freehold	73
Great Otway NP – addition of Anglesea Heath (ALCOA lease)	6,367
Truganina South Nature Conservation Reserve – previously freehold	38
Western Grassland Nature Conservation Reserve – purchased freehold	1,200
Mount Ridley Nature Conservation Reserve – previously freehold	44
Plenty Gorge Parklands Park (addition) – purchased freehold	42
Woowookarung Regional Park – previously Reserved Forest (previously known as Canadian Regional Park)	640

(Data source: Parks Victoria, 2018)

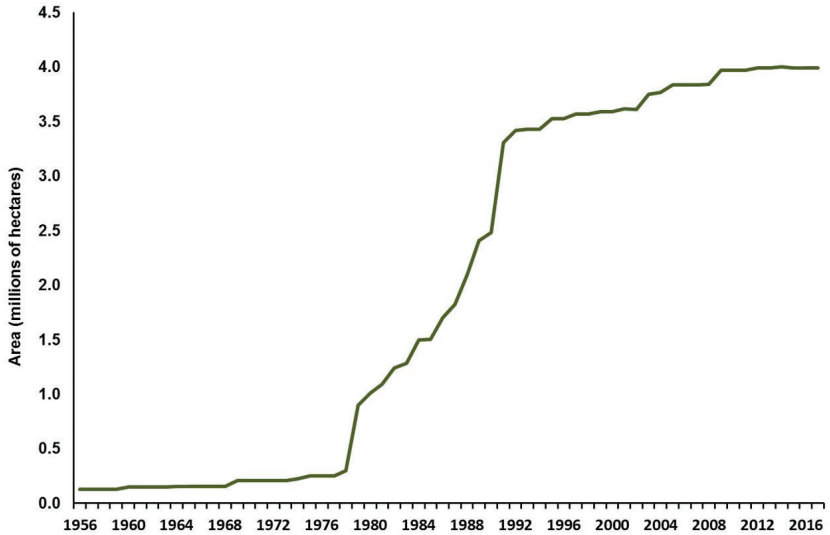


Figure Fo.11 Change in Victoria's formal protected area (parks and conservation reserves), 1956–2016

(Data source: Parks Victoria, 2018)

IUCN protected areas

The International Union for Conservation of Nature (IUCN) is the global authority on the status of the natural world. IUCN defines a protected area as 'a clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values'[46].

Australia compares favourably against other countries with respect to forest conservation.[47]

Under *Australia's Strategy for the National Reserves System 2009–2030*, all state and territory governments have agreed to adopt IUCN international standards for defining and reporting areas of protected area management.

All Victorian formal reserves are assigned an IUCN protected area category based on protection status and primary land management. Victorian terrestrial IUCN protected areas is described in Figure Fo.12. The IUCN assigned area categories may be refined occasionally. Informal reserves are not assigned an IUCN protected area category.

There was an increase of about 13% in IUCN protected areas overall between 2004 and 2016 (Table Fo.6), indicating better protection of Victoria's forests.

Type V (protected landscape/seascape) and Type VI (protected area with sustainable use of natural resources) areas increased most, by more than 200% each. Type Ia (strict nature reserve) and Type III (natural monument or feature) areas increased gradually. (Type Ia area is protected for biodiversity and strictly controlled to avoid any intervention. Type III area is to protect a specific natural monument such as a cave.)

Significant changes have been made to the network of protected areas, including the expansion of Great Otway National Park, additions to conservation parks and reserves (Table Fo.6), and more accurate GIS mapping, and clarifications and changes from on-ground managers.

46. The International Union for Conservation of Nature, 'Australia', Suva, Fiji https://www.iucn.org/theme/protected-areas/about Accessed 11 January 2019.
47. The International Union for Conservation of Nature, 'Australia', Suva, Fiji https://www.iucn.org/regions/oceania/get-involved/members/australia Accessed 4 December 2018.

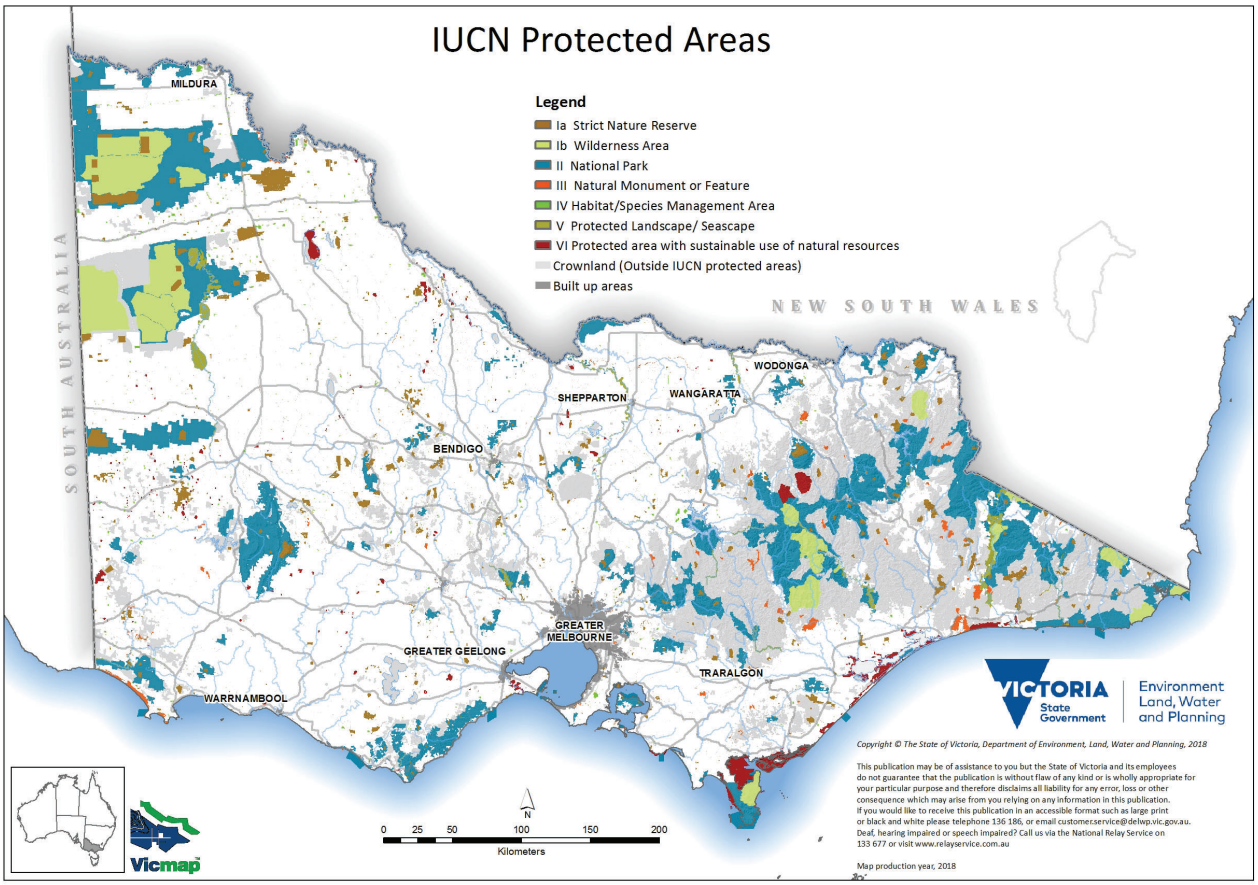


Figure Fo.12 Victorian terrestrial IUCN protected areas, 2018

(Data source: DELWP, 2018)

Table Fo.6 Victorian protected areas by IUCN category and informal Special Protection Zone reserves, 2004–2016

Formal protection IUCN Category	Area (hectares)							Proportion of forest cover (%) (a)
	2004	2006	2008	2010	2012	2014	2016	
Ia	356,300	366,200	381,900	380,700	388,600	421,600	421,500	83.37
Ib	815,500	815,300	815,700	815,700	815,500	740,900	740,900	78.50
II	2,128,600	2,182,400	2,224,200	2,309,700	2,371,300	2,374,400	2,373,700	83.89
III	55,000	48,900	49,500	51,300	78,000	75,500	75,600	73.68
IV	48,000	44,900	43,800	43,700	47,400	47,500	47,500	54.74
V	58,500	57,800	56,600	49,200	26,800	135,200	135,200	58.58
VI	91,100	89,200	94,500	85,100	130,600	208,300	206,200	23.13
All IUCN Protected Area	3,553,000	3,604,700	3,666,200	3,735,400	3,858,200	4,003,400	4,000,600	
Informal protection area								
Special protection zone (SPZ)	828,100	828,100	783,100	783,100	753,100	747,300	761,100	97.19
Total	**4,381,100**	**4,432,800**	**4,449,300**	**4,518,500**	**4,611,300**	**4,750,700**	**4,761,700**	**81.44**

(a) Proportion of forest cover refers to the proportion of this reserve class under forest

(Data source: DELWP, 2018)

Currently, there is little evidence on how well these classifications protect species. Detailed research is necessary to identify the benefits of different IUCN protected areas for target species, such as those on the IUCN Red List of Threatened Species.

A viability analysis has been completed for the ash-type forests of the Central Highlands of Victoria for the threatened species Leadbeater's possum (*Gymnobelideus leadbeateri*). Leadbeater's possum is listed on the IUCN Red List, and listed as threatened in the *FFG Act 1988*. The viability analysis indicates that the entire mountain ash resource needs to be protected from timber harvesting to achieve sustainable populations of Leadbeater's possum, and other species of possums, gliders and large forest owls in the medium term.[48,49]

48. Todd CR, Lindenmayer DB, Stamation K, Acevedo-Catteneo S, Smih S, Lumsden LF 2016, 'Assessing reserve effectiveness: application to a threatened species in a dynamic fire prone forest landscape', *Ecological Modelling*, 338, pp. 90-100.
49. Taylor C, Cadenhead N, Lindenmayer DB, Wintle BA 2017, 'Improving the design of a conservation reserve for a critically endangered species', *PLOS One*, 12, e0169629.

To reflect this, DELWP established a 200-metre-radius timber-harvesting exclusion zone (THEZ) to gauge the impact of exclusion zones on the conservation of Leadbeater's possum.[50] Two years of intensive surveying found that the addition of 4,046 hectares (through an increase of the special protection zone in the Central Highlands from 30,520 to 34,566 hectares) resulted in the protection of 436 additional Leadbeater's possum colonies.[51] Nonetheless, the population in the protected area will be at a high risk of extinction if a single bushfire event is factored into the analysis.[52]

50. DELWP 2017 'A review of the effectiveness and impact of establishing timber harvesting exclusion zones around Leadbeater's Possum colonies', Melbourne, Victoria https://www.wildlife.vic.gov.au/__data/assets/pdf_file/0033/73869/eadbeaters-Possum-Review-Report-July-2017.pdf Accessed 4 December 2018.
51. Nelson JL, Durkin LK, Cripps JK, Scroggie MP, Bryant DB, Macak PV, Lumsden LF 2017, 'Targeted surveys to improve Leadbeater's Possum conservation', Arthur Rylah Institute for Environmental Research Technical Report Series No. 278. Department of Environment, Land, Water and Planning, Heidelberg, Victoria https://www.wildlife.vic.gov.au/__data/assets/pdf_file/0032/27896/Targeted-survey-report-2015_final-7Oct15r.pdf Accessed 4 December 2018.
52. Woinarski J 2017, 'Independent review report: assessment of the conservation benefit provided to Leadbeater's Possum by the establishment of timber harvesting exclusion zones'. Charles Darwin University, Darwin, Northern Territory https://www.wildlife.vic.gov.au/__data/assets/pdf_file/0025/73870/Independent-Review-of-LBP-Review-Report-Conservation-Benefits-Analysis.pdf Accessed 4 December 2018.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:04 Fragmentation of native forest cover					?	DATA QUALITY Fair
Data custodian DELWP						

Forest fragmentation is a metric to describe forest quality. It assumes that the highest-quality forests are at the centre, and that the larger the area, the more resilient the forest is to disturbances.[53,54,55] Forest loss and the deterioration of forest health via increasing fragmentation pose significant threats to biodiversity, and endanger the sustainability of ecological goods and services from forested land.[56,57,58,59]

This indicator measures the loss of forest cover and the spatial configuration of that loss to show the level of fragmentation in Victoria's forests and the likely impacts on forest-dependent species.

Analysis of the satellite Landsat data captured in 2013 (Table Fo.7 and Table Fo.8) shows that on a state scale:

- On average, approximately 75% of Victoria's forest cover in each bioregion is classed as 'interior' (for example, core non-fragmented forest) and about 13% as 'edge area', with boundaries between interior forest and non-forest landcover (Table Fo.8). 25% of Victoria's total land area is interior forest, and about 4% is edge area (Table Fo.7).
- Bioregions with the highest proportion of interior forest are concentrated in Victoria's east. Main areas include the Australian Alps (91% interior forest), South East Corner (89% interior forest) and South Eastern Highlands (85% interior forest). Riverina is the most fragmented bioregion, and also has the highest proportion of forest patches (20%).
- Except for the Riverina bioregion, the most fragmented areas are on private land within each bioregion (Figure Fo.14). On average, about 85% of state forest (SF) and parks and reserves (PR) have interior areas. But on private land, the proportion of interior forest drops to one-third. Proportionally, the sum of 'edge', 'transitional' (deteriorating forest fragmentation from interior type to patch or edge) and patch (small and isolated remnant vegetation) areas in private land was six times greater than in SF and PR.
- In the South East Coastal Plain (SECP), PR appears more fragmented than SF; however, there is significantly more area of PR than SF. Moreover, a large area of SECP was transferred to PR when native-forest timber harvesting ceased in the Otway Ranges in the early 2000s.

A map of statewide forest fragmentation is provided in Figure Fo.13. Due to differences in mapping methodology and improvements in satellite imaging resolution, it is not possible to compare this data with that of previous years. This makes it difficult to assess overall trends in forest fragmentation in different bioregions and for different forest types.

53. Forman RTT, Godron M 1986, 'Landscape ecology', John Wiley, New York, USA.
54. Turner MG 1989, 'Landscape ecology: the effect of pattern on process', *Annual Review of Ecology and Systematics*, 20, pp. 171-197.
55. Levin SA 1992, 'The problem of pattern and scale in ecology'. *Ecology*, 73, pp. 1943-1967.
56. Harris LD 1984, 'The fragmented forest. Island biogeography theory and the preservation of biotic diversity', University of Chicago Press, Chicago, Illinois, USA.
57. Lovejoy TE, Bierregaard RO, Rylands AB, Malcolm JR, Quintela CE, Harper LH, Brown KS, Powell AH, Powell GVN, Schubart HOR, Hays MB 1986, 'Edge and other effects of isolation on Amazon forest fragments', In Soulé ME, editor. Conservation biology: the science of scarcity and diversity, Sinauer Associates, Sunderland, Massachusetts, USA.
58. Bierregaard RO, Lovejoy TE, Kapos V, dos Santos AA, Hutchings RW 1992, 'The biological dynamics of tropical rainforest fragments', *BioScience*, 42, pp. 859-866.
59. Laurance WF, Laurance SG, Ferreira LV, Rankin-de Merona JM, Gascon C, Lovejoy TE 1997, 'Biomass collapse in Amazonian forest fragments', *Science*, 278, pp. 1117-1118.

Fragmentation category	2018 (ha)	% of total state area
Non-forest	15,053,953	66.24
Patch	223,483	0.98
Transitional	273,889	1.21
Edge	979,423	4.31
Perforated	436,091	1.92
Interior	5,772,863	25.40
Undetermined	1,455	0.01
Total	**22,741,158**	**100**

Table Fo.7 Victorian forest fragmentation, 2018

(Data source: DELWP, 2018)

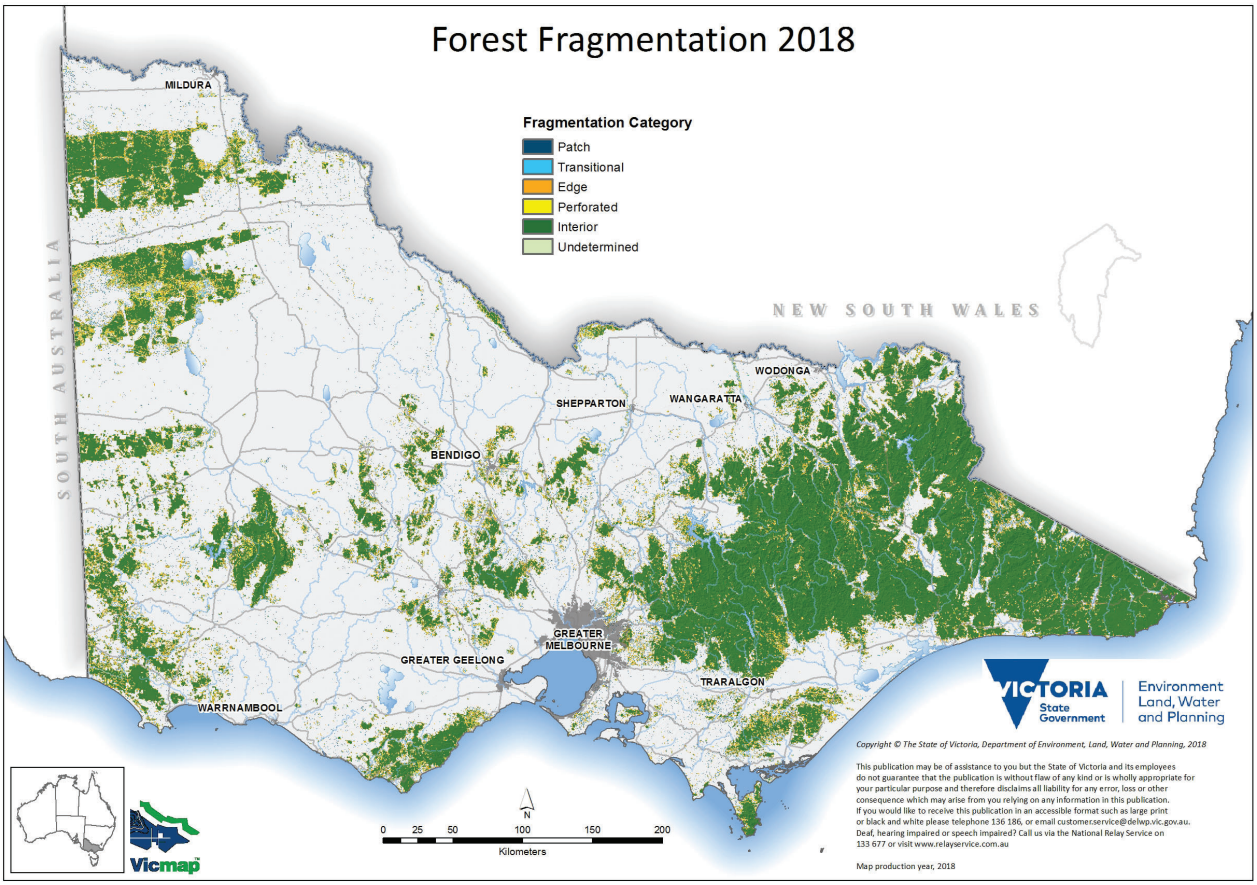


Figure Fo.13 Forest fragmentation in Victoria, 2018

(Data source: DELWP, 2018)

Table Fo.8 Proportion of forest fragmentation category by bioregion, 2018

Bioregion	Forest Cover Fragmentation category (% of bioregion total area)				
	Patch	Transitional	Edge	Perforated	Interior
Australian Alps	<1	1	5	4	91
Flinders	1	4	15	6	74
Murray–Darling Depression	4	5	16	10	64
Naracoorte Coastal Plain	2	4	19	9	67
NSW South Western Slopes	5	7	22	7	59
Riverina	20	16	28	13	22
South East Coastal Plain	8	9	26	9	48
South East Corner	1	1	6	3	89
South Eastern Highlands	1	2	8	3	85
Victorian Midlands	5	7	22	8	59
Victorian Volcanic Plain	11	9	24	7	49
Victoria (statewide)	**3**	**4**	**13**	**6**	**75**

(Data source: DELWP, 2018)

Figure Fo.14 Relative proportion of forest fragmentation categories by region and land type, based on % of total cover, 2018

(Data source: DELWP, 2018)

Long-term monitoring and detailed spatial research have been conducted at a regional scale to investigate the effects of fragmentation on native forests and biodiversity.

One example is the research conducted on mountain ash forests. These are fragmented by roads and logging coupes,[60] which work as barriers to the movement of animals such as Leadbeater's possum.[61,62] It has also been found that these barriers promote the rate of collapse of large old trees, which are key habitat for cavity-dependent fauna.[63,64] This disturbance is intensifying with the addition of more logging coupes under the Timber Release Plan.[65,66,67]

To compensate for this, DELWP Arthur Rylah Institute (ARI) surveyed 176 sites between September 2015 and April 2016 for presence of Leadbeater's possum in the Central Highlands.[68] Fifty-four of those sites were in areas designated for timber harvesting under the 2013–2016 Timber Release Plan; Leadbeater's possum was detected in 38 of the 54. THEZs were subsequently established in these areas to protect the species.

Intensification of forest fragmentation has been observed in other parts of Victoria, such as in the box-ironbark forests in Central Victoria, where greater abundance and widespread distribution of generalist egg predators of many bird species where observed, including the Regent honeyeater (*Anthochaera phrygia*).[69] State-scale assessments of threatened species need to be conducted, and intense management should be taken in areas where mitigation actions are required.

60. Lindenmayer DB, Blair D, McBurney L, Banks S 2015, *Mountain Ash: Fire, logging and the future of Victoria's giant forests to 'Mountain Ash: Fire, logging and the future of Victoria's giant forests'*, CSIRO Publishing, Melbourne, Victoria.
61. Blair D, McBurney L, Lindenmayer DB, Banks S, Blanchard W 2017, ***The Leadbeater's Possum review***, The Australian National University, Canberra.
62. Blair D, McBurney L, Lindenmayer DB 2018, 'Failing to conserve Leadbeater's Possum and its Mountain Ash forest habitat', *Australian Zoologist*, 39(3), pp. 442-448. Doi:https://doi.org/10.7882/AZ.2018.008.
63. Lindenmayer DB, Blanchard W, Blair D, McBurney L 2018, 'The road to oblivion – quantifying pathways in the decline of large old trees', *Forest Ecology and Management,* 430, pp. 259-264.
64. Lindenmayer DB, Blanchard W, Blair D, McBurney L, Stein J, Banks SC 2018, 'Empirical relationships between tree fall and landscape-level amounts of logging and fire', *PLOS One*, 13(2), e0193132.
65. VicForests, 'Timber release plan', Melbourne, Victoria http://www.vicforests.com.au/planning-1/timber-release-plan-1/timber-release-plan Accessed 4 December 2018.
66. Lindenmayer DB, Blanchard W, Blair D, McBurney L 2018, 'The road to oblivion – quantifying pathways in the decline of large old trees', *Forest Ecology and Management,* 430, pp. 259-264.
67. Lindenmayer DB, Blanchard W, Blair D, McBurney L, Stein J, Banks SC 2018, 'Empirical relationships between tree fall and landscape-level amounts of logging and fire', ***PLOS One***, 13(2), e0193132.
68. Nelson JL, Durkin LK, Cripps JK, Scroggie MP, Bryant DB, Macak PV, Lumsden LF 2017, 'Targeted surveys to improve Leadbeater's Possum conservation'. Arthur Rylah Institute for Environmental Research Technical Report Series No. 278. Department of Environment, Land, Water and Planning, Heidelberg, Victoria https://www.wildlife.vic.gov.au/__data/assets/pdf_file/0032/27896/Targeted-survey-report-2015_final-7Oct15r.pdf Accessed 4 December 2018.
69. Meney B, Cunningham S, Weston MA, Whisson DA 2018, 'Woodland birds and rural towns: artificial clutch survival in fragmented Box-Ironbark forests', *The Royal Society of Victoria*, 130, pp. 7-17.

Genetic Diversity

	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
Fo:05 Number of in situ and ex situ conservation efforts for forest dependent species Data custodian DELWP	● ○ ○ ○	?	DATA QUALITY Poor

Several conservation measures are being applied for sustainable forest management of locally and regionally adapted native species. These measures require a combination of in-situ and ex-situ approaches. In-situ conservation is conducted by declaring, as protected, areas such as parks, genetic and ecological conservation areas, and reserved stands. Ex-situ conservation measures include seed banks, long-term captive breeding, animal translocation and gene banks for the preservation of components of biological diversity outside of natural habitats.

Previous SoF reports used the Actions for Biodiversity Conservation (ABC) system to describe the extent of conservation efforts for native species.[70] However, the system was decommissioned in 2013, making comparisons with past data difficult. The data provided here has been collated by DELWP's regional implementation teams.

Table Fo.09 shows the level of management activity for each forest-dependent threatened species for eight action categories, as provided by DELWP's regional implementation teams. The categories are:

- community engagement
- policy and planning
- survey and monitoring
- habitat protection and restoration
- pest and weed control
- population manipulation
- captive management
- research.

The two levels of management activity provide a qualitative measure of conservation efforts in Victoria; however, it is difficult to evaluate whether the current approach has a strong impact on achieving positive species conservation status. The management activities need to be linked with state-scale monitoring programs to evaluate the effectiveness of in-situ and ex-situ conservation efforts.

70. DELWP, 'Actions for biodiversity conservation', Melbourne, Victoria https://www.environment.vic.gov.au/conserving-threatened-species/actions-for-biodiversity-conservation Accessed 11 January 2019.

Table Fo.09 Management activity for each forest-dependent threatened species, 2013–2017

Common name	Community engagement	Policy and planning	Survey and monitoring	Habitat protection and restoration	Pest and weed control	Population manipulation	Captive management	Research
Mammals								
Broad-toothed rat								
Brush-tailed phascogale								
Brush-tailed rock wallaby								
Eastern horseshoe bat								
Greater glider								
Grey-headed flying-fox								
Leadbeater's possum								
Long-footed potoroo								
Long-nosed potoroo								
Smoky mouse								
Spot-tailed quoll								
Squirrel glider								
Swamp antechinus								
White-footed dunnart								
Yellow-bellied glider								
Yellow-bellied sheathtail bat								
Birds								
Barking owl								
Brown treecreeper								
Chestnut-rumped heathwren								
Glossy black-cockatoo								
Grey goshawk								
Helmeted honeyeater								
Hooded robin								
Masked owl								
Powerful owl								
Regent honeyeater								
Sooty owl								
Speckled warbler								
Spotted quail-thrush								

Note: Yellow cells denote minor activity – routine or ad hoc. Green cells denote substantial activity – targeted or sustained. Blank cells denote no activity.

Common name	Community engagement	Policy and planning	Survey and monitoring	Habitat protection and restoration	Pest and weed control	Population manipulation	Captive management	Research
Birds								
Square-tailed kite								
Swift parrot								
Turquoise parrot								
White-bellied sea-eagle								
Reptiles								
Alpine bog skink								
Eastern she-oak skink								
Lace monitor								
Rosenberg's goanna								
Swamp skink								
Amphibians								
Baw baw frog								
Booroolong tree frog								
Brown toadlet								
Giant burrowing frog								
Green and golden bell frog								
Large brown tree frog								
Martin's toadlet								
Southern toadlet								
Spotted tree frog								
Fish								
Australian grayling								
Barred galaxias								
Cox's gudgeon								
Dwarf galaxias								
Empire gudgeon								
Flat-headed galaxias								
Macquarie perch								
Murray cod								
Trout cod								
Invertebrates								
Orbost spiny cray								

Common name	Community engagement	Policy and planning	Survey and monitoring	Habitat protection and restoration	Pest and weed control	Population manipulation	Captive management	Research
Plants								
Baw baw berry								
Blackfellow's hemp								
Brown guinea-flower								
Colquhoun grevillea								
Eastern pomaderris								
Elegant daisy								
Forest geebung								
Forest phebalium								
Forest sedge								
Gippsland stringybark								
Gully grevillea								
Leafless pink-bells								
Outcrop guinea-flower								
Oval fork-fern								
Oval-leaf grevillea								
Sandfly zieria								
Serpent heath								
Slender fork-fern								
Small fork-fern								
Smooth geebung								
Tall astelia								
Tasmanian wax-flower								
Toothed leionema								
Tree geebung								
Upright pomaderris								
Veined pomaderris								
Velvety geebung								

(Data source: DELWP, 2018)

Note: Yellow cells denote minor activity – routine or ad hoc. Green cells denote substantial activity – targeted or sustained. Blank cells denote no activity.

Species Diversity

	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
Fo:06 The status of forest dependent species at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment	○ ○ ● ○	↘	DATA QUALITY Good

Data custodian DELWP

Identifying the conservation status of forest-dependent species at risk is an important initial step to developing action plans for successful protection. Current conditions of rare and threatened species are useful indicators for recognising species particularly at risk and the state of the forest communities. Changes in conservation status can be used to assess the effectiveness of biodiversity management and species recovery programs.

This indicator is reported based on information from DELWP's Threatened Species Advisory List, and the threatened species and communities listed under the FFG Act.

In 2018, Victoria signed the Intergovernmental Memorandum of Understanding Agreement on a Common Assessment Method for Listing of Threatened Species and Threatened Ecological Communities (CAM MoU).[71] The CAM MoU requires signatories to adopt the IUCN Red List categories and criteria through legislative reform to establish a single operational list of threatened species in each jurisdiction and to collaborate in the assessment and periodic review of the conservation status of native species in Australia.

The IUCN Red List of Threatened Species provides taxonomic, conservation status and distribution information on plants, fungi and animals that have been globally evaluated using the IUCN Red List categories and criteria.[72] The system is designed to determine the relative risk of extinction, with the main purpose of cataloguing and highlighting those plants, fungi and animals that are facing higher risk of global extinction. Following assessment, plants, fungi and animals are listed as either: critically endangered, endangered, vulnerable, near threatened, least concern, data deficient, not evaluated, extinct or extinct in the wild.[73]

DELWP is currently working on a project to reassess all listed Victorian rare and/or threatened species, according to the IUCN Red List categories and criteria, including species listed in the FFG Act Threatened List and the DELWP advisory list. In addition to yielding a single, comprehensive list of Victorian threatened species, this work will also provide the baseline for key targets in *Biodiversity 2037*. This new list will not be comparable to the current DELWP Advisory List, but will instead create a new baseline for trend reporting. An update on this new, comprehensive Victorian threatened species list will be made available in 2019.

At the time of writing, DELWP was also leading a review process for the FFG Act. This review process included public consultation to inform the development of reforms to the FFG Act. The Flora and Fauna Guarantee Amendment Bill was introduced into Victorian Parliament on 23 May 2018. The Bill was debated in the Legislative Assembly and passed without amendment. It was subsequently introduced into the Legislative Council, but was not debated before the final scheduled parliamentary sitting day of the 58th Parliament of Victoria.

71. Australian Department of the Environment and Energy 2015, 'Intergovernmental Memorandum of Understanding. Agreement on a common assessment method for listing of threatened species and threatened ecological communities', Canberra, Australia https://www.environment.gov.au/system/files/resources/36ece4ab-82dc-4de9-aac6-9cc54bd7a820/files/mou-cam.docx Accessed 4 December 2018.
72. International Union for Conservation of Nature 2000, 'IUCN Red List categories and criteria', Gland, Switzerland https://portals.iucn.org/library/sites/library/files/documents/RL-2001-001-2nd.pdf Accessed 4 December 2018.
73. International Union for Conservation of Nature Standards and Petitions Subcommittee 2014, 'Guidelines for using the IUCN Red List categories and criteria. Version 11', Gland, Switzerland https://cmsdata.iucn.org/downloads/redlistguidelines.pdf Accessed 4 December 2018.

Since 2013, the only species group to be updated is vascular plants, in 2014 (Table Fo.10).[74] (However, assessing changes in plant species on DELWP advisory list can be difficult. Frequent changes in botanical nomenclature means that apparently new plants may simply have been renamed.) The status of the 461 species listed in 2013 has not changed. Vascular plants represent by far the greatest proportion of these species (Figure Fo.15). This might be due to greater knowledge and awareness of vascular plants within the scientific community, and their relative ease of detection.

Since 2007–08, no changes have been observed in the number of rare or threatened amphibians. Conservation status of mammals is a concern, with approximately 40% of the species on the list close to extinct or already extinct in the wild. This suggests a deteriorating trend in some forest species groups at risk, though fair strategies are in place to monitor the current status.

Deterioration in the overall status of species has been observed in the Central Highlands. Between 1990 and 2015, the numbers of species listed under the IUCN Red List categories in the Central Highlands increased from 16 to 44. The increasing number of listed species in threatened species categories is also described in other studies.[75,76]

As recommended in Fo:03 Area of forest type by growth stage distribution in protected zones, results from viability analyses for key threatened forest-dependent taxa are important to adjust current management strategies to mitigate the risks of not being able to maintain viable breeding populations.

74. Victorian Department of Environment and Primary Industries 2014, 'Advisory list of rare or threatened plants in Victoria'. Melbourne, Victoria https://www.environment.vic.gov.au/__data/assets/pdf_file/0021/50448/Advisory-List-of-Rare-or-Threatened-Plants-in-Victoria-2014.pdf.
75. Keith H, Vardon M, Stein JA, Stein JL, Lindenmayer DB 2017, 'Ecosystem accounts define explicit and spatial trade-offs for managing natural resources', *Nature Ecology and Evolution*, 1, pp. 1683–1692.
76. Keith H, Vardon M, Stein JA, Stein JL, Lindenmayer DB 2017, 'Experimental ecosystem accounts for the Central Highlands of Victoria. Summary Report', The Australian National University and the Threatened Species Recovery Hub, Canberra, Australia.

Table Fo.10 Number of species by conservation status, 2018

Species group	Extinct in the wild	Extinct	Regionally extinct	Critically endangered	Endangered	Vulnerable	Near threatened	Data deficient	Total
Amphibians				7	3	2		3	15
Birds				4	15	17	15		51
Fish				2		3	1		6
Invertebrates				5	7	12	1	9	34
Mammals	1	8	9	2	7	6	14	2	49
Reptiles				5	7	8	7		27
Vascular plants					4	10			14
Other flora					92	165	6	1	264
Total	**1**	**8**	**9**	**25**	**135**	**223**	**44**	**15**	**460**

(Data source: DELWP, 2018)

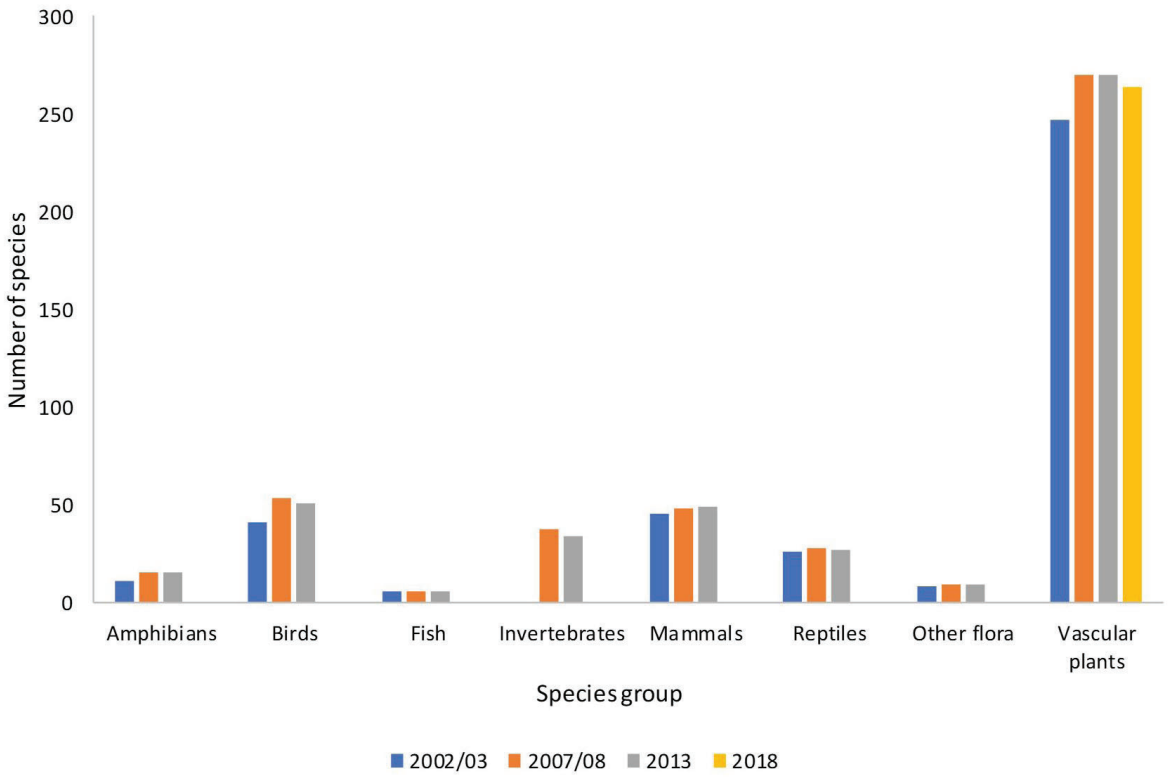


Figure Fo.15 Change in numbers of rare or threatened species on the advisory list, by reporting period

(Data source: DELWP, 2018)

The Victorian Environmental Assessment Council (VEAC) is responsible for conducting investigations that are requested by the Victorian Government relating to the protection and ecologically sustainable management of the environment and natural resources of public land.

VEAC's 2017 'Conservation values of state forests: assessment report' focuses on the state forests in the Central Highlands, North East, Gippsland and East Gippsland regions, where most commercial native-timber harvesting is in place, to identify forest-dependent species.[77] An identification process was conducted by a group of expert biologists convened by DELWP. Of 79 forest-dependent species identified, 35 were selected that could be adversely affected by native-timber harvesting. Of the 79 species, 28 are listed as critically endangered, endangered, or vulnerable in the *Environment Protection and Biodiversity Conservation Act 1999* 54 are listed as a threatened taxon under the FFG Act (see Appendix 2 in the VEAC report). Although a time-series trend analysis and status assessment were not conducted, this information is useful, as it provides a specific list of forest-dependent species in areas where most commercial native-timber harvesting has taken place.

The list of forest-dependent species used for this analysis was developed with DELWP expert opinion, and is consistent with previous SoF reports. However, as the list in Table Fo.10 has not been published and differs from other lists (such as that published in the VEAC report), there may be some ambiguities in future analyses. (Care should be taken, in particular, to avoid the inadvertent omission of species that require critical attention.) A formal and agreed list of forest-dependent species would assist the consistency and transparency of this analysis.

77. VEAC 2017, 'Conservation values of state forests: assessment report', Melbourne, Victoria http://www.veac.vic.gov.au/documents/Complete%20report%20for%20web%20page.pdf Accessed 3 December 2018.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:07 Degree of disturbance to native forest species caused by invasive species Data custodian DELWP					↘	DATA QUALITY Good

Invasive species are defined here as any species that are non-native to a particular Victorian ecosystem, and whose introduction and spread causes adverse sociocultural, economic and/or environmental impact. As invasive species often do not have natural predators in Victoria's ecosystems (outside of their native range), they can spread, reproduce and compete for habitat, causing severe ecological degradation. Understanding the degree of disturbance caused by invasive species can provide an indication of the effectiveness of management/control actions, and assist with evaluation of policy responses.

Invasive species on public land in Victoria are managed by a biosecurity approach.[78] This approach focuses on asset-based protection measures that aim to minimise the impact of invasive species on the environment, economy and society. The Invasive Plants and Animals Policy Framework aims to protect Victoria's native flora, fauna and primary producers from harm caused by invasive species. The VFMP collects data on the presence and abundance of weed species across the state, including monitoring the impacts of weeds on native-forest species for the Victorian public forest estate. This data was collected for the first time between 2011 and 2012, and reported in SoF 2013. However, as the 2013 report was based on only 50% of the total plots measured, the information available for this report cannot be compared with previous data. The data in this indicator could be significantly different from that of the previous report.

The data shows that the proportion of weed species to total species is highest in the New South Wales Southwestern Slopes bioregion (24%) and the Riverina bioregion (20%). As shown in Fo:04 Fragmentation of native forest cover, the Riverina bioregion is the most highly fragmented bioregion and has the largest proportion of edge and patch areas.

Considering the cumulative effects of a high number of invasive weed species and fragmentation, the Riverina bioregion's capability to deliver long-term sustainable forest management is under threat. The edges of forest patches, such as roadsides, are highly susceptible to invasion by exotic species. In addition, forests in the Riverina bioregion have developed on active floodplains, and flooding could promote the abundance, proliferation and spread of weeds.

78. Victorian Department of Economic Development, Jobs, Transport and Resources, 'Protecting Victoria from pest animals and weeds', Bacchus Marsh, Victoria http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/protecting-victoria-from-pest-animals-and-weeds Accessed 4 December 2018.

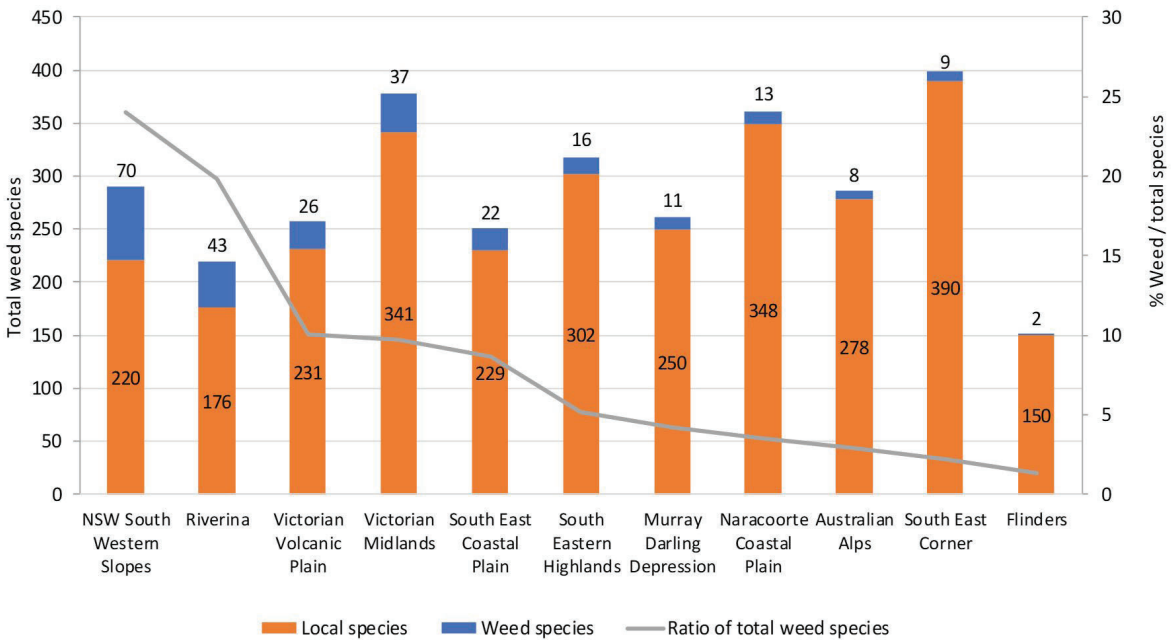


Figure Fo.16 Proportional distribution of weed species in bioregions, 2018

(Data source: DELWP, 2018)

The major insects and pathogenic agents found on public land are listed in Table Fo.12. Overall, damage by most identified pathogens and insect agents in Victoria during the reporting period stabilised or decreased. However, the distribution and destruction of a few species on native forests, plantations and urban/farm forests has increased. It is crucial to continue monitoring the impacts of insect and pathogen species, and also consider climate change impacts on these identified species, and the potential introduction of new insect and pathogenic agents in Victoria.

Table Fo.11 Colour code for Table Fo.12, indicating scale of distribution and impact of insects and pathogenic agents on native forests, plantation and urban/farm forest

Code	Scale of distribution	Impact
0	Does not occur, or not observed in assessment period	No impact
1	Restricted (<25%)	Minimal
2	Restricted (<25%)	Adverse
3	Widespread (>25%)	Minimal
4	Widespread (>25%)	Localised adverse
5	Widespread (>25%)	Widespread adverse

Table Fo.12 Common insect and pathogen agent, distribution and impact, 2007–08 to 2017–18

		Native forests										
Agent common	**Agent scientific**	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**2014-15**	**2015-16**	**2016-17**	**2017-18**
Insects												
Autumn gum moth	Mnesampela privata											
Christmas beetle	Anoplognathus spp											
Chrysomelid leaf beetles	Chrysophtharta agricola											
Cup moth	Doratifera spp											
Five-spined bark beetle	Ips grandicollis											
Goldern-haired beetle	Hylurgus ligniperda											
Gum leaf skeletoniser	Uraba lugens											
Leaf blister sawfly	Phylacteophaga froggatti											
Longicorn borers	Phorocantha spp											
Monterey pine aphid	Essigella californica											
Mountain ash psyllid	Cardiaspina bilobata											
Red gum basket lerp	Cardiaspina retator Taylor											
Sawflies	Perga spp											
Sirex	Sirex noctilio											
Spurlegged phasmatid	Didymuria violescens											
Sycamore lace bug	Corythucha ciliata											
Pathogens												
Armillaria	Armillaria luteobubalina											
Corky leaf spot	Aulographina eucalypti											
	eucalypti											
Cyclaneusma needle cast	Cyclaneusma minus											
Cypress canker	Seridium sp											
Diplodia	Diplodia pinea											
Dothistroma needle blight	Dothistroma septosporum											
Eucalyptus canker	Holocryphia eucalypti											
Lophodermium	Lophodermium pinastri											
Mycosphaerella leaf disease	Mycosphaerella spp											
Myrtle rust	Uredo rangelii											
Myrtle wilt	Chalara australis											
Phytophthora	Phytophthora cinnamomi											
Septoria leaf blight	Kirramyces eucalpti											

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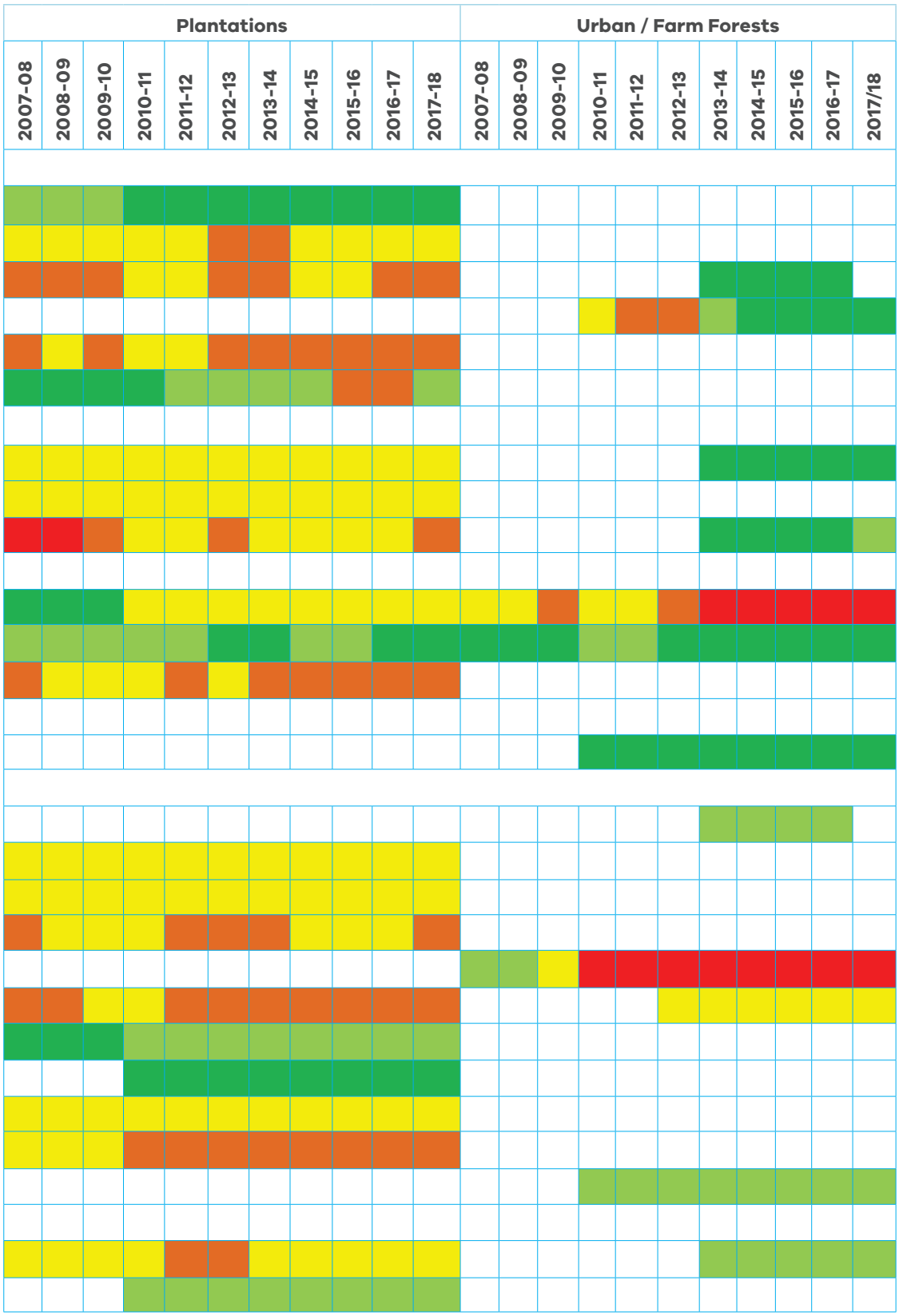


(Data source: DELWP, 2018)

Public land management programs across Victoria are helping to reduce the impact of invasive species. Some of the key programs are:

- Weeds and Pests on Public Land Program – an ongoing program investing in weed, predator and herbivore control to protect Victoria's key biodiversity assets
- Peri-Urban Weed Management Partnership Initiative – a project to protect key biodiversity assets on public land in Melbourne's peri-urban areas from high-threat weeds
- Good Neighbour Program – a program to support public land managers to control weeds and pests at the interface of public and private land for the protection of private land values.

Figure Fo.17 shows the area of invasive species control by actions in Victoria since SoF 2013. The analysis excludes private land programs coordinated through the Department of Economic Development, Jobs, Transport and Resources (DEDJTR).

The Biodiversity chapter presents further assessments related to the management of invasive species, specifically indicators B:20 (Change in suitable habitat) and B:21 (Area of management in priority locations).

Action	Treated area (ha)
Feral cat control	66,054
Deer control	153,219
Fox control	2,409,659
Feral goat control	1,085,221
Feral pig control	91,576
Rabbit control	5,649,919
Weed control	4,223,328
Fencing	300,055
Total	13,979,031

Figure Fo.17 Area of invasive species control, by action, in public and private land between 2013–14 and 2017–18 financial year

(Data source: DELWP, 2018)

Note: Excludes private land programs coordinated through DEDJTR

Ecosystem Health

	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
Fo:08A Scale and impact of agents and processes affecting forest health and vitality – mortality, dieback, canopy health sub-section Data custodian DELWP, BoM		?	DATA QUALITY Fair

Forest health and vitality are critically related to a variety of natural disturbances, which are strongly influenced by climate. In Victoria, natural disturbances can include fire, non-native species invasions, floods, disease outbreaks and climatic events such as windstorms, extreme temperatures and millennial drought events. All of these events influence the composition, structure and functions of forests.

The effects of such disturbances are not always negative. Rather, they can be an important part of natural processes essential to the long-term health of ecosystems. Forests have evolved to overcome and regenerate from certain natural disturbances. However, there have been major shifts recently in the frequency, scale and intensity of the agents and processes that can cause significant disruptions in forest ecosystems, resulting in a dramatic increase in the susceptibility of forest health and vitality. Capturing these shifts through monitoring programs is vital, as predictions indicate that forest ecosystems will be increasingly exposed to these events due to climate change.[79]

Condition of the forest canopy is used globally as an indicator of forest health.[80] This report presents three measures of tree-canopy quality: mortality, crown dieback and canopy health. Mortality is defined as the proportion of the stand basal area (m^2/ha) in dead trees. Basal area is the cross-sectional area of a tree's trunk, measured at 1.3 m above the ground. Crown dieback is the amount of withered branches within the canopy, often over a certain period. This is measured by the VFMP as the proportion of dominant branches in tree crowns lacking living foliage. The crown canopy impacted is a measure of canopy health through defoliation and discolouration, and this is gauged as the percentage of existing foliage over an estimated foliage volume. Due to the application of different methods from previous SoF reports, not all data for this indicator can be compared with previous reports for trend analysis.

Across all Victorian bioregions, the average percentage of areas showing mortality, crown dieback and canopy health impacted are 14.3%, 20.3% and 23.3%, respectively.

As a result of a wide confidence interval of the mortality rate in every forest tenure and in each bioregion (Figure Fo.18), it is difficult to identify significant differences between bioregions and between parks, reserves and state forests-except for the Victorian Volcanic Plains, where a higher mortality rate was identified in state forests.

On average, the crown dieback by bioregion was between 16% and 24% of the total large-tree basal area (Figure Fo.19). Bioregions with more than 20% crown dieback included the Australian Alps, Murray–Darling Depression, Riverina and Victorian Volcanic Plains. The eastern parts of Victorian bioregions (South East Coastal Plain, South East Corner and South Eastern Highlands) had lower dieback rates.

In the comparison of parks and reserves with state forests, Riverina had the highest difference: dieback rates in the parks and reserves area were about three times greater than in state forests. The Australian Alps and South East Corner bioregions also had a greater proportion of dieback rates in the parks and reserves than state forests category (about 10% greater). This may be due to a range of factors, including different site conditions, management history and current uses.

79. Ian F 2009, 'Fires, Forests and Futures: The ANU Westoby Lecture', *Australian Forestry*, 72(4), pp. 195-205.
80. Stone C, Haywood A 2006, 'Assessing canopy health of native eucalypt forests', *Ecological Management & Restoration*, 7, pp. S24-S30.

Figure Fo.20 summarises average canopy health affected for measured plots by bioregion. At the bioregion level, canopy condition was worst affected in the Naracoorte Coastal Plain and the western areas of the South East Coastal Plain (around Cape Otway) as well as in the pockets of the Victorian Volcanic Plain, Victorian Midlands, southern areas of the Mallee and eastern areas of the Australian Alps (Central Highlands).

Plot-derived canopy health data was interpolated across the state using the kriging method in ArcGIS software that is widely used for spatial analytics (Figure Fo.21). This method is a geostatistical technique that can predict certain status, in this case canopy health, based on a scattered set of spatial data points from field measurements through the VFMP. This method has been used internationally to estimate forest cover[81] and forest health.[82] Figure Fo.21 demonstrates that there are several Victorian bioregions where degree of leaf damage is more than the average of 30%: Naracoorte Coastal Plain, South Eastern Highlands (including the Otway region), Central Highlands, south of Murray–Darling Depression and Victorian Midlands.

The Australian Alps, which has experienced multiple fires over the past 10 years, has a high proportion of dead stems (Figure Fo.18). Data suggests a similar condition in the Riverina; however, these dead stems occur in isolated pockets, leading to significant variation across the bioregion.

Overall, it would be counterproductive to determine the current status of forest health and vitality in Victoria using tree mortality and dieback rate, as there is no comparative threshold. Although the data presented cannot be used for trend analysis, recent research has shown mortality-rate trends in mountain ash forests in the Central Highlands. Between 1997 and 2015, 25% of the measured population died on unburnt sites, while 61% died on burnt sites.[83] Monitoring trends that relate to forest health and vitality is critical to develop strategies and management actions to mitigate deterioration.

81. Dindaroğlu T 2014, 'The use of the GIS Kriging technique to determine the spatial changes of natural radionuclide concentrations in soil and forest cover', *Journal of Environmental Health Science and Engineering*, 12(1), pp. 130.
82. Conkling BL 2011, 'Forest health monitoring: 2007 national technical report', General Technical Reports SRS-147, Asheville, NC, US Department of Agriculture Forest Service, Southern Research Station, 147, pp. 1-59.
83. Lindenmayer DB, Blanchard W, Blair D, McBurney L 2018, 'The road to oblivion – quantifying pathways in the decline of large old trees', Forest Ecology and Management, 430, pp. 259-264.

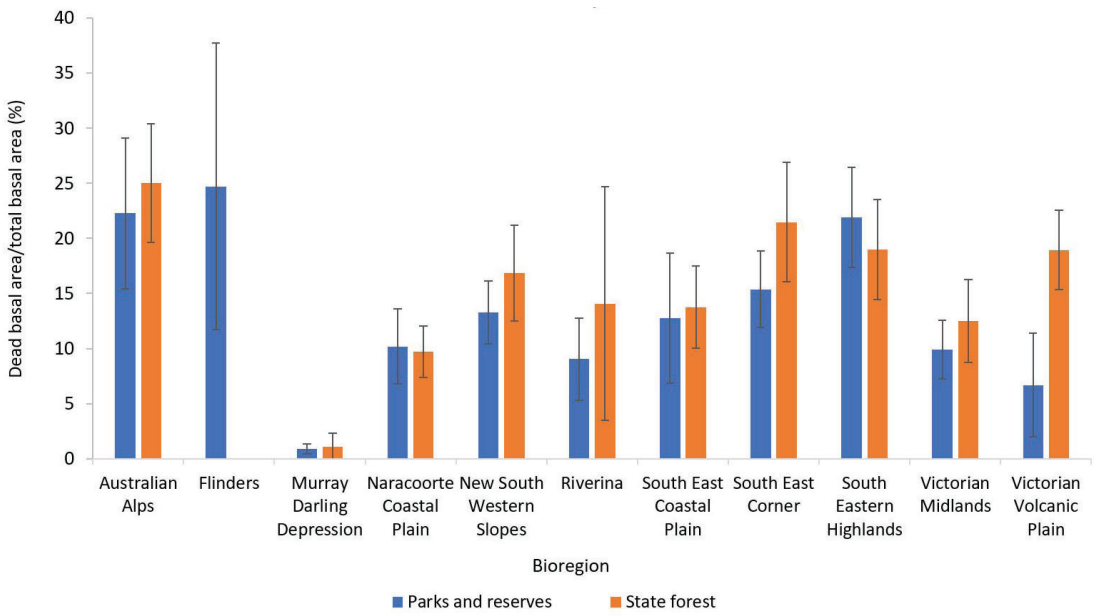


Figure Fo.18 Mortality by bioregion as a proportion of total dead basal area to total live basal area for large trees

Note: Number of plots by bioregion is described in Table Fo.1.

(Data source: DELWP, 2018)

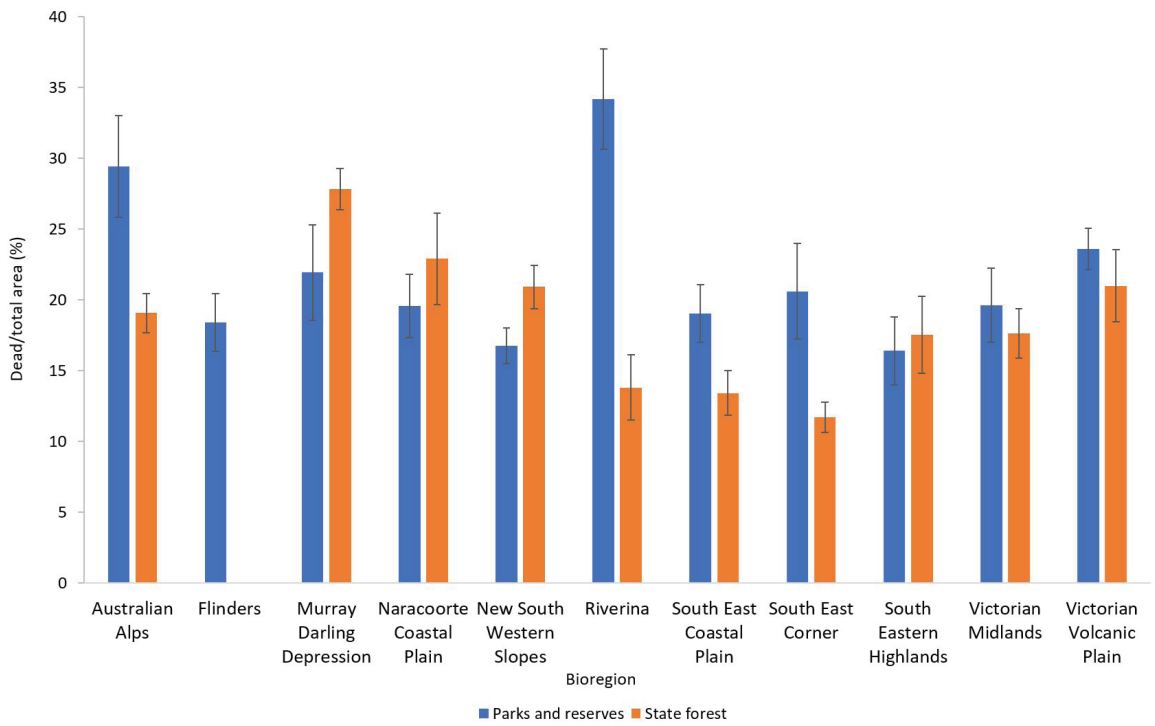


Figure Fo.19 Average canopy dieback and defoliation rates for measured plots by bioregion

Note: Number of plots by bioregion is described in Table Fo.1.

(Data source: DELWP, 2018)

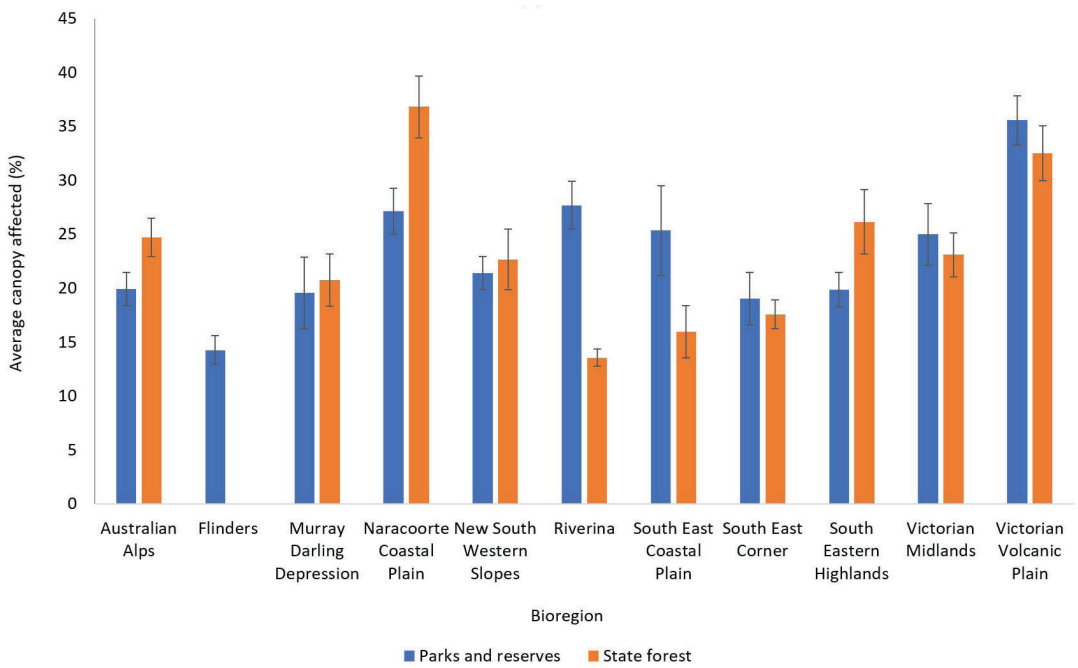


Figure Fo.20 Canopy health as characterised through discolouration and defoliation, by bioregion

(Data source: DELWP, 2018)

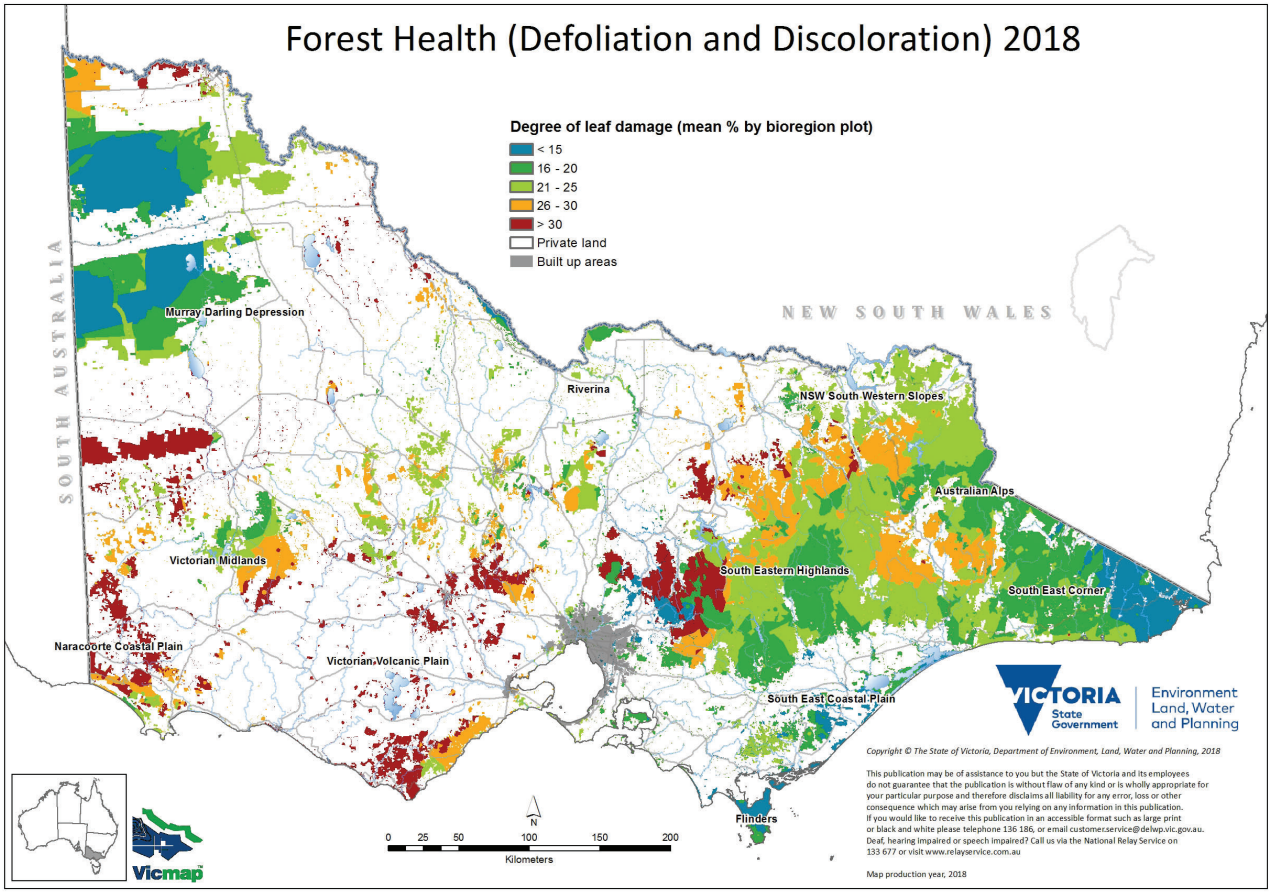


Figure Fo.21 Canopy health (defoliation and discolouration), 2018

(Data source: DELWP, 2018)

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:08B Scale and impact of agents and processes affecting forest health and vitality – Bushfire affected area and climate sub-section Data custodian DELWP, BoM			●		↘	DATA QUALITY Good

Bushfire Affected Area

Native flora and fauna in Victoria evolved by adapting for bushfires of varying frequency and intensity. In fact, many native species have become dependent on natural fire regimes for health and survival. Fire regimes comprise four parameters: fire intensity, fire frequency (between-fire interval), seasonality of fire occurrence and type of fire (above or below-ground).[84]

The effects of fire on forest ecosystems are determined by fire intensity. 'Fire intensity' varies depending on the position of the periphery of the fire.[85] Victorian forests can experience very intense canopy fires during summer where warm, dry and windy weather conditions occur, and this can lead to large-scale replacement and regeneration of mature tree populations. Victorian mountain ash and alpine ash forests are especially susceptible to significant alterations, as the canopy-tree species are fire-sensitive, and can be replaced by acacia scrub if burnt by two fires at an interval less than the time it takes for the eucalypts to reach sexual maturity. The effects of intense, extensive fires also extend to long-term effects on streamflow, threatened species survival and subsequent invasions by exotic species. Therefore, it is important to understand fire-affected areas for sustainable forest management.

Unattended campfires constitute a large proportion of the fires reported on public land. Compliance concerning campfire use is managed by Parks Victoria, together with DELWP, Victoria Police and the Country Fire Authority (CFA). The most damaging bushfire on record is the Wye River-Jamieson Track fire, instigated by lightning on 19 December 2015. The fire exceeded control lines on Christmas Day under extreme weather conditions, burning 2,520 hectares of national park and private properties, including an estimated 160 houses.

Between 2013 and 2014, Victoria experienced its most significant fire season since 2008, which challenged emergency services and Victorian communities. Across the season, Victoria had 19 days of Extreme and Severe Fire Danger Rating and 16 days of Total Fire Ban. More than 463,000 hectares of public and private land was burnt, and 80 residences destroyed.[86]

The respective land management and fire agencies (including the CFA, Department of Environment and Primary Industries and their Networked Emergency Management partners, consisting of Parks Victoria, VicForests and Melbourne Water and the Metropolitan Fire Brigade) responded to more than 4,600 bushfires and grassfires over a five-month period. The years between 2015 to 2017 have seen relatively low fire activity.

84. Gill AM 1975, 'Fire and the Australian flora: a review' Australian Forestry, 38, pp. 4-25.
85. Ibid

86. Emergency Management Victoria 2013, 'Post season operations review: fire danger period 2013/14', Melbourne, Victoria http://files.em.vic.gov.au/EMV-web/Fire-Danger-Period-Operational-Review-2013-14.pdf Accessed 4 December 2018.

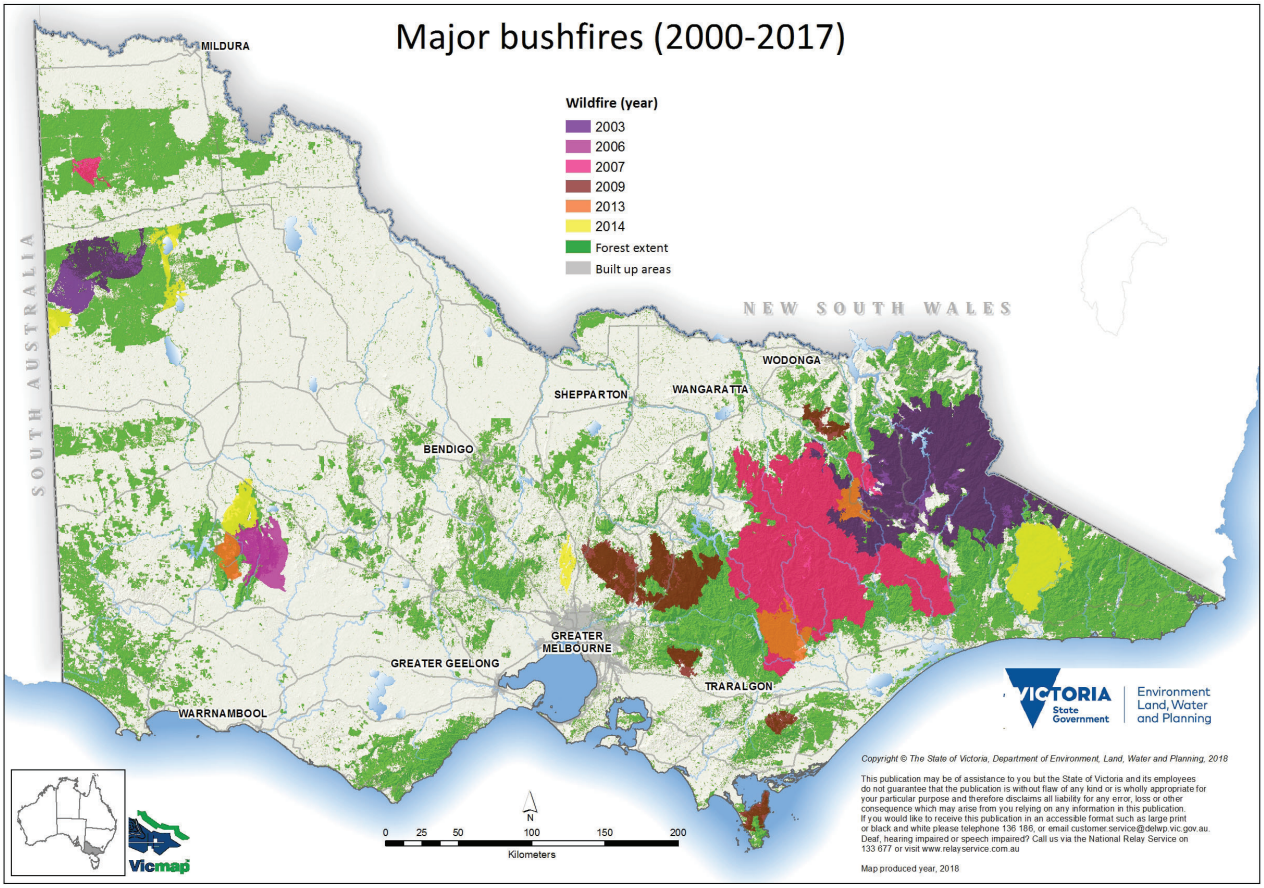


Figure Fo.22 Major bushfires in Victoria, 2000–17

(Data source: DELWP, 2018)

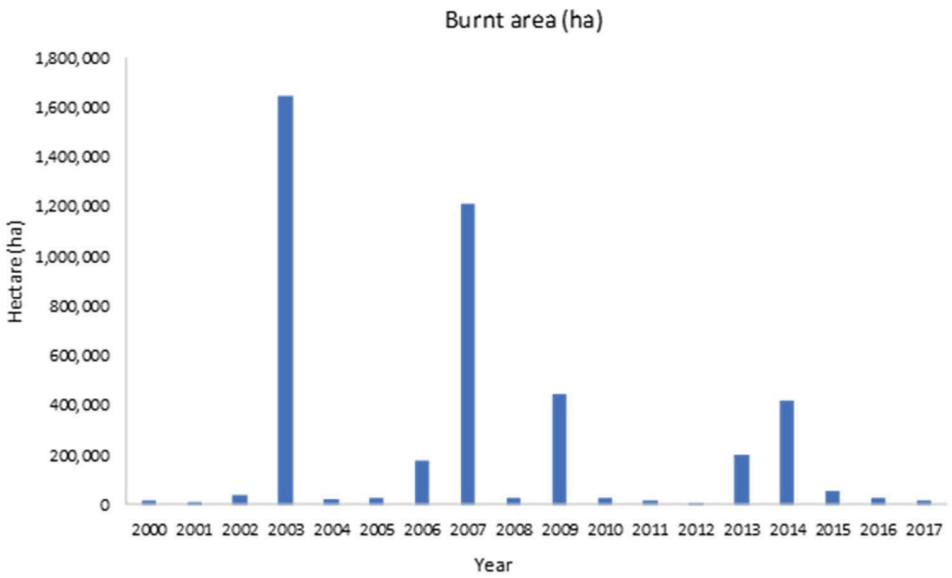


Figure Fo.23 Total area affected by bushfires, 2000–17

(Data source: DELWP, 2018)

Climate

The health and vitality of forests are critically related to climatic patterns and events. Forest health and vitality are affected by conditions such as rainfall deficit and extreme temperatures, with impacts on mortality, defoliation and withering in trees and their understorey, and reduced productivity, regenerative abilities and resources for forest-dependent species.

High temperatures and drought can also augment fire activity and degrade overall land condition. Forests under stress from drought are also more prone to infections and insect invasions. Recent events related to anthropogenic climate change have created an extreme climatic environment, in which it is becoming increasingly difficult to maintain healthy and vital forest ecosystems.[87] The native ecosystems in which species have evolved have been rapidly changing, and studies[88, 89] have indicated that the speed of the change could be too fast for some native species to adapt. This could lead to significant consequences, including species extinction.

The Victorian climate has been gradually warming since the 1950s (Figure Fo.24). Since SoE 2013, every year has been among the top-ten warmest in Victoria on record,[90] with 2014 the second-warmest year on record (behind 2007). The temperature increase is observed in both daytime (maximum) and overnight (minimum) temperatures, with the greatest degree of warming in summer (+0.14 °C per decade) and the smallest in winter (+0.06 °C per decade).

The temperature increase in Victoria was widespread, with the greatest increases in the central and southern parts of the state. A uniform increase in daytime temperature can be observed throughout the state, with the exception of parts of Gippsland, the far-west, and north-east of the state, where the increase was marginally slower. The southern coastal areas have experienced the greatest increases in overnight temperature, with a smaller degree of night-time warming in inland parts of Victoria. This could be a result of reduced rainfall and cloud cover in the cool season, which may have mitigated some effects of global warming in the central region.

A greater number of extreme heat events in Victoria are a consequence of the warmer climate, as indicated by an increase in the number of unusually warm days per year in Victoria (Figure Fo.25). Unusually warm days have been calculated based on average temperatures recorded each day from 1910 until 2015. Data for those 105 years was then used to calculate average temperature by month. This result is compared to the average temperature each day for 105 years of data: days in the top 1% for each month are counted as 'unusually warm'.

87. Keenan RJ 2015, 'Climate change impacts and adaptation in forest management: a review', Annals of Forest Science, 72(2), pp. 145-167.
88. Thuiller W 2007, 'Biodiversity: climate change and the ecologist', *Nature*, 448(2), pp. 550-552.
89. Dawson TP, Jackson ST, House JI, Prentice IC, Mace GM 2011, 'Beyond predictions: Biodiversity conservation in a changing climate', Science, 332, pp. 53-58.
90. Bureau of Meteorology, 'Heatwave Service for Australia', Melbourne, Victoria www.bom.gov.au/australia/heatwave Accessed 4 December 2018.

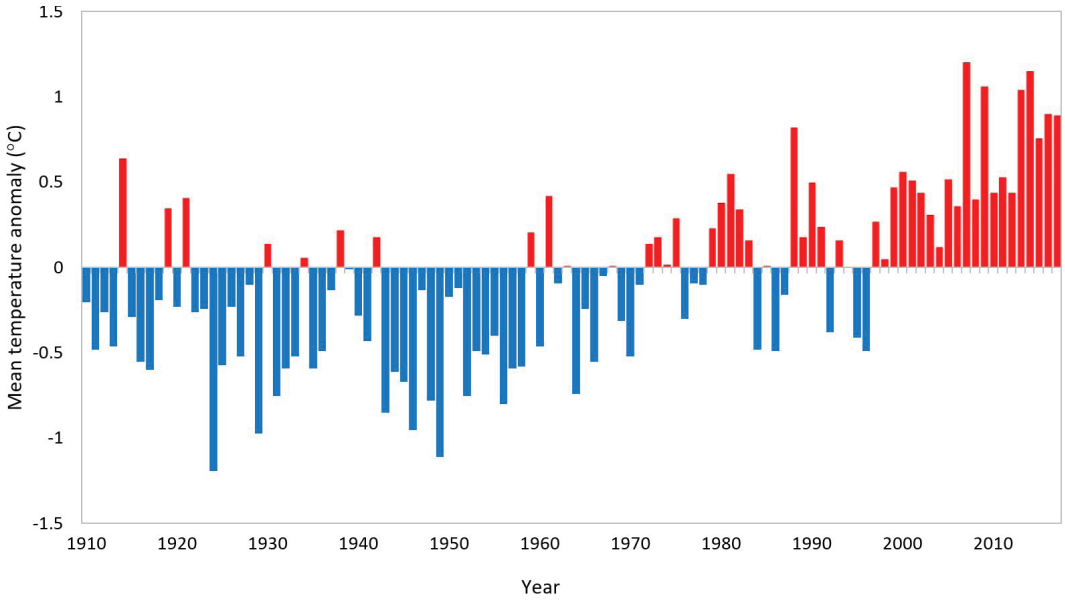


Figure Fo.24 Mean temperature anomaly in Victoria, 1910–2017

(Data source: BoM, 2018[91])

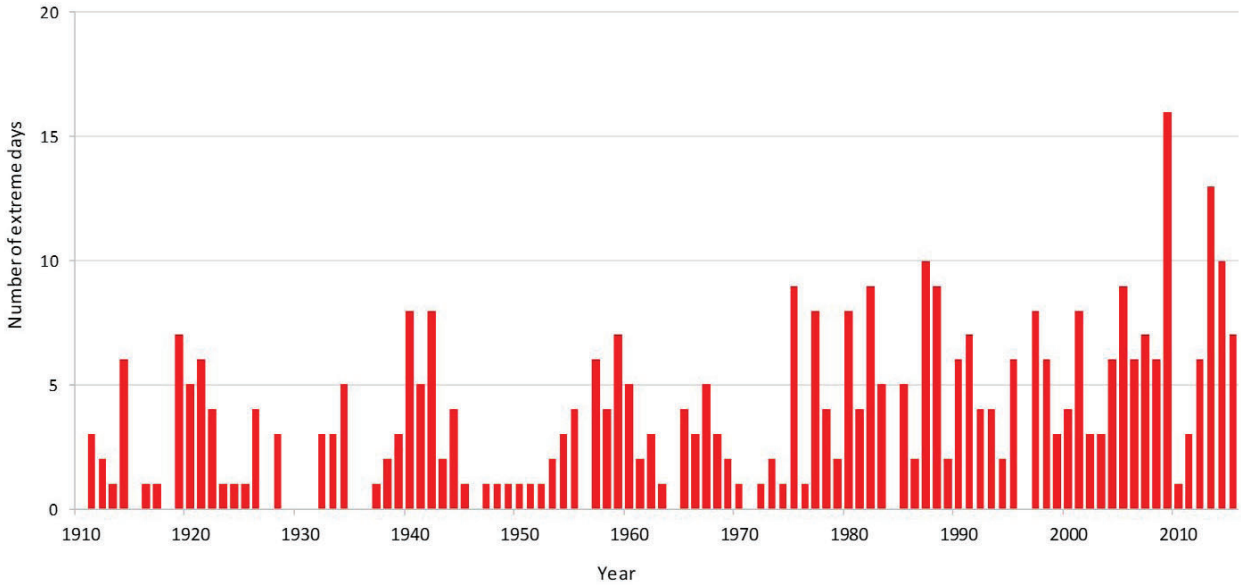


Figure Fo.25 Number of days annually when the Victorian area-averaged daily mean temperature is 'unusually warm', 1910–2015

Note: Extreme days are those above the 99th percentile for the month from 1910–2015.

(Data source: BoM, 2018[92])

91. Bureau of Meteorology, 'Climate change and variability', Canberra, Australia. http://www.bom.gov.au/climate/change/index.shtml#tabs=Tracker&tracker=timeseries Accessed 9 January 2019.
92. Bureau of Meteorology, 'Climate change and variability', Canberra, Australia. http://www.bom.gov.au/climate/change/index.shtml#tabs=Tracker&tracker=timeseries Accessed 13 January 2019.

Fo:09 Area and type of human-induced disturbance

Disturbance is the transition of a short-term change in environmental conditions to the long-term change of an ecosystem. The impacts of human-induced disturbances (intentional or unintentional) on forest ecosystems have been extensively reported throughout the world.[93] In Victoria, extensive planned fire activities, intensive grazing, and roads have been identified as factors that have great potential to affect forest ecosystem health. Observing the various forms and significance of these disturbances would allow better understanding of anthropogenic impacts on forest health, as well as help to formulate appropriate mitigation strategies. This report discusses two major causes of disturbances: planned burns and grazing.

	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
Fo:09A Area and type of human-induced disturbance – Planned burns	FAIR	?	DATA QUALITY: Good
Data custodian DELWP			

Fuel management is an effective way to manage bushfire risk on large areas of public land. Fuel management reduces the amount of fuel available to a bushfire, which can reduce its intensity and rate of spread, thereby increasing opportunities for firefighters to suppress it. Victoria mainly manages fuel by planned burns, but also by mechanical treatment. Definition of planned and unplanned burns is provided in Table Fo.13. For fuel management purposes, Victoria has four fire management zones:

- Asset Protection Zone (APZ): an area around properties and infrastructure where fuel is intensively managed to provide localised protection to reduce radiant heat and ember attack on life and property in the event of a bushfire
- Bushfire Moderation Zone (BMZ): an area around properties and infrastructure where fuel is managed to reduce the speed and intensity of bushfires and to protect nearby assets, particularly from ember attack in the event of a bushfire
- Landscape Management Zone (LMZ): an area where fuel is managed to minimise the impact of major bushfires, to improve ecosystem resilience and for other purposes (such as to regenerate forests and protect water catchments)
- Planned Burning Exclusion Zone (PBEZ): an area where planned burning is avoided, mainly because ecological assets in this zone cannot tolerate fire.

DELWP conducts planned burns to meet the objectives of the relevant fire management zone and other site-specific objectives.

Following the 2010 final report by the 2009 Victorian Bushfires Royal Commission, the Victorian Government committed to expanding its planned-burning approach by aiming to reduce fuel hazards and protect human life.

But in 2016, based on recommendations by the Inspector-General for Emergency Management, the government began to shift from a hectare-based approach to a risk-based approach which to bushfire management. This focuses on areas where the likelihood of a bushfire starting, spreading and impacting on people, property and the environment is greatest, based on fire-modelling results. The government is developing a system of bushfire management strategies to reduce risk, which will be delivered by 2020. For further discussion, see the Fire chapter.

Due to the new approaches for planned burns since 2016–17, trend analysis could not be conducted.

93. Zamorano-Elgueta C, Cayuela L, Ray-Benayas MR, Donoso PJ, Geneletti D, Hobbs RJ 2014, 'The differential influences of human-induced disturbances on tree regeneration community: a landscape approach', Ecosphere, 5(7), pp. 90.

Table Fo.13 Definitions of planned and unplanned burns

Planned Fire	Unplanned Fire
Fire started in accordance with a fire management plan, or some other type of planned-burning program or wildfire response procedure. Usual reasons for such fires may include: • fulfilling the ecological requirements of flora and fauna • protecting of human life and property • maintaining and promoting sustainable production values • maintaining cultural resources and practices.	Fire started naturally, accidentally or deliberately, but not in accordance with planned fire management activities. Examples include: • lightning strikes • escaped campfires or barbeques • fires resulting from equipment or machinery • fires deliberately lit without the necessary permits or authority (and those lit with malicious intent) • escaped planned burns.

(Data source: DELWP, 2018)

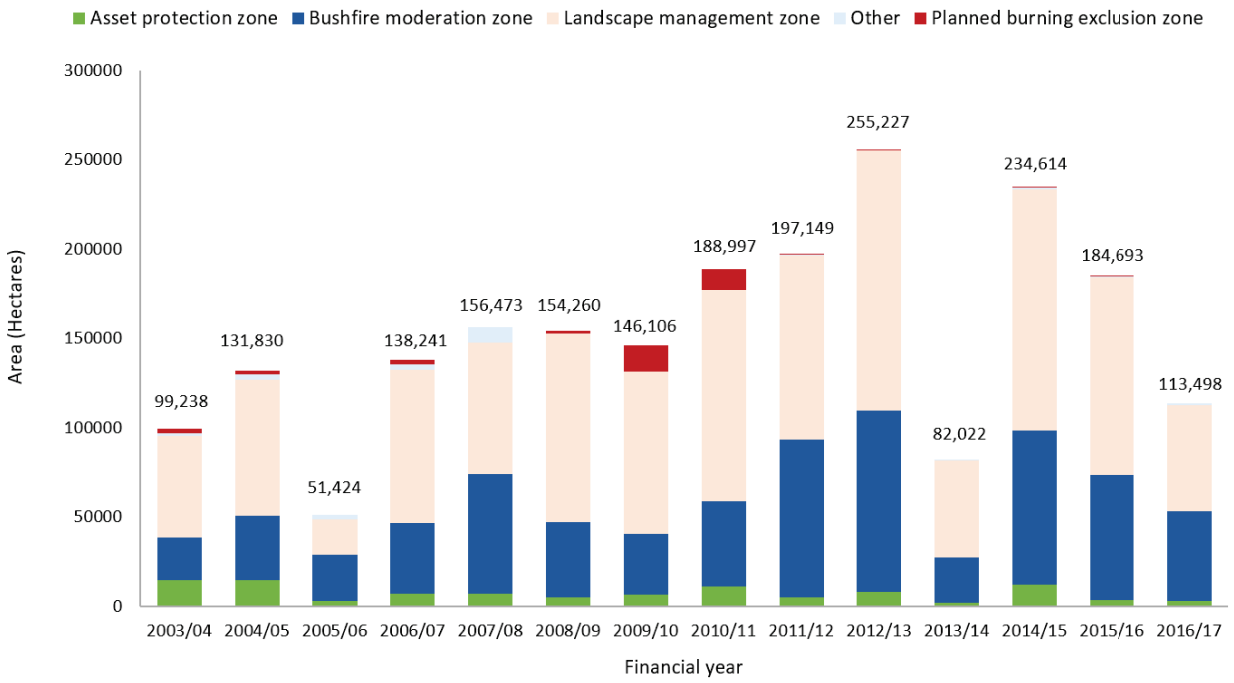


Figure Fo.26 Annual area of planned burns on public land, by fire management zone, 2003–04 to 2016–17

(Data source: DELWP, 2018)

	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
Fo:09B Area and type of human-induced disturbance – grazing		→	DATA QUALITY: Poor

Data custodian DELWP

Analysis of grazing activity helps to assess and address issues relating to conservation of native plant biodiversity, water yield and agricultural practices. Pastoral farming is a major contributor to Australia's economy. About two-thirds of Australia's land has been modified for human use, primarily grazing of livestock, including on natural vegetation.[94] Studies indicate that grazing by non-native animals such as cattle and sheep could damage native plant biodiversity and water yield.[95,96]

To balance conservation with agricultural needs, the Victorian Government regulates grazing by issuing licences and permits. These are annual licences with invoices issued each October. Licences can be issued under the *Land Act 1958* and *Forests Act 1958*. They give the licence-holder the right to occupy stipulated Crown land for agricultural purposes, grazing and some cropping (although purposes can vary).

Annual invoices, shown in Table Fo.14, are the sum of payment for rent or other activities on Crown land. Between 2012 and 2013 and 2016 and 2017, licence numbers have been stable. However, the data does not indicate area used for grazing activities. In addition, There is also no/limited information about where grazing is occurring under licence. Grazing in some areas, such as those near catchment areas, may be more harmful to the environment. Therefore, it is difficult to determine whether the current number of grazing licences is environmentally sustainable. An evidence-based approach to determining the sustainable level is urgently needed.[97]

Table Fo.14 Number of licences issued for grazing activities, 2012–13 to 2016–17

Year	No. of licences	Invoiced	Invoices (exc. GST)
2012–13	1,689	253,171	230,156
2013–14	1,681	239,307	217,551
2014–15	1,692	240,661	218,783
2015–16	1,698	240,220	218,382
2016–17	1,710	241,162	219,238

(Data source: DELWP, 2018)

94. Australian Bureau of Statistics 2010, '4613.0-Australia's environment: issues and trends, Jan 2010', Belconnen, Australia, http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/4613.0Chapter95Jan+2010 Accessed 4 December 2018.
95. Bromham L, Cardillo M, Bennett AF, Elgar MA 2009, 'Effects of stock grazing on the ground invertebrate fauna of woodland remnants', Austral Ecology, 24(3), pp. 199-207.
96. Lunt ID 2005, 'Effects of stock grazing on biodiversity value in temperate native grasslands and grassy woodlands in SE Australia: a literature review'. Technical Report 18, Wildlife Research and Monitoring, Lyneham, Australia https://www.environment.act.gov.au/__data/assets/pdf_file/0007/576520/technicalreport18effectsofstockgrazingonbiodiversityvalues.pdf Accessed 4 December 2018.
97. Dorrough J, Yen A, Turner V, Clark SG, Crosthwaite J, Hirth R 2004, 'Livestock grazing management and biodiversity conservation in Australian temperate grassy landscapes', Australian Journal of Agricultural Research, 55(3), pp. 279-295.

Carbon Cycles

	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
Fo:10 Total forest ecosystem biomass and carbon pool by forest type, age class and succession all stages Data custodian DELWP	○ ○ ● ○	?	DATA QUALITY Fair

Carbon is a fundamental component of terrestrial forest ecosystems, including above- and below-ground biomass, organic soil matter, woody debris and litter. The natural process of photosynthesis by plants enhances terrestrial uptake of atmospheric carbon,[98] making forests ideal for reducing net carbon emissions from anthropogenic activities. Strategies to increase forest-stored carbon would thus assist in meeting state and national carbon emissions commitments.

This indicator provides information on the contribution of Victorian forests to the carbon cycle. Estimates of total forest biomass over time are vital to monitor the changes in regional and localised carbon pool distribution, particularly as carbon stocks are contingent on environmental and land-use conditions.[99]

The total biomass is estimated through field measurements taken between 2011 and 2015 from 786 plots of the VFMP across Victoria, located in parks and reserves and state forests. A standard biomass factor of 0.5[100] is applied in converting total biomass to the amount of carbon (C), to obtain the values found in Figure Fo.28 and Figure Fo.29. The carbon mass is presented by each bioregion, tenure, type and pool. A single time period is presented as provided from the VFMP; however, trend analysis will be possible from 2020, once the five-year panel system is fully implemented.

98. Zhu K, Zhang J, Niu S, Chu C, Luo Y 2018, 'Limits to growth of forest biomass carbon sink under climate change', Nature Communications, 9(1), pp. 2709.
99. Keith H, Mackey B, Lindenmayer D, Likens G 2009, 'Re-evaluation of forest biomass carbon stocks and lessons from the world's most carbon-dense forests', Proceedings of the National Academy of Sciences of the United States of America, 106(28), pp. 11635-11640.
100. Penman J, Gytarsky M, Hiraishi T, Krug T, Kruger D, Pipatti R, Buendia L, Miwa K, Ngara T, Tanabe K, Wagner F 2003, 'Good practice guidance for Land Use, Land Use Change and Forestry'. Intergovernmental Panel on Climate Change National Greenhouse Gas Inventories Programme, Institute for Global Environmental Studies (IGES), Kanagawa, Japan https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/GPG_LULUCF_FULL.pdf Accessed 4 December 2018.

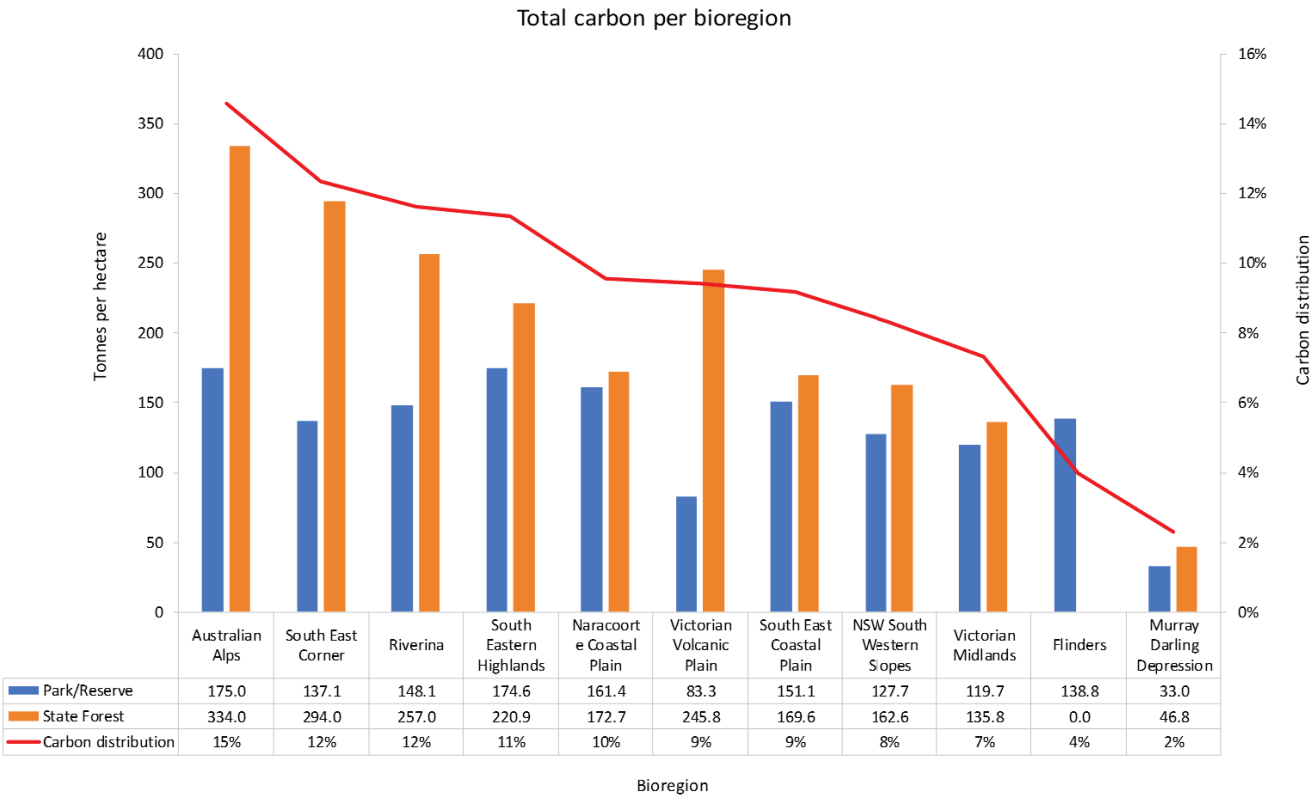
Existing data shows that across all Victorian public forests, the average C and biomass per hectare is 166.2 and 332.3 tonnes per hectare, respectively. The Murray–Darling Depression[101] has the lowest average C and biomass per hectare, with 39.9 and 79.9 tonnes per hectare, respectively.

Across all bioregions, total carbon per hectare is 40% higher on average in state forests than in parks and reserves, with the exception of Flinders. Although parks and reserves are known to occupy a higher proportion of total Crown land,[102] state forests support greater sink capacity through total plant biomass. The higher prevalence of old-growth trees restricted for timber harvest in state forests,[103] relative to younger stands, may contribute to better carbon storage.[104] The following factors also play a role:

- Parks and reserves often have areas of non-forest areas. For example, in the Australian Alps bioregion, the reserve area includes the area above the tree line.
- State forests are managed to achieve high stocking rates while reserves are not managed in the same manner.

101. Australian Department of the Environment and Energy 2008, 'Murray-Darling Depression bioregion', Canberra, Australia https://www.environment.gov.au/system/files/resources/a8015c25-4aa2-4833-ad9c-e98d09e2ab52/files/bioregion-murray-darling-depression.pdf Accessed 4 December 2018.
102. Victorian Department of Environment and Primary Industries 2013, 'Victorian Crown Land Area Statement', Melbourne, Victoria https://www.parliament.vic.gov.au/images/stories/committees/enrc/Invasive_Animals_on_Crown_land/210A._2016.09.13_Attachment_1_-_Victorian_Crown_Land_Area_Statement.pdf Accessed 4 December 2018.
103. VAGO 2013, 'Managing Victoria's native forest timber resources', Melbourne, Victoria http://www.vicforests.com.au/static/uploads/files/20131211-timber-resources-wfsdlrklejjj.pdf Accessed 4 December 2018.
104. Keith H, Lindenmayer D, Mackey B, Blair D, Carter L, McBurney L, Okada S, Konishi-Nagano T 2014, 'Managing temperate forests for carbon storage: impacts of logging versus forest protection on carbon stocks', Ecosphere, 5(6), pp. 75.

- Carbon from successive fires, in 2003, 2007 and 2009, from large dead trees in the Australian Alps reserves is high compared with other bioregions. The reserves have at least twice as much carbon from large dead trees than any other bioregion.



	Australian Alps	South East Corner	Riverina	South Eastern Highlands	Naracoorte Coastal Plain	Victorian Volcanic Plain	South East Coastal Plain	NSW South Western Slopes	Victorian Midlands	Flinders	Murray Darling Depression
Park/Reserve	175.0	137.1	148.1	174.6	161.4	83.3	151.1	127.7	119.7	138.8	33.0
State Forest	334.0	294.0	257.0	220.9	172.7	245.8	169.6	162.6	135.8	0.0	46.8
Carbon distribution	15%	12%	12%	11%	10%	9%	9%	8%	7%	4%	2%

Figure Fo.27 Total carbon (tonnes) per hectare in Victoria's public forest (state forests and parks/reserves) by bioregion estimated based on field measurements between 2011 and 2015

Note: Weighted means by bioregion. Proportional distribution of carbon in Victoria's forest per region is indicated as a red line on the secondary y-axis.

(Data source: DELWP, 2018)

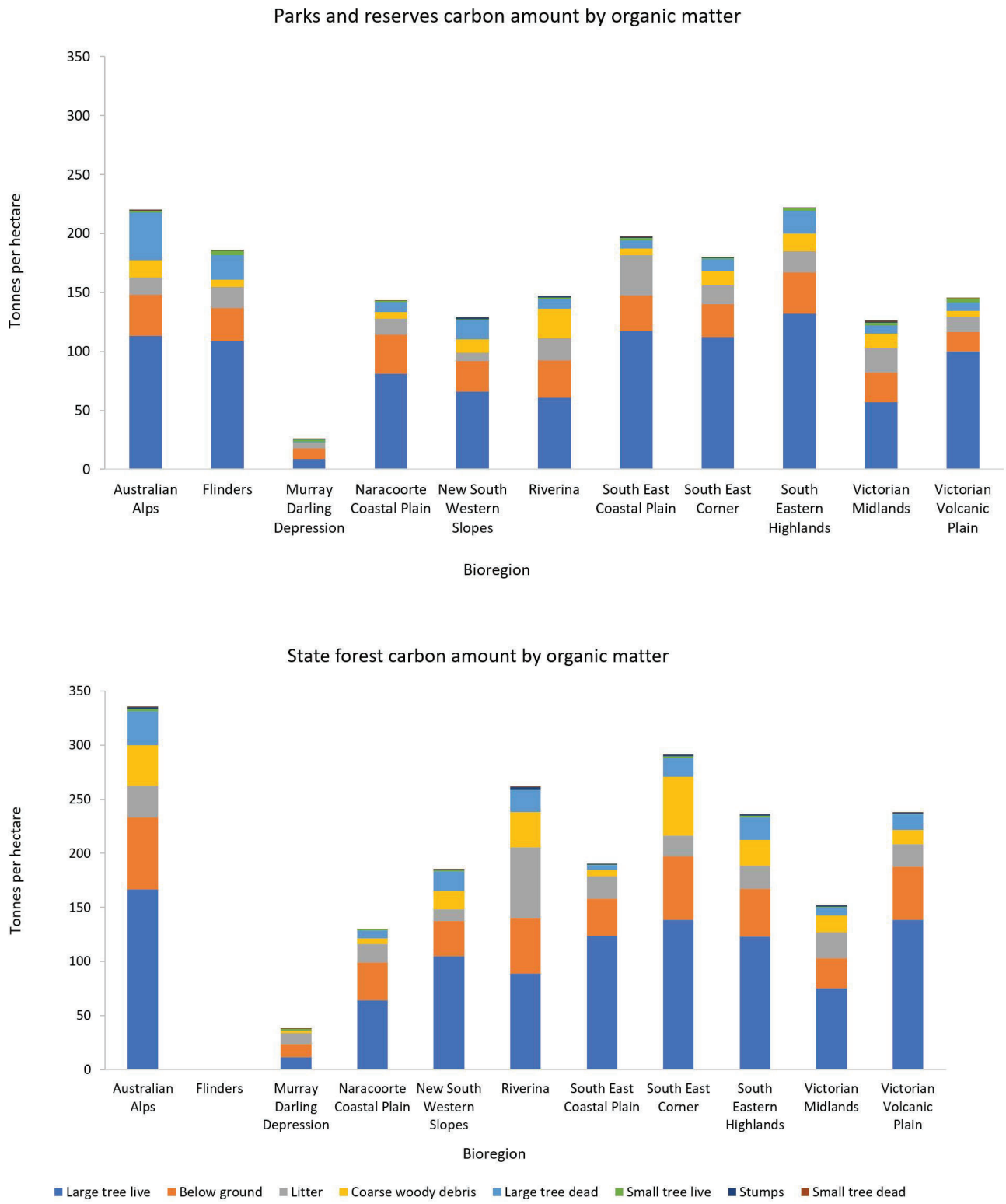


Figure Fo.28 Carbon stores by pool and bioregion in Victoria's public forests (state forests and parks/reserves)

(Data source: DELWP, 2018)

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:11 Contribution of forest ecosystems to the global greenhouse gas balance Data custodian DELWP					↗	DATA QUALITY Good

Increasing the concentration of greenhouse gases (GHG) intensifies climate change. Monitoring the contribution of Victorian forest ecosystems to the global GHG balance is vital, as forest management can have a positive or negative impact on the balance.[105]

In 2017, the Victorian Government announced that Victoria's *Climate Change Act 2017* would establish a target of net-zero GHG emissions by 2050.[106] For about 20 years, from 1990, Victoria's net GHG emissions gradually increased by 35% to 110,469 gigagrams $CO_{2\text{-}e}$. In 2016, net GHG emissions in Victoria were 91,459 gigagrams CO_2– about a 12% increase from 1990 emissions (Figure Fo.29).

The 20-year increase from 1990 was due principally to emissions from the energy sector, the greatest contributor to net emission outflow. The sector includes production of electricity and direct combustion of fossil fuels in other industries, such as manufacturing.

However, the energy sector's contribution has stabilised since 2004, and the Land Use, Land-Use Change and Forestry (LULUCF) sector has become a net sink of carbon emissions, except for the years when major bushfires occurred, including 2003, 2007 and 2009 (see forest management net outflow in Figure Fo.30). The primary driver of forest-related carbon sequestration (removal) is afforestation/reforestation activities; however, these figures peaked in 2012 and decreased gradually until 2016.

By contrast, since 2011, sequestration from forest management activities has increased, primarily due to 20 vegetation projects funded by the Emissions Reduction Fund over the past 5 years. This trend is observed through an upsurge in the Kyoto Australian Carbon Credit Unit (KACCU, Figure Fo.31), which represents abatement from activities that contribute to the nation's emission targets under the Kyoto protocol.

However, estimated net contribution of the fund to the sequestration in LULUCF is still relatively low. Compared to other sectors, including waste and agriculture, proportional contribution of forest-related activities is minimal. As indicated in Fo:01 (Area of forest by type and tenure), no area of new plantation has been established since 2011. In 2016, about 10% of total carbon emissions were sequestrated by forest-related activities (afforestation, reforestation, forest management and revegetation) (Figure Fo.29 and Figure Fo.30).

105. Keenan R, Nitschke CR 2016, 'Forest management options for adaptation to climate change: a case study of tall, wet eucalypt forests in Victoria's Central Highlands region', Australian Forestry, 79(2), pp. 96–107.
106. DELWP, 'Emissions reduction targets', Melbourne, Victoria, https://www.climatechange.vic.gov.au/reducing-emissions/emissions-targets Accessed 4 December 2018.

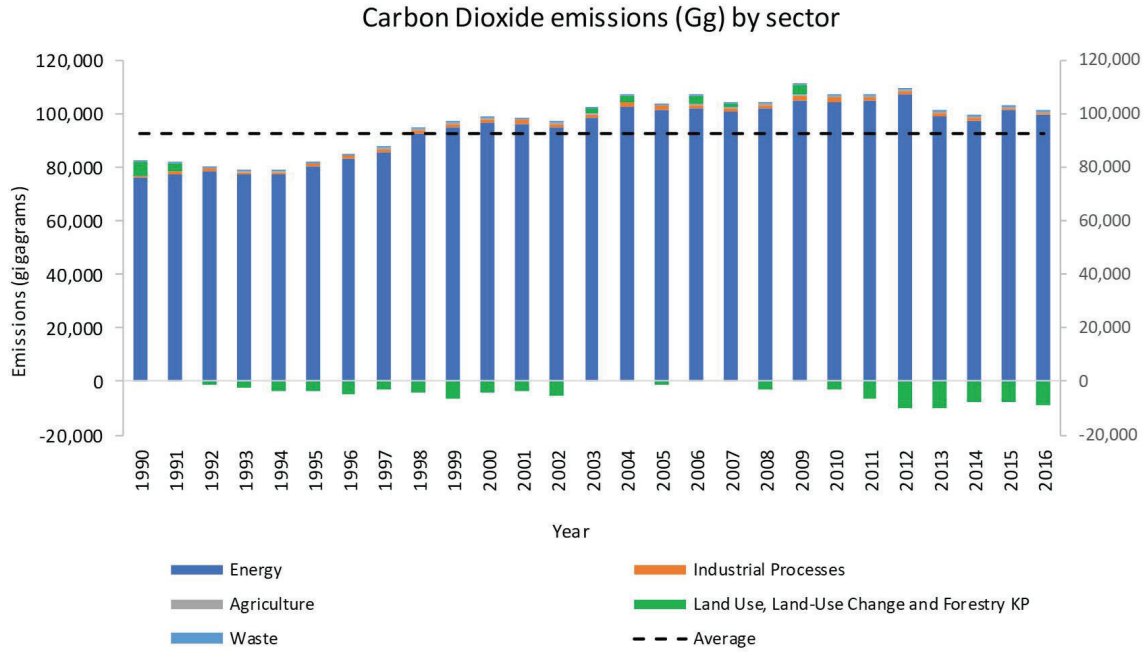


Figure Fo.29 GHG inventory (carbon dioxide) trend by sector in Victoria, 1990–2016

(Data source: Australian Government, Australian Greenhouse Emissions Information System, 2018)

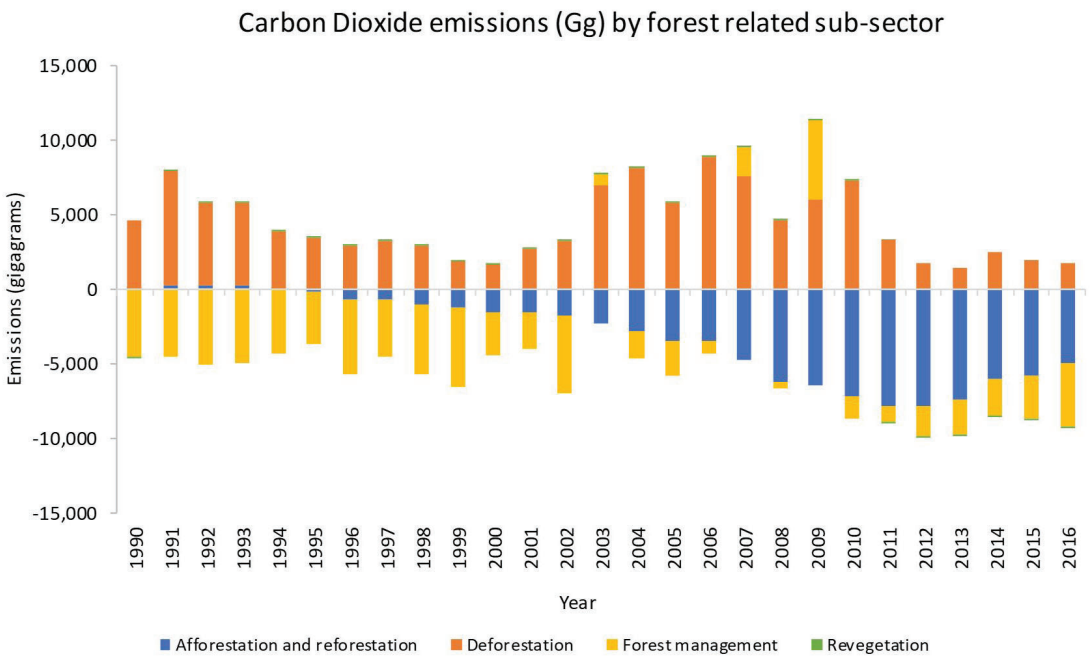


Figure Fo.30 GHG inventory (carbon dioxide) trend by subsector in Victoria, 1990–2016

(Data source: Australian Government, Australian Greenhouse Emissions Information System, 2018)

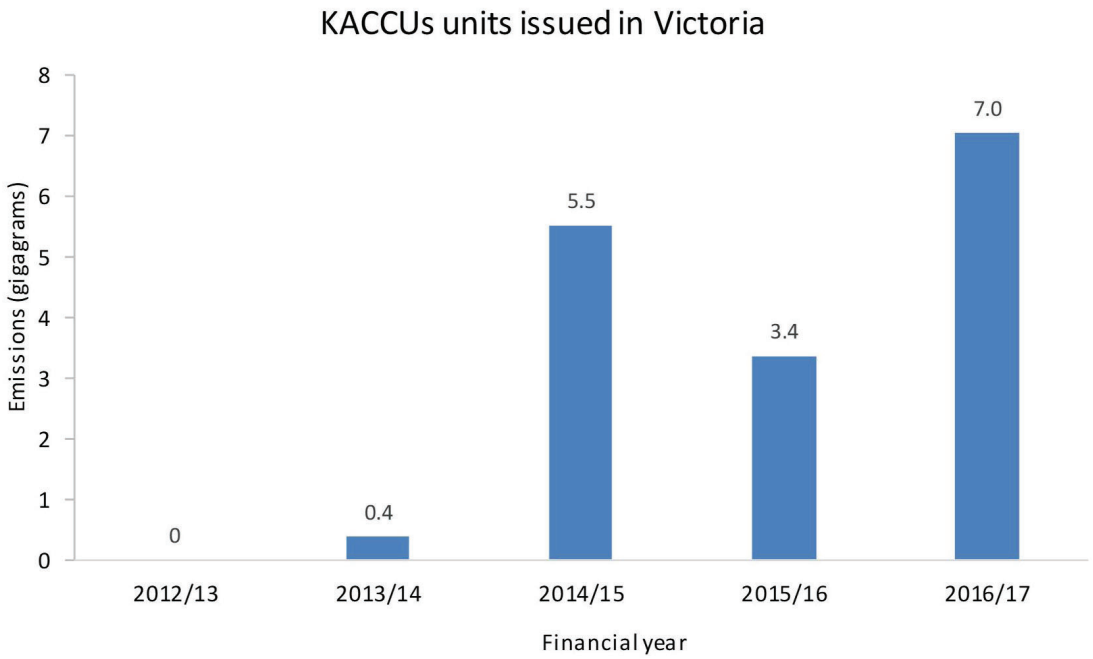


Figure Fo.31 Kyoto Australian Carbon Credit Units (KACCUs) using the 'vegetation method'

Note: Each KACCU unit represents one tonne of carbon dioxide equivalent (tCO_{2-e}) and converted to gigagrams to match Figure Fo.29 and Figure Fo.30.

(Data source: Australian Government, 2018)

Productive Capacity

	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
Fo:12 Area and percentage of forest and net area of forest available and suitable for wood production Data custodians DELWP, VicForests		↘	DATA QUALITY Good

The area of forest available for timber production, and forest types and age classes, are key planning input for determining long-term sustainable timber production rates. Monitoring trends in available forest area assists the forest sector in managing any change that will affect resource availability. It also provides insight into the changing balance of management objectives across the forested landscape.

Not all public forests are available for commercial native timber harvesting. Commercial trees are those large enough and close enough to a market to allow them to be harvested. In Victoria, most commercially viable native forests are in the east, including the Central Highlands. Data from VicForests (the Victorian government business responsible for the harvest, commercial sale and regrowing of native timber from state forests) shows that approximately 0.04% of native forests are harvested each year.

Table Fo.15 summarises the total available and unavailable area for timber production, in both state forests and parks and conservation reserves. It shows that unavailable area for timber production has increased by more than 200,000 hectares. This is because the area zoned for the protection of threatened species, such as Leadbeater's possum, has increased.

VicForests's Resource Outlook has also reduced the available timber production area in state forests. The Resource Outlook defines the volume of hardwood timber products from native forests to be made available to the market. It separates the species groups of timber supply, as either ash or mixed-species.[107]

Meanwhile, reduced availability of sawlog resource in areas such as the Central Highlands can be attributed to the effects of fire in estimates of sustained yield.[108, 109]

Overall, the trend indicates less timber production in state forests in the future. It is likely that more emphasis will be placed on activities associated with species conservation and carbon sequestration.

107. VicForests 2016, '2016-2017 Resource Outlook', Melbourne, Victoria http://www.vicforests.com.au/static/uploads/files/vicforests-resource-outlook-2016-17-wfasdtpknkdp.pdf Accessed 4 December 2018.

108. Lindenmayer DB 2017, 'Halting natural resource depletion: engaging with economic and political power', The Economic and Labour Relations Review, 28, pp. 41-56.

109. Lindenmayer DB 2018, 'Flawed forest policy: flawed Regional Forest Agreements', Australasian Journal of Environmental Management, 25, pp. 258-266.

Table Fo.15 Area available for harvest in native forest, 2006, 2008, 2012, 2016

Tenure	Forest management zone	Year and Area ('000 ha)				
		2006	**2008**	**2012**	**2014**	**2016**
Available						
State forest	General management zone	2,403	2,318	2,110	2026	2,112
	Special management zone	182	172	275	263	159
Parks and conservation reserves	Limited timber production	12	12	18	14	19
Total available		2,597	2,502	2,403	2,302	2,290
Not available						
State forest	Special Protection Zone	828	783	753	747	761
Parks and conservation reserves	No timber production	3,820	3,825	3,982	4,117	4,106
Total not available		4,648	4,608	4,735	4,864	4,862
Grand total		**7,245**	**7,110**	**7,138**	**7,166**	**7,153**

(Data source: DELWP, 2018)

	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
Fo:13 Area of native forest harvested	FAIR	→	DATA QUALITY: Good

Data custodians DELWP, DEDJTR, VicForests

Monitoring and assessing levels of timber harvest from native forest is an essential part of sustainable forest management. Tracking annual harvest rates in native forests against the available level of harvest rate is important for evaluating whether the current approach is sustainable.

The native-timber industry in Victoria produces a variety of wood products. These include the sawlogs that are used in furniture, construction and flooring, as well as logs of lower quality, used for firewood and pulp or paper production. Sawlogs are mostly sourced from the ash forests of north-eastern Victoria and Gippsland, but can also be derived from mixed-species forests with comparatively lower-quality timber. Mixed-species forests, which have two or more eucalypt species, are widespread among native Victorian forests.

During the harvest process, not all trees or tree elements are deemed sawlog-quality. Some trees are too young or knotty, and tree components such as branches of the upper trunk are considered unsuitable for sawlog production. This 'residual timber' constitutes approximately two-thirds of the harvested volume, and is primarily used for pulp/paper production with a smaller quantity sold as firewood. VicForests suppliestimber harvested from operations in eastern and western Victoria for sawlog processing to roughly 20 mills.[110] Around 90% of this timber is processed by the largest 10 mills.[111]

The mechanism used to determine the sustainable harvest level for native forests in Victoria is the Allocation Order 2013 (AO). The AO was created under Section 13 of the *Sustainable Forests (Timber) Act 2004*. The AO describes the location and extent of timber resources allocated to VicForests for harvest and sale. Timber-harvesting activity beyond the designated locations is not allowed.

The AO[112] has been reviewed three times since its introduction. The first review was of the 'Allocation to VicForests Order 2004' (the predecessor to the AO) to account for the impact of the major bushfires in 2006–07 and 2009.

Following a second review in 2010, the ash forest five-year harvest area limit was increased to allow VicForests to undertake salvage harvesting of the burnt forests following the 2009 bushfires. After another review in 2010, the accounting process used to monitor harvesting compliance with the AO changed from a net area tally to a gross coupe area tally. (Net area is the extent of timber harvesting: the actual area, or 'footprint' of tree felling. Gross coupe area is the area of state forest where timber resources are potentially available to VicForests for harvest and sale. It includes areas that can be harvested and areas that will not be harvested, including those protected under the *Code of Practice for Timber Production 2014*; areas where the timber available is not commercially suitable or commercially viable.)

Since August 2004, the AO has specified the maximum area that may be harvested, setting five-year harvest area limits. The AO currently species a five-year harvest area limit of 14,200 hectares (gross) for ash forest type, and 70,000 hectares (gross) for mixed-species forest type (Table Fo.18). The five-year harvest limit sets a harvest area 'ceiling'. Assuming a commercial forest life of about 100 years, the five-year harvest area limit is a maximum of around 5% of the total area in any five-year period.

110. VAGO 2013 'Managing Victoria's native forest timber resources', Melbourne, Victoria http://www.vicforests.com.au/static/uploads/files/20131211-timber-resources-wfsdlrklejjj.pdf Accessed 4 December 2018.
111. Ibid
112. Victorian Department Economic Development, Jobs, Transport and Resources, 'Timber Allocation Order', Victoria http://agriculture.vic.gov.au/agriculture/forestry/timber-allocation-order Accessed 4 December 2018.

The area of harvesting has not reached the five-year harvest area levels. The area of harvest compared to the AO are:

- In the five years up to June 2009, VicForests harvested some 66% of the ash forest and 57% of the mixed-species forest allocated for that five-year period for non-fire affected forest. In this period VicForests also undertook salvage harvesting of fire-affected forests (Table Fo.16).
- In the period before the current AO from 2009 to 2013 (four years), VicForests harvested some 71% of the ash forest five-year harvest area limit and 24% of the mixed-species forest five-year harvest area limit. VicForests undertook salvage harvesting of fire-affected forests (Table Fo.17 and Table Fo.19) in this period.
- In the period 2013 to 2017 (four years), VicForests harvested 66% of the ash forest five-year harvest area limit and 15% of the mixed-species forest five-year harvest area limit (Table Fo.18).

Table Fo.19 indicates that the area of state forest harvested between 2011–12 and 2016–17 was between 4,400 and 5,600 hectares per year. The average area harvested is less than 1% of the total area available for timber harvesting (see Fo:11 (Area and percentage of forest and net area of forest available and suitable for wood production)). Note that Table Fo.19 presents net area data – not gross area data – and so does not correlate with with Table Fo.17 and Table Fo.18.

The data for this report was finalised before 21 November 2018, when ABC News published an online article and broadcast a story on its *7.30* program speculating about potential timber-harvesting activity by VicForests outside its allocation boundary.[113, 114] However, on 17 November 2018, a joint statement provided to the ABC from the Minister for Energy, Environment and Climate Change, and the Minister for Agriculture, stated that DELWP confirmed that no harvesting occurred in protected areas,[115] and that the apparent discrepancy ABC News identified was due to differences between the legally enforceable map (see appendix 1 of the AO) and a spatial data file provided to the ABC.[116]

The re-elected Andrews Labor Government has committed to providing more detailed spatial data maps for any future AOs.[117] DEDJTR,[118] VicForests[119] and DELWP[120] have also responded to this issue. In addition, the Victorian Government ordered an independent review of timber-harvesting regulations. The recommendations of the independent review will be released publicly.[121] The Office of the Commissioner for Environmental Sustainability will consider this issue in the next reporting cycle, potentially developing a new indicator to address the specific issue of allocation boundaries.

113. ABC NEWS, 'Australia's endangered forests are being 'stolen' and sold in hardware and office stores' https://www.abc.net.au/news/2018-11-21/victorian-forests-appear-to-have-been-logged-illegally/10496424#statements Accessed 4 December 2018.
114. ABC 7.30 Report, 'Government-owned logging company accused of illegally logging state forest' https://www.abc.net.au/7.30/government-owned-logging-company-accused-of/10520270 Accessed 4 December 2018.
115. Joint statement from the Minister for Environment Lily D'Ambrosio and Minister for Agriculture Jaala Pulford, November 17: https://www.documentcloud.org/documents/5194121-Joint-Ministerial-Response.html Accessed 4 December 2018.
116. Response from DELWP spokesperson, November 16 and 18: https://www.documentcloud.org/documents/5194115-DELWP-Response.html Accessed 4 December 2018.
117. Joint statement from the Minister for Environment Lily D'Ambrosio and Minister for Agriculture Jaala Pulford, November 17: https://www.documentcloud.org/documents/5194121-Joint-Ministerial-Response.html Accessed 4 December 2018.
118. Response from the Department of Economic Development, Jobs, Transport and Resources (DEDJTR), November 16: https://www.documentcloud.org/documents/5194120-DEDJTR-Response.html Accessed 4 December 2018.
119. Response from VicForests spokesperson, November 16: https://www.documentcloud.org/documents/5194125-VicForests-Response.html Accessed 4 December 2018.
120. Response from DELWP spokesperson, November 16 and 18: https://www.documentcloud.org/documents/5194115-DELWP-Response.html Accessed 4 December 2018.
121. Joint statement from the Minister for Environment Lily D'Ambrosio and Minister for Agriculture Jaala Pulford, November 17: https://www.documentcloud.org/documents/5194121-Joint-Ministerial-Response.html Accessed 4 December 2018.

Table Fo.16 Harvest area (net hectares) 2004–05 to 2008–09 (five years) compared to the Allocation to VicForests Order 2004.

	2004–05	2005–06	2006–07	2007–08	2008–09	Total	AO max. area for period 1 (5 yrs)	Total area harvested compared to AO (%)
Ash	1,271	1,078	850	1,022	933	5,154	7,810	66
Mixed-species	2,520	2,701	2,325	2,366	2,424	12,336	21,660	57

Note: Additional harvest in this time included 6,110 hectares of fire-affected and salvage harvesting. The AO provided a total allocation of 56,540 hectares of fire-affected and salvage forest stands.

(Data source: DSE1122)

Table Fo.17 Gross coupe area 2009–10 to 2012–13 (four years) compared to AO 2013

	2009–10	2010–11 (gross hectares)	2011–12 (gross hectares)	2012–13 (gross hectares)	Total (4 yrs)	AO five-year harvest area limits (5 yrs)	Total area harvested compared to AO (%)
Ash	3,712	2,776	3,238	2,594	12,629	17,400	71
Mixed-species	5,880	5,032	3,525	2,724	9,332	71,800	24

Note: The Gross Coupe Area listed above includes forest stands impacted by fire. The use of gross area as the Allocation Order harvest area accounting parameter began in May 2010. In this table, the gross area harvest in 2009–10 (before May 2010) is provided.

(Data source: DEDJTR (2017). Internal)

Table Fo.18 Gross coupe area 2013–14 to 2016–17 (four years) compared to AO 2013

	2013–14 (gross hectares)	2014–15 (gross hectares)	2015–16 (gross hectares)	2016–17 (gross hectares)	Total (4 yrs)	AO five-year harvest area limits (5 yrs)	Total area harvested compared to AO (%)
Ash	2,090	2,273	2,583	2,386	9,332	14,200	66
Mixed-species	2,034	2,820	2,847	3,003	10,704	70,000	15

(Data source: VicForests (2018) VicForests annual harvesting and regeneration report 2016–17)

122. State of Victoria 2010, 'Monitoring annual harvesting performance in Victoria's State forests 2008-09', Melbourne, Victoria.

Table Fo.19 Net area (ha) harvested by regime to 2016–17

Year		Net area harvested (ha)				
	Clear fall regime [(a)]	Thinning regime	Salvage regime	Seed Tree	Selection regime	Total (all regimes)
2011–12	1,400	1,200	100	2,200	700	**5,600**
2012–13	1,500	1,800		1,400	800	**5,500**
2013–14	1,500	1,200		1,400	500	**4,600**
2014–15	1,300	1,000		1,700	400	**4,400**
2015–16	1,100	1,700		1,700	300	**4,800**
2016–17	900	1,500		1,800	600	**4,800**

(a) Clear fall includes Regrowth Retention Harvesting method[123]

(Data source: VicForests, 2018)

123. VicForests, 'Regrowth retention harvesting', Melbourne, Victoria http://www.vicforests.com.au/leadbeaters-possum1/regrowth-retention-harvesting-1 Accessed 4 December 2018.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:14 Annual production of wood products from State forests compared to sustainable harvest levels					↘	DATA QUALITY Good
Data custodians DELWP, VicForests						

Of 7.9 million hectares of Crown land in Victoria, about 3.7 million hectares are listed as national parks and reserves, and 3.2 million hectares of multi-use state forest. Both tenures have approximately 3 million hectares of forest cover. According to 2016-17 Resource Outlook, approximately 450,000 hectares in eastern Victoria are considered commercially suitable for timber production;[124] however, only a fraction on this area is actually harvested, with approximately 0.04% (gross area) commercially harvested each year since 2010.

Data shown in Table Fo.20 and Figure Fo.32 indicates that total timber annual production from state forests has been gradually decreasing. The production rate for sawlogs has decreased over the past two decades, from 729,000 m^3 in 1996–97 to 299,740 m^3 in 2016–17. Pulpwood production has decreased at a similar rate to sawlogs since 2004–05. However, production of other products, such as 'E grade' (low grade) logs and cull logs, has increased. Since 2012–13, overall production of wood products from state forests has been stable.

The Resource Outlook (RO) is a forecast of available sawlog hardwood timber in native forests to be commercially supplied from state forests in eastern Victoria.[125] VicForests has a statutory obligation to achieve sustainable production of timber products from native forests. Although the available Ash D+ sawlog volume is expected to reduce between 2020–21 and 2029–30, RO forecasts a consistent supply in the range of 100,000 m^3 until 2029–30 for mixed-species D+ sawlog.[126] The reduction in Ash D+ sawlog will be approximately 90,000 m^3 per annum compared to the 2013 RO. VicForests suggests that this is mainly due to:

- increased protection for Leadbeater's possum and other threatened species
- spatial fragmentation of the remaining available forest, as a result of the proximity and density of Leadbeater's possum populations
- increased protection (12,000 m^3/annum) of old-growth forest (all pre-1900 ash stands are in a forest management area)
- the removal of forest from the model that VicForests considers unlikely to be able to be accessed due to community and/or market concerns for ecological values.[127]

Sustainable harvest levels have been more than halved over the past decade. A 2017 VEAC report, showing modelling of predicted climate change impacts, suggests that by the end of the century, standing volume and stand density will be reduced by 15%.[128] This would further reduce resource outlook.

VicForests has a statutory obligation to sustainably produce timber from native forests. It takes into account the risk of bushfires and excludes areas of high community interest, such as those with Leadbeater's possum colonies, in its modelling for commercial sawlog timber supply.[129]

124. VicForests, 'Area Statement', Melbourne, Victoria http://www.vicforests.com.au/planning-1/area-statement Accessed 4 December 2018.
125. VicForests 2016, '2016-2017 Resource Outlook', Melbourne, Victoria http://www.vicforests.com.au/static/uploads/files/vicforests-resource-outlook-2016-17-wfasdtpknkdp.pdf Accessed 4 December 2018.
126. Ibid
127. VicForests 2017, 'Annual Report 2016-17', Melbourne, Victoria http://www.vicforests.com.au/static/uploads/files/vicforests-2016-17-annual-report-wfsjtsyiepto.pdf Accessed 4 December 2018.
128. VEAC 2017, 'Fibre and wood supply: Assessment report', Melbourne, Victoria http://veac.vic.gov.au/investigation/fibre-and-wood-supply-assessment/reports Accessed 4 December 2018.
129. VicForests 2016, '2016-2017 Resource Outlook', Melbourne, Victoria http://www.vicforests.com.au/static/uploads/files/vicforests-resource-outlook-2016-17-wfasdtpknkdp.pdf Accessed 4 December 2018.

There has been some concern about sustainable timber production predictions given strong uncertainty about bushfires and previous production rates.[130, 131, 132] VicForests has therefore increased exclusion areas, where timber harvesting is not allowed, leading to a reduction in wood production.[133]

Moreover, the age structure of the ash forests – mainly mountain ash (*Eucalyptus regnans*) and alpine ash (*Eucalyptus delegatensis*) species – in the Central Highlands in Victoria is heavily imbalanced due to landscape-scale bushfires, including the 1939 'Black Friday' bushfires and 2009 Black Saturday bushfires (Figure Fo.33). In eastern Victoria, where most commercial native-timber harvesting takes place, most forest stands have regenerated from the 1939 bushfires. However, impacts of the 2009 fires intensified the imbalance of age-class distribution of ash species forests in eastern Victoria. As the Victorian sawlog industry currently relies heavily on the 1939 regrowth ash forests, this will cause a significant decrease of available sawlog production from native forests for a few decades.

130. Burgman MA, Church R, Ferguson I, Giijsbers R, Lau A, Lindenmayer DB, Loyn RH, McCarthy M, Vandenberg W 1994, 'Wildlife planning using FORPLAN: a review and examples from Victorian forests', Australian Forestry, 57, pp. 131-140.
131. Blair D, McBurney LM, Blanchard W, Banks SC, Lindenmayer DB 2016, 'Disturbance gradient shows logging affects plant functional groups more than fire', Ecological Applications, 26, pp. 2280-2301.
132. Blair D, McBurney L, Lindenmayer DB, Banks S, Blanchard W 2017, 'The Leadbeater's Possum review', The Australian National University, Canberra, Australia.
133. VicForests 2016, '2016-2017 Resource Outlook', Melbourne, Victoria http://www.vicforests.com.au/static/uploads/files/vicforests-resource-outlook-2016-17-wfasdtpknkdp.pdf Accessed 4 December 2018.

Table Fo.20 Annual production of wood products from state forests, 1996–97 to 2016–17

Year	Volume (cubic metres, m^3)			
	Sawlogs[A]	Pulpwood	Other products[B]	Total
1996–97	729,000	1,033,000	N/A	1,762,000
1997–98	804,000	1,120,000	N/A	1,924,000
1998–99	821,000	1,165,000	N/A	1,986,000
1999–2000	820,000	1,403,000	N/A	2,223,000
2000–01	667,000	1,580,000	N/A	2,247,000
2001–02	682,000	1,365,000	111,000	2,158,000
2002–03	638,000	1,208,000	117,000	1,963,000
2003–04	[C]530,000	1,291,000	112,000	1,933,000
2004–05	[D,E] 583,000	1,335,000	123,000	2,041,000
2005–06	[D,F] 497,000	1,329,000	109,000	1,935,000
2006–07[G]	428,000	1,241,000	124,000	1,793,000
2007–08	433,000	1,478,000	147,000	2,058,000
2008–09	413,000	1,141,000	158,000	1,712,000
2009–10	443,000	1,250,000	172,000	1,865,000
2010–11	329,525	1,210,024	213,600	1,753,149
2011–12	290,546	980,889	182,503	1,453,938
2012–13	332,054	750,633	189,574	1,272,261
2013–14	304,651	756,425	209,742	1,270,818
2014–15	306,672	758,858	241,205	1,306,735
2015–16	344,746	685,612	285,305	1,315,663
2016–17	299,740	703,730	260,901	1,264,371

A: Prior to 2004–05, sawlog volume is expressed as net volume (gross volume minus allowances for defects).

B: Other products include E-grade (low grade) logs and cull logs. Data not available before 2001–02.

C: Includes 118,000 m^3 fire salvage; normal harvest was 412,000 m^3.

D: Gross sawlog volume

E: Includes 50,000 m^3 fire salvage; normal harvest was 533,000 m^3.

F: Includes 27,000 m^3 fire salvage; normal harvest was 470,000 m^3.

G: Over six years (2006–07 to 2011–12), approximately 650,000 m^3 of D+ sawlog was harvested from areas burnt by fire.

(Data source: VicForests[134], 2018)

134. The data is derived from Harvesting History Shapefile from VicForests

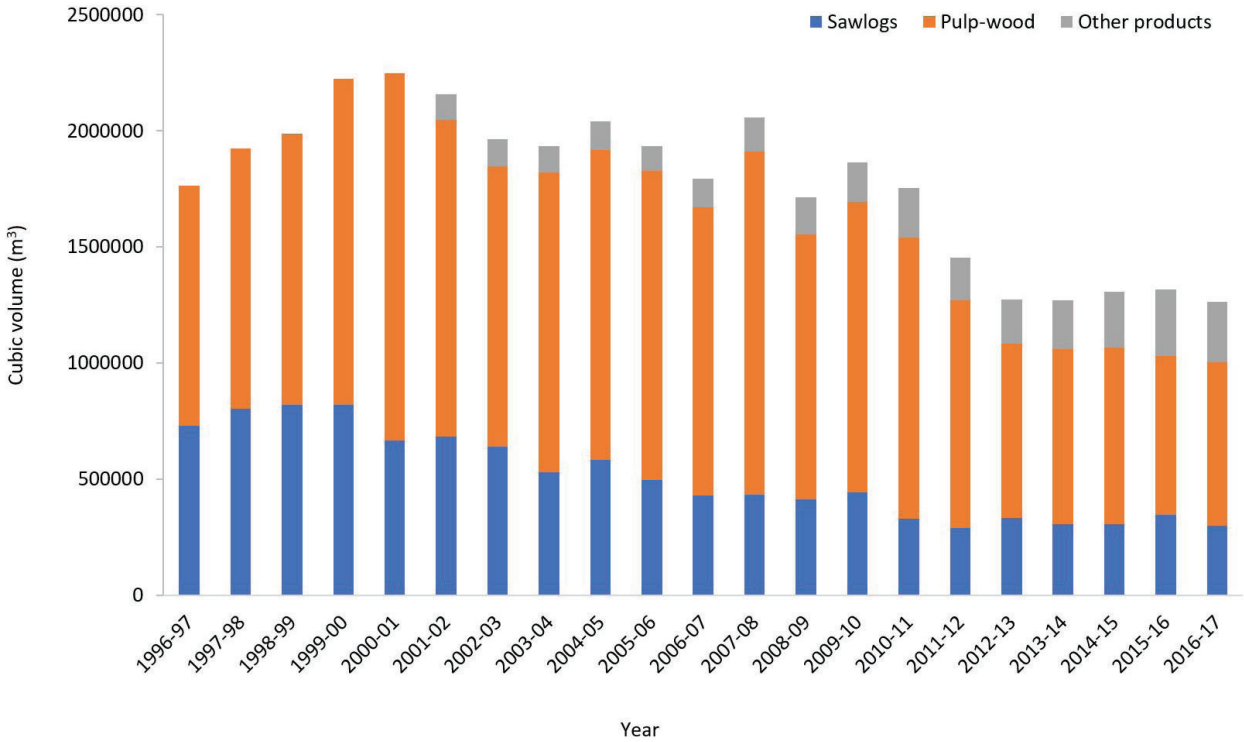


Figure Fo.32 Annual production of wood products from state forests by sawlogs, pulpwood and other products, 1996–97 and 2016–17

(Data source: VicForests, 2018)

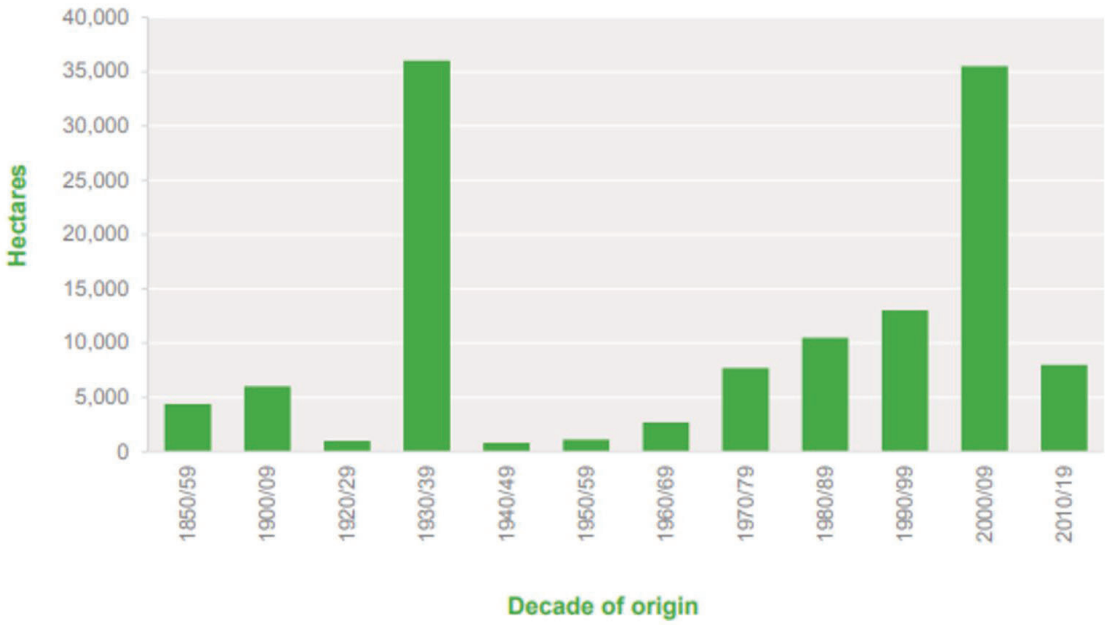


Figure Fo.33 Age class distribution of ash forests

(Data source: VEAC[135], 2018)

135. VEAC 2017, 'Fibre and wood supply: Assessment report', Melbourne, Victoria http://veac.vic.gov.au/investigation/fibre-and-wood-supply-assessment/reports Accessed 4 December 2018.

Firewood

The collection of firewood is allowed in Victoria's state forest and in some forest parks. For many Victorians, firewood is an important energy source for heating and cooking. Most of the firewood used is collected by households for domestic use; the rest is taken by commercial firewood collectors. Firewood collection within the forest estate is restricted to certain areas and times of the year. In September 2011, the licence system for domestic firewood collection was discontinued, but licences are still required for commercial collection. Because of the discontinuation, the amount of domestic firewood collected in state forests after 2011–12 is unknown (Table Fo.21). In terms of commercial firewood, total firewood collected in state forests and some forest parks fluctuated between 2001–02 and 2012–13.

Many invertebrate species depend on the availability of dead wood for survival. It is therefore important to monitor and respond to trends in firewood use as part of sustainable forest management. Although volume of firewood will not be an indicator of threat status to an overall ecosystem, it is difficult to assess the impacts of ongoing firewood collection on forest ecosystems.

Table Fo.21 Volume (m^3) of firewood collected with domestic and commercial licences in state forests, 2001-02 to 2016-17

Year	Domestic	Commercial	Total
2001–02	48,207	12,256	60,463
2002–03	54,826	16,022	70,848
2003–04	54,454	18,736	73,190
2004–05	56,660	26,980	83,640
2005–06	51,330	14,149	65,479
2006–07	35,926	9,061	44,987
2007–08	24,484	12,184	36,668
2008–09	24,365	12,530	36,895
2009–10	33,645	8,348	41,993
2010–11	38,981	6,106	45,087
2011–12*	11,652	6,400	11,747
2012–13	N/A	18,165	18,165
2013–14	N/A	14,979	14,979
2014–15	N/A	26,041	26,041
2015–16	N/A	31,971	31,971
2016–17	N/A	35,720	35,720

* The volume of domestic firewood collected is unknown after 2011–12, as the requirement to licence domestic collection was discontinued.

(Data source: VicForests, 2018)

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:15 Proportion of timber harvest area successfully regenerated by forest type Data custodian DEDJTR, VicForests					→	DATA QUALITY Good

To achieve a sustainable level of timber production, regeneration following timber-harvesting activities (post-harvest regeneration) is a key part of maintaining the productive capacity of forests. Monitoring the success of forest regeneration informs understanding of the future availability of forest resources and any impacts long-term forest productivity. This information supports forest policy and planning activities, and continual improvement in regeneration practices.

The *Code of Practice for Timber Production 2014* (the code) determines that all state forest areas subject to timber-harvesting operations will be regenerated to standards that approximate the original forest composition. Timber harvest managers are required to regenerate all harvested areas.

Successful regeneration is usually achieved at the first attempt 85% to 95% of the time. Failure of regeneration can be due to a range of environmental factors, including death from drought, browsing of seed or seedlings (for example, by wallabies or insects), and frost and snow damage. For areas not regenerated successfully the first time, the harvest manager is required to undertake further regeneration treatments until the minimum standards are met.

The 'Management standards and procedures for timber-harvesting operations in Victoria's state forests 2014', incorporated in the code lists the minimum regeneration standards required. The standards outline three regeneration features:

1. minimum 65% of plots stocked (standard intensity)
2. no discrete unstocked areas greater than one hectare in even aged stands, or greater than two hectares in uneven aged stands
3. at least 10 acceptable seedlings/coppice of those eucalypt species present on the site prior to harvesting must be present on the regenerated site.

The code also lists the survey techniques that must be followed by the harvest manager to confirm regeneration success. The surveys are to be undertaken 15 to 30 months after seedfall and/or sowing in even aged stands, and 15 to 36 months after seedfall in uneven aged stands.

Table Fo.22 indicates the total harvested area of native forest between 2011–12 and 2016–17, and the total harvested area effectively regenerated between 2011–12 and 2016–17. The areas reported as harvested and the areas regenerated for each year relate to different areas given the time period required to report on regeneration success. Between 2011–12 to 2016–17, 2,059 more hectares have been harvested than regenerated. However, DEDJTR states that this does not indicate that sustainable harvest has not been achieved. This data needs to be carefully monitored to ensure that the successful post-harvest timber harvest is fully achieved.

Note that the regeneration data supplied is for eastern Victoria only. Generally, no regeneration is required for harvesting in western Victoria as the harvesting operations are not clearing-style harvesting, but thinning-style harvesting.

The 2013 audit report of the Victorian Auditor-General's Office (VAGO), *Managing Victoria's Native Forest Timber Resource*, found that the harvest manager, VicForests, was meeting the required regeneration standards. However, VAGO recommended improvements in reporting to better align the reporting of harvesting and its corresponding regeneration.

Table Fo.22 Total area of native forest harvested, and effectively regenerated, 2011-12 to 2016-17

Year	Native forest area harvested (ha)	Native Forest Area effectively regenerated (ha)	Net area regenerated
2011–12	4,298	4,055	–243
2012–13	3,327	3,397	70
2013–14	2,981	2,242	–739
2014–15	4,331	3,459	–872
2015–16	2,900	2,426	–474
2016–17[136]	2,800	2,999	199
Total	20,637	18,578	–2,059

(Data source: DEDJTR[137] and VicForests[138], 2018)

136. VicForests and DEDJTR, 'Cengea Site establishment cube'.
137. Department of Economic Development, Jobs, Transport and Resources, 'Harvest History database (LOGSEASON)', Melbourne, Victoria.
138. VicForests, '2015-16 sustainability report', Melbourne, Victoria http://www.vicforests.com.au/about-vicforests/corporate-reporting-1/sustainability-report-2016 Accessed 4 December 2018.

Legal, Institutional and Economic

	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
Fo:16 Extent to which the legal framework (laws, regulations, guidelines) supports the conservation and sustainable management of forests	FAIR	↗	DATA QUALITY Fair

Data custodian DELWP

A legal framework with laws, regulations and guidelines is necessary to support continuous improvements in sustainable forest management. Such a system assists to establish transparency and public participation in policy and decision-making processes.

There are currently 33 legislations that regulate forest management in Victoria, which creates legislative complexity (Table Fo.23 summarises the legislation, the tenure to which they apply, and lists key amendments made during the reporting period). VEAC seeks to address the problem of legislative complexity in the final report of its *Statewide Assessment of Public Land*, released in May 2017. The report includes several recommendations to reform the public land legislative framework, in particular changes to the:

- *Land Act 1958*
- *Forests Act 1958*
- *National Parks Act 1975*
- *Crown Land (Reserves) Act 1978*.

The rationale for legislative reform is to strengthen, modernise and simplify Crown land legislation to ensure it is responsive to modern challenges and demands. The Victorian Government has accepted, in principle or in part, all recommendations made by VEAC, including committing to rewriting the Crown land legislation over the next four years.

Beekeeping

Between 2013 and 2018, the regulation of beekeeping in Victoria was changed. In March 2016, primary Land Acts were amended to allow for bee-site licences to apply for a longer period of up to 10 years.[139] Administrative processes were altered to enable the revision of licence terms and conditions and the streamlining of licence expiration. These regulatory changes include greater protections between bee sites and other public land boundaries through the requirement of an 800-metre buffer from the centre of a bee site to the boundary of wilderness parks, wilderness zones, reference areas and natural catchment areas.[140]

139. Victorian Government 2016, 'Authorised version No.128, *Land Act 1958*. No 6284 of 1958: Authorised version incorporating amendments as at 19 September 2016', Melbourne, Victoria http://www.legislation.vic.gov.au/domino/Web_Notes/LDMS/LTObject_Store/ltobjst9.nsf/DDE300B846EED9C7CA257616000A3571/305521026ADDC945CA258030001C8255/$FILE/58-6284aa128%20authorised.pdf Accessed 4 December 2018.

140. *Crown Land Legislation Amendment (Canadian Regional Park and Other Matters) Act 2016*. http://www.legislation.vic.gov.au/Domino/Web_Notes/LDMS/PubStatbook.nsf/51dea49770555ea6ca256da4001b90cd/21CF72B25E443BA2CA257F8C0019032A/$FILE/16-012aa%20authorised.pdf Accessed 4 December 2018.

Table Fo.23 Main legislation relevant to sustainable forest management in Victoria

Agency	Legislation	Summary of legislation purpose	Applicable tenure	Key amendments, 2013-17
DELWP	*Conservation, Forests and Lands Act 1987*	To provide a framework for a land management system, to make necessary administrative, financial and enforcement provisions, and to establish a system of land management co-operative agreements	Public/ Private (where applicable)	Streamlining of provisions relating to the making of codes of Practice
DELWP, DEDJTR	*Sustainable Forests (Timber) Act 2004*	To provide a framework for sustainable forest management and sustainable timber harvesting in state forests	State forests	Key amendments during this period are listed below. In 2013: • streamline AO process by vesting timber with VicForests • responsibility for Timber Release Plan approval transferred to VicForests • removal of timber-harvesting operator licences. In 2014: • Establish Timber Harvesting Safety Zones
Victorian Plantations Corporation	*Victorian Plantations Corporation Act 2003*	To establish the Victorian Plantations Corporation to manage state plantations and to require that timber harvesting comply with a code of practice	State forests	No amendments made since 7 June 2012
DELWP	*Forests Act 1958*	To provide for the management and protection of state forests, including timber harvesting and fire management	State forests and all public land for fire matters	Allowance for collection of domestic firewood without a permit, in certain areas, at specified times
DELWP	*Forests (Fire Protection) Regulations 2014*	To provide for the protection of state forests, national parks and protected public land from damage by fire	National parks (including state parks), state forests and protected public land	No amendments
DELWP	*Forests (Recreation) Regulations 2010*	To regulate camping and other activities in certain public land tenures including forests reserves and forest parks	Public land	No amendments

Agency	Legislation	Summary of legislation purpose	Applicable tenure	Key amendments, 2013-17
DELWP	*Flora and Fauna Guarantee Act 1988*	To establish a legal and administrative structure to enable and promote the conservation of Victoria's native flora and fauna, and to provide for a choice of procedures which can be used for the conservation, management or control of flora and fauna and the management of potentially threatening processes	All	No amendments
DELWP	*Catchment and Land Protection Act 1994*	To set up a framework for the integrated management and protection of catchments, to encourage community participation in the management of land and water resources, and to set up a system of controls on noxious weeds and pest animals	All	No amendments
DELWP	*Land Act 1958*	To set out the law relating to the sale and occupation of Crown lands, including provision for a range of licences	Public land	Provision for uniform licensing of bee sites on most Crown land
Parks Victoria	*National Parks Act 1975*	To provide a framework for establishment and management of national parks and other parks	Public national parks and other parks and reserves referred to in the Act	• establishment of new park areas including Lake Tyers Park (8,680 ha) • additional areas added to Great Otway National Park • introduction and removal of power for Minister to grant leases of up to 99 years over certain areas • introduction of total prohibition on cattle grazing in alpine national parks and in the six river redgum national parks.
Parks Victoria	*Parks Victoria Act 2018*	To establish Parks Victoria. There were major changes to the legislative framework, which resulted in having a broad range of direct powers to manage Victoria's parks and waterways	National parks and other conservation reserves	No amendments

Agency	Legislation	Summary of legislation purpose	Applicable tenure	Key amendments, 2013-17
Environment Protection Authority Victoria	*Environment Protection Act 1970*	To establish an Environment Protection Authority and to provide a framework for preventing pollution and environmental damage by setting environmental quality objectives and establishing programs to meet them	All	In 2017, a new Environment Protection Act was passed by the Parliament of Victoria.[141] The Environment Protection Act 2017 also has the function of establishing the Environment Protection Authority. The two Acts are operating together currently, in the transitional period for the reforms.
Environment Protection Authority Victoria	*Environment Effects Act 1974*	To provide a framework for preparation of an Environmental Effects Statement for public works that the Minister considers capable of having a significant effect on the environment	All	No amendments
DELWP	*Heritage Rivers Act 1992*	To make provision for Victorian heritage rivers by providing for the protection of public land, in particular parts of rivers and river catchment areas in Victoria that have significant nature conservation, recreation, scenic or cultural heritage attributes	Public land	No amendments
DELWP	*Crown Land (Reserves) Act 1978*	To provide for the reservation of Crown lands for certain purposes and for the management of such reserved lands	Reserved Crown land	Key amendments are creation of two new regional parks
DELWP	*Reference Areas Act 1978*	Provides for the protection, control and management of certain special areas of Crown land to be preserved in their natural state, as far as is possible, due to their ecological interest and significance	Public	No amendments

141. The Parliament of Victoria 2017, 'Environment Protection Act 2017: No. 51 of 2017', Melbourne, Victoria http://www.legislation.vic.gov.au/Domino/Web_Notes/LDMS/PubStatbook.nsf/51dea49770555ea6ca256da4001b90cd/ABB3C4D755B99F3BCA2581C30009DE28/$FILE/17-051aa%20authorised.pdf Accessed 4 December 2018.

Agency	Legislation	Summary of legislation purpose	Applicable tenure	Key amendments, 2013-17
DELWP, local government	*Planning and Environment Act 1987*	To establish a framework for planning the use, development and protection of land in Victoria in the present and long-term interests of all Victorians. Provides for the protection of natural processes and genetic diversity, and conservation of places of scientific, aesthetic or special conservation value. Requires administration and enforcement of planning schemes that specify appropriate controls on the use, development and protection of land, including timber production on private land	All	No amendments
CFA	*Country Fire Authority Act 1958*	To confer on the authority a responsibility to prevent and suppress fire on all land (urban and rural) outside the Melbourne Metropolitan Fire District, but does not include any forest, national park or protected public land	Private	No amendments
DEDJTR	*Climate Change Act 2017*	To separate ownership of the land from ownership of the trees on the land, and provide legal security to the 'Forest Property Owner'. Recognises carbon sequestration rights and enables ownership of these rights separately from the trees and the land	All forested land	No amendments
DELWP	*Road Management Act 2004*	To establish a coordinated management system for public roads to promote safe and efficient state and local public road networks and the responsible use of roads	Public land	No amendments
DELWP	*Safety on Public Land Act 2004*	Provides for public safety in state forests by providing for the establishment and enforcement of public safety zones	State forests	No amendments

Agency	Legislation	Summary of legislation purpose	Applicable tenure	Key amendments, 2013-17
DELWP	*Forests (Wood Pulp Agreement) Act 1996*	To ratify an agreement between the Minister administering the Forests Act 1958 and AMCOR Limited with respect to the supply of pulpwood for the manufacture of wood pulp and for other purposes	Public	No amendments
DELWP	*Land Conservation (Vehicle Control) Act 1972*	To makes provisions for vehicular traffic on public land, as well as the prevention of soil erosion on, and damage to, public land	Public	Increases in maximum penalties for offences
Department of Premier and Cabinet; DELWP	*Aboriginal Lands Act 1991*	To authorise the granting of the reservations and Crown Grants of certain lands for Aboriginal cultural and burial purposes	Public	No amendments
Department of Premier and Cabinet	*Aboriginal Heritage Act 2006*	To provide for the protection of Aboriginal cultural heritage in Victoria.	All	Major amendments were made to the Act between 2013 and 2018 including changes to: • determine whether a mandatory cultural heritage management plan (CHMP) is required • Change CHMP from a guidance document to an approval document • require involvement of Traditional Owners where there is no Registered Aboriginal Party (RAP) • expand liability for offences and civil penalty provisions • allow for disclosure of Aboriginal heritage surveys.
Department of Justice and Regulation	*Traditional Owner Settlement Act 2010*	To provide for the making of negotiated agreements for land claims between Traditional Owner groups and government	All	No amendments

Agency	Legislation	Summary of legislation purpose	Applicable tenure	Key amendments, 2013-17
DELWP	*Catchment and Land Protection Act 1994*	To set up a framework for the integrated management and protection of catchments and to encourage community participation in the management of land and water resources	All	No amendments
DELWP	*Climate Change Act 2010*	To support climate policy, including the state's adaptation planning framework.	All	No amendments
DELWP	*Marine and Coastal Act 2018*	To provide for coordinated strategic planning and management for the Victorian coast	All	No amendments
DELWP	*Water Act 1989*	To provide for the integrated management of all elements of the terrestrial phase of the water cycle and to promote the orderly, equitable and efficient use of water resources	All	No amendments
DELWP	*Wildlife Act 1975*	To establish procedures, and provide for banning notices and exclusion orders in order to promote the protection and conservation of wildlife, and the prevention of taxa of wildlife from becoming extinct	All	No amendments

(Data source: DELWP, 2018)

	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
Fo:17 Extent to which the institutional framework supports the conservation and sustainable management of forests					↘	DATA QUALITY Fair

Data custodian DELWP

Institutional frameworks aim to encourage certain activities or behaviours within a sector. The processes, resources and activities provided through institutional frameworks create an environment that influences how effectively and efficiently the aims of the framework are delivered. The level of commitment and ability of the framework to produce outcomes can be monitored through the extent to which current conservation and sustainable forest management aims are being supported.

This indicator provides data on the governance framework to support conservation and sustainable forest management of public and private forests. The framework includes laws, plans, policies, public engagement and participation. Table Fo.24 provides an overview of the institutional framework elements in Victoria for conservation and sustainable forest management in both public and private forests. Table Fo.25 outlines key institutions involved in each element of the framework and key activities undertaken during the reporting period.

Table Fo.24 Institutional framework elements in Victoria for conservation and sustainable forest management, 2013-17

Element	Public*	Private*	Responsible organisation	Key activities in period
Administrative arrangements	Yes	Yes	DELWP; local government; Parks Victoria; VicForests; Catchment Management Authorities	Tenure transfer – state forest to Park
Public engagement and participation	Yes	Yes	DELWP; local government	
Periodic forest-related planning	Yes	No	DELWP	
Periodic assessment of forest values	Yes	No	DELWP; VicForests	Victorian Forest Monitoring Program
Periodic review of forest-related policy	Yes	Yes	DELWP	RFA review
Relevant skills development and maintenance	Yes	Yes	Universities; Registered Training Organisations; DELWP	
Infrastructure	Yes	Part	DELWP; Parks Victoria; local government	Access roads Recreation and fire management infrastructure
Law enforcement	Yes	Yes	DELWP; Parks Victoria; local government	Timber-harvesting compliance General forest and park compliance

* 'Yes' or 'no' indicates whether the relevant element has been conducted. 'Part' indicates partial completion

(Data source: DELWP, 2018)

The Victorian Government is responsible for ensuring that commercial timber harvesting activities comply with Victoria's environmental regulatory framework. Harvest coupes are assessed by auditors, and if non-compliance is found, the magnitude of impact is determined based on the following categories: severe, major, moderate, minor, negligible and no impact. More information is available on the DELWP website.[142]

Table Fo.25 demonstrates the overall assessment results of compliant and non-compliant audit elements, by different environmental impact categories, between 2007 and 2017. Audits since 2014 have targeted elements of the regulatory framework that have been assessed as having a 'high risk' of causing environmental harm. While the high-risk elements have been targeted, VicForests has indicated a high level of compliance with

142. DELWP, 'Forest audits', Melbourne, Victoria https://www.forestsandreserves.vic.gov.au/forest-management/forest-audits Accessed 4 December 2018.

prescriptions for timber production harvesting and coupe closure activities throughout the reporting period. Four environmental impacts arising from non-compliances were assessed based on the environmental impact assessment (EIS) tool. The assessment method is provided in the audit report.[143] The majority of non-compliances have been found to have no impact, or to be negligible or to have minor environmental impact.

However, it is important to note that the major environmental impact category has shown an increase. The reason for this must be investigated and identified.

Table Fo.25 Audit results for harvesting and coupe completion operations in Victoria, 2007 to 2016-17

Audit report year	2007	2011	2013	2014	2015–16	2016–17
Harvesting year	2006–07	2008–09	2010–11 & 2011–12	2013–14	2014–15	2015–16
No. coupes assessed	43	27	40	24	83	30
Compliant elements (%)	94	95	96	90	86	91
Severe	0	0	0	0	0	0
Major	16	2	16	6	25	37
Moderate	30	31	21	14	53	35
Minor	43	28	51	70	100	14
Negligible	55	49	34	23	106	9
No impact	25	40	36	19	3	0
Areas with <90% compliance	• Rainforest boundary tracks • Camp maintenance areas • Log landings and dumps	• Major – rainforest • Moderate – waterway, filters	• Major – roading, coupe planning	• Water and soils • Roading	• Planning for crossings • Design and construction of crossings • Removal and rehabilitation of crossings • Water-quality, river-health and soil protection • Planning and design of in-coupe roads • Construction of in-coupe roads • Maintenance, operations, closure and rehabilitation of in coupe roads • Road drainage	• Soils • Water • Roading design • Roading construction • Roading maintenance and closure

(Data source: FAP reports and SoF 2013)

143. Jacobs 2016, 'Forest Audit Program 2015: audit of in-coupe roads: environmental audit of the construction and maintenance of in-coupe roads', Jacobs Group (Australia) Pty Limited, Bendigo, Victoria https://www.forestsandreserves.vic.gov.au/__data/assets/pdf_file/0026/118367/fap2015-in-coupe-roads-final-020320161.pdf Accessed 4 December 2018.

Furthermore, relevant to this indicator is the current focus on the definition of 'old-growth forests'. For example, 'old growth' in mountain ash in the Central Highlands has been defined in two ways. One definition suggests old growth is determined by age structure of the individual tree (between 120 and 150 years old), its senescence and its ability to bear hollows.[144] Another definition uses only age structure (over 250 years, late mature and senescent growth stage) with height and trunk diameter.[145] Old growth in mountain ash can also be determined by the understorey; for example, tree ferns that are greater than 350 years.[146]

These variations in old-growth definitions highlight that each vegetation type has its own ecological characteristics and age structures that need to be considered in determining an ecologically meaningful definition of old growth - rather than applying a one-size-fits-all approach.

In addition, the number of species listed on the IUCN Red List categories in the Central Highlands is expected to increase dramatically within the next 25 years (see indicator Fo:06 (The status of forest-dependent species at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment)). This demonstrates that the current framework needs to improve to better support biodiversity conservation in Victorian public forests.

144. Lindenmayer DB, Blair D, McBurney L, Banks SC 2015, 'Mountain Ash: Fire, Logging and the Future of Victoria's Giant Forests', CSIRO Publishing, Clayton South, Victoria.
145. VicForests 2015, 'Ecologically sustainable forest management plan: working plan Version 1.0', Melbourne, Victoria http://www.vicforests.com.au/static/uploads/files/ecologically-sustainable-forest-management-plan-v1-0-wfctkbfzjkxi.pdf Accessed 4 December 2018.
146. Lindenmayer DB, Blair D, McBurney L, Banks SC 2015, 'Mountain Ash: Fire, Logging and the Future of Victoria's Giant Forests', CSIRO Publishing, Clayton South, Victoria.

	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
Fo:18 Extent to which the economic framework supports the conservation and sustainable management of forests	FAIR	?	DATA QUALITY: Fair

Data custodian DELWP

This indicator assesses whether the current economic framework supports sustainable forest management. It lists the economic framework elements considered important for supporting conservation and sustainable management of both public and private forests. The indicator includes assessment of new policies and key developments.

This indicator is assessed using the best available state and national data – but note that state-scale datasets are extremely limited. This makes assessment of this indicator, including comparison of past and present economic frameworks, difficult.

A recent report from Forest and Wood Products Australia indicates that the forest industry contributed about $7.3 billion to the Victorian economy in 2017–18.[147] This consisted of $1.9 billion in direct sales of wood and fibre and $5.4 billion in flow-on effects from other industries involving forest products (socio-economic activities).

Since SoE 2013, several state and federal government investments have contributed to progress for Victorian native forests. As part of Victoria's Regional Tourism Strategy from 2013 to 2016, the 2013–14 state budget committed $13 million to improve tourism in national parks, state forests and on public land.[148] This facilitated upgrades and continual management of Victorian regions containing forests, such as Gippsland, the Macedon Ranges and Daylesford.[149] (A drawback of this is the potential for ecological damage from the removal of prohibitions against private-sector development in national parks. While sustainable environmental outcomes are encouraged in the tourism development guidelines,[150] there are no current assessments for ecological affects due to private-sector development.)

In 2013–14, DEDJTR made grants of $620,000 to a number of wood processing enterprises, as a part of the Regional Growth Fund.[151] However, limited benchmarks and targets meantthe only quantifiable outcomes were in relation to financial returns or employment.[152]

From 2014 to 2017, the Australian Government provided $3 million to enhance the environmental and cultural values of the Dandenong Ranges.[153] The initiative, delivered through the National Landcare Program, funded community groups to undertake activities to strengthen wildlife habitat, regulate weeds and decrease bushfire fuel-loads. As this was a sub-program, outcomes of the fund have not been examined in detail, but will be reviewed as part of the National Landcare Program.[154]

147. Forest & Wood Products Australia 2018, 'Media release: Forest industry adds 7.3 billion to Victorian economy: research', https://www.fwpa.com.au/news/1632-forest-industry-adds-7-3-billion-to-victorian-economy-research.html Accessed 4 December 2018.
148. State Government Victoria 2013, 'Victoria's regional tourism strategy 2013-2016', Melbourne, Victoria https://corp.rdp.tourismnortheast.com.au/wp-content/uploads/sites/54/6588_victoria_-regional_tourism_strategy_2013-16_WEB-1.pdf Accessed 4 December 2018.
149. Ibid
150. DELWP 2015, 'Tourism lease in National Parks: guidance note', Melbourne, Victoria https://www.ecotourism.org.au/assets/Resources-Hub-Protected-Area-Management/tourism-leases-in-national-parks.pdf Accessed 4 December 2018.
151. Department of State Development Business and Innovation 2014, 'Annual report 2013-14', Melbourne, Victoria https://web.archive.org/web/20150301094836/http:/dsdbi.vic.gov.au/__data/assets/pdf_file/0018/1006353/DSDBI-ANNUAL-REPORT-2013-14-FINAL_web.pdf Accessed 4 December 2018.
152. VAGO 2015, 'Regional growth fund: outcomes and learnings', Melbourne, Victoria https://www.audit.vic.gov.au/report/regional-growth-fund-outcomes-and-learnings Accessed 4 December 2018.
153. Australian Government, 'Dandenong Ranges', Canberra, Australia http://www.nrm.gov.au/national/local/dandenong-ranges Accessed 4 December 2018.
154. Australian Department of the Environment and Energy and Australian Department of Agriculture and Water Resources 2017, 'Report on the review of the national landcare program', Canberra, Australia http://www.nrm.gov.au/system/files/resources/fb8af1b3-f8fc-4b07-9334-4ae013da9188/files/nlp-review-final-report.pdf Accessed 4 December 2018.

Information to evaluate this indicator is scant. However, a regional set of environmental–economic accounts for the Central Highlands[155, 156] has been developed to assess ecosystem assets and their benefits for human wellbeing, including a framework to measure conservation and sustainable forest management. This assessment of native forest management uses the United Nations System of Environmental and Economic Accounting (SEEA) framework, which has been adopted in more than 45 countries.[157] In the Central Highlands, the results show that the economic value of water, tourism and plantation industries on private land is greater than the economic value of the native timber harvesting industry. (This excludes 2009–10, due to the 2009 Black Saturday bushfires.) The value of plantation forestry was found to be greater than that for native forestry, even though the size of the area managed for plantations is only 14% of the area of native forest available for harvest.[158]

Results from the trade-off analysis show that cesasing native forest timber harvesting could increase the economic value of ecosystem assets such as carbon. This trade-off analysis provides an opportunity to systematically and regularly assess the costs and benefits of changing ecosystem assets and services. However, the analysis in this study focuses only on the Central Highlands and does not include a state-scale assessment. A rigorous and scientific state-scale approach to assess the economic framework for sustainable forest management, following the international SEEA standard, is critical for policy development and implementation. This environmental–economic accounts approach has been discussed in Fo:23 (Value ($) of forest derived ecosystem services).

155. Keith H, Vardon M, Stein JA, Stein JL, Lindenmayer DB 2017, 'Ecosystem accounts define explicit and spatial trade-offs for managing natural resources'. Nature Ecology and Evolution, 1, pp. 1683-1692.
156. Keith H, Vardon M, Stein JA, Stein JL, Lindenmayer DB 2017, 'Experimental ecosystem accounts for the Central Highlands of Victoria. Summary Report'. The Australian National University and the Threatened Species Recovery Hub, Canberra, Australia.
157. United Nations 2012, 'System of Environmental-Economic Accounting Central Framework', New York, USA https://seea.un.org/content/seea-central-framework Accessed 4 December 2018.
158. Keith H, Vardon M, Stein JA, Stein JL, Lindenmayer DB 2017, 'Ecosystem accounts define explicit and spatial trade-offs for managing natural resources', Nature Ecology and Evolution, 1, pp. 1683-1692.

With the exception of 2006-07, 2008-09 and 2011-12, VicForests has made a net profit since its inception in 2004 and up until 2015–16. Its profitability was significantly undermined by the 2006-07 'Great Divide' bushfires and 2009 Black Saturday bushfires.[159] VAGO has indicated that VicForests had a loan facility of $26.8 million in 2013 from the Treasury Corporation of Victoria to cover cashflow problems resulting from the impacts of catastrophic bushfires and some delays in payments from mills.[160] This needs to be repaid.

There are different opinions relating to the economic sustainability and profitability of native forest harvesting in Victoria. Those who believe the harvesting is unprofitable cite evidence of the declining number of people directly employed in state forest industries, down 28.4% in total employment in the forest industry between 2006 and 2016.[161, 162] Others cite profit-loss and Victorian Government loans to VicForests as further evidence of the lack of profitability.[163, 164]

159. VAGO 2013, 'Managing Victoria's native forest timber resources', Melbourne, Victoria http://www.vicforests.com.au/static/uploads/files/20131211-timber-resources-wfsdlrklejjj.pdf Accessed 4 December 2018.
160. Ibid
161. Schirmer J, Mylek M, Magnusson A, Yabsley B, Morison J 2018, 'Socio-economic impacts of the forest industry Victoria (exc. The Green Triangle)'. Forest & Wood Products Australia, Melbourne, Victoria https://www.fwpa.com.au/resources/reports/other/1631-socio-economic-impacts-of-the-forest-industry-victoria-exc-the-green-triangle.html Accessed 4 December 2018.
162. Australian Department of Agriculture, Fisheries and Forestry, 'Australia's Green Triangle: a growing region with significant opportunities for forest sector investment', Canberra, Australia http://www.agriculture.gov.au/SiteCollectionDocuments/forestry/green_triangle_investment_ver8.pdf Accessed 4 December 2018.
163. VicForests 2013, 'Corporate and business plans, 2013-2014 to 2015-2016', Melbourne, Victoria.
164. Lindenmayer D 2017, 'Halting natural resource depletion: engaging with economic and political power', The Economic and Labour Relations Review, 28(1), pp. 41-56.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:19 Capacity to conduct and apply research and development aimed at improving forest management, including development of scientific understanding of forest ecosystem	○	○	○	●	→	DATA QUALITY Good

Data custodian DELWP

Forest ecosystems in Victoria are highly diverse and complex in terms of ecosystem diversity and health, carbon sequestration, and genetic diversity. This indicator assesses Victoria's capacity to conduct and apply research and development to improve sustainable forest management.

The number of forest researchers employed by the Victorian Government has declined slightly from 21.9 to 17.9 full-time-equivalent (FTE) workers between 2011–12 and 2015–16. All research personnel have focused on native forest, with a significant proportion working on fire ecology (6.8 FTE), fauna ecology (5.8 FTE) and sustainable forest management (1.5 FTE) in 2015–16.

The data on FTE forest researchers in government agencies, shown in Table Fo.26 and Table Fo.27, include employees of DELWP, VicForests and Arthur Rylah Institute.

In addition, there were 26.3 FTE academics working in forest research and development in Victoria. This figure includes those funded by DELWP through the Integrated Forest and Ecosystem Research (IFER) program at the University of Melbourne, and by the BNHCRC (Bushfire and Natural Hazards Co-operative Research Centre (BNHCRC).

These personnel all focused on native forests, and for 2015–16 included 5.2 FTE working on forest hydrology, 12.9 FTE on fire behaviour, 4.5 FTE on fire ecology, 0.9 FTE on sustainable forest management and 2.8 FTE on forest health.

Table Fo.26 Numbers of FTE government staff engaged in forest-related research and development, by state, 2010–11 and 2015–16

	FTE staff					
	Plantations		Native forest		Total	
State	**2010–11**	**2015–16**	**2010–11**	**2015–16**	**2010–11**	**2015–16**
ACT	0.0	0.0	7.0	7.0	7.0	7.0
NSW	12.5	8.0	12.5	8.0	25.0	16.0
NT	3.2	0.9	0.0	0.2	3.2	1.1
Qld	31.6	20.5	0.9	1.2	32.5	21.7
SA	15.8	0.0	0.8	0.0	16.6	0.0
TAS	52.5	2.1	62.8	5.3	115.3	7.3
VIC	0.0	0.0	21.9	17.8	21.9	17.8
WA	0.0	0.0	22.0	15.6	22.0	15.6
Total	**115.6**	**31.5**	**127.9**	**55**	**243.5**	**86.5**

(Data source: Australia's State of the Forests 2018)

Note: This table shows the numbers of research personnel reported by each state and territory for 2011–12 and 2015–16. NSW total staff numbers have been split equally between plantations and native forest.

Table Fo.27 demonstrates trends in research focuses in Victoria, in government agencies and academia, between 2011–12 and 2016–17. The data on FTEs in government agencies includes DELWP employees (policy leads for IFER and BNHCRC projects), VicForests employees, and ARI employees. Academic FTEs include those funded by DELWP through the IFER program and BNHCRC, who represent a subset of the total number of researchers in Victoria. The overall number of FTE employees is unchanged. FTE employees in academia increased by about 4 FTE in total in fire behaviour and forest hydrology, and decreased by about 4 FTE in government agencies (in fire and flora ecology). For both years, topics related to fire, ecology and hydrology accounted for 80% of overall FTE employees.

Table Fo.27 Numbers of FTE employees engaged in forest-related research and development, by research focus, 2011–12 and 2016–17

Research and development activity	Government agencies		Academia	
	Native forest			
	2011–12	2016–17	2011–12	2016–17
Silvicultural research	0.50	0.50		
Tree breeding (not horticultural)				
Forest hydrology	0.23	0.28	4.00	5.20
Timber use				
Fire behaviour	0.20	0.85	9.78	12.91
Forest pathology				
Agroforestry				
Fauna ecology	5.68	5.79		
Fire ecology	10.12	6.84	5.25	4.50
Forest entomology				
Flora ecology	0.63	0.00		
Non-timber forest products				
Climate change				
Statistical analysis				
Other (aquatic biota)	2.00	1.00		
Other (forest biotechnology)				
Other (forest industries)				
Other (sustainable forest management)	1.51	1.51	0.90	0.90
Other (plantations & health)	1.02	1.02	2.80	2.80
Total number of research FTEs	**21.89**	**17.79**	**22.73**	**26.31**

Note: Only includes the time fraction of researchers, technicians and other staff directly involved with research and development activity. Does not include the time fraction of overhead staff (for example, administrative and general service employees, personnel officers and janitors).

Note: The data on FTEs in government agencies includes DELWP employees (policy leads for IFER and BNHCRC projects), VicForests employees, and ARI employees. Academic FTEs include those funded by DELWP through the IFER program and BNHCRC, thus representing a subset of the total number of researchers in Victoria.

Note: Nobody engaged in research in plantations and private companies; therefore, these were excluded in the table

Note: While FTE data was mostly available, it was derived for BNHCRC by dividing the annual cost of a researcher (approximately $180,000). ARI and academic FTE was data taken from DELWP internal spreadsheets.

(Data source: DELWP, 2018)

The two main research head agreements (with the University of Melbourne and BNHCRC) are the major providers involved in forestry research and development in Victoria.

1. University of Melbourne – IFER

IFER[165] is a research agreement between the School of Ecosystem and Forest Sciences at the University of Melbourne, and DELWP. It aims to enhance the evidence base for managing the impacts of fire, climate and management regimes on multiple forest values in Victoria's forest ecosystems. The IFER program investigates forest ecosystems in Victoria under six main landscape-level themes: biodiversity, carbon, integration, social and economic values, vulnerability and water.

2. BNHCRC (successor of the Bushfire CRC)

As a consequence of Victoria's Black Saturday bushfires in February 2009, the Commonwealth Government granted the Bushfire CRC an extension of funding to examine national issues arising from the tragedy. This led to a new three-year research program for the Bushfire CRC from 2010 to 2013. The research built on outputs from the CRC's first seven years of research to give communities and fire managers a solid basis to better prepare for, manage and respond to severe bushfires. The research focused on understanding the risks associated with bushfires, how to better communicate these risks to the public, and how to better manage direct threats of bushfire.

BNHCRC,[166] established in 2013, builds on the work of the Bushfire CRC and is conducting coordinated and interdisciplinary research. This includes working with communities to improve disaster resilience and reduce the human, social, economic and environmental costs of bushfires and other natural hazards. Research undertaken by BNHCRC supports the development of cohesive, evidence-based policies, strategies, programs and tools to build a more disaster-resilient Australia. The BNHCRC provides long-term research that directly supports emergency services and other government and non-government agencies as they work to prevent, prepare for, respond to and recover from natural disasters.

The BNHCRC, like the Bushfire CRC before it, is 'end-user driven'. This means its partners, including various emergency service agencies, departments and non-government organisations around the country, have a significant say in the development and use of the research program.

DELWP's current budget allocation for research and development is based on identification and prioritisation of research directions. For trends in financial investment in research and development, see indicators 6.2b and 6.2c of the SoF 2018 report.

165. University of Melbourne, 'Integrated forest ecosystem research (iFER)', Parkville, Victoria https://ecosystemforest.unimelb.edu.au/research/research-programs/integrated-forest-ecosystem-research-ifer Accessed 4 December 2018.

166. Bushfire & Natural Hazards CRC, https://www.bnhcrc.com.au/ Accessed 4 December 2018.

Socio-economic Benefits

	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
Fo:20 Investment and expenditure in forest management		→	DATA QUALITY Good

Data custodian DELWP

Effective sustainable forest management relies on adequate investment and expenditure. This ensures that infrastructure, facilities, forest health and conservation values are maintained.

This indicator measures trends in forest management expenditure, reported as Victorian Government expenditure on forest-management-related activities. This includes expenditure on state forests, and parks and reserves, as well as VicForests's expenditure on forest management.

There are two main investment components: forest and fire management, and conservation and recreation.

The agency responsible for managing natural resources, including state forests, in Victoria has changed several times during the reporting period. In April 2013, the Department of Sustainability and Environment merged with the Department of Primary Industries to form the Department of Environment and Primary Industries (DEPI). In January 2015, DELWP, which has broad responsibility for Victoria's natural environments (including forest management, and fire and emergency management), was created following a government restructure. Together with Parks Victoria and VicForests, DELWP is responsible for managing Victoria's parks and reserves, and state forests. VicForests is a separate government-owned business responsible for the harvest, commercial sale and regrowing of wood from Victoria's state forests.

Table Fo.28 shows expenditure on managing Victoria's forests, parks and public land between 2012–13 and 2016–17. Expenditure has steadily increased over the five-year period. Forest and fire expenditure has remained comparatively steady, with a slight decrease in 2016–17 mainly attributed to a less-severe fire season. Expenditure on conservation and recreation increased significantly in 2013–14 and continued to increase during the period. The changes over five years may indicate that the Victorian Government has increased focus on and investment in conservation and recreational values in state forests, parks and reserves.

Table Fo.29 shows the forest management expenditure on general maintenance, capital roading and capital bridge works between 2012–13 and 2016–17. Total expenditure decreased across the period, particularly on maintenance work. This was mainly due to decreasing timber production and available production areas, which reduced the maintenance works required for state forests, and parks and reserves.

Table Fo.28 Victorian Government expenditure on forest management, 2012–13 to 2016–17

	Expenditure ($ millions)				
Expenditure category	**2012–13**	**2013–14**	**2014–15**	**2015–16**	**2016–17**
Forest and fire management	383.5	382.3	347.8	396.5	372.3
Conservation and recreation	199.0	199.3	298.9	328.2	369.8
Total	582.5	581.6	646.7	724.7	742.1

(Data source: DELWP, 2018)

Table Fo.29 Victorian Government forest management expenditure on maintenance, capital roading and capital bridges, 2012–13 to 2016–17

	Expenditure ($ millions)				
Expenditure category	**2012–13**	**2013–14**	**2014–15**	**2015–16**	**2016–17**
Maintenance	16.0	16.8	12.6	9.0	7.9
Capital roading	0.2	0.7	0.4	0.3	0.2
Capital bridges	2.2	2.4	2.6	3.2	1.4
Total	18.3	19.9	15.5	12.5	9.5

(Data source: DELWP, 2018)

	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
Fo:21 Value ($) of forest derived ecosystem services Data custodian DELWP					?	DATA QUALITY Fair

Environmental/economic accounting provides a framework for valuing the economic benefit of ecosystem services to the economy and society. The contribution forests make to the economy is partly captured in the System of National Accounts (SNA), which accounts for goods and services from forests, such as timber and tourism, when they are produced and consumed in the economy. The System of Environmental Economic Accountng (SEEA) extends the SNA by including forests environmental assets, and the natural inputs and ecosystem services forests produce.

Forest ecosystems provide a suite of ecosystem services, including climate regulation, carbon sequestration, water supply and filtration, and habitat. The management and condition of forests determines the level and extent of these services and, in turn, the benefits to the economy and community. A qualitative example of forest ecosystem accounting – from asset to benefits – is set out in Table Fo.30.

Table Fo.30 Qualitative example of ecosystem accounting for Victorian forests

Asset extent	Asset condition	Ecosystem services	Benefits
Forests can be classified into different assets using EVCs or production forest classes	Condition assessment must be linked to the impact on asset's ability to provide ecosystem services Size of habitat	Examples include: • habitat • water supply and filtration • climate regulation (carbon sequestration • temperature regulation • nourishment for bees • opportunities for recreation and tourism • opportunities for cultural connection • landscape	Examples include: • water consumption by humans and animals • timber • avoided impacts from climate change • urban cooling • apiculture (pollination or crops and honey) • recreation and tourism • avoided health impacts • cultural connection • visual amenity

(Data source: DELWP, 2018)

Ecosystem accounting has increasingly been applied to forest areas in Australia and around the world. In 2015, Parks Victoria and DELWP accounted for forest ecosystem assets in parks as part of an assessment of benefits from ecosystem services provided by Victorian parks.[167] The analysis estimates that Victorian parks contribute about $1 billion in gross value and 14,000 jobs. The park-based apiary sector was estimated to contribute between $3.4 million and $4.6 million per annum (between $0.6 million and $1 million per annum, respectively).

At the regional scale, the Australian National University has published ecosystem accounts for the Central Highlands across state forests and parks, focusing on water provisioning, timber provisioning, tourism and carbon sequestration.[168] The key findings show that the value of ecosystem services for agriculture production has the greatest value ($121 million) – because of pollination services as an ecosystem service – followed by the water provisioning service ($101 million). By contrast, the native timber provisioning service was valued at just $19 million. The tourism sector in the Central Highlands is estimated to produce benefits of $71.1 million as direct and indirect gross value added, with corresponding increases in employment of 470 direct jobs and 280 indirect jobs after 10 years of investment in the tourism industry.[169]

Forests provide a key natural input that is priced in the economy: timber. Once harvested, timber is accounted for in the SNA. Environmental/economic accounts can record the stock of native forest and plantation forest assets over time, which can increase due to natural growth or decrease due to timber harvesting or other events such as bushfires. The Australian Bureau of Statistics produces accounts on native and plantation timber resources for the whole of Australia, and reported a net value of $11.6 billion in 2016–17, or $471.6 per person. Of this, $9.9 billion is plantation timber and $1.7 billion is native timber.

Currently there is no state-scale approach to quantifying the dollar-value of forest-derived ecosystem services in Victoria. Environmental/economic accounting provides a consistent framework for assessing the range of natural inputs and ecosystem services provided by forests, and the benefits each of these deliver to the economy and community. This type of information, presented in a consistent and comparable format, can help to improve understanding of the different benefits forests provide, and can be used to inform land use and forest management trade-offs and decision-making.

167. Varcoe T, Betts O'Shea H, Contreras Z 2015, 'Valuing Victoria's parks: Accounting for ecosystems and valuing their benefits', DELWP and PV, Melbourne, Victoria https://parkweb.vic.gov.au/__data/assets/pdf_file/0010/695764/Valuing-Victorias-Parks-Report-Accounting-for-ecosystems-and-valuing-their-benefits.pdf Accessed 4 December 2018.
168. Keith H, Vardon M, Stein JA, Stein J, Lindenmayer DB 2017, 'Experimental Ecosystem Accounts for the Central Highlands of Victoria', The Australian National University and the Threatened Species Recovery Hub, Canberra, Australia.
169. Nous Group 2017, 'Great forests national park: economic contribution of park establishment, park management, and visitor expenditure: The Wilderness Society', Melbourne, Victoria http://www.greatforestnationalpark.com.au/uploads/1/5/5/7/15574924/nous_gfnp_economic_contribution_study_3_february_2017.pdf Accessed 4 December 2018.

Future Focus

Understand the impacts of forest fragmentation on biodiversity and improve assessment of protected areas

A systematic approach to understanding the status and future trends of Victorian public forests is critical. DELWP developed the Victorian Forest Monitoring Program (VFMP) in 2011. The VFMP completed its first full cycle of field measurements in 2015 and is expected to complete its second cycle by 2020. It is critical that minimal changes to the VFMP data-collection methods occur following the completion of the second full cycle of data retrieval. Consistency in methodology, with only essential amendments, would allow the identification of underlying trends and improve the utility of the evidence base. Any changes to data collection and analysis methods to achieve more accurate data must not disrupt comparative analysis with existing datasets or future trend analyses.

Furthermore, although the VFMP maps forest fragmentation at the state scale (including private forests), it does not provide a complete assessment of forest fragmentation and its impacts on biodiversity in native forests. Long-term monitoring and detailed spatial research have been conducted to explore impacts of fragmentation on native forests and forest-dependent species at the regional scale (such as mountain ash forests in the Central Highlands) and this research has demonstrated that forest fragmentation is becoming intensified, and its impact on threatened species has been increasing.[170, 171, 172, 173, 174] The study of biodiversity impacts from forest fragmentation is also impeded by the lack of an authoritative list of Victorian forest-dependent species.

Further research is critical as a complement to VFMP mapping and to understand the impact of forest fragmentation on biodiversity at the state scale. This research program would also assist in the establishment and management of protected areas. The International Union for Conservation of Nature (IUCN) protected areas in Victoria increased by 140,000 hectares between 2004 and 2016. However, there is little evidence of the level of long-term species protection provided by the classification of these areas. A viability analysis, for example, would provide risk assessment and management options to better protect target species in protected areas. Such analysis would also provide an indication of species conservation benefits if an increase in protected areas was to occur.

Recommendation 8: That DELWP maintain their commitment to resourcing and maintaining the VFMP and enhance it to (i) improve statewide understanding of the impacts of forest fragmentation on forest-dependent species (including the development of an authoritative list of Victorian forest-dependent species) and (ii) improve assessment of protected areas by conducting detailed research to identify the benefits of various types of IUCN-protected areas for target species. Any amendments to the VFMP must not disrupt future trend analyses.

170. Lindenmayer DB, Blair D, McBurney L, Banks S 2015, 'Mountain Ash: Fire, logging and the future of Victoria's giant forests', CSIRO Publishing, Melbourne.
171. Blair D, McBurney L, Lindenmayer DB, Banks S, Blanchard W 2017, 'The Leadbeater's Possum review', The Australian National University, Canberra.
172. Blair D, McBurney L, Lindenmayer DB 2018, 'Failing to conserve Leadbeater's Possum and its Mountain Ash forest habitat', Australian Zoologist, 39(3), 442-448. Doi:https://doi.org/10.7882/AZ.2018.008.
173. Lindenmayer DB, Blanchard W, Blair D, McBurney L 2018, 'The road to oblivion – quantifying pathways in the decline of large old trees', Forest Ecology and Management, In re-review.
174. Meney B, Cunningham S, Weston MA, Whisson DA 2018, 'Woodland birds and rural towns: artificial clutch survival in fragmented Box-Ironbark forests', The Royal Society of Victoria, 130, 7-17.

Accounting for the Environment

Environmental/economic accounting provides a framework for linking forests (a type of land account) to the natural inputs and ecosystem services they produce that benefit the economy and society. The contribution forests make to the economy is partly captured in the SNA, which accounts for goods and services from forests, such as timber and tourism, when they are produced and consumed in the economy. The SEEA extends the SNA by including forests environmental assets and the natural inputs and ecosystem services they produce.

See indicator Fo.23 (Value ($) of forest-derived ecosystem services) for further analysis.

Case Study: A pilot approach to estimating the potential for forests to provide habitat services

A key service provided by forest ecosystems is habitat for species. Fauna and flora species have different habitat requirements. They need a place to live and reproduce. They also need to tolerate changes in the weather as well as flood and fire disturbances. Because of these different needs, species are found in different locations across the landscape. Some species have highly specific habitat requirements (such as hollow-dependent arboreal marsupials that are present only in limited parts of mountain ash and alpine ash forests that support hollow-bearing trees), while other species can thrive in many different habitat types.

Habitat distribution models (HDMs) have been developed for all rare or threatened Victorian species where sufficient data is available. For this assessment, 1,750 HDMs were used. HDMs collect and compare information on where a species has been recorded and relate that data to environmental variables, such as soil, prevailing climate and topography. Sophisticated statistical and mathematical processes are then used to estimate the distribution of a species's habitat. The HDMs do not predict whether or not a species currently occupies the habitat at a particular location. Many factors can influence whether a species is present in the habitat at any given time, including: biogeography; size of the habitat patch and distance from other suitable habitat; the condition of the habitat; natural disturbance cycles; historical catastrophes; the impact of predators or disease; and seasonal factors.[175]

A pilot approach to estimating the potential for forests to provide habitat services is to examine the links between the distribution of important Victorian species to the extent of forest cover in Victoria. This approach describes the relative importance of forests in providing potential habitat for species. However, as HDMs do not predict whether or not a species occupies the habitat at a particular location, this approach does not reveal whether forest assets are actually providing habitat services. Forest-cover extent is used as a proxy for potential habitat, and this approach does not incorporate the condition of forest ecosystem assets, which is a key factor in providing habitat. In 2015, this approach was used to account for the habitat services provided by Victorian parks.[176] Approaches to measuring the flow of habitat services provided by ecosystem assets is a complex area that can be refined in the lead-up to a systematic approach to accounting for the environment (see Recommendation 19).

Figure Fo.34 and Table Fo.31 show the extent of forest cover within the intersection of bioregions[177] and natural resource management[178] (NRM) regions across Victoria. Figure Fo.36 is an intersection between bioregion/NRM region and the 1,750 HDMs. It represents the number of HDMs that intersect with each bioregion/NRM class, which indicates the potential for these areas to provide habitat services.

175. DELWP 2017 'Biodiversity information explanatory document: measuring value when removing or offsetting native vegetation', Melbourne, Victoria https://www.environment.vic.gov.au/__data/assets/pdf_file/0025/91267/Biodiversity-information-explanatory-document-Measuring-value-when-removing-or-.pdf Accessed 4 December 2018.
176. Varcoe T, Betts O'Shea H, Contreras Z 2015, 'Valuing Victoria's parks: Accounting for ecosystems and valuing their benefits', DELWP and PV, Melbourne, Victoria https://www.forestsandreserves.vic.gov.au/__data/assets/pdf_file/0027/57177/Valuing-Victorias-Parks-Report-Accounting-for-ecosystems-and-valuing-their-benefits.pdf Accessed 4 December 2018.
177. Australian Department of the Environment and Energy, 'Interim Biogeographic Regionalisation for Australia (IBRA7) codes', Canberra, Australia http://www.environment.gov.au/land/nrs/science/ibra/ibra7-codes Accessed 4 December 2018.
178. CSIRO 'Impacts and adaptation information for Australia's NRM regions', Climate Change in Australia: projections for Australia's NRM regions, Canberra, Australia https://www.climatechangeinaustralia.gov.au/en/impacts-and-adaptation/nrm-regions/ Accessed 4 December 2018.

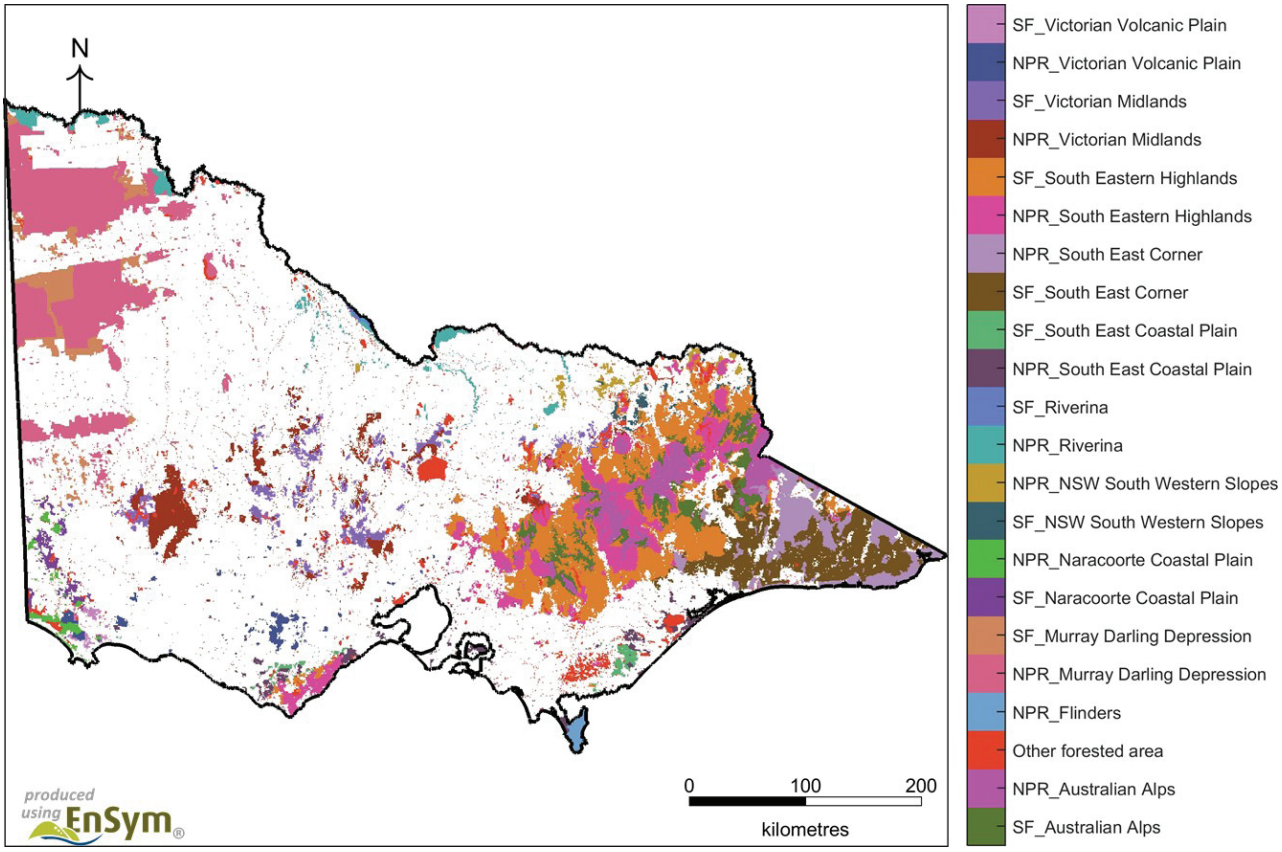


Figure Fo.34 Forest cover by bioregion/NRM class in Victoria

(Data source: DELWP, 2018)

Table Fo.31 Forested area in each bioregion/NRM class (per cent)

Bioregion	NRM Region	Area (ha)	Forest (%)
Australian Alps	Murray Basin	370,412	5
Flinders	Murray Basin	40,141	1
Murray–Darling Depression	Murray Basin	1,476,822	19
Naracoorte Coastal Plain	Murray Basin	67,847	1
NSW South Western Slopes	Murray Basin	68,926	1
Riverina	Murray Basin	211,861	3
South East Coastal Plain	Murray Basin	156,420	2
South East Corner	Murray Basin	429,514	5
South Eastern Highlands	Murray Basin	684,825	9
Victorian Midlands	Murray Basin	420,261	5
Victorian Volcanic Plain	Murray Basin	96,739	1
Australian Alps	Southern Slopes	336,865	4
Murray–Darling Depression	Southern Slopes	302,859	4
Naracoorte Coastal Plain	Southern Slopes	71,981	1
NSW South Western Slopes	Southern Slopes	43,108	1
Riverina	Southern Slopes	11,688	0
South East Coastal Plain	Southern Slopes	51,924	1
South East Corner	Southern Slopes	696,317	9
South Eastern Highlands	Southern Slopes	1,373,900	17
Victorian Midlands	Southern Slopes	284,708	4
Victorian Volcanic Plain	Southern Slopes	23,838	0
Other forested area	Southern Slopes	641,911	8
Total		**7,862,867**	**100**

(Data source: DELWP, 2018)

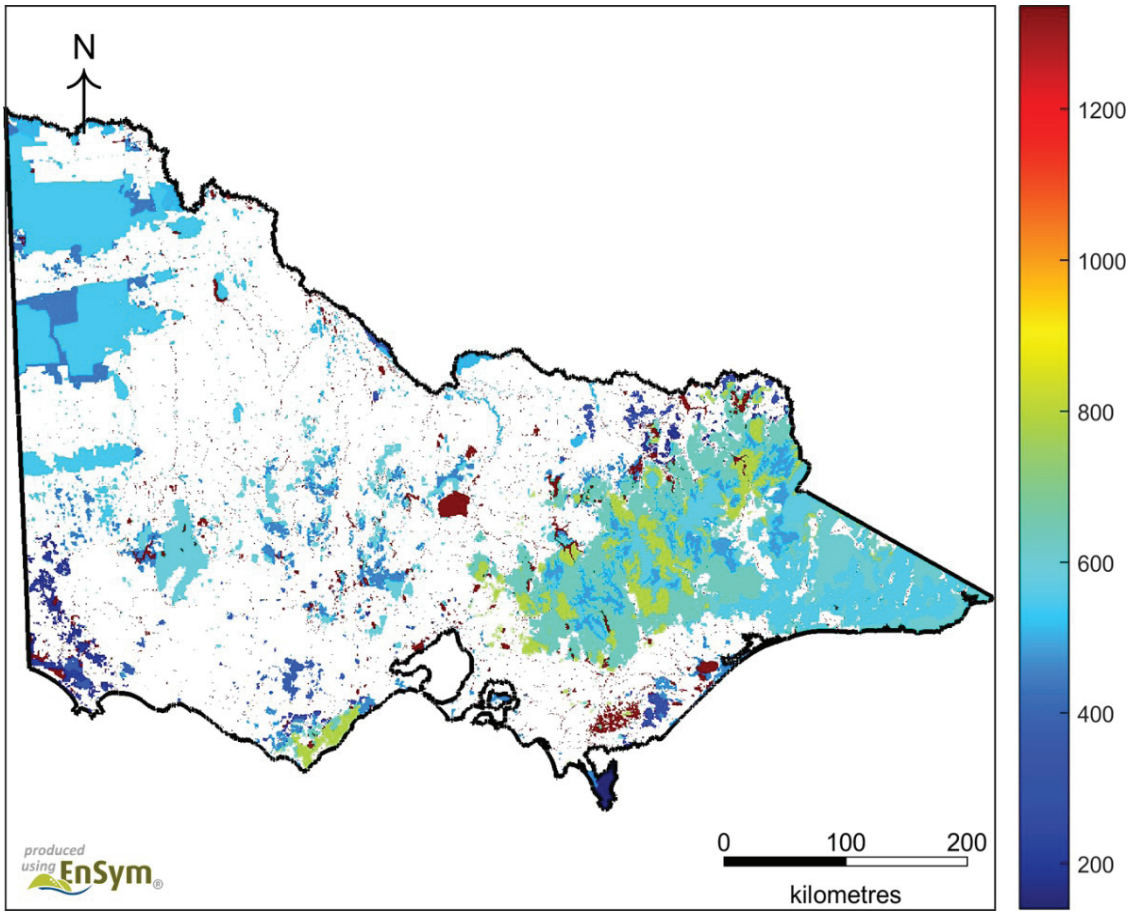


Figure Fo.35 Number of HDMs in each bioregion/NRM class in Victoria

(Data source: DELWP, 2018)

Figure Fo.36 is the same as Figure Fo.35, but with data classified for easier viewing. Note that there are large areas that intersect with more than 500 HDMs, suggesting that these forest areas may potentially provide valuable habitat services.

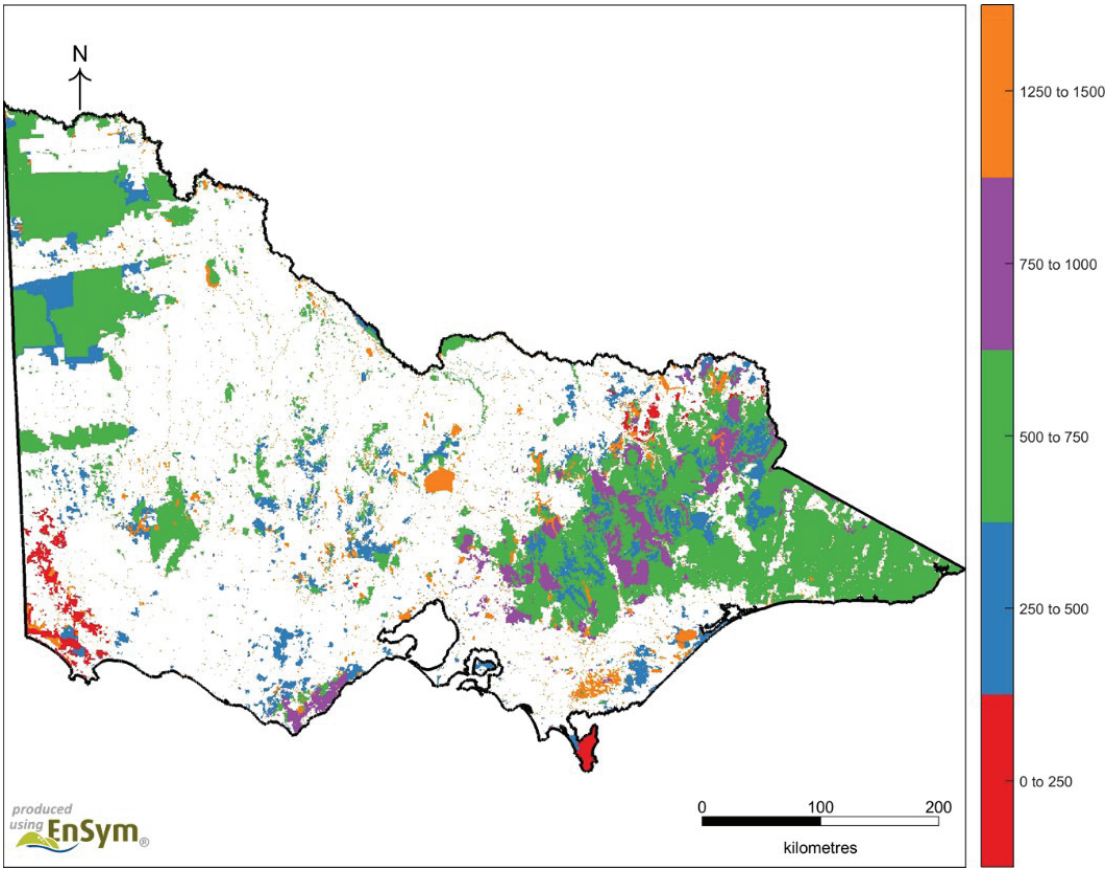


Figure Fo.36 Number of HDMs in each bioregion/NRM class in Victoria – grouped by count

(Data source: DELWP, 2018)

Table Fo.32 shows the potential species habitat presence for each bioregion/NRM class, out of the 1,750 species for which habitat distribution has been modelled. 9 out of 22 classes have potential habitat for species presence of greater than 500 species based on the HDMs. These nine bioregion/NRM classes represent 80% of the bioregion area. Note that the larger areas are expected to have an intersection with more species HDMs. Further work would be required to disaggregate the larger areas into specific management areas (for example, into regions and coupes) to gain a more accurate representation of the links to HDMs.

Table Fo.32 Number of HDMs for species within bioregion/NRM classes in Victoria

Bioregion	NRM region	Number of species HDM				
		Low		Medium		High
		0–250	250–500	500–750	750–1,000	1,250–1,500
Australian Alps	Murray Basin			✓		
Flinders	Murray Basin	✓				
Murray–Darling Depression	Murray Basin			✓		
Naracoorte Coastal Plain	Murray Basin	✓				
NSW South Western Slopes	Murray Basin		✓			
Riverina	Murray Basin			✓		
South East Coastal Plain	Murray Basin		✓			
South East Corner	Murray Basin			✓		
South Eastern Highlands	Murray Basin				✓	
Victorian Midlands	Murray Basin			✓		
Victorian Volcanic Plain	Murray Basin		✓			
Australian Alps	Southern Slopes		✓			
Murray–Darling Depression	Southern Slopes		✓			
Naracoorte Coastal Plain	Southern Slopes	✓				
NSW South Western Slopes	Southern Slopes	✓				
Riverina	Southern Slopes		✓			
South East Coastal Plain	Southern Slopes		✓			
South East Corner	Southern Slopes			✓		
South Eastern Highlands	Southern Slopes			✓		
Victorian Midlands	Southern Slopes		✓			
Victorian Volcanic Plain	Southern Slopes	✓				
Other forested area	Southern Slopes					✓
Total		**5**	**8**	**7**	**1**	**1**

(Data source: DELWP, 2018)

Table Fo.33 and Table Fo.34 show potential species habitat presence for each bioregion/NRM class, specifically for endangered and vulnerable species.

Table Fo.33 shows the potential endangered species habitat presence for each bioregion/NRM class. 6 classes have potential endangered species habitat presence of greater than 100 species, based on the HDMs. 10 bioregions have potential endangered species habitat presence of 50 to 100; 6 bioregions have potential endangered species habitat presence of less than 50.

Table Fo.33 Number HDMs for endangered species within bioregions/NRM classes in Victoria

Bioregion	NRM region	Number of endangered species HDM			
		0–50	50–100	100–150	250–300
Australian Alps	Murray Basin		P		
Flinders	Murray Basin	✓			
Murray–Darling Depression	Murray Basin			✓	
Naracoorte Coastal Plain	Murray Basin	✓			
NSW South Western Slopes	Murray Basin		✓		
Riverina	Murray Basin			P	
South East Coastal Plain	Murray Basin		✓		
South East Corner	Murray Basin		✓		
South Eastern Highlands	Murray Basin			✓	
Victorian Midlands	Murray Basin			✓	
Victorian Volcanic Plain	Murray Basin		✓		
Australian Alps	Southern Slopes	✓			
Murray–Darling Depression	Southern Slopes		✓		
Naracoorte Coastal Plain	Southern Slopes	✓			
NSW South Western Slopes	Southern Slopes	P			
Riverina	Southern Slopes		P		
South East Coastal Plain	Southern Slopes	P			
South East Corner	Southern Slopes		P		
South Eastern Highlands	Southern Slopes		P		
Victorian Midlands	Southern Slopes			P	
Victorian Volcanic Plain	Southern Slopes		P		
Other forested area	Southern Slopes				P
Total		**6**	**10**	**5**	**1**

(Data source: DELWP, 2018)

Table Fo.34 shows the potential vulnerable species habitat presence for each forest class. 10 forest classes have potential vulnerable species habitat presence of greater than 150 species, based on the HDMs. 6 forest classes have potential vulnerable species habitat presence of 100 to 150; 6 forest classes have potential vulnerable species habitat presence of less than 50.

Table Fo.34 Number of HDMs for vulnerable species within bioregions/NRM classes in Victoria

Bioregion	NRM region	Number of species HDM				
		50–100	100–150	150–200	200–250	400–450
Australian Alps	Murray Basin			✓		
Flinders	Murray Basin	✓				
Murray–Darling Depression	Murray Basin			✓		
Naracoorte Coastal Plain	Murray Basin	✓				
NSW South Western Slopes	Murray Basin		✓			
Riverina	Murray Basin			✓		
South East Coastal Plain	Murray Basin		✓			
South East Corner	Murray Basin			✓		
South Eastern Highlands	Murray Basin				✓	
Victorian Midlands	Murray Basin			✓		
Victorian Volcanic Plain	Murray Basin		✓			
Australian Alps	Southern Slopes		✓			
Murray–Darling Depression	Southern Slopes			✓		
Naracoorte Coastal Plain	Southern Slopes	✓				
NSW South Western Slopes	Southern Slopes	✓				
Riverina	Southern Slopes		✓			
South East Coastal Plain	Southern Slopes	✓				
South East Corner	Southern Slopes			✓		
South Eastern Highlands	Southern Slopes			✓		
Victorian Midlands	Southern Slopes		✓			
Victorian Volcanic Plain	Southern Slopes	✓				
Other forested area	Southern Slopes					✓
Total		**6**	**6**	**8**	**1**	**1**

(Data source: DELWP, 2018)

Case Study: accounting for water supply from forests

This case study shows how an environmental/economic accounting framework can be applied – both conceptually and quantitatively – to forest ecosystems to demonstrate the link between biophysical information and socio-economic benefits.

Asset extent and condition

As shown in Table Fo.35, and illustrated in Figure Fo.36, there are 3,499,602 hectares of forest across the prescribed water supply catchment (PWSC) areas that contain ash forest in Victoria. Of this, 459,393 hectares (or 13%) are eucalypt ash forest of mountain ash (*Eucalyptus regnans*) and alpine ash (*Eucalyptus delegatensis*). The largest extent of forest assets are in the catchment areas of Lake Hume, Mitchell River, Ovens River, Upper Goulburn and Tambo River. The largest extent of ash forest assets are in the catchment areas of Mitchell River, Lake Hume, Upper Goulburn and Upper Yarra.

Table Fo.35 Extent of forest assets by catchment area

PWSC with ash forest	Ash forest (ha)	Other forest (ha)	Other land cover (ha)	Total area (ha)
Armstrong Creek	2,039	2,074	73	4,186
Barham River	3,566	1,591	1,198	6,355
Bemm River	2,009	88,592	2,647	93,248
Britannia Creek	1,580	239	-	1,819
Brodribb River (Orbost)	455	91,903	1,247	93,605
Buchan River (Buchan)	10,930	67,629	3,072	81,631
Buckland River	6,414	25,520	446	32,380
Buffalo River (Lake Buffalo)	9,697	101,633	4,283	115,613
Bunyip River	3,084	859	32	3,975
Cann River	241	59,039	3,075	62,355
Cement Creek	808	0	0	808
Deep Creek & Loch River (Noojee)	6,686	4,691	517	11,894
Drouin	309	1,081	36	1,426
Gellibrand River	3,086	36,122	10,121	49,329
Gellibrand River (South Otway)	1,971	11,526	3,131	16,628
Glenmaggie	18,753	155,843	15,546	190,142
Kilmore	1,186	1,952	141	3,279
King River (Lake William Hovell)	8,469	24,303	258	33,030
Kinglake	5,006	5,913	89	11,008
Lake Hume	44,058	211,065	65,756	320,879
Lake Hume Northern Section	55,617	434,098	197,642	687,357
Lorne	1,001	1,651	28	2,680
Maroondah	13,605	4,135	197	17,937
McCraes Creek	192	353	0	545
McMahons Creek	3,689	728	8	4,425
Merrimans Creek (Seaspray)	27	31,748	21,896	53,671
Micks Creek	29	325	129	483
Mitchell River	58,553	315,098	17,349	391,000
Nicholson River	724	45,386	1,587	47,697
Ovens River (Bright)	7,503	25,088	2,070	34,661
Ovens River (Wangaratta)	5,153	148,930	143,344	297,427
Starvation Creek	3,532	88	25	3,645
Tambo River	18,476	202,815	49,227	270,518
Tanjil River	13,168	29,297	8,221	50,686
Tarago River	7,818	905	2,342	11,065

PWSC with ash forest	Ash forest (ha)	Other forest (ha)	Other land cover (ha)	Total area (ha)
Tarra River	391	2,201	237	2,829
Thomson River (stage 3)	5,540	8,886	738	15,164
Thomson River (stages 1,1a,2)	15,693	17,310	182	33,185
Tomahawk Creek (Gembrook)	287	30	0	317
Tyers River	7,039	22,085	2,834	31,958
Upper Barwon	1,475	12,608	1,210	15,293
Upper Goulburn	49,679	178,606	50,711	278,996
Upper Goulburn (Upper Delatite)	4,876	12,270	6,741	23,887
Upper Kiewa	15,435	17,717	7,549	40,701
Upper Kiewa (East Kiewa U2)	1,627	75	0	1,702
Upper Yarra	37,915	9,395	871	48,181
Total	**459,391**	**2,413,403**	**626,806**	**3,499,600**

(Data source: DELWP, 2018)

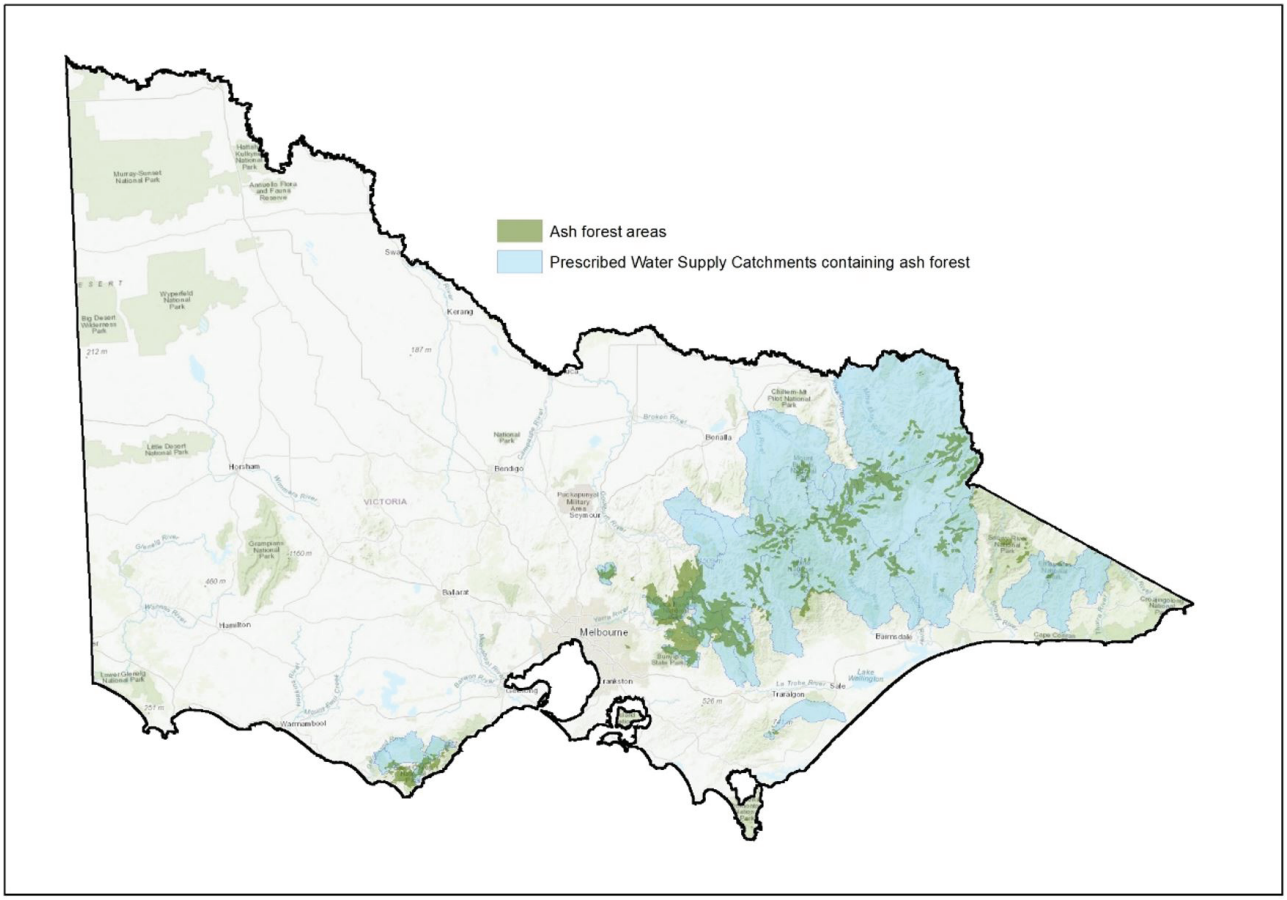


Figure Fo.37 Prescribed water supply catchments and ash forest extent in Victoria

(Data source: DELWP, 2018)

Ecosystem services and benefits

Forest assets provide a range of ecosystem services, as outlined in Figure Fo.39. This case study focuses on quantifying the water supply services provided by forest assets in the Kilmore, Mitchell River and Nicholson River catchment areas. Due to stream flow data limitations, absolute yearly flows could not be determined for other catchment areas listed in Figure Fo.39, including the Melbourne water catchments.

Asset extent

422,899 hectares of forest across Kilmore, Mitchell and Nicholson catchments:

- 60,463 hectares of ash forest
- 362,436 hectares of other forest

Condition

63 per cent of ash forest across Kilmore, Mitchell and Nicholson catchments has been disurbed since 1989, comprising:

- 62 per cent of ash forest disturbed by fire
- 1 percent of ash forest disturbed by logging

Services

Habitat

Water supply and filtration

Climate regulation (carbon sequestration)

Temperature regulation

Nourishment for bees

Opportunities for recreation and tourism

Opportunities for cultural connection

Landscape

Benefits

Water

Climate change mitigation

Timber resources

Pollination services

Recreation and tourism

Figure Fo.38 Forests in an environmental / economic accounting framework

(Data source: DELWP, 2018)

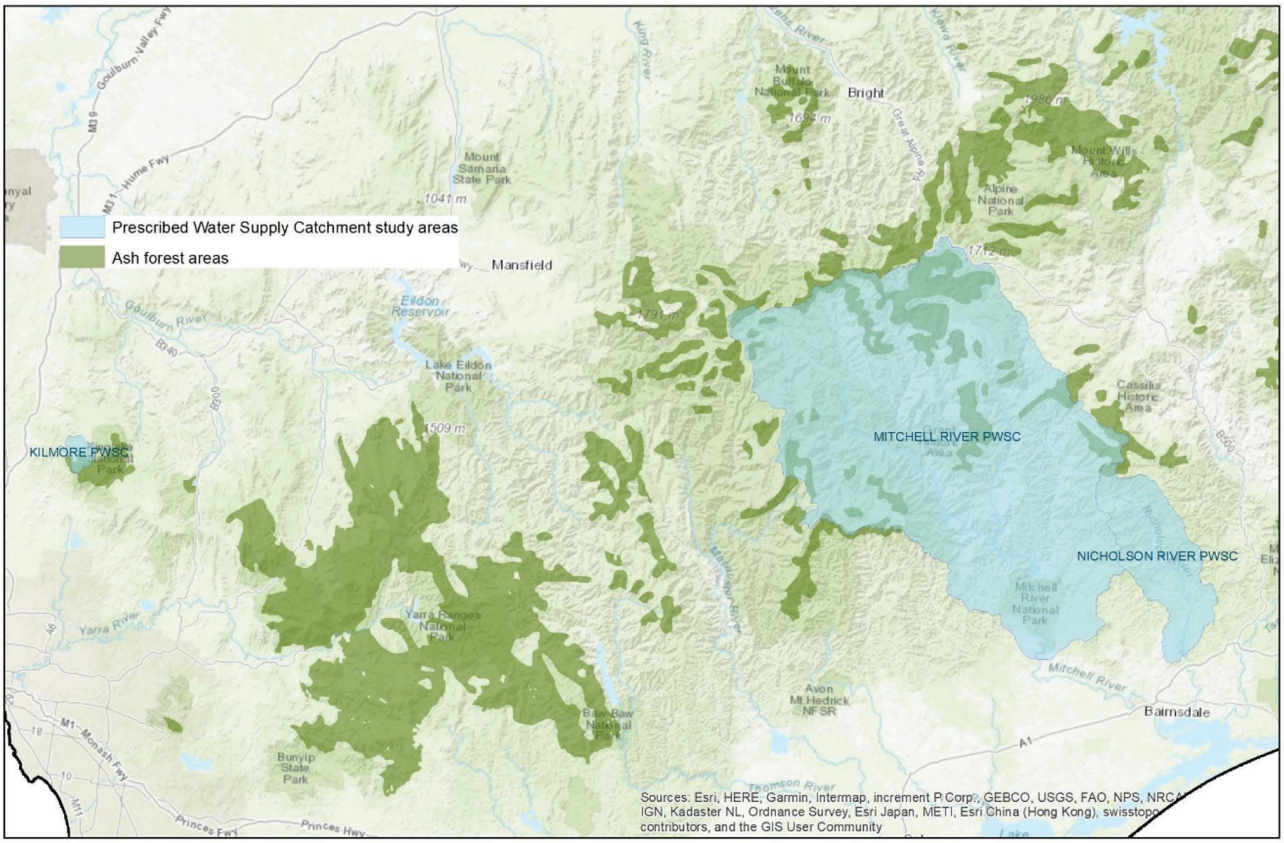


Figure Fo.39 Case study catchment areas

(Data source: DELWP, 2018)

The extent of forest ecosystem assets and yearly flow of water supply services for the three catchment areas is presented in Table Fo.37 and Table Fo.37. In 2017, the Kilmore PWSC area supplied 1,646 ML of water, the Mitchell River PWSC area supplied 504,098 ML of water, and the Nicholson River PWSC area supplied 4,979 ML of water.[179]

Table Fo.36 Forest ecosystem asset extent across three catchments

Forest type	Kilmore (ha)	Mitchell (ha)	Nicholson (ha)	Total (ha)
Ash forests	1,186	58,553	724	60,463
Other forests	1,952	315,098	45,386	362,436
Other land cover	141	17,349	1,587	19,077
Total	**3,279**	**391,000**	**47,697**	**441,976**

(Data source: DELWP, 2018)

Table Fo.37 Ecosystem-service flow – water supply – for three catchments, 2013-17

Catchment	Recorded annual flow (ML) – actual				
	2013	2014	2015	2016	2017
Kilmore	3,767	2,891	1,570	2,245	1,646
Mitchell River	841,139	519,979	486,647	1,125,627	504,098
Nicholson River	37,303	38,891	51,950	62,492	4,979
Total	**882,209**	**561,761**	**540,167**	**1,190,364**	**505,744**

(Data source: DELWP, 2018)

Table Fo.37 shows the annual flow of water-supply ecosystem services. However, to understand and value the benefit for the economy and society, the relevant agencies must develop an understanding of water-use.

An example in the context of the Mitchell River is useful. The largest remaining river system in Victoria that is not dammed, it provides valuable irrigation water to Lindenow Valley farmers in East Gippsland, as well as supplying urban water users. The Mitchell River supplies water to Bairnsdale and Paynesville, and to towns in adjacent river basins including Bruthen, Nicholson, Nowa Nowa, Johnsonville, Swan Reach, Metung and Lakes Entrance. It also supplies environmental flows to the Gippsland Lakes.

The Mitchell River underpins a substantial economic base in the region, including irrigated agricultural production, tourism, a growing number of small businesses and manufacturers, and an increasing population. The Gippsland Lakes are important environmental assets and are partially dependent on water from the environmental water reserve in the Mitchell Basin. The lakes are listed as internationally significant wetlands under the Ramsar Convention and rely on freshwater inputs from the Mitchell Basin to function ecologically. Other environmental assets that rely on the environmental water reserve include heritage river reaches, fish populations (Australian grayling, black bream), waterbirds (great egret) and botanical values (yellowwood).

179. Stream gauge data sourced from the Victorian Water Measurement Information System (WMIS) http://data.water.vic.gov.au/monitoring.htm Accessed 4 December 2018.

Diversions take out a relatively small proportion of total inflows, varying from approximately 1.5% during wetter years to 4.5% during drier years.[180] Applying these proportions to the amount of water supplied annually from forest assets gives the volumes outlined in Table Fo.38. In 2017, water supply that can be attributed to diversion for use was estimated at 7,561 ML to 22,684 ML.

Table Fo.38 Water supply to Mitchell River – diversions (ML), 2013-17

	2013	2014	2015	2016	2017
Lower bound (1.5%)	12,617	7,800	7,300	16,884	7,561
Upper bound (4.5%)	37,851	23,399	21,899	50,653	22,684
Total	**50,468**	**31,199**	**29,199**	**67,537**	**7,561**

(Data source: DELWP, 2018)

For the forest assets supplying regional and rural Victoria, water supply can be valued for agricultural users and regional townships using current entitlement prices.[181] This valuation approach is conservative, because the value of water to households is likely to be higher than for irrigated agriculture in many situations.

The value of water yields flowing to regulated rivers can be calculated using average high-reliability entitlement prices ($1,350/ML) across Victorian-regulated trading zones. This approach reflects the fact that the water is callable from water storages, and high-reliability entitlements are, therefore, the appropriate valuation basis.

The value of water yields flowing to unregulated rivers can be calculated using low-reliability entitlement prices ($190/ML) across Victorian unregulated trading zones. For unregulated flows outside trading zones (such as flows to Bass Strait), a zero value can be assumed, as these are likely non-consumptive uses. This approach yields conservative valuation estimates.

As the Mitchell River is an unregulated (undammed) river, applying the second value to the proportion of annual water supply from forest assets that is expected to be diverted gives an estimated value of the benefit from ecosystem services of between $1.4 million and $4.3 million in 2017. There are also additional benefits from environmental flows which have not been estimated.

180. Southern Rural Water 2014, 'Local Management Plan: Mitchell River Basin', Maffra, Victoria http://www.srw.com.au/files/Local_management_rules/Mitchell_River_Basin_LMP_January_2014.pdf Accessed 4 December 2018.

181. This valuation approach was used in Varcoe T, Betts O'Shea H, Contreras Z 2015, 'Valuing Victoria's parks: Accounting for ecosystems and valuing their benefits', DELWP and PV, Melbourne, Victoria https://parkweb.vic.gov.au/__data/assets/pdf_file/0010/695764/Valuing-Victorias-Parks-Report-Accounting-for-ecosystems-and-valuing-their-benefits.pdf Accessed 4 December 2018.

Impact of ash forest disturbance on water-supply services

Major disturbance to ash forests, and subsequent seed-bed regeneration, causes major reductions in water yield for up to 100 years, peaking at approximately 33 years post-disturbance with approximately 50% reductions in flow.[182] Post-1989 disturbance in the Kilmore, Mitchell River and Nicholson River catchment area is illustrated in Table Fo.39.[183] Theoretical maximum water yield from these catchments has been modelled and is reported in Table Fo.40. Theoretical maximum water yield has been calculated using the 3PG+ model within the EnSym[184] framework, assuming no forest disturbance since the 1939 'Black Friday' bushfires. This will create a conservative maximum yield estimate, as the water-yield impact of the 1939 Black Friday bushfires are still being experienced and will not return to normal until the middle of this century.

The difference between actual recorded flows and theoretical maximum flows is reported in Table Fo.40. For instance, if there was no ash forest disturbance post-1939 in the Mitchell River catchment area, there would have been an additional 18,503 ML of water supply in 2017. This type of analysis can help to assess the potential impacts of fire, fire management and forest harvesting on forest assets and the ecosystem services they provide.

Table Fo.39 Forest ecosystem asset condition across three catchments, since 1989

	Kilmore (ha)	**Mitchell** (ha)	**Nicholson** (ha)	**Total** (ha)
Ash disturbed by fire since 1989 (%)	87	61	54	62
Ash disturbed by logging since 1989 (%)	5	1	4	1
Total ash disturbed since 1989 (%)	92	62	58	63

(Data source: DELWP, 2018)

182. Kuczera G 1987, 'Prediction of water yield reductions following a bushfire in ash-mixed species eucalypt forest', Journal of Hydrology, 94(3-4), pp. 215-236.
183. CRCSI, '4.104 LandFor: Landsat for forests – a monitoring and forecasting framework for the sustainable management of SE Australian forests at the large area scale', Docklands, Victoria http://www.crcsi.com.au/research/4-1-agriculture-natural-resources-and-climate-change/4-104-landfor-landsat-for-forests/ Accessed 4 December 2018.
184. DELWP, 'EnSym native vegetation regulations tool', Melbourne, Victoria https://ensym.biodiversity.vic.gov.au/cms/ Accessed 4 December 2018.

Table Fo.40 Ecosystem-service flow – theoretical maximum water supply from forest assets in three catchments, 2013-17

Catchment	Theoretical maximum annual flow with no post-1939 ash forest disturbance (ML)				
	2013	2014	2015	2016	2017
Kilmore	6,511	4,776	2,732	3,567	2,853
Mitchell River	857,006	535,634	506,186	1,144,856	522,601
Nicholson River	38,234	39,823	52,749	63,525	5,301
Total	**895,240**	**575,457**	**558,935**	**1,208,381**	**522,601**

(Data source: DELWP, 2018)

Table Fo.41 Ecosystem-service flow – theoretical loss of water supply due to disturbance in three catchments, 2013-17

Catchment	Theoretical additional recorded annual flow (ML) under a no post-1939 ash forest disturbance, compared to actual recorded flow				
	2013	2014	2015	2016	2017
Kilmore	2,744	1,885	1,161	1,322	1,207
Mitchell River	15,867	15,655	19,539	19,228	18,503
Nicholson River	931	932	799	1,033	322
Total	**16,798**	**16,587**	**20,338**	**20,261**	**18,825**

(Data source: DELWP, 2018)

FIRE (Fi)

SCIENTIFIC ASSESSMENTS Part III

Commissioner *for* Environmental Sustainability Victoria

Fire

The Fire chapter has four indicators that discuss the impacts of bushfire and planned burns on humans, property and biodiversity. This chapter does not provide comprehensive discussions about fire ignition control, which includes aerial attack capability and the overall likely impact of climate change on the Victorian community. Instead, this chapter focuses on the link between climate change and fire. In addition, this chapter does not provide detailed information and interpretation of each threatened fauna species in relation to fire, but demonstrates a need for a dual-scale (state and regional) approach for successful biodiversity monitoring in response to fire in Victoria.

Background

Fire regimes play a vital, yet complex role in Victorian ecosystems, which provide habitat for a diverse range of fire-adapted native flora and fauna species, with some plant species only germinating after stimulation by heat or smoke. The beneficial effects of fire on ecosystem processes are well researched. Locally, fire catalyses plant nutrient cycles by decomposing organic materials into available nutrients that provide fertile soil conditions. At the landscape level, fire assists key processes such as tree decay, tree collapse and stand tree germination.[1, 2, 3, 4] However, unanticipated or inappropriate fire regimes will impact dangerously on the survival of threatened flora and fauna species. These ecological complexities highlight another important aspect of optimising fire management in Victoria.

Compounded by population growth and residential incursion into previously uninhabited forest areas, the risk of fire to people and property has increased. It is estimated that about $8.5 billion (or 1.15%) of Australia's gross domestic product accounts for the total annual cost of fires in Australia.[5] In Victoria, the economic cost of the 2009 Black Saturday fires was evaluated as $4.4 billion.[6]

Fire managers and communities must plan for more frequent and extreme bushfire events.[7, 8] It is predicted that Victoria will encounter more dangerous conditions than other states.[9] Climate change predictions show the likely impact on biodiversity, with some effects being noticed already – such as changes in plant growth rates, fuel loads and moisture content, as a result of longer periods of weather associated with high fire risk.[10] Although many native Australian flora and fauna species are tolerant of individual fires, an increase in fire intensity and frequency may impose a variety of negative impacts on biodiversity. Some habitats and species are more likely to be adversely influenced than others.[11] In addition, the *Flora and Fauna Guarantee Act 1988* listed inappropriate fire regimes and high-frequency fires as potentially threatening processes to the survival of flora and fauna in Victoria.

1. Lindenmayer DB, Blanchard W, Blair D, McBurney L 2018, 'The road to oblivion – quantifying pathways in the decline of large old trees', Forest Ecology and Management, 430, pp. 259-264.
2. Lindenmayer DB, Blanchard W, Blair D, McBurney L, Banks SC 2018, 'Empirical relationships between tree fall and landscape-level amounts of logging and fire', PLOS One, 13(2), e0193132.
3. Lindenmayer DB, Blanchard W, McBurney L, Blair D, Banks S, Likens GE, Franklin JF, Stein J, Gibbons P 2012, 'Interacting factors driving a major loss of large trees with cavities in an iconic forest ecosystem', PLOS One, 7, e41864.
4. Smith AL, Blair D, McBurney L, Banks SC, Barton PS, Blanchard W, Driscoll DA, Gill AM, Lindenmayer DB 2014, 'Dominant drivers of seedling establishment in a fire-dependent obligate seeder: climate or fire regimes?' Ecosystems, 17, pp. 258-270.
5. Ashe B, Mc Aneney KJ, Pitman AJ 2009, 'Total cost of fire in Australia' Journal of Risk Research, 12, pp. 121-136.
6. Teague B, McLeod R, Pascoe S 2010, '2009 Victorian Bushfires Royal Commission Final Report', 2009 Victorian Bushfires Royal Commission, Parliament of Victoria, Melbourne, Victoria http://royalcommission.vic.gov.au/finaldocuments/summary/PF/VBRC_Summary_PF.pdf Accessed 4 December 2018.
7. Hughes L 2003, 'Climate changes and Australia: trends, projections and impacts', *Austral Ecology*, 28, pp. 423-443.
8. Downie C 2006, 'Heating up: bushfires and climate change'. The Australia Institute, Manuka, ACT. http://www.tai.org.au/sites/defualt/files/WP92_8.pdf Accessed 4 December 2018.
9. Dowdy JA 2018 'Climatological variability of fire weather in Australia', Journal of Applied Meteorology and Climatology, 57, pp. 221-234.
10. Enright NJ, Fontaine JB, Bowman DMJS, Bradstock R, Williams RJ 2015, 'Interval squeeze: altered fire regimes and demographic responses interact to threaten woody species persistence as climate changes', Frontiers in Ecology and the Environment, 13, pp. 265-272.
11. Williams D, Bowman D, Little J 2014, 'Climate Change, Fire and Terrestrial Biodiversity: information sheet six', James Cook University, Townsville, Queensland http://nccarf.jcu.edu.au/terrestrialbiodiversity/documents/information_sheet_6_fire_final.pdf Accessed 4 December 2018.

Smoke from fires (planned burns and bushfires) has health implications for surrounding communities. In some cases, the area of effect can expand to 50 km from the source of the fire.[12] Particulate matter and noxious gases associated with smoke can reduce air quality in rural and urban areas and may affect people's health.[13] In addition, smoke can also have economic impacts – tainting grapes, for example,[14] or forcing road closures that prevent or delay transportation of goods and services,[15] and hinder emergency transport. The critical challenges facing Victoria's bushfire management now and in the future include:

- minimising the impact of major bushfires on human life, communities, essential and community infrastructure, industries, the economy and the environment
- monitoring responses of biodiversity (flora and fauna) to both planned burns and bushfires on regional and state scales
- maintaining or improving the resilience of natural ecosystems and their ability to deliver services such as biodiversity, water, carbon storage and forest products[16]
- maintaining the persistence of key fire-response species to increasing fire frequency and intensity
- increasing community awareness and establishing effective emergency management systems, especially in peri-urban areas
- developing a structured framework for analysing the impacts of bushfires on human life and property
- protecting human health from more frequent smoke exposure.

12. Goodrick SL, Achtemeier GL, Larkin NK, Liu Y, Strand TM 2013, 'Modelling smoke transport from wildland fires: a review', International Journal of Wildland Fire, 22, pp. 83-94.
13. Health Victoria, 'Bushfire smoke and planned burns', Melbourne, Victoria. https://www2.health.vic.gov.au/public-health/environmental-health/climate-weather-and-public-health/bushfires-and-public-health/bushfire-smoke-and-planned-burns Accessed 4 December 2018.
14. Whiting J, Krstic M 2007, 'Understanding the sensitivity to timing and management options to mitigate the negative impacts of bush fire smoke on grape and wine quality-scoping study', Project report (MIS No. 06958 and CMI No. 101284), Victorian Department of Primary Industries, Knoxfield, Victoria https://www.wineaustralia.com/getmedia/7e0159f4-037c-42e5-a642-05585f07be9e/200707_Understanding-impacts-of-bush-fire-smoke.pdf Accessed 4 December 2018.
15. Stephenson C 2010, 'A literature review on the economic, social and environmental impacts of severe bushfires in south-eastern Australia', Fire and adaptive management Report no.87, Bushfire CRC, East Melbourne, Victoria https://www.ffm.vic.gov.au/__data/assets/pdf_file/0009/21114/Report-87-A-Lit.Rvw-On-The-Economic,-Social-and-Envtal-Impacts-of-Severe-Bushfires-In-SE-Aust..pdf Accessed 4 December 2018.
16. DSE 2012, 'Code of practice for bushfire management on public land', Melbourne, Victoria https://www.ffm.vic.gov.au/__data/assets/pdf_file/0006/21300/Code-of-Practice-for-Bushfire-Management-on-Public-Land.pdf Accessed 4 December 2018.

Current Victorian Government Settings: Legislation, Policy, Programs

The Victorian Government published *Safer Together: A New Approach to Reducing the Risk of Bushfire in Victoria* in 2015 based on recommendations from the Inspector-General for Emergency Management (IGEM). *Safer Together* adopts a risk reduction target, replacing the previous hectare target approach to bushfire fuel management on public land. This approach enables the government to act more strategically, by planning and implementing risk-reduction activities in areas that will derive the greatest benefit. The government has committed to maintaining residual bushfire risk at or below 70%. In addition, the Department of Environment, Land, Water and Planning (DELWP), along with the Country Fire Authority (CFA) and Forest Fire Victoria, now involves local communities in prioritising fuel management activities and identifying opportunities to reduce risk across all land tenures.

Since the new approach was initiated, IGEM has published two monitoring reports that review DELWP's progress in response to the recommendations.[17] These recommendations are to reform bushfire risk management since the 2015 review and investigation. All of four recommendations are being implemented as part of *Safer Together*. The recommendations will be continually monitored as part of ongoing assurance activities, including breaches of planned burn control lines.

Underpinning the government's efforts to reduce risk of bushfires is the Code of Practice for Bushfire Management on Public Land. The code was adapted from its 2006 iteration, following the 2009 Victorian Bushfires Royal Commission. Risk-based planning, where human life is afforded the highest priority, is a fundamental part of the code; however, it also recognises the impacts of fire on the natural environment and thereby considers risk to human life, infrastructure and ecological assets within its approach.

17. Inspector-General for Emergency Management Victoria 2017, 'Annual report: implementation of recommendations on bushfire fuel management', Melbourne, Victoria https://www.igem.vic.gov.au/sites/default/files/embridge_cache/emshare/original/public/2018/01/6d/d7d449083/Annual_Report_Implementation_of_bushfire_fuel_management_recommendations_2017.pdf Accessed 4 December 2018.

Indicator Assessment

Legend

Status

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

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

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

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

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

Trend

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

? **Unclear**

↘ **Deteriorating**

→ **Stable**

↗ **Improving**

Data quality

Poor
Evidence and consensus too low to make an assessment

Fair
Limited evidence or limited consensus

Good
Adequate high-quality evidence and high level of consensus

FIRE

Indicator	Summary	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend
Fi:01 Area of native vegetation burnt in planned fires and bushfires **Region** Victoria **Measures** Annual planned burn area and annual total area affected by bushfires **Data custodian** DELWP	The area of annual planned burns have been decreasing since 2012-13 due to weather-related constraints. Since 2016-17 the area-based target (5% annual burn of public land) has concluded and a risk-based approach has commenced. Bushfire affected area has been decreasing since 2003. The change in planned burn strategy from area to risk based approach was used as a threshold to determine status.	○ ● ○ ○ DATA QUALITY Good	↘

	Summary	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend
Indicator **Fi:02** Impacts of bushfires **Region** Victoria **Measures** Impacts of bushfires on human settlements, businesses and natural resources **Data custodian** None	The Bushfire Co-operative Research Centre was the leading agency collating evidence on bushfire impact. Since 2013, there has been a lack of clarity regarding responsibility for data collation and dissemination to utilise for evidence-based future decision making. Fragmented information has been identified from EMV and DHHS.	POOR DATA QUALITY Poor	?
Indicator **Fi:03** Actual fire regimes compared to optimal fire regimes **Region** Victoria **Measures** Tolerable Fire Interval (TFI) and Growth Stage Structure (GSS) distribution on public forests between 2007 and 2017 **Data custodian** DELWP	Victorian Government uses tolerable fire internal as a metric to determine the current resilience condition of key fire response species. An increase in area where lower than minimum TFI and ongoing reduction in long unburnt habitats between 2007-17 is a threat to biodiversity. Future large fires may determine if current TFI regimes are appropriate.	FAIR DATA QUALITY Good	↘
Indicator **Fi:04** Bushfire risk **Region** Victoria **Measures** Residual risk Impact of climate change on fire weather Data on biodiversity in response to fire **Data custodian** DELWP and BOM	The impact of the risk-based planned-burning approach on biodiversity, particularly fauna species is not currently monitored at a state-scale but isolated data exists. DELWP has a system to monitor bushfire risks to human and property.	FAIR DATA QUALITY Poor Data quality for biodiversity is poor while that for life and property is assessed as good	↘

	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
Fi:01 Area of native vegetation burnt in planned fires and bushfires		↘	DATA QUALITY Good

Data custodian DELWP

Until 2015–16, the Victorian Government had an annual planned-burning target. Prior to 2010–11, the annual target was 130,000 hectares. This increased to 200,000 hectares in 2010–11, 225,000 hectares in 2011–12 and 250,000 hectares in 2012–13. These increases were responses to recommendations from inquiries into large fires since 2002, including the 2009 Victorian Bushfires Royal Commission, which recommended an annual planned-burning target of 390,000 hectares (from 1.3% to 5% of public land).[18] The annual planned-burning targets aimed to reduce risks to life and property.

Planned burns are always dependent on weather and fuel conditions. Burning is not possible when conditions are too hot and dry, nor when conditions are too wet. Weather conditions therefore dictate the amount of burning carried out in a given year to meet planned-burning targets, and account for much of the annual fluctuations.

In order to meet the targets each year, the Victorian Government progressively increased the annual planned-burning area until 2012–13. The following year (2013–14) provided very few days that permitted planned burns. Regular showers and unstable weather conditions, especially in the Far South West, Otways and Midlands districts, limited burning opportunities. As a result, DELWP was only able to treat 82,022 hectares through planned burns. The subsequent years also had few days when planned burns could be conducted, resulting in burning of less than the annual target of 390,000 hectares until 2015–16.

In 2016–17, the annual burn area target was abolished, based on the recommendations from IGEM, and replaced by a risk-reduction target. In response to the recommendations, DELWP initiated the Safer Together program,[19] which is in development and will be fully functional for forest fuel management by 2020.

Between 2003–04 and 2016–17, just over 2 million hectares of native vegetation was burnt in planned fires in Victoria (Figure Fi.1). Much of the ecological and fuel-reduction burns were concentrated on the eastern part of Victoria (Figure Fi.2). The majority of planned burns (86%) were carried out for fire suppression purposes by reducing fuel levels. While the area of the fuel-reduction burn has been decreasing from a maximum of 94% in 2006–07 to 76% in 2016–17 (Figure Fi.1), ecological-burn activities have proportionally increased from 3% to 22% over the same period. The increase in planned-burning area since 2009–10 was a response to recommendations by royal commissions[18] that opportunities for planned burns should be maximised where possible to reduce fuel loads in Victorian forests. However, such recommendations do not adequately address aspects of forest ecosystem health, such as the risk of extinction in a range of native species. Biodiversity in the Mallee shrublands and in the woodlands of north-western Victoria is particularly at risk.[20]

18. State of Victoria 2012, 'Bushfire Royal Commission Implementation Monitor: Final report 2012', State of Victoria, Melbourne, Victoria https://www.igem.vic.gov.au/sites/default/files/embridge_cache/emshare/original/public/2017/07/01/d8b8a164d/Publication%20-%20brcim_final_report_July%202012.PDF Accessed 4 December 2018.

19. DELWP 2015, 'Safer Together: A new approach to reducing the risk of bushfire in Victoria', Melbourne, Victoria http://www.delwp.vic.gov.au/__data/assets/pdf_file/0004/319531/DELWP_SaferTogether_FINAL_17Nov15.pdf Accessed 4 December 2018.

20. Giljohann KM, McCarthy MA, Regan TJ 2015, 'Choice of biodiversity index drives optimal fire management decisions', Ecological Applications, 25(1), pp. 264-277.

Since 2015–16, the hectare-based target has shifted from a hectare-based approach to a risk-based approach for fire management. The new risk-based approach focuses on strategic areas near housing and infrastructure where there is a high chance of fire impacting on people and property. This shift is also in-line with research that demonstrates that fuel treatments close to property will more effectively mitigate impacts from bushfires in peri-urban communities than standard (hectare-based approaches).[21] But significant risk of human loss from bushfires still remains, depending on the rate of fuel treatment.[22] More information can be found in the indicator Fi:04 Bushfire risk.

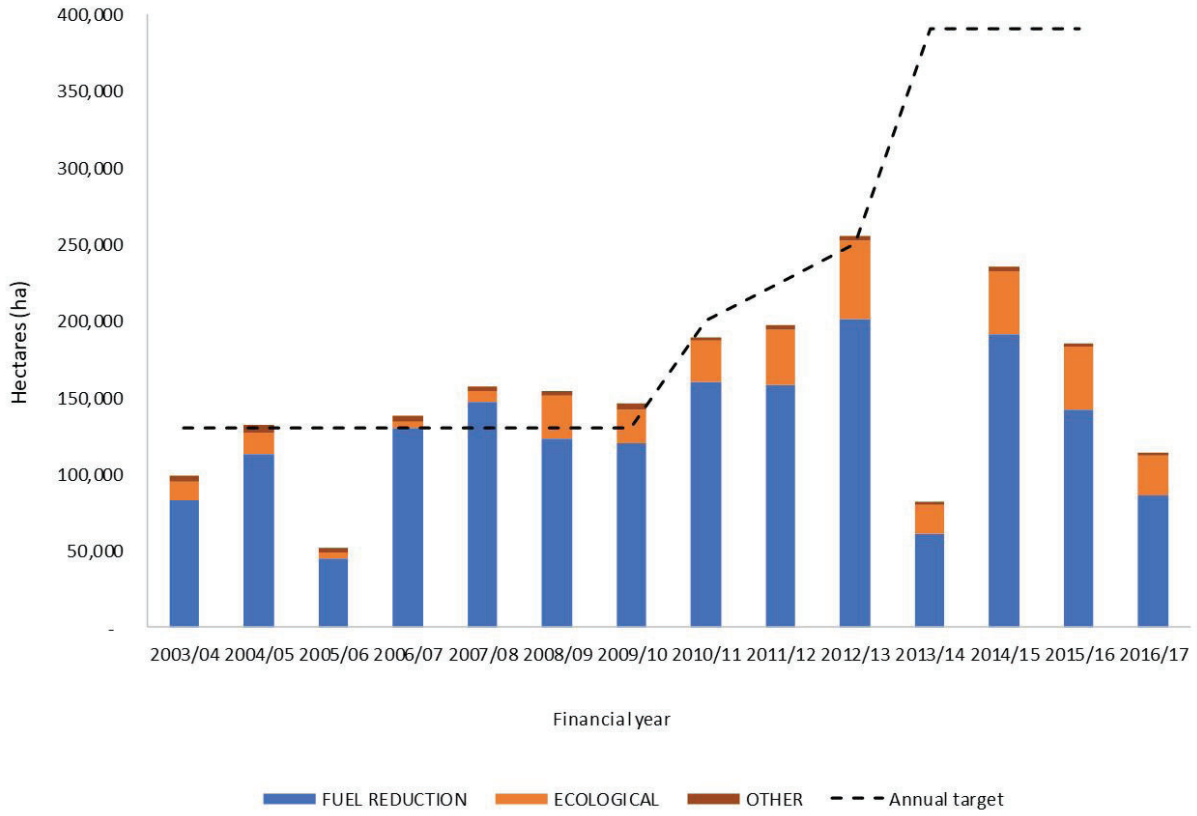


Figure Fi.1 Area of planned burns by type, 2003–04 to 2016–17

(Data source: DELWP, 2018)

21. Gippsons P, van Bommel L, Gill AM, Cary GJ, Driscoll DA, Ross A, Bradstock RA, Knight E, Moritz MA, Stephens SL, Lindenmayer DB 2012, 'Land management practices associated with house loss in wildfires'. PLOS One, 7, e29212.
22. Bradstock RA, Cary GJ, Lindenmayer, Price OF, Williams RJ 2012, 'Wildfires, fuel treatment and risk mitigation in Australian eucalypt forests: insights from landscape-scale simulation', Journal of Environmental Management, 105, pp. 66-75.

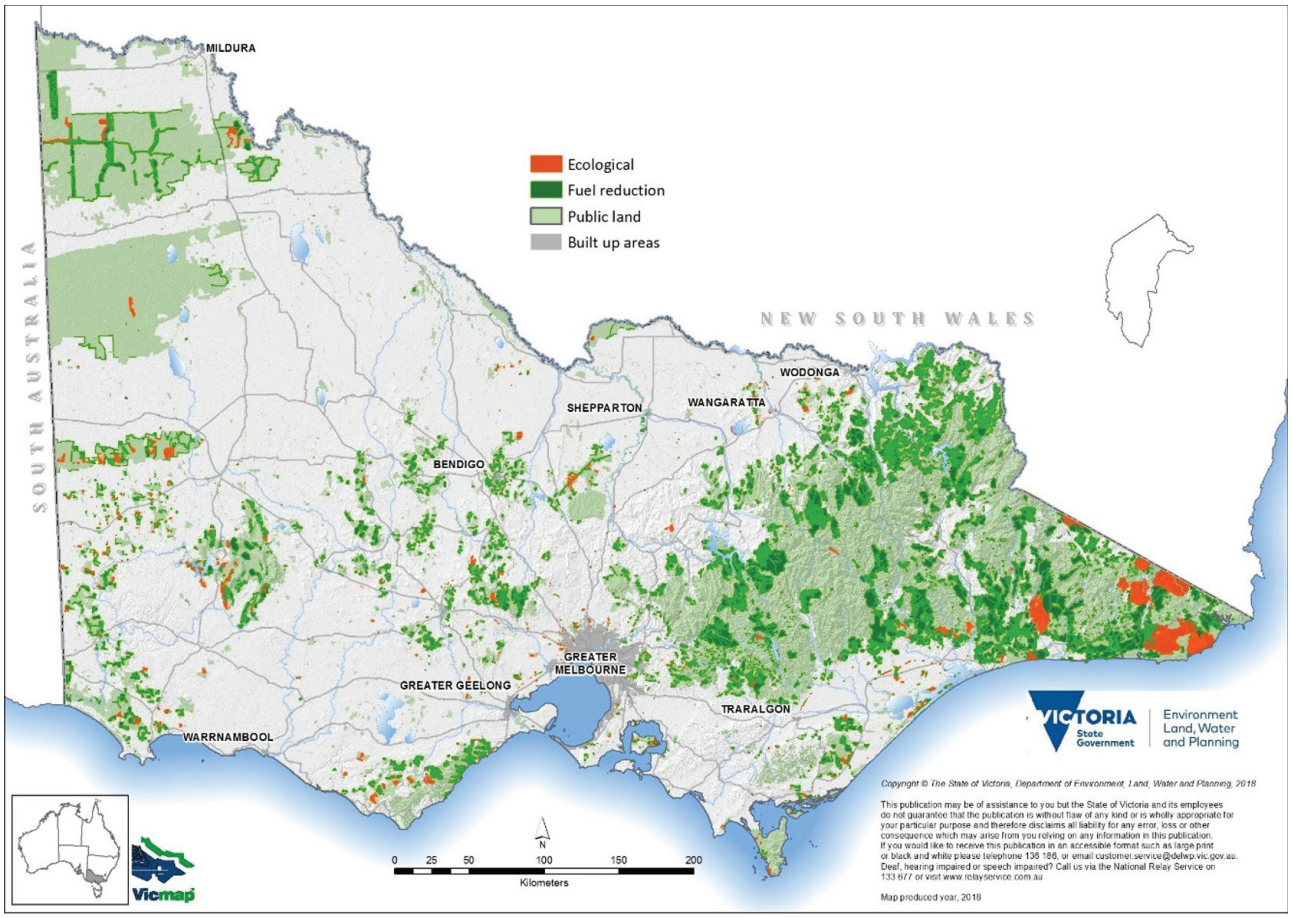


Figure Fi.2 Map of planned-burn areas in Victoria, 2000–2017

(Data source: DELWP, 2018)

Area of Planned Burns by Region and Fire District

DELWP applies fire management plans throughout six Victorian regions: Hume, Gippsland, Port Phillip, Grampians, Loddon Mallee and Barwon South West. Each region is comprised of several districts. The Gippsland region accounted for the largest area of planned burns between 2003–04 and 2016–17, with 829,000 hectares or 39% of the total planned-burning area. The Hume region was the second-largest area, with 621,000 hectares or 29% of the total planned-burning area. The high proportion of the state's planned burns in Gippsland and Hume (Figure Fi.3) is explained by the extent of public land close to assets in these regions, which has remained relatively consistent over time. The Snowy district in the Gippsland region was subject to extensive planned burns over the period, accounting for 19% (403,000 hectares). Upper Murray, in the Hume region, and Tambo, also in the Gippsland region, had 14% (293,000 hectares) and 12% (250,000 hectares) of the total area burnt over the period respectively (Figure Fi.4).

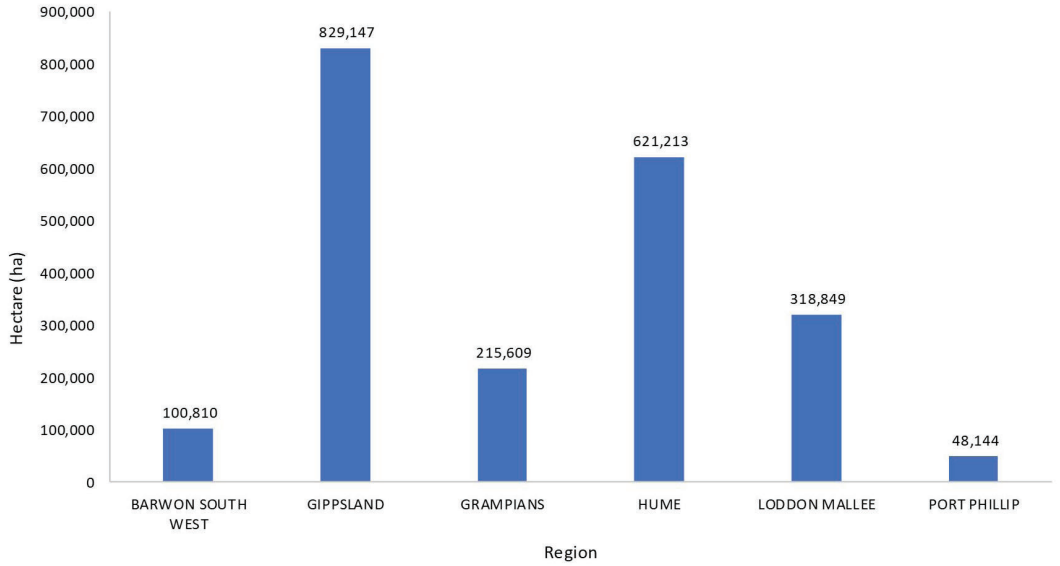


Figure Fi.3 Cumulated planned-burning area in Victoria by region, 2003–04 to 2016–17

(Data source: DELWP, 2018)

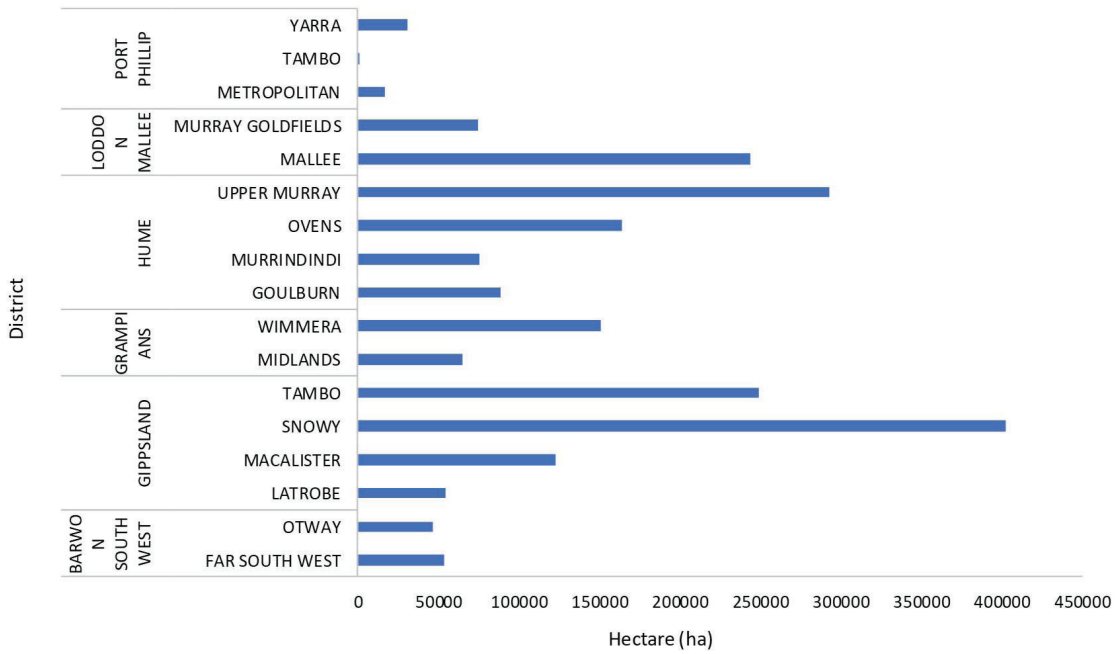


Figure Fi.4 Cumulated planned-burning area in Victoria by fire district, 2003–4 to 2016–17

(Data source: DELWP, 2018)

Area Burnt by Bushfire

More than 85% of the area burnt by bushfire in Victoria between 2003–04 and 2016–17 was burnt in four extensive bushfires between 2003 and 2017: 2003 (1.6 million hectares), 2007 (1.2 million hectares), 2009 (446,000 hectares) and 2014 (415,000 hectares). The 2003, 2007 and 2009 bushfires occurred during the millennium drought of 1996 to 2010, which increased the frequency and severity of large bushfires (Figure Fi.5 and Figure Fi.6).

In 2013–14, Victoria experienced its most significant fire season since 2008–09, challenging both emergency services and Victorian communities. Across the season, Victoria had 19 days of 'extreme' and 'severe' fire danger rating, and 16 days of 'total fire ban'. More than 463,000 hectares of public and private land was burnt, and 80 residences were destroyed.[23] The respective land management and fire agencies (including the CFA and DELWP, and their Networked Emergency Management partners – Parks Victoria, VicForests and Melbourne Water (DEPI/NEO) – and the Metropolitan Fire Brigade) responded to more than 4,600 bushfires and grassfires over a five-month period.

The Hazelwood mine fire also occurred in 2014, releasing significant amounts of smoke and ash that settled on the adjacent township of Morwell.[24] Following the fire, IGEM identified issues around the initial availability of air-quality monitoring, health-monitoring data, decision-making protocols and community information. These issues were addressed through two inquiries into the fire and the EPA inquiry, and their recommendations are now being implemented are now being implemented, as discussed in indicator A:09 (Health impacts of air pollution).[25]

Subsequent years up to 2017 have seen relatively low fire activity.

23. Emergency Management Victoria 2014, 'Post season operations review: Fire danger period 2013/14', Melbourne, Victoria https://www.emv.vic.gov.au/publications/post-season-operations-review-2013-14 Accessed 4 December 2018.
24. Environmental Protection Australia Victoria 2015, 'Summarising the air monitoring and conditions during the Hazelwood mine fire, 9 February to 31 March 2014', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1598.pdf Accessed 4 December 2018.
25. Hazelwood Mine Fire Inquiry 2014, 'Hazelwood Mine Fire Inquiry Report', Melbourne, Victoria http://report.hazelwoodinquiry.vic.gov.au/wp-content/uploads/2014/08/Hazelwood_Mine_Inquiry_Report_Intro_PF.pdf Accessed 4 December 2018

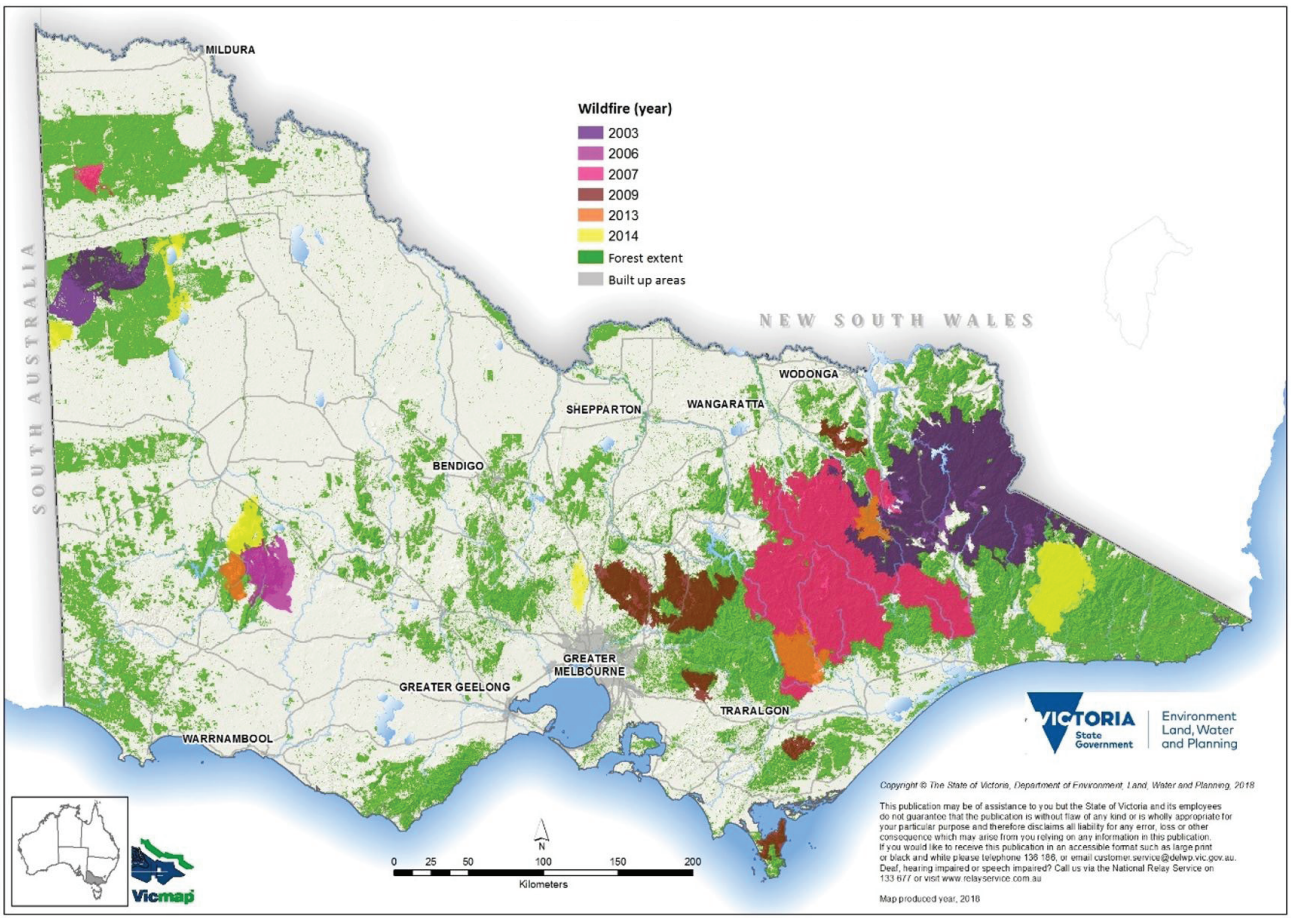


Figure Fi.5 Major bushfires in Victoria, 2000–2017

(Data source: DELWP, 2018)

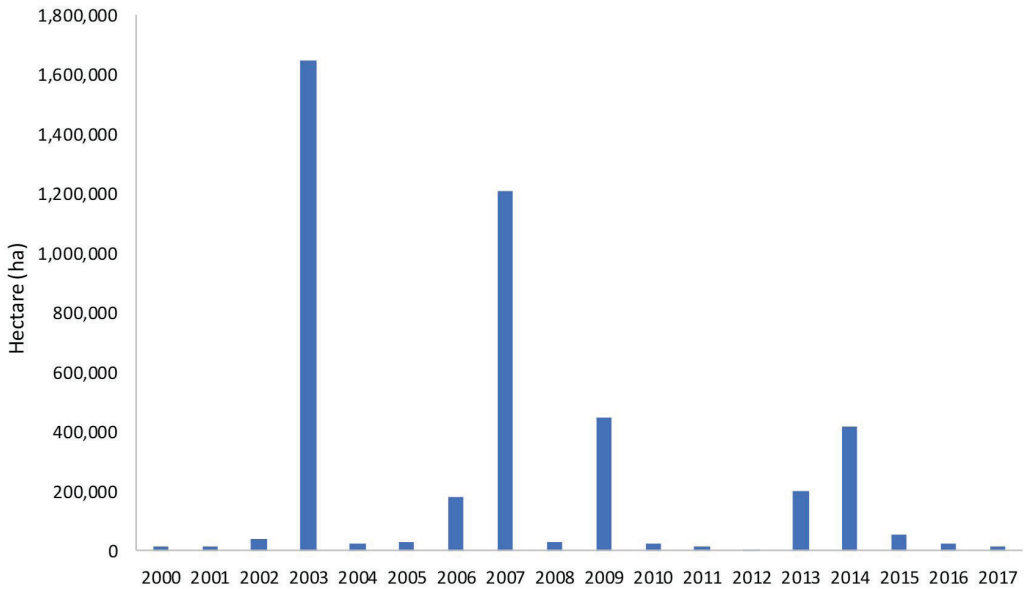


Figure Fi.6 Total area in Victoria affected by bushfires, 2000–2017

(Data source: DELWP, 2018)

	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
Fi:02 Impacts of bushfires		?	DATA QUALITY Poor
Data Custodian None			

The Victorian Government's highest priority is to protect people, property and infrastructure. It is therefore extremely important to monitor and evaluate the cumulative impacts on society of bushfires.

Given the cost of fire responses, the drain on water resources, and the devastating impact of bushfires on biodiversity and communities, it is critical to identify data custodians responsible for collating information on the impacts of fire on essential community infrastructure (i.e. hospitals, power supplies), businesses, water resources, biodiversity and the cost of fire responses.

Previously, the Bushfire Cooperative Research Centre was the leading agency collating evidence on the economic, social and environmental impacts of bushfires in Victoria, with funding provided by the Victorian Government.[26, 27] Since 2013, the only information that was identified to be held by emergency management agencies was property loss from bushfires over the past three years (Table Fi.1).

During major emergencies, the Department of Health and Human Services (DHHS) is responsible for:

- overseeing and coordinating the health system's response, including understanding the impacts on the community, the health sector, and the department's clients and services, and working with EPA Victoria where there may be significant impacts on, or risks to, public health
- coordinating regional relief and recovery, the social recovery environment and the following services:
    - emergency shelter, housing and accommodation
    - emergency financial assistance
    - health, medical assistance and first aid
    - psychosocial support.

No specific bushfire-related information was available from DHHS for this report. DHHS referred to its annual reports,[28] which aggregate data from all emergency events, such as flooding, storms and thunderstorm asthma events.

Impact of bushfire on biodiversity is discussed in the next indicator (Fi:03 Actual fire regimes compared to optimal fire regimes).

Table Fi.1 Available property-loss data from bushfires, 2015–16 to 2017–18

Year	Property loss
2015–16	148 (116, from Wye River bushfire)
2016–17	1
2017–18	27 (26, South West Complex; 1, Carrum Downs fire)

(Data source: Emergency Management Victoria, 2018)

26. Stephenson C 2010, 'A literature review on the economic, social and environmental impacts of severe bushfires in south-eastern Australia', Fire and adaptive management Report no.87, Bushfire CRC, East Melbourne, Victoria https://www.ffm.vic.gov.au/__data/assets/pdf_file/0009/21114/Report-87-A-Lit.Rvw-On-The-Economic,-Social-and-Envtal-Impacts-of-Severe-Bushfires-In-SE-Aust..pdf Accessed 4 December 2018.
27. Stephenson C 2010, 'The impacts, losses and benefits sustained from five severe bushfires in south-eastern Australia'. Fire and adaptive management Report no. 88, Bushfire CRC, Melbourne, Victoria https://www.ffm.vic.gov.au/__data/assets/pdf_file/0010/21115/Report-88-The-Impacts-Losses-and-Benefits-Sustained-from-Five-Severe-Bushfires-in-SE-Aust..pdf Accessed 4 December 2018
28. DHHS 2017, 'Annual report 2016-17', Melbourne, Victoria https://dhhs.vic.gov.au/dhhs-annual-report-2016-17-pdf Accessed 4 December 2018.

	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
Fi:03 Actual fire regimes compared to optimal fire regimes	FAIR	↘	DATA QUALITY: Good

Data custodian DELWP

A fire regime is a combination of factors including frequency, intensity, size, pattern, season, interval and severity. Inappropriate fire regimes can cause disruption to sustainable ecosystems and result in a loss of biodiversity by changing the structure of plant communities and the composition of fauna communities.

Fires impact on the habitat extent of some fauna species. For example, sugar glider (*Petaurus breviceps*) and Leadbeater's possum (*Gymnobelideus leadbeateri*) are subject to high-severity bushfire.[29] Landscape-level fire severity was found to have strong effects on bird species richness and the detection frequency of the majority of bird species after the 'Black Saturday' bushfire event in 2009.[30] For any given plant community, the suitable fire interval to maintain species composition is dictated by the life-history attributes of the plant species in that community, particularly the time required for species to mature and set seed, as well as their time to mortality in the absence of fire. The tolerable fire interval for a vegetation community is defined by the minimum and maximum intervals between fires of the species in that community that are most sensitive to fire. These are denoted as 'key fire response species (KFRS)'.[31] If fire frequency is above or below minimum fire tolerance intervals, KFRS may not be able to reproduce and repopulate and thus the vegetation community may change. Information on the vital attributes of plants that define their KFRS status is collated and subject to regular updating by DELWP, but is not published publicly and if requested, the status of KFRS is available. This information is regularly updated from ongoing field-monitoring activities. The KFRS is created based on the life-history characteristics or 'vital attributes' of flora species. The vital attributes of plants will dictate the response of a plant population to a particular disturbance.[32] At a minimum, three vital attributes of plants are required to determine their response to fire and tolerable fire intervals:

1. Method of persistence
2. Conditions for establishment
3. Relative longevity of each life stage.

Once the vital attributes of a species are identified, the sensitivity of a species to repeated fire can be determined. The purpose of defining the vital attributes of individual species is to ensure the viability of all species at a given location. However, it is impractical to manage all individual species at all locations across the landscape. Mapping of vegetation using floristic information is conducted at the community level. Thus, the viability of the community can be defined to a large extent by the viability of the individual species in the community. By identifying the plant species within each plant community which will be either significantly reduced in abundance by too frequent fire or by fire exclusion for long periods. These species are the key fire response species for the community. Once these KFRS have been identified, these species can be monitored regularly to see if they are developed to survive from next fire.

29. Lindenmayer DB, Blanchard W, McBurney L, Blair D, Banks SC, Driscoll D, Smith AL, Gill AM 2013, 'Fire severity and landscape context effects on arboreal marsupials', Biological Conservation, 167, pp. 137-148.
30. Lindenmayer DB, Blanchard W, McBurney L, Blair D, Banks SC, Driscoll DA, Smith A, Gill AM 2014, 'Complex responses of birds to landscape-level fire extent, fire severity and environmental drivers', Diversity and Distributions, 20, pp. 467-477.
31. Cheal D 2010, 'Growth stages and tolerable fire intervals for Victoria's native vegetation data sets', Fire and adaptive management Report no.84, Bushfire CRC, Melbourne, Victoria https://www.ffm.vic.gov.au/__data/assets/pdf_file/0009/21114/Report-87-A-Lit.Rvw-On-The-Economic,-Social-and-Envtal-Impacts-of-Severe-Bushfires-In-SE-Aust..pdf Accessed 4 December 2018.
32. Noble IR, Slatyer RO 1981, 'Concepts and models of succession in vascular plant communities subject to recurrent fire', In '*Fire and the Australian biota*', Eds Gill Am, Groves RH, Noble IR, pp. 311-335, Australian Academy of Science, Canberra, ACT.

At a landscape level, the Victorian Government uses Tolerable Fire Interval (TFI) as a metric to determine the current resilience condition of ecosystems. TFI thresholds provide minimum and maximum fire intervals to ensure ecosystem resilience. Currently, TFIs are determined based on expert elicitation, which uses a combination of published knowledge of plant vital attributes and information derived from experts on the responses of plants and plant communities to fire[33]. To complete the database of vital attributes for Victorian flora species, extensive and labour-intensive field measurements are needed. This requires field-surveys and long-term monitoring of plant communities. This could be a fundamental caveat of the system as the database is incomplete currently. However DELWP regularly updates the vital attributes dataset to establish TFIs on the basis of field-collected data.

Vegetation types in Victoria are classified by ecological vegetation classes (EVC).[34] EVCs are described through a combination of ecological characteristics, lifeforms and floristics. In order to use the EVC system in fire management for general monitoring, evaluation and reporting (MER) process, an Ecological Vegetation Division system was developed so that EVC data is grouped into larger ecological vegetation divisions (EVD) map units, based on EVC groups that have similar ecological characteristics. In addition, EVC data is attributed using an Ecological Fire Group (EFG) attribute field that provides specific fire-response information for particular (subsets of) EVCs. The interval since the last fire for each EFG has been estimated based on the mapped history of bushfires and planned burning in Victoria over recent decades. TFI analysis provides an opportunity for detecting the potential of vegetation to undergo fundamental ecological changes related to the extinction of KFRS in the event of a recurrence or absence of fire.

The proportion of public land below minimum TFI is representative of the total area that is younger than that recommended for the recurrence of fire. For example, if a recommended minimum TFI is 15 years for a given vegetation, and it was last burnt 10 years ago, the land is now below the minimum TFI and will continue to be for another five years. By contrast, the proportion of public land above maximum TFI is the percentage that remained unburnt longer than the recommended interval. The proportion of public land with no fire history is the percentage for which no identifiable record was found – or the percentage of land with vegetation that does not have a recommended TFI.

Figure Fi.7 (a) demonstrates that in 2017, 54% (4,119,000 hectares) of native vegetation was found to be below minimum TFI, with only 2% (163,000 hectares) above the maximum TFI. This means that more than half of Victoria's native vegetation is in a state where another fire would threaten the persistence of that vegetation type on that site, because, for example, many key plant species will not have set seed to replace themselves. Only 20% of native vegetation assessed was found to be within the required TFI to successfully maintain vegetation communities in 2017. The trend over the past decades to maintain their condition has been slightly deteriorating for Victorian vegetation. Figure Fi.7 (b) demonstrates that areas below minimum TFI increased by 5% (443,815 hectares) between 2007 and 2017, while areas within the TFI threshold decreased by 2% (107,914 hectare). The area below minimum TFI reflects a large number of extensive fires over that period.

33. Cheal D 2010, 'Growth stages and tolerable fire intervals for Victoria's native vegetation data sets', Fire and adaptive management Report no.84, Bushfire CRC, Melbourne, Victoria https://www.ffm.vic.gov.au/__data/assets/pdf_file/0009/21114/Report-87-A-Lit.Rvw-On-The-Economic,-Social-and-Envtal-Impacts-of-Severe-Bushfires-In-SE-Aust.pdf Accessed 4 December 2018.
34. Ibid

This index is a warning sign that future subsequent fires before minimum TFI is reached may have a large ecological impact, with the potential to drive localised extinction of some plant species. When a subsequent fire occurs in young forest at an immature stage, and where there is an absence of mature vegetation, the area dominated by young forest has potential to preclude the development of new cohorts of old-growth forest,[35] with corresponding negative impacts on the persistence of biodiversity.[36] Many bushfire-affected vegetation types have relatively long minimum TFIs (between 15 and 80 years), so the reported increases in areas below minimum TFI can remain for a considerable time.

Between 2007 and 2017, areas with no fire history reduced by 11% (834,000 hectares). This is partly a consequence of areas with no recorded history of fire being impacted by bushfires. Some of these areas are long-unburnt habitats, which could potentially impact on biodiversity. An extensive report on suitable growth stages for different habitat types observed that early growth stages 'can be created far more easily than can late (mature) stages'.[37] Recently burnt vegetation can be created in a single season. Some important habitat features occur only in mature to senescent vegetation and thus take decades, or even centuries, to develop. The decrease of long-unburnt area is a great concern as these habitats are very hard to re-establish once lost.

Long-unburnt areas provide an essential habitat: hollow-bearing trees. There is scant monitoring of bushfire impact on critical habitat structures, especially tree hollows, hollow logs and coarse woody debris on the ground, which are critically important to threatened species in Victoria.

'Hollow tree' is defined as 'a cavity in tree >20 mm diameter that appears to extend beyond the surface of bark/wood (i.e. has some 'depth', such that it could shelter a bird or mammal), or fissure extending beyond outer surface into interior of tree'.[38] Several peer-reviewed studies have indicated the importance of maintaining or improving the presence of a large range of tree hollows in the landscape.[39, 40, 41] Frequent fires can damage these important structural components of forests and woodlands.

A study by DELWP also demonstrates that planned burns in Gippsland significantly increase the risk of collapse of hollow-bearing trees, which is likely to result in loss of habitat for fauna species that rely on hollows for survival, such as Great gliders (*Petauroides volans*).[42] Thus, planned burns, which typically utilise low-intensity prescription burns, may cause some destruction of hollow-bearing trees.[43]

35. Lindenmayer DB, Hobbs RJ, Likens GE, Krebs C, Banks S 2011, 'Newly discovered landscape traps produce regime shifts in wet forests', Proceedings of the National Academy of Sciences, 108, pp. 15887-15891.
36. Todd CR, Lindenmayer DB, Stamation K, Acevedo-Catteneo S, Smith S, Lumsden LF 2016, 'Assessing reserve effectiveness: application to a threatened species in a dynamic fire prone forest landscape', Ecological Modelling, 338, pp. 90-100.
37. Cheal D 2010, 'Growth stages and tolerable fire intervals for Victoria's native vegetation data sets', Fire and adaptive management report no.84, Bushfire CRC, Melbourne, Victoria https://www.ffm.vic.gov.au/__data/assets/pdf_file/0009/21114/Report-87-A-Lit.Rvw-On-The-Economic,-Social-and-Envtal-Impacts-of-Severe-Bushfires-In-SE-Aust..pdf Accessed 4 December 2018.
38. Clarke M, personal communication dated 25/08/2018 (Leonard S, Haslem A, Bennett A, Clarke M 2018, 'Guidelines for ecosystem resilience monitoring, evaluation and reporting within the Victorian Bushfire Monitoring Program: scientifically-based monitoring project – final report', Latrobe University, Melbourne, Victoria).
39. Stares MG, Collins L, Law B, French K 2018, 'Long-term effect of prescribed burning regimes and logging on coarse woody debris in South-Eastern Australia', Forests, 9(5), pp. 242.
40. Lindenmayer DB 2009, 'Forest pattern and ecological process: a synthesis of 25 years of research'. CSIRO Publishing, Collingwood, Victoria.
41. Lindenmayer DB, Cunningham RB, Tanton MT, Smith AP 1990, 'The conservation of arboreal marsupials in the montane ash forests of the Central Highlands of Victoria, southeast Australia: II. The loss of trees with hollows and its implications for the conservation of Leadbeater's possum *Gymnobelideus leadbeateri* McCoy (Marsupialia: Petauridae)'. *Biological Conservation*, 54, pp. 133-145.
42. Bluff L 2016, 'Reducing the effect of planned burns on hollow-bearing trees'. Fire and adaptive management report no. 95, DELWP, Melbourne, Victoria https://www.ffm.vic.gov.au/__data/assets/pdf_file/0006/21120/Report-95-Reducing-the-effect-of-planned-burns-on-hollow-bearing-trees-2016.pdf Accessed 4 December 2018.
43. Parnaby H, Lunney D, Ian S, Fleming M 2010, 'Collapse rates of hollow-bearing trees following low intensity prescription burns in the Pilliga forests, New South Wales', Pacific Conservation Biology, 16(3), pp. 209-220.

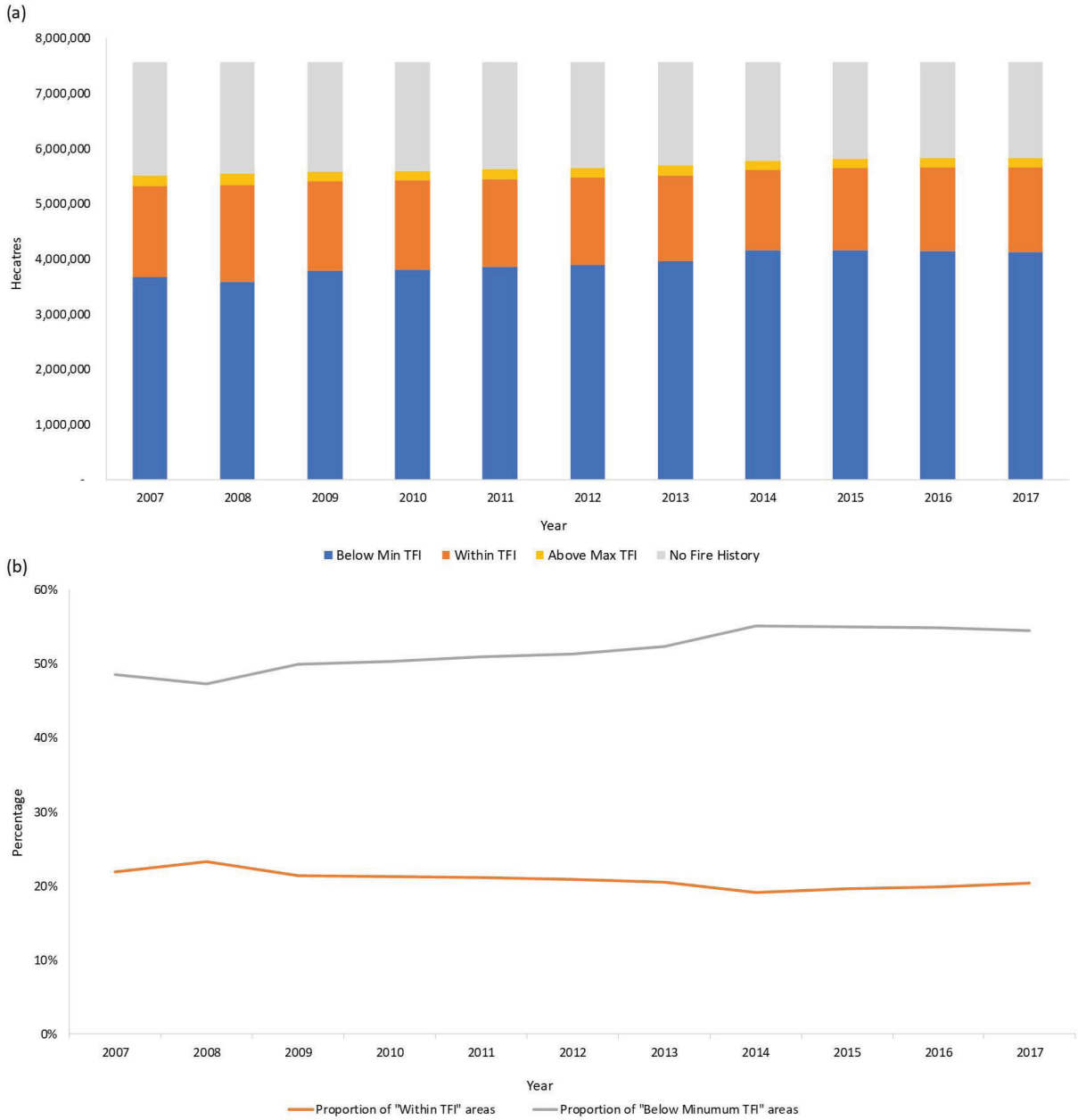


Figure Fi.7 Tolerable fire interval status on Victoria's public land

Graph (a) Area of native vegetation on Victoria's public land by TFI status, 2007–2017

Graph (b) Proportion of areas 'Within TFI' and 'Below minimum TFI', 2007-2017

(Data source: DELWP, 2018)

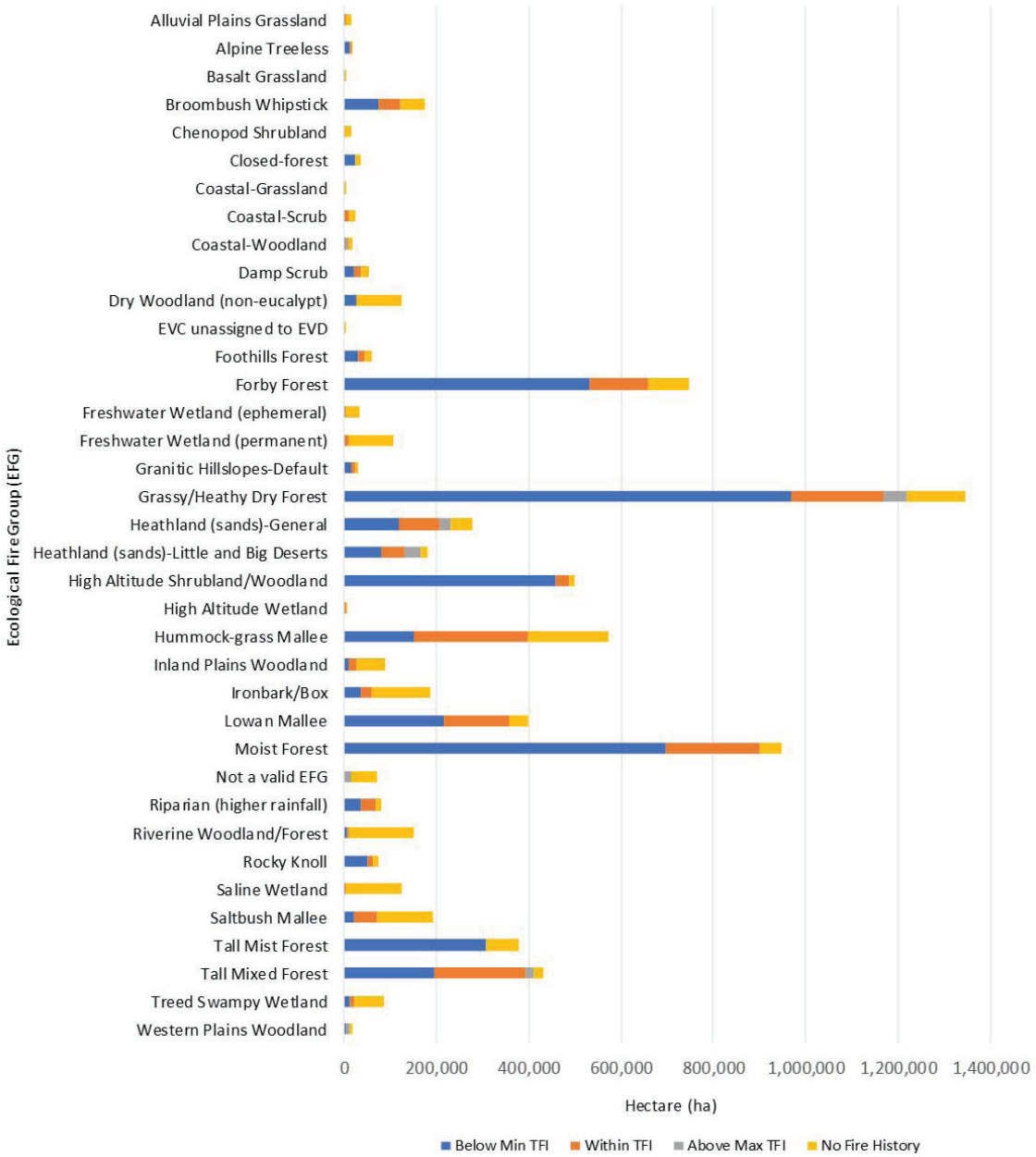


Figure Fi.8 Area of below minimum TFI, within TFI, above maximum TFI with no fire history in each EFG, 2016–17

(Data source: DELWP, 2018)

When Victorian public land is categorised by Ecological Fire Group (EFG), only 12 of 37 ecological groups have more than 25% of land that meets the required TFI standard. More than half (19) have more than 25% of land below the minimum TFI standard.

Hummock-grass Mallee and Tall Mixed Forest have the highest area within TFI, with 43% and 46% respectively. Three EFGs have more than 75% of the area below minimum TFI: Alpine Treeless, High Altitude Shrubland/Woodland, and Tall Mist Forest. Data for these fire groups is a warning that subsequent fires may impose more local or regional extinction risk on key threatened species. Detailed assessment of impacts on threatened vegetation community and/or species is an important process to ensure successful management of the Victorian environment.

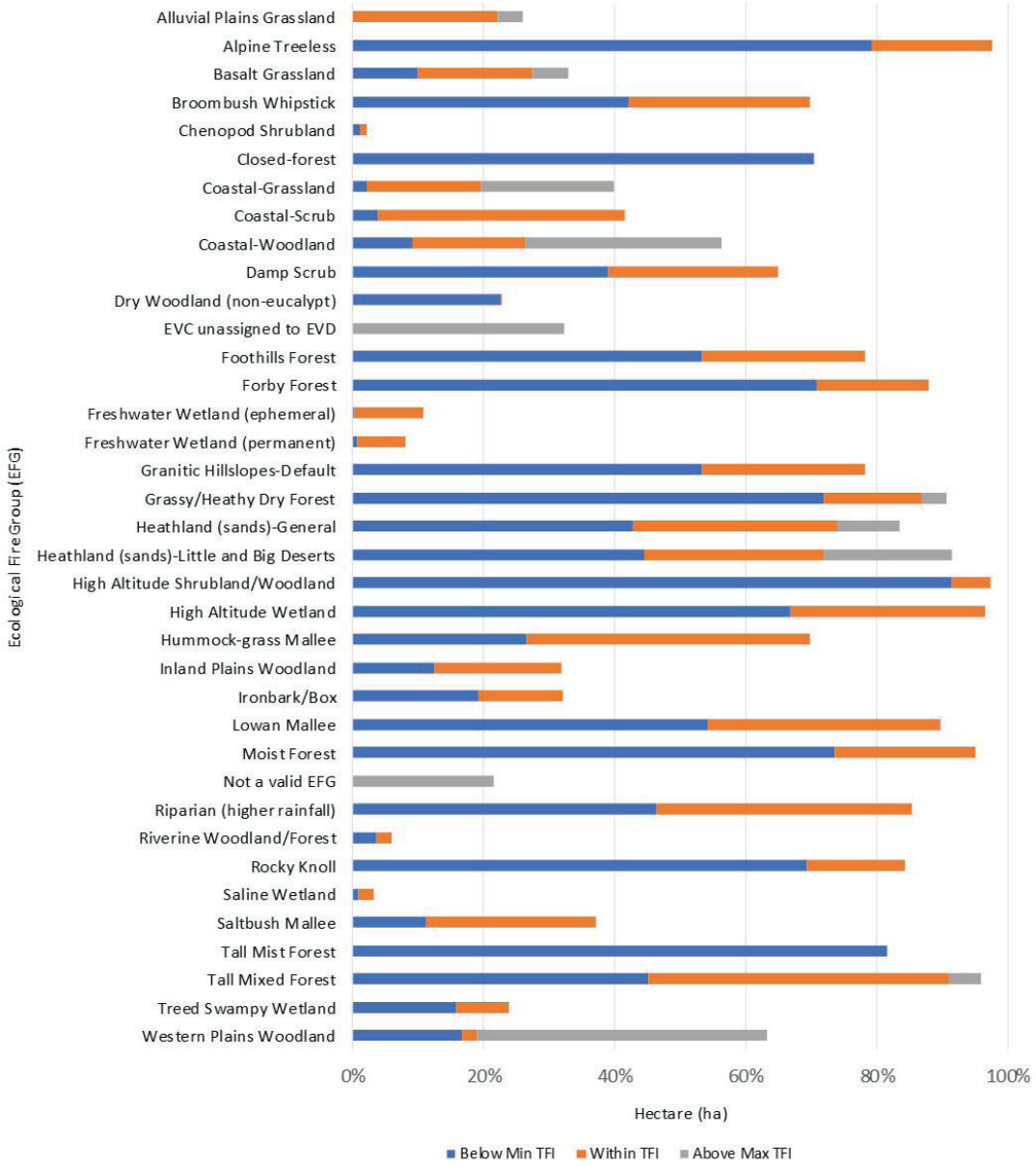


Figure Fi.9 Proportional distribution of below minimum TFI, within TFI and above maximum TFI in EFGs, 2016–17

(Data source: DELWP, 2018)

Vegetation growth stage structure (GSS) is used to indicate ecosystem resilience at a landscape level, as well as TFI. GSS is a mix of different age stages: juvenile, adolescent, mature and old. A vegetation's GSS depends on when it was last burnt or otherwise disturbed.

Figure Fi.10 shows changes in GSS for Victorian public land between 2007 and 2017 and demonstrates that overall, vegetation on public land has aged. There has been a 9% decrease in vegetation (724,400 hectares) in the juvenile growth stage, but a 10% increase in the adolescent growth stage (779,500 hectares) and a 4% increase in the mature growth stage (20,000 hectares). Areas that have no fire history were decreased by approximately 325,000 hectares within the same period, similar to Figure Fi.7 (a). This potentially means that some areas experienced an ongoing reduction in long-unburnt habitats as they succumbed to recent bushfires.

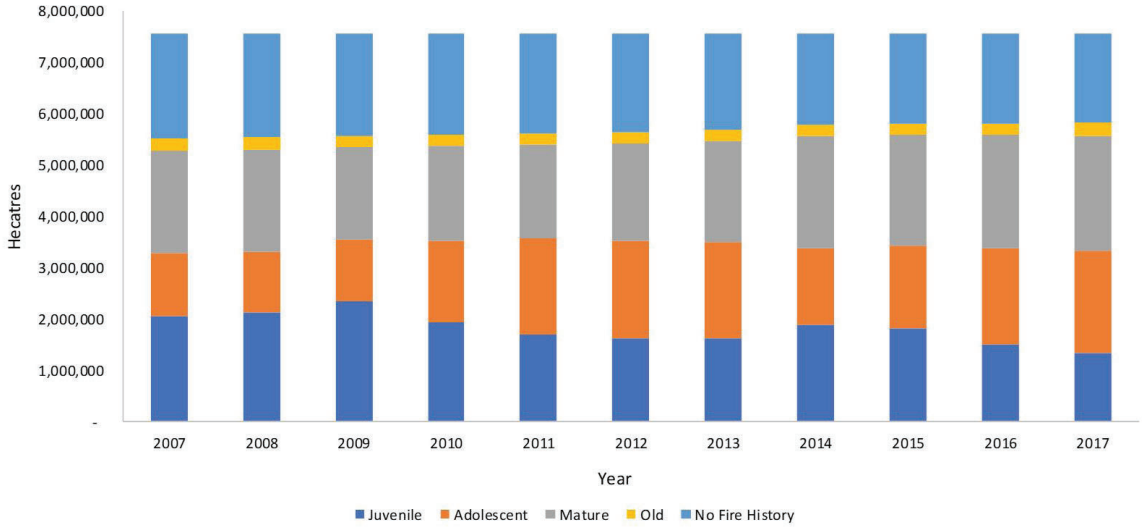


Figure Fi.10 Area of vegetation growth stage on Victoria's public land, 2007–2017

(Data source: DELWP, 2018)

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fi:04 Bushfire risk	○	○	●	○	↘	DATA QUALITY
Data custodian DELWP, BoM						Poor

Bushfire risk is composed of two variables: the likelihood of a fire starting, and its impact on communities and the environment. Planned burns are the main tool used to reduce bushfire risk globally.

Planned burns aim to reduce fuel loads at target locations to hinder fire intensity and spread rate. They are also used to provide benefits to key native fauna and flora species by providing heterogeneous landscape in nature. However, planned burns could harm biodiversity, including homogenised landscapes, if their impact is not properly assessed.[44]

As explained above, the Victorian Government set an annual burn-area target until 2015–16, which increased from 130,000 hectares to 390,000 hectares between 2003–04 and 2015–16 (Figure Fi.1). The government then shifted from a hectare-based approach to a risk-based approach for fire management. The new risk-based approach focuses on strategic areas near housing and infrastructure where there is a high chance of fire impacting on people and property.

To achieve this, the Victorian Government has adopted a fire-behaviour simulation program, PHOENIX RapidFire. The program provides a method to estimate bushfire risk by comparing the predicted difference in house loss in a maximum-risk scenario with maximum fuel load, with a scenario with fuel loads after a planned burn on public land.[45] The difference between the two scenarios is known as 'residual risk'. Residual risk can be expressed as a ratio of the average property impact from a modified risk scenario following planned burning, to the average impact of the maximum risk scenario, reported as a percentage.

The government's goal is to keep residual risk below 70%. DELWP estimated that residual risk in Victoria in 2018 was 63%[46] (Figure Fi.11). The figure below also indicates how dramatically residual risk fell after major bushfire events, such as the 'Ash Wednesday' fires in 1983, and the Black Saturday fires in 2009, and the comparatively higher-impact bushfires have had on residual risk than planned burns as those 1983 and 2009 bushfires dropped residual risk sharply.

44. Holland GJ, Clarke MF, Bennett AF 2017, 'Prescribed burning consumes key forest structural components: implications for landscape heterogeneity'. Ecological Applications, 27(3), pp. 845-858.

45. DELWP 2015, 'Measuring bushfire risk in Victoria', Melbourne, Victoria http://www.delwp.vic.gov.au/__data/assets/pdf_file/0009/318879/DELWP0017_BushfireRiskProfiles_rebrand_v5.pdf Accessed 4 December 2018.

46. DELWP 2015, 'Safer Together: a new approach to reducing the risk of bushfire in Victoria', Melbourne Victoria http://www.delwp.vic.gov.au/__data/assets/pdf_file/0004/319531/DELWP_SaferTogether_FINAL_17Nov15.pdf Accessed 4 December 2018.

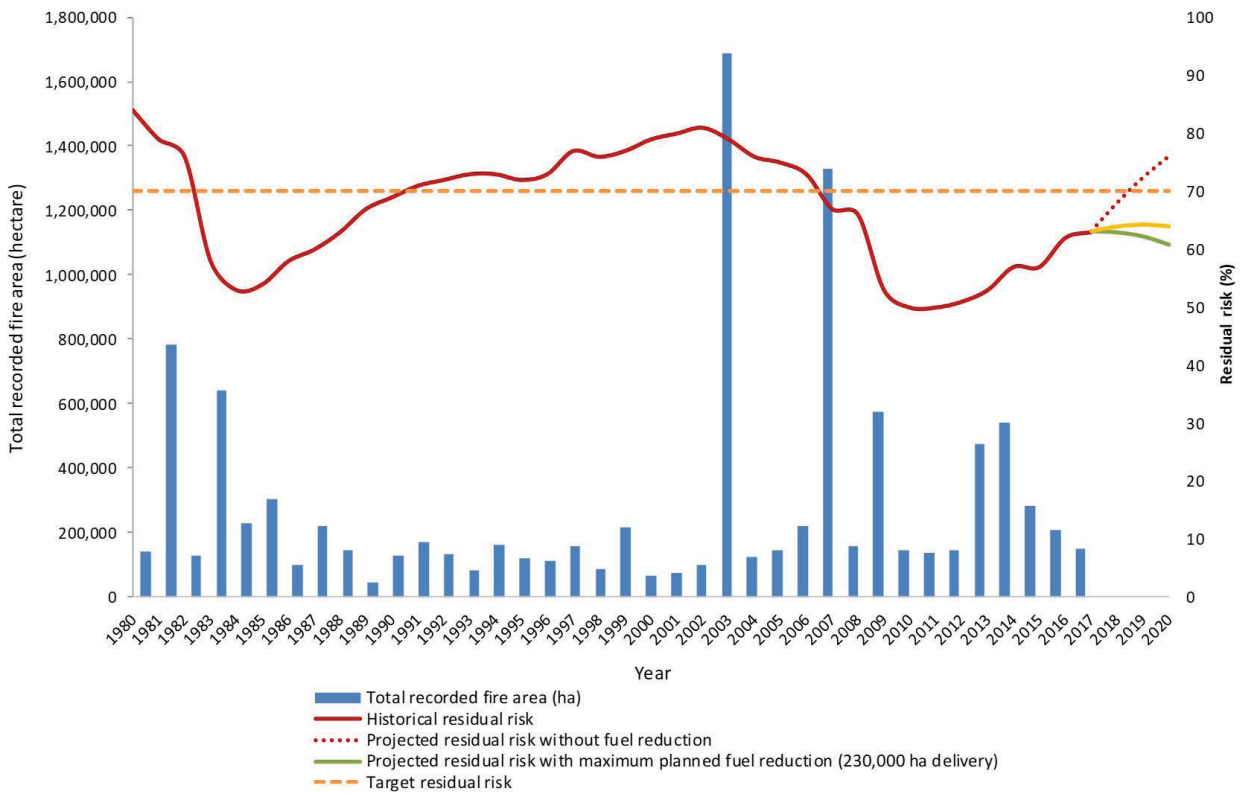


Figure Fi.11 Residual risk profile in Victoria, 1980–2020

(Data source: DELWP[47])

One criticism levelled at forest fire management agencies was that the previous hectare-based approach to planned burns did not adequately address potential harm to Victorian ecosystems.[48, 49] A similar concern may be raised regarding the current approach under the Safer Together program. However, Safer Together provides a framework for assessing the new burning approach in relation to ecological resilience and biodiversity. Although it has been in an establishment phase over the past two years, it has yet to incorporate the risk to biodiversity in the residual risk calculations. Therefore, data quality for biodiversity is assessed as 'poor' while that for life and property is assessed as 'good'.

It is important to note that after disturbances such as logging or fire, forests are prone to subsequent high-severity fires (typically crown-scorching fires). A 2018 study found that in tall, wet forests dominated by ash-type eucalypts, post-disturbance stands of trees could be more than eight times as likely to burn than mature stands.[50] In some areas, especially the alps areas, areas below minimum TFI may be more prone to subsequent high-severity fires, resulting in forest degradation and loss of the original formation of forests.

While the use of planned burns may still be necessary for the management of some native species, variability of subsequent high-severity fires must be considered in risk assessment.

47. Ibid.
48. Ingamells P 2012, 'Statewide fuel reduction target threatens biodiversity', Park Watch, 249, pp. 16-17.
49. Kelly L, Giljohann K, McCarthy M 2015, 'Burning issues: state-wide percentage targets for planned burning are blunt tools that don't work', Decision Point, 88, pp. 4-5.

50. Zylstra PJ 2018, 'Flammability dynamics in the Australian Alps', Austral Ecology, 43, pp. 578-591.

Climate Change

The impact of climate change on weather conducive to fire is well understood by researchers and land managers.[51, 52] There is a trend towards more dangerous weather conditions for bushfires in south-east Australia, including significant increases in the frequency and magnitude of extreme conditions in some regions.

The figures provided are for the Forest Fire Danger Index (FFDI), which is configured from temperature, rainfall, humidity and wind speed, and used throughout Victoria by fire agencies. Fire weather is monitored with FFDI in Australia. FFDI patterns have changed in recent decades, with the strongest increases to the index generally in summer and spring. This upward trend in FFDI is due to increasing temperatures and drying conditions.[53] Changes to the springtime pattern indicate a shift towards an earlier start to the fire season (Figure Fi.12). These recent changes are attributable, at least in part, to anthropogenic (human-related) climate change, including increasing temperatures.

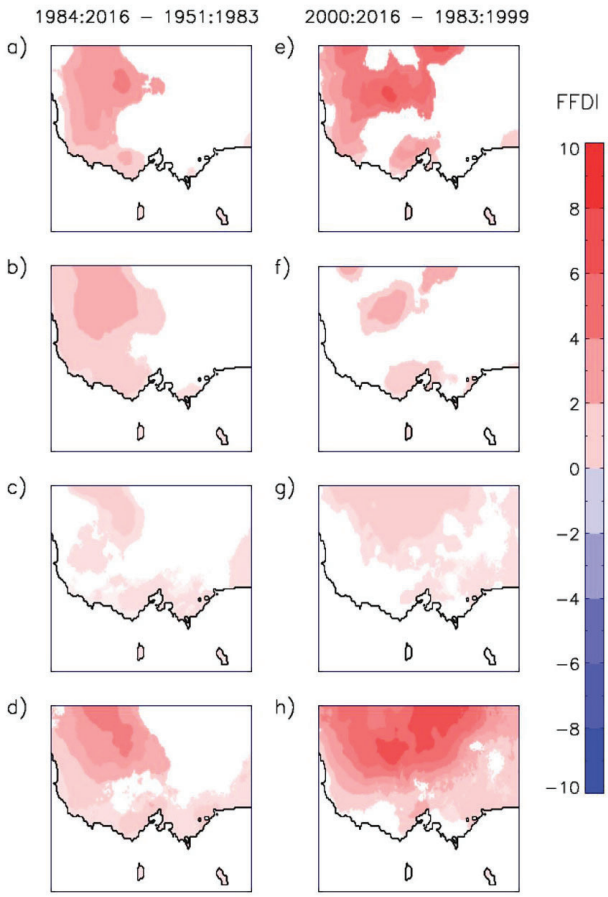


Figure Fi.12 Long-term changes in seasonal mean FFDI values

Note: This is shown for the change from the first half (1951–83) to the second half (1984–2016) of the study period during (a) December–February, (b) March–May, (c) June–August and (d) September–November. This is also shown for the change from 1983–1999 period to 2000–2016 period during the same four seasons mentioned above for (e), (f), (g) and (h) respectively. The coloured regions represent locations where the magnitude of the change is significant at the 95% confidence level.[54] (Figure (a) – (h) are modified by the author).

(Data source: Dowdy[55])

51. Hennessy, K, Lucas C, Nicholls N, Bathols J, Suppiah R, Ricketts J 2005, 'Climate change impacts on fire-weather in south-east Australia'. CSIRO, Aspendale, Victoria http://www.cmar.csiro.au/e-print/open/hennessykj_2005b.pdf Accessed 4 December 2018.
52. Clarke H, Evans JP 2018, 'Exploring the future change space for fire weather in southeast Australia', Theoretical and Applied Climatology, pp. 1-15.
53. CSIRO and Bureau of Meteorology 2016, 'State of the Climate 2016'. http://www.bom.gov.au/state-of-the-climate/State-of-the-Climate-2016.pdf Accessed 4 December 2018.
54. Dowdy AJ 2018, 'Climatological variability of fire weather in Australia', American Meteorological Society, 57, pp. 221-234.
55. Ibid.

Fire authorities use the Southern Australia Seasonal Bushfire Outlook for making strategic decisions on resource planning and prescribed fire management. Each year, the outlook is developed at an annual workshop attended by relevant expert practitioners, and convened by the Bushfire & Natural Hazards CRC and Australian Fire and Emergency Services Authorities Council Limited (AFAC). Throughout the workshop, stakeholders discuss fire weather, landscape conditions and potential areas where above-normal or below-normal fire season may occur in Australia in the upcoming fire season.

The most recent outlook through to the end of 2018 in Victoria demonstrates that much of East Gippsland will have above normal fire potential due to two consecutive years of record low rainfall during autumn and winter, leading to forests in East Gippsland being more flammable than normal (Figure Fi.13).[56] The outlook also stated that there is extensive and historically unprecedented dryness across the majority of southern Australia, due to the combination of increasing temperatures and drying conditions.

Given the intensifying impacts of climate change, addressing the risks and impacts of climate change that are facing the emergency management sector, including fire, is an urgent and significant challenge for fire management agencies. The agencies have been working collaboratively to identify key risks and priorities for action.[57] In response to this, the Emergency Management Climate Change Program was initiated in 2017, led by Emergency Management Victoria. The program will work with the emergency management sector to tackle potential risks to the Victorian environment, community and economy.

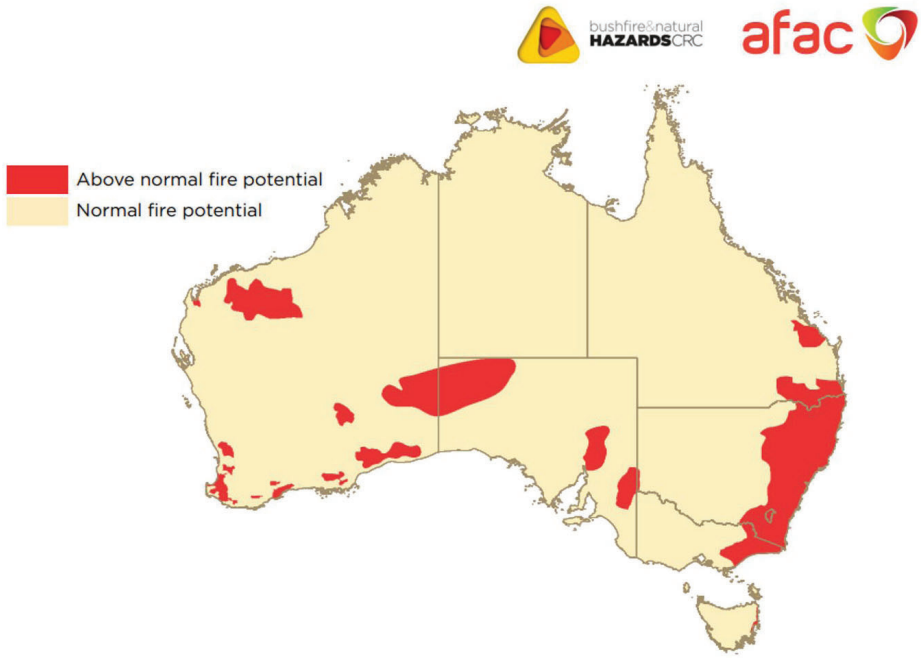


Figure Fi.13 Areas where higher and normal fire potential exist in Australia through to the end of 2018

(Data source: Bushfire & National Hazards CRC, 2018)

56. Bushfire & Natural Hazards CRC and Australian Fire and Emergency Services Authorities Council Limited 2018, 'Southern Australia seasonal bushfire outlook 2018', Hazard Note Issue 51, Bushfire & Natural Hazards CRC, Melbourne, Victoria https://www.bnhcrc.com.au/hazardnotes/51 Accessed 4 December 2018.
57. Australian Fire and Emergency Services Authorities Council Limited 2018, 'Climate change and the emergency management sector: discussion paper version 1.0', Australian Fire and Emergency Services Authorities Council Limited, East Melbourne, Victoria https://files-em.em.vic.gov.au/public/EMV-web/AFAC-Climate-Change-Discussion-3July2018FINAL.pdf Accessed 4 December 2018.

Future Focus

Understand fire impacts on the environment statewide using a structured, integrated framework

Ecological values are not currently included in the DELWP residual risk prediction program (PHOENIX RapidFire) used to inform the risk-based approach to forest fire management, Safer Together.[58] To address this and assess the impact of current fire management strategies on Victoria's native species and ecosystems, as recommended by the 2009 Victorian Bushfires Royal Commission,[59] DELWP, in partnership with La Trobe University, developed an ecosystem resilience monitoring program in 2017–18 to collect, analyse and interpret comprehensive data on how bushfire and fire management activities affect plants, animals and their habitats in the landscape.

This program is described in the *Guidelines for Ecosystem Resilience Monitoring, Evaluation and Reporting within the Victorian Bushfire Monitoring Program: Scientifically-based Monitoring Project – Final Report*. The ecosystem-resilience monitoring program has been piloted and includes recommendations for deployment. It is structured around a dual-scale approach to monitoring: regional and statewide. Regional monitoring activities focus on the immediate and short-term effects of fuel-management actions (primarily planned burns) on species of local interest and/or significance (such as the impact of planned burns on the greater glider by causing the loss of hollow-bearing trees in Alpine-North East). The statewide program would examine the effects at a broader scale and the long-term relationships between plants and animals, and fire, at sites across the landscape with a varied fire history.

The full implementation of this program would help establish a science-based, state-scale approach to the monitoring, evaluation and reporting framework for ecosystem resilience on public land in Victoria. An approach that includes both flora and fauna species at the state scale has never been implemented before.

Conserving flora and fauna species in fire-prone landscapes in Victoria requires an evidence-based approach to identify how fires affect ecosystems that can be modified by cumulative threats. There are two contemporary fire management paradigms: fire mosaic paradigm and functional types paradigm.[60] Current fire management has adopted the functional types paradigm, which focuses on plant responses to recurrent fires. This paradigm is guided by life-history traits of plants such as the Tolerable Fire Interval (TFI), and aims for temporal variation within acceptable fire intervals. By contrast, the fire mosaic paradigm focuses on animal responses to fire events, aiming to create spatially diverse fire mosaics for promoting biodiversity and assisting the persistence of isolated, localised species.

Research indicates[61] that both paradigms need to be integrated in evidence-based monitoring for fire management for biodiversity conservation, as animals and plants are interdependent and influenced by the spatial and temporal dimensions of fire regimes. The new ecosystem-resilience program will provide an opportunity to integrate these two paradigms to better evaluate and report on the effectiveness of bushfire for maintaining resilient and biodiverse ecosystems.

Recommendation 9: That the Victorian Government establish a structured framework based on the findings of the dual-scale ecosystem-resilience monitoring program, piloted by DELWP in 2017–18, and undertake a detailed analysis of the persistence of key fire-response species to increased fire frequency in Victoria, particularly in areas where below-minimum TFI exists.

58. DELWP 2015, 'Measuring bushfire risk in Victoria', Melbourne, Victoria http://www.delwp.vic.gov.au/__data/assets/pdf_file/0009/318879/DELWP0017_BushfireRiskProfiles_rebrand_v5.pdf Accessed at 5 December 2018.
59. Teague B, McLeod R, Pascoe S 2010, 2009 'Victorian Bushfires Royal Commission Final Report', Parliament of Victoria, Melbourne, Victoria.
60. Kelly LT, Brotons L, Giljohann KM, McCarthy MA, Pausas JG, Smith AL. 2018, 'Bridging the divide: integrating animal and plant paradigms to secure the future of biodiversity in fire-prone ecosystems', Fire, 29, 1-8.
61. Ibid

Accounting for the Environment

Forest and grass fires impact on both built and natural assets, affecting the production of goods and services, that benefits the economy and society.

The impact of fire on the economy is partly captured in the System of National Accounts (SNA) through changes to stock of built assets and the flow of goods and services. However, the SNA does not capture the impact of fire on the environment, and the ecosystem services that flow from the environment to the economy. The System of Environmental-Economic Accounting (SEEA) provides a framework for measuring the impact of fire on the environment (ecosystem assets including wetlands, rivers and ecological vegetation) and the connection between this and the economy and society.

When fire burns an area of land, it can affect both the extent and condition of different types of vegetation (different ecosystem assets). Most Victorian plant communities are fire tolerant and exhibit some form of recovery after fire. However, under certain circumstances fire can change the mix of environmental assets in an area by killing one type of vegetation, which is then replaced by another. Depending on the ecological vegetation type and the severity and frequency of fire, fire can increase or reduce the extent and condition of ecosystem assets.

Fire can impact on the ecosystem services produced by ecosystem assets. For example, fire can increase the habitat services provided by ecosystems, as some flora species depend on fire or smoke for seed germination. However, fire can reduce the timber resources available from native or plantation forests, as well as reduce carbon storage, water filtration and soil stabilisation services. For example, when fire burns plants that stabilise soil, water runoff can carry increased amounts of soils and nutrients into rivers and water storages. This reduces the quality of water for human and animal consumption. The risk of landslides can increase, potentially impacting on other ecosystem assets or built assets such as roads or buildings. For example, in 2003, the Australian Capital Territory was significantly affected by fire. In the aftermath, storm events resulted in sediment entering Canberra's water storages, and the closure of these storages for water supply.[62] This illustrates the connection between fire and water supply and quality accounts (discussed further in the Water Resources, Water Quality, and Forests chapters).

62. Daniell T, White I 2005, 'Bushfires and their implications for management of future water supplies in the Australian Capital Territory', Climatic and Anthropogenic Impacts on the Variability of Water Resources, HydroSciences Montpellier, pp. 1-15 http://www.bom.gov.au/water/about/waterResearch/document/Daniell_and_White_Montpellier_2005.pdf Accessed 4 December 2018.

Case Study: Accounting for the Impact of Fire on Ash Eucalypt Vegetation

This case study draws on the numerous studies on the ash-reseeding.[63, 64, 65, 66, 67, 68]

In the past 15 years, bushfires have burnt large areas of forest in the alpine area of Victoria, with major fires in 2003 (Alpine fires), 2006–07 (Great Divide fires), 2009 (Black Saturday fires) and 2013 (Harrietville, Tomahawk and Aberfeldy fires). Although most Victorian plant communities are well adapted to fire, the eucalypt ash forests of mountain ash (*Eucalyptus regnans*) and alpine ash (*Eucalyptus delegatensis*) are particularly vulnerable to increased fire frequency and intensity.[69] Ash eucalypt species are vulnerable to demographic collapse if their life cycles become de-synchronised with the fire regimes to which they are adapted.[70]

Data is available on the area of public and private land burnt by bushfire, including the area of ash eucalypt species burnt, and the proportion of this that is burnt immature ash regrowth. That is, ash that had already been burnt prior to reaching sexual maturity. Mature ash eucalypt forests can recover from a single high-intensity fire through mass seed regeneration. But if the regenerated forest is subject to another high-intensity fire prior to setting seed, management intervention (revegetation) is needed for the ecosystem asset to be maintained. After major fires in the Victorian alpine areas, DELWP, VicForests and Parks Victoria intervened to maintain ash ecosystem assets, through aerial sowing (via helicopter) and planting seedlings.

Available data has been used to construct account tables for each of the major fires (see from Table Fi.2 to Table Fi.5).[71] Each account shows an opening stock of assets burnt, the loss of ash forest due to fire (where immature ash forest was burnt), and additions to ash forest. Additions are either from human activity (aerial sowing or planting seedlings) or additions to other forest type as the composition of ecosystem assets changes where areas of burnt immature ash have not been revegetated (termed 'reclassifications' under SEEA).

Overlap of areas burnt in each fire event has resulted in increasing losses of ash eucalypt species relative to the size of the fires. For example, Table Fi.5 shows that the total area of the 2013 fires (126,002 hectares) was much smaller than the area burnt in previous years; however, 5,537 hectares of immature ash was still killed in 2013. The areas of immature ash killed in 2013 included some areas of triple-burnt ash stands – that is, areas that were burnt three times between 2003 and 2013.

63. Fagg P, Lutze M, Slijkerman C, Ryan M, Bassett O 2013, 'Silvicultural recovery in ash forests following three large bushfires in Victoria'. Australian Forestry, 76(3-4), pp. 140-155.
64. Jewell C, Lutze M, Fagg P, Ryan M 2008 'Bushfire recovery - forest values (silviculture). 2007 regeneration report', Department of Sustainability and Environment, Melbourne, Victoria.
65. Slijkerman C, Lutze M, Fagg P 2010, '2006/07 great divide fire recovery (forest values) 2008 regeneration report', Department of Sustainability and Environment, Melbourne, Victoria (internal report).
66. Slijkerman C, Fagg P, Lutze M, Notman W, Patrick R, Cleaver J, Harper E, Doherty K 2011, 'Bushfire recovery silviculture report-2009 Black Saturday fires', Department of Sustainability and Environment, Melbourne, Victoria (internal report).
67. Stabb T 2013, 'Alpine fires - north east Victoria & Gippsland bushfire recovery plan', Department of Environment and Primary Industries (internal report), Melbourne, Victoria. Spreadsheet 'Sowing summary_area_kg_fire-ln20-20130705.xls' as supplied by Carolyn Slijkerman
68. Slijkerman et al (2010) 2006/2007 Great Divide Fire recovery (Forest Values) 2008 Silviculture Report. Department of Sustainability and Environment, Victoria (internal report)
69. Williams RJ, Bradstock RA, Cary GJ, Enright NJ, Gill AM, Liedloff AC, Lucas C, Whelan RJ, Andersen AN, Bowman DJMS, Clarke PJ, Cook GD, Hennessy KJ, York A 2009, 'Interactions between climate change, fire regimes and biodiversity in Australia: A preliminary assessment', Australian Department of Climate Change and Department of the Environment, Water, Heritage and the Arts, Canberra, ACT.
70. Keeley JE 1986, 'Resilience of Mediterranean shrub communities to fires. In: Resilience in Mediterranean-type ecosystems', pp 95-112, Springer, Netherlands.

71. Re-seeding data sourced from numerous DELWP internal fire recovery documents and associated reports, each listed at the end of this chapter.

Table Fi.2 Change in stock of assets burnt in 2003 Alpine fires (hectares)

	State forest and other public land		Private land	Total
	Ash eucalypt species	Other species (a)		
	ha	ha	ha	ha
Opening stock of assets	81,000	923,000	96,000	1,100,000
Reductions in stock				
Losses due to natural events	3,550			
Total reductions in stock	*3,550*	-	-	-
Additions to stock				
Improvements due to human activity – aerial seeding	2,000			
Reclassifications		1,550		
Total additions to stock	*2,000*	*1,550*	-	-
Closing stock of assets	**79,450**	**924,550**	**96,000**	**1,100,000**

(a) Other species are fire tolerant, so while they were burnt, this does not necessarily change the ecosystem type

(Data source: DELWP, 2018)

Table Fi.3 Change in stock of assets burnt in 2006–07 Great Divide fires (hectares)

	State forest and other public land		Private land	Total
	Ash eucalypt species	Other species		
	ha	ha	ha	ha
Opening stock of assets	65,000	1,020,000	105,000	1,190,000
Reductions in stock				
Losses due to natural events	15,000			
Total reductions in stock	*15,000*	-	-	-
Additions to stock				
Improvements due to human activity – aerial seeding	5,880			
Improvements due to human activity – seedling planting	376			
Reclassifications		8,744		
Total additions to stock	*6,256*	*8,744*	-	-
Closing stock of assets	**56,256**	**1,028,744**	**105,000**	**1,190,000**

(Data source: DELWP, 2018)

Table Fi.4 Change in stock of assets burnt in 2009 Black Saturday fires (hectares)

	State forest and other public land		Private land	Total
	Ash eucalypt species	Other species		
	ha	ha	ha	ha
Opening stock of assets	43,000	244,000	119,000	406,000
Reductions in stock				
Losses due to natural events	4,500			
Total reductions in stock	*4,500*	-	-	-
Additions to stock				
Improvements due to human activity – aerial seeding	3,965			
Improvements due to human activity – seedling planting	102			
Reclassifications		433		
Total additions to stock	*4,067*	*433*	-	-
Closing stock of assets	**42,567**	**244,433**	**119,000**	**406,000**

(Data source: DELWP, 2018)

Table Fi.5 Change in stock of assets burnt in 2013 Harrietville, Tomahawk and Aberfeldy fires (hectares)

	State forest and other public land		Private land	Total
	Ash eucalypt species	Other species		
	ha	ha	ha	ha
Opening stock of assets	7,800	105,332	12,870	126,002
Reductions in stock				
Losses due to natural events	5,537			
Total reductions in stock	*5,537*	-	-	-
Additions to stock				
Improvements due to human activity – aerial seeding	2,425			
Improvements due to human activity – seedling planting	-			
Reclassifications		3,112		
Total additions to stock	*2,425*	*3,112*	-	-
Closing stock of assets	**4,688**	**108,444**	**12,870**	**126,002**

(Data source: DELWP, 2018)

Cost data associated with management intervention – revegetation of ash forest – is available (see Table Fi.6). If information on the ecosystem services provided under different scenarios (for example, revegetation or no revegetation) was available, this could be assessed against management intervention to help determine where management interventions are likely to deliver greatest benefits for the community.

Table Fi.6 Cost of additions to stock from human activity (revegetation of ash forest)

	Aerial sowing	Seedling planting	Total
	$	$	$
2003 Alpine fires	899,600	-	899,600
2006–07 Great Divide fires	1,813,578	793,020	2,606,598
2009 Black Saturday fires	1,615,060	249,000	1,864,060
2013 Harrietville, Tomahawk and Aberfeldy fires	787,445	-	787,445

(Data source: DELWP, 2018)