FORESTS (Fo)

SCIENTIFIC ASSESSMENTS Part III

Commissioner *for* Environmental Sustainability Victoria

Traditional Owners

The Commissioner for Environmental Sustainability proudly acknowledges Victoria's Aboriginal community and their rich culture and pays respect to their Elders past and present.

We acknowledge Aboriginal people as Australia's first peoples and as the Traditional Owners and custodians of the land and water on which we rely. We recognise and value the ongoing contribution of Aboriginal people and communities to Victorian life, and how this enriches us.

We embrace the spirit of reconciliation, working towards the equality of outcomes and ensuring an equal voice.

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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

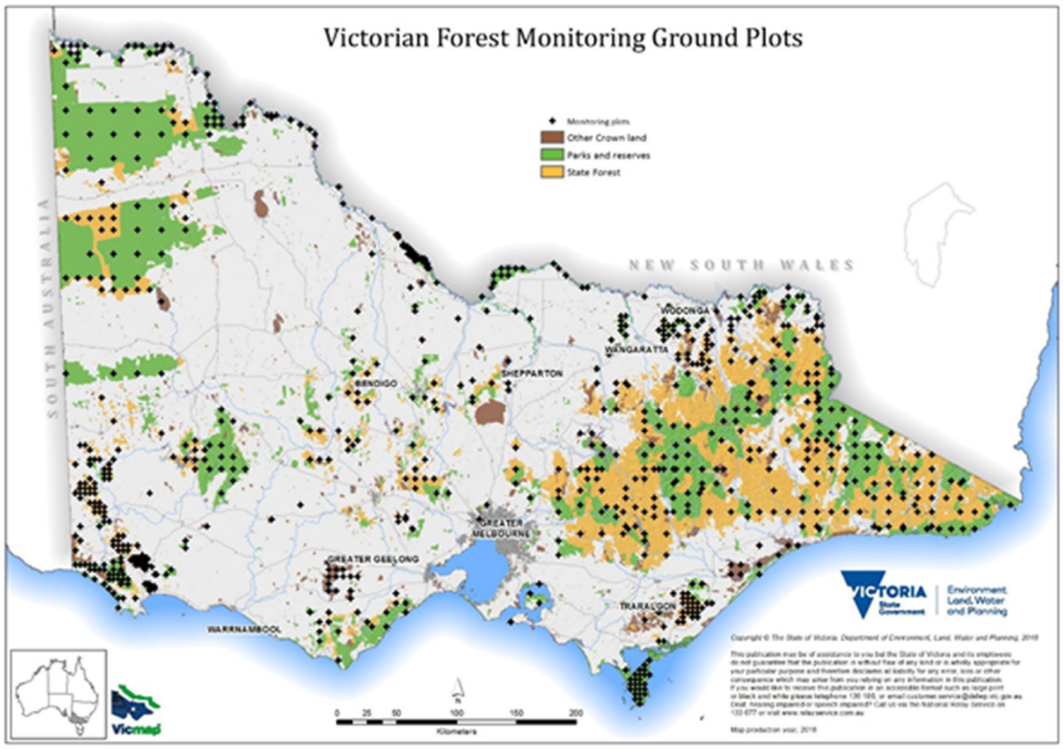

Figure Fo.2 Location of sampling units for VFMP

(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)

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

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

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

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

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

Data custodian DELWP

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

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

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

Figure Fo.4 Victorian forest cover, 2018

(Data source: DELWP, 2018)

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

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

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

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

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

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

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

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

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

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

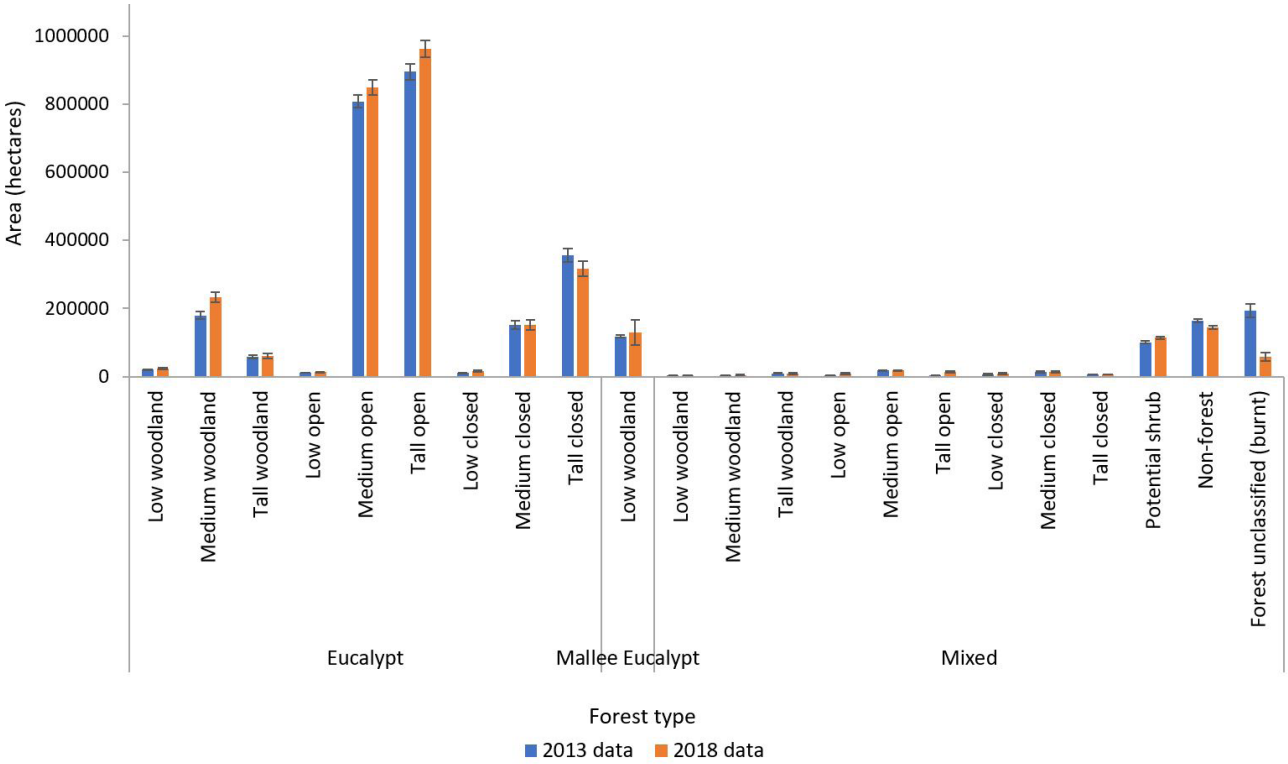

Figure Fo.5 Area of forest by broad forest type, height and canopy cover in state forest

(Data source: DELWP, 2018)

Table Fo.2 State forest area estimates

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

Note: C.I. = confidence interval

(Data source: DELWP, 2018)

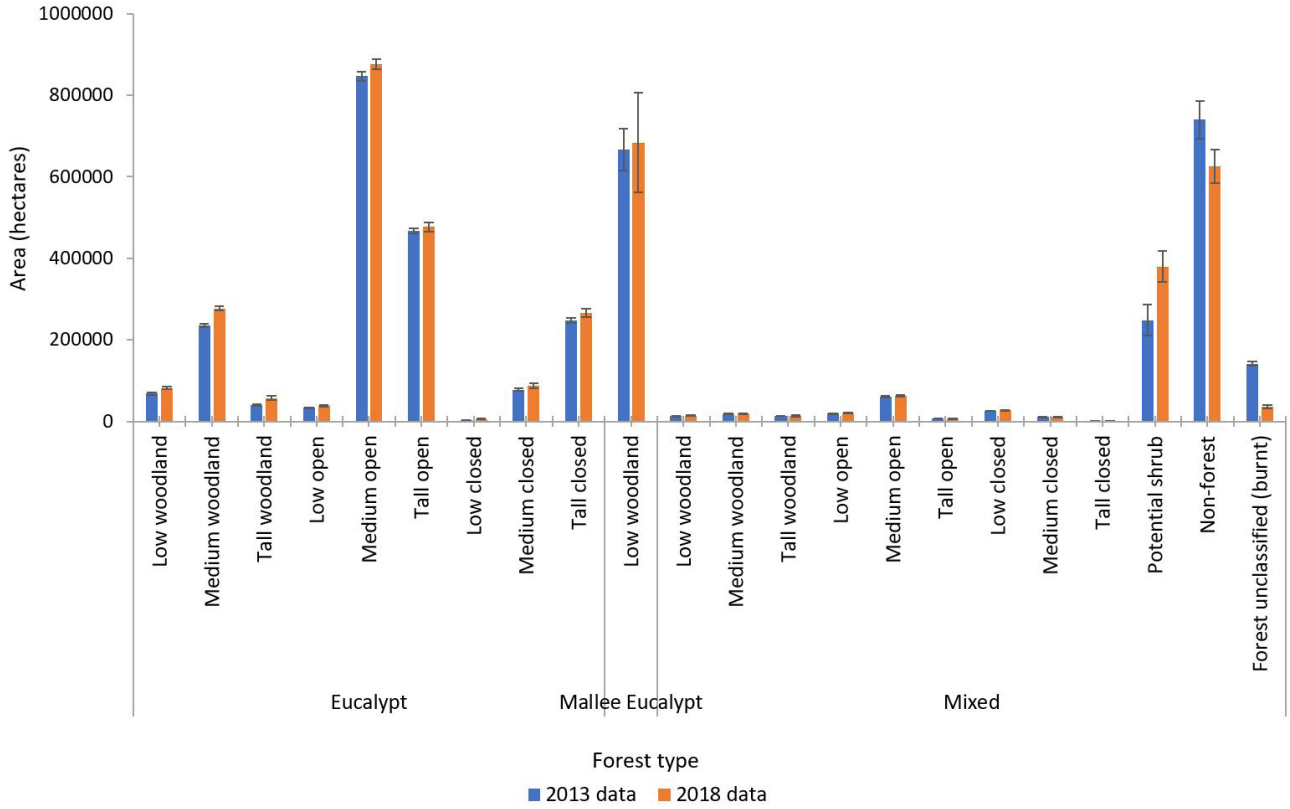

Figure Fo.6 Area of forest by broad forest type, height and canopy cover in parks and reserves

(Data source: DELWP, 2018)

Table Fo.3 Parks and reserves area estimates

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

Note: C.I. = confidence interval

(Data source: DELWP, 2018)

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

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

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

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

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

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

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

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

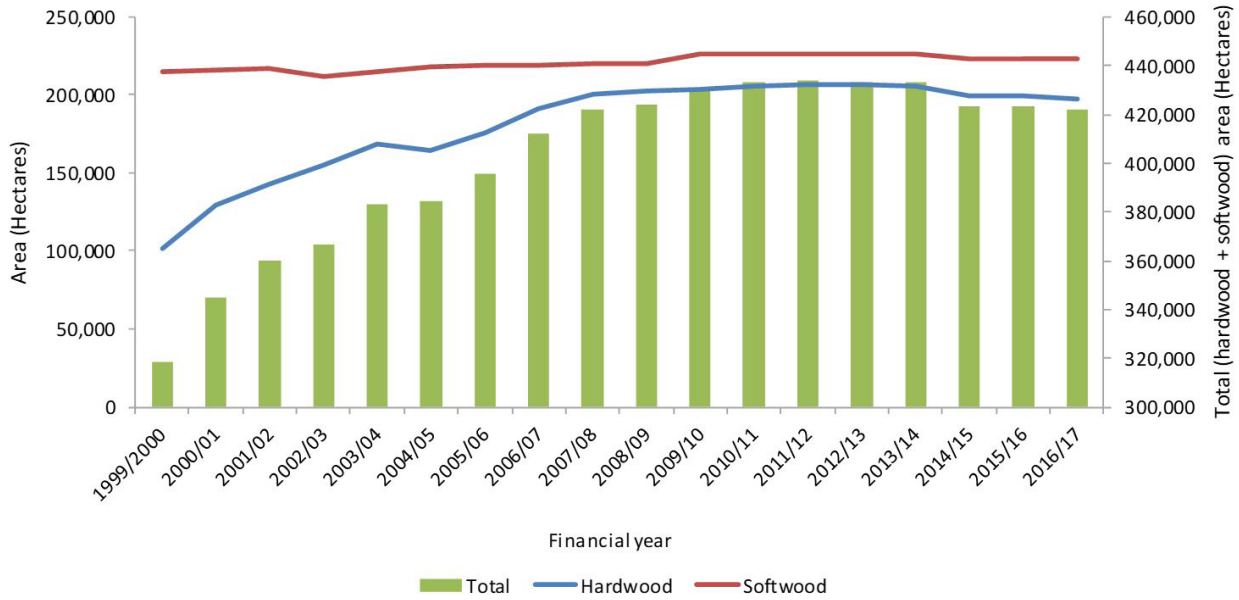

Figure Fo.7 Plantation areas in Victoria, 1999–2000 to 2016–17 [37, 38]

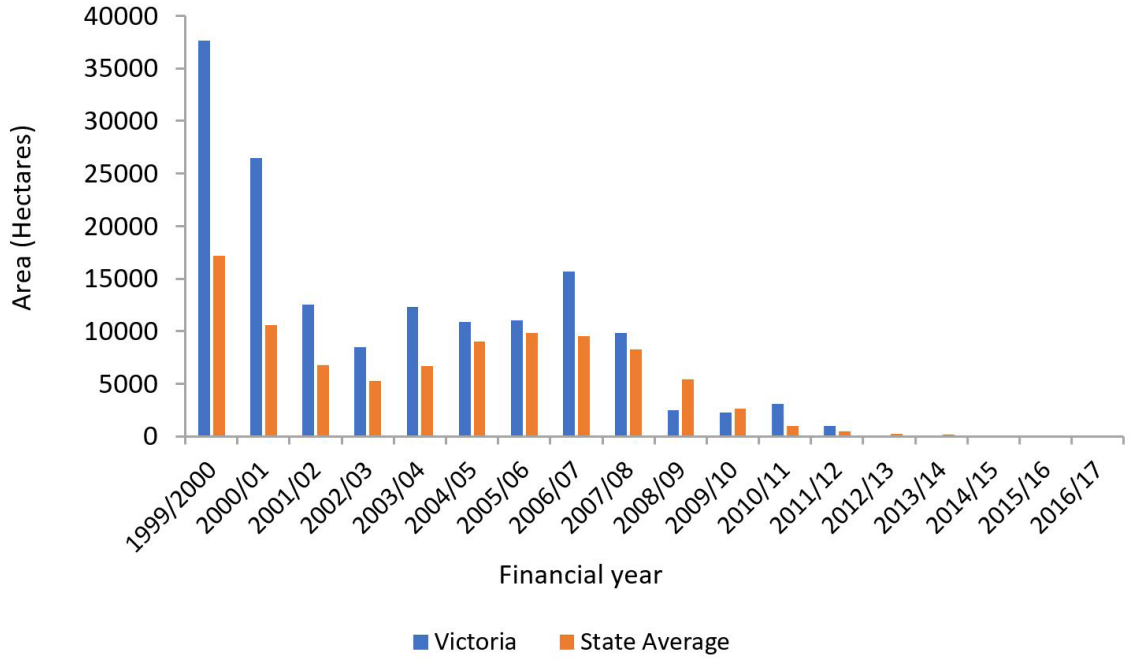

Figure Fo.8 Area of new plantation establishment in Victoria, 1999–2000 to 2016–17[40]

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

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

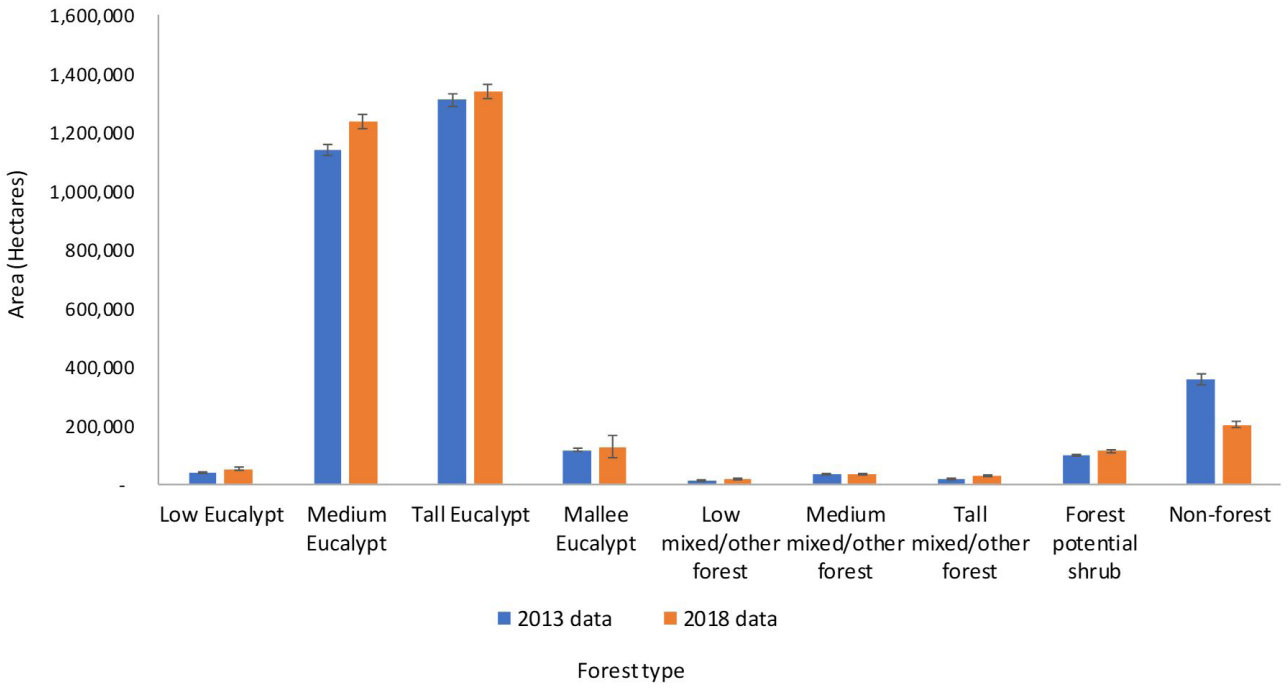

Figure Fo.9 Area of state forest by forest type, 2013 and 2018

(Data source: DELWP, 2018)

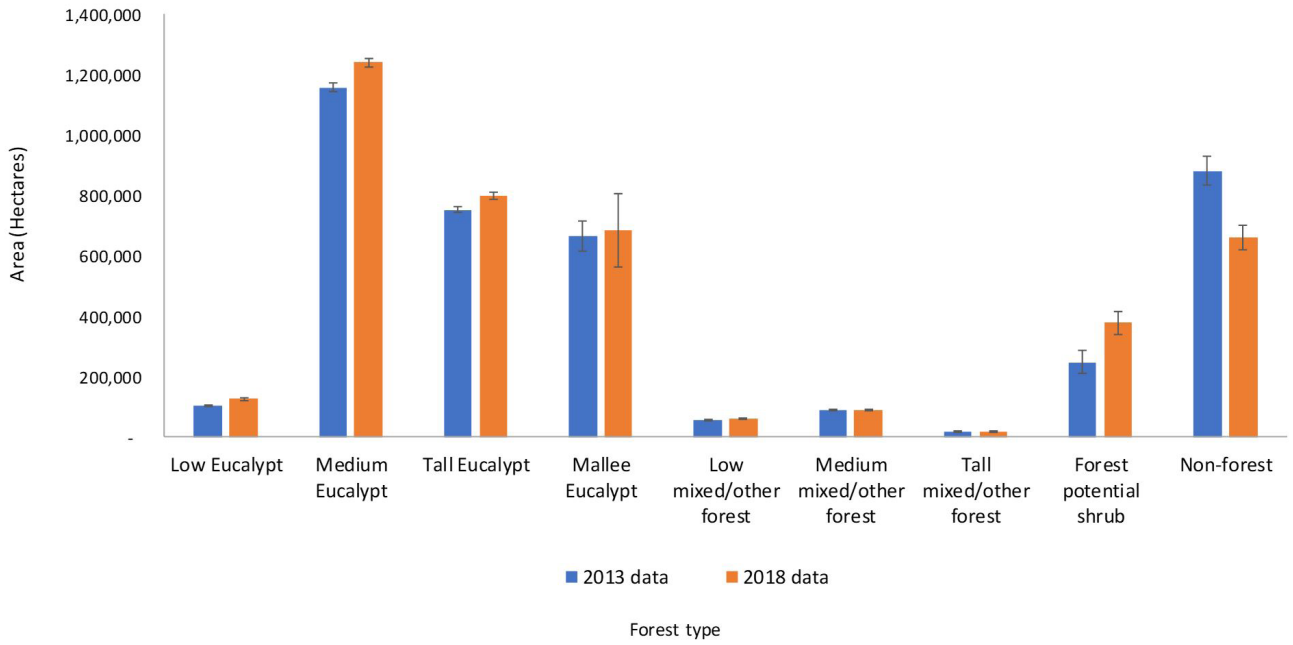

Figure Fo.10 Area of parks and reserves by forest type, 2013 and 2018

(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)

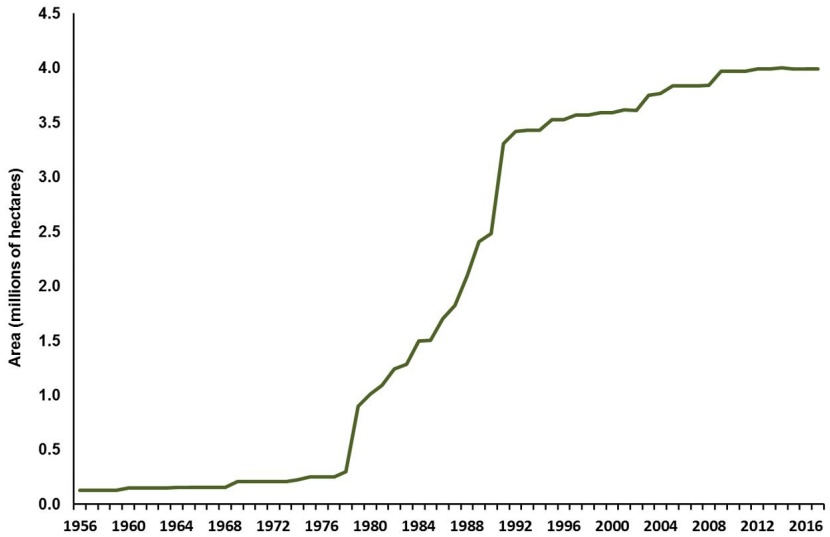

Figure Fo.11 Change in Victoria's formal protected area (parks and conservation reserves), 1956–2016

(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.

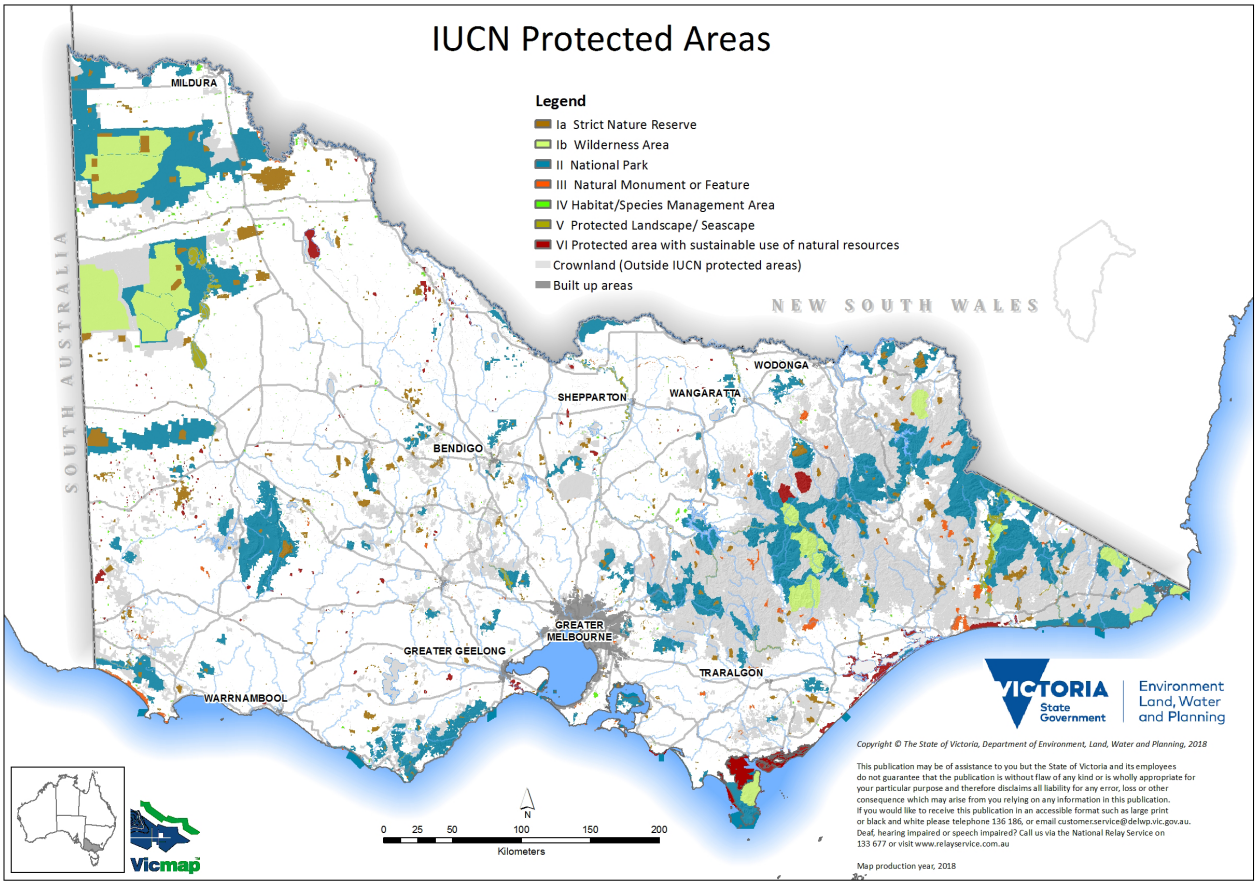

Figure Fo.12 Victorian terrestrial IUCN protected areas, 2018

(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 UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
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)

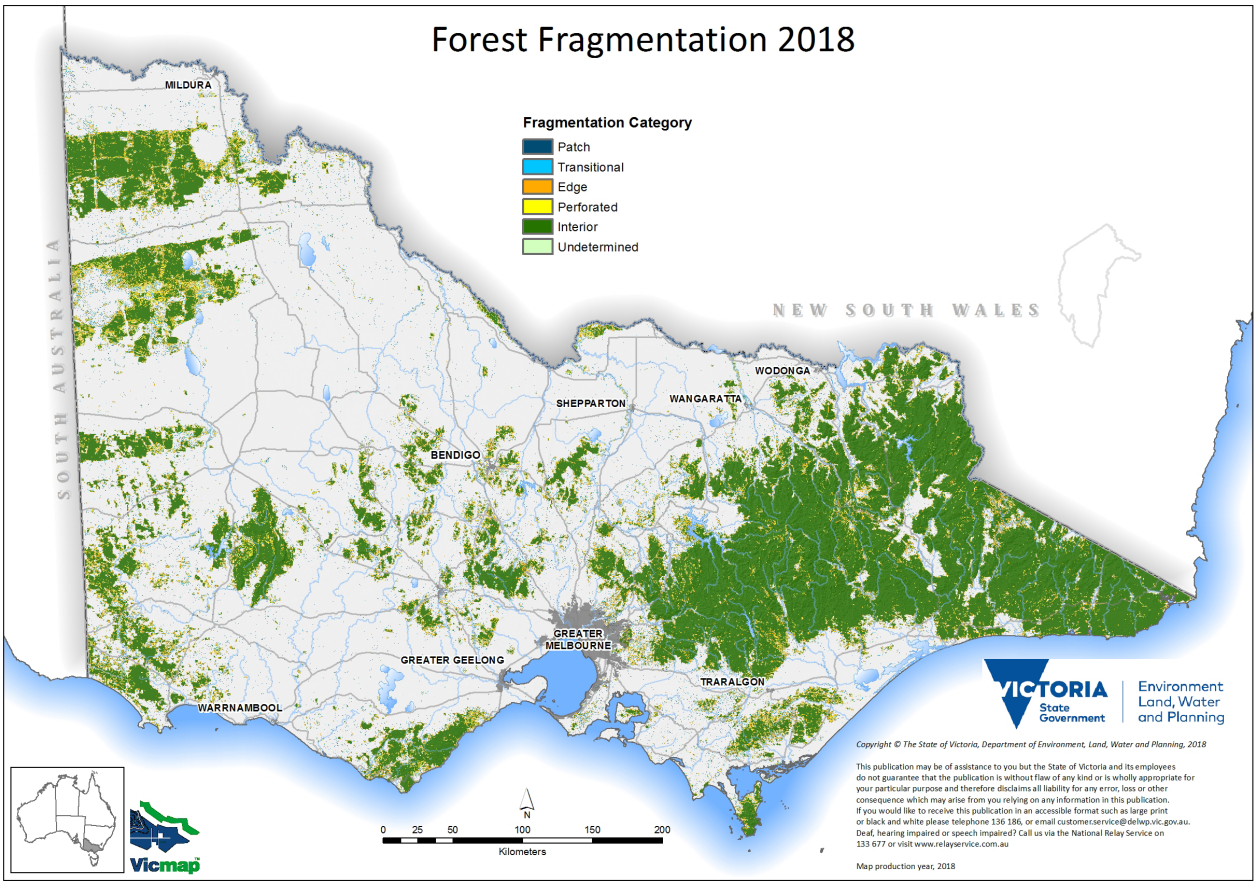

Figure Fo.13 Forest fragmentation in Victoria, 2018

(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)

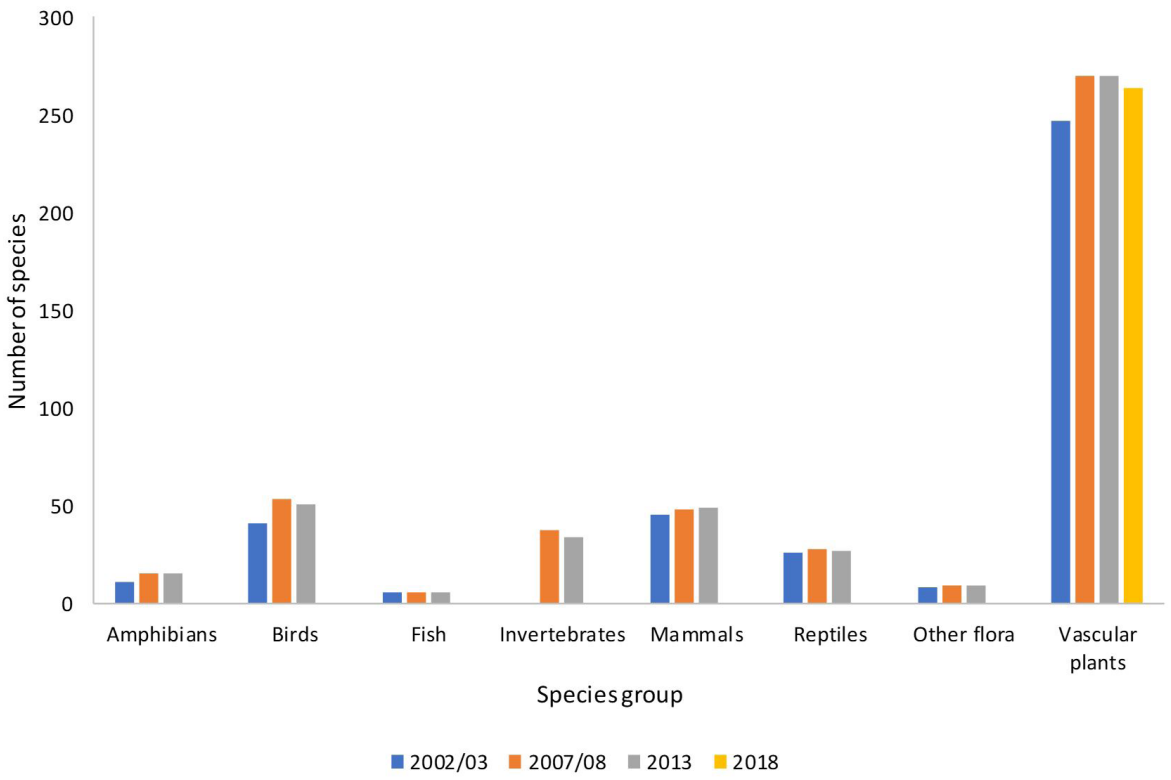

Figure Fo.15 Change in numbers of rare or threatened species on the advisory list, by reporting period

(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 UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
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.

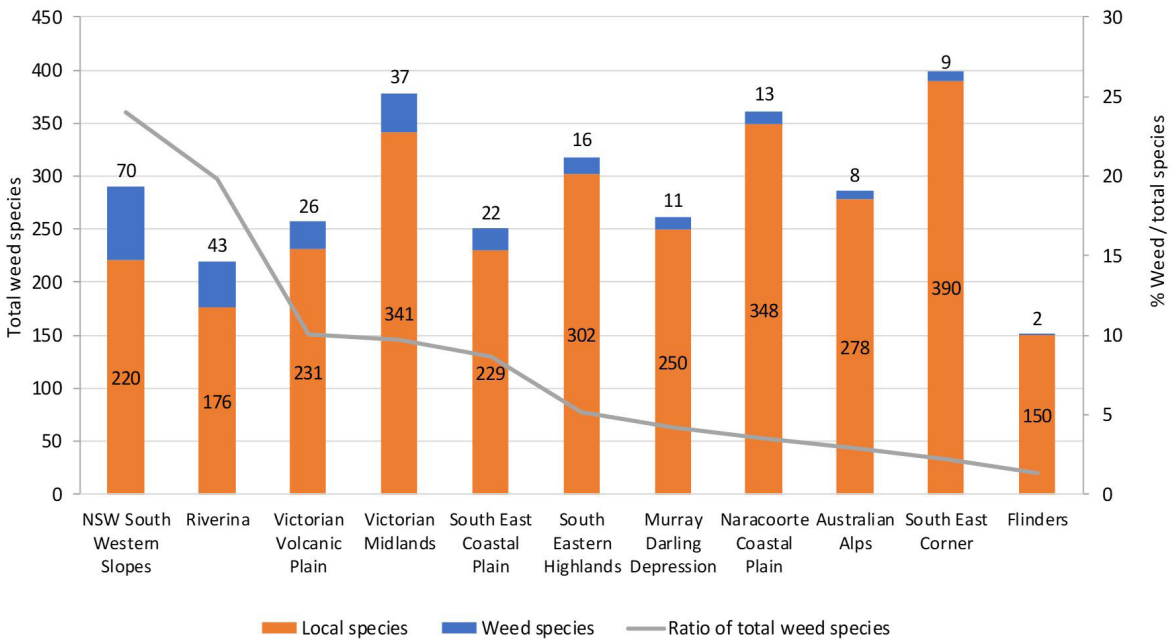

Figure Fo.16 Proportional distribution of weed species in bioregions, 2018

(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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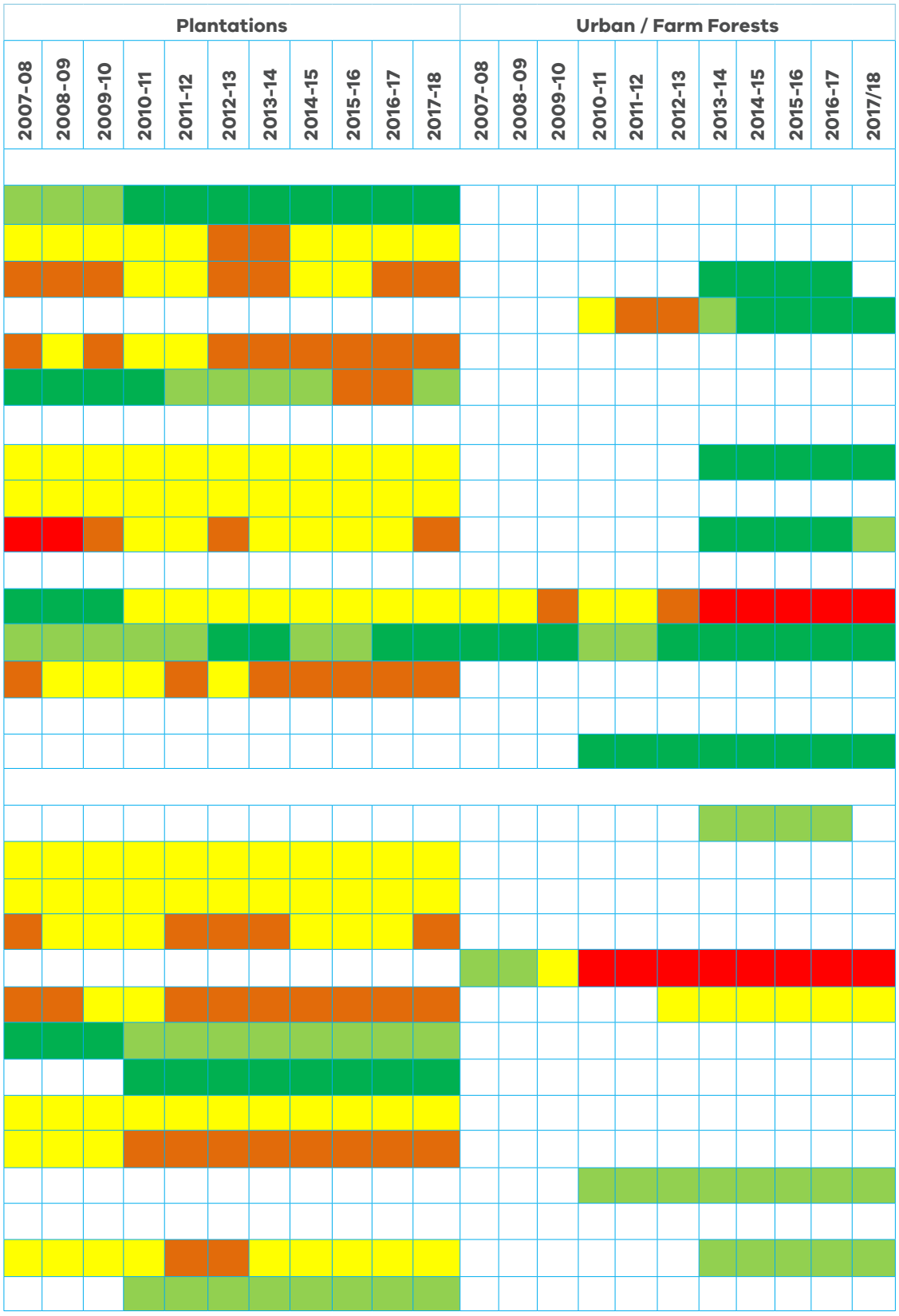


(Data source: DELWP, 2018)

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.

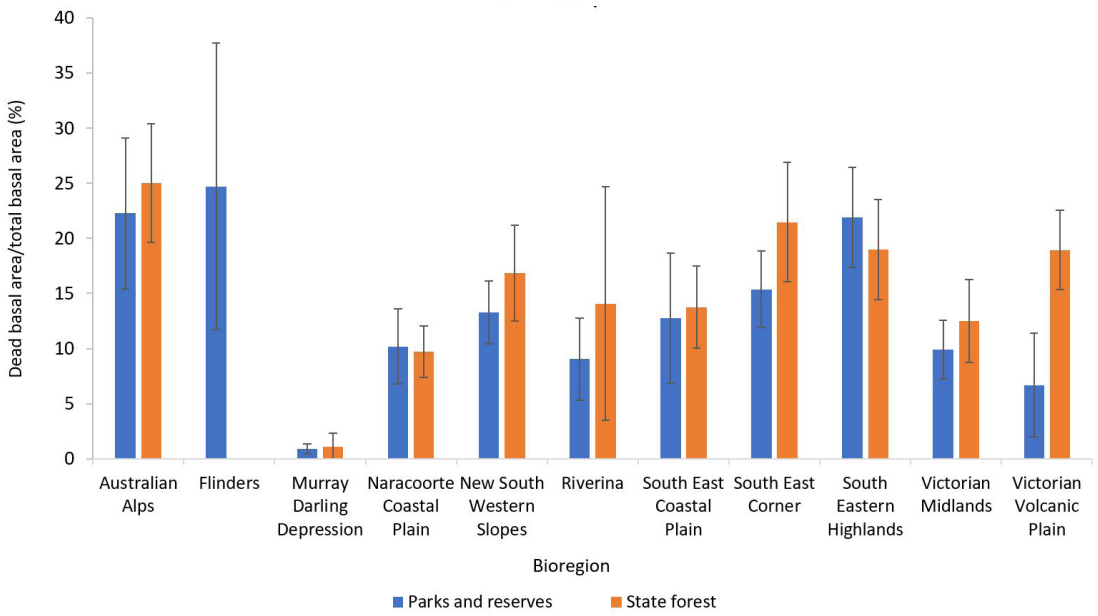


Figure Fo.18 Mortality by bioregion as a proportion of total dead basal area to total live basal area for large trees

Note: Number of plots by bioregion is described in Table Fo.1.

(Data source: DELWP, 2018)

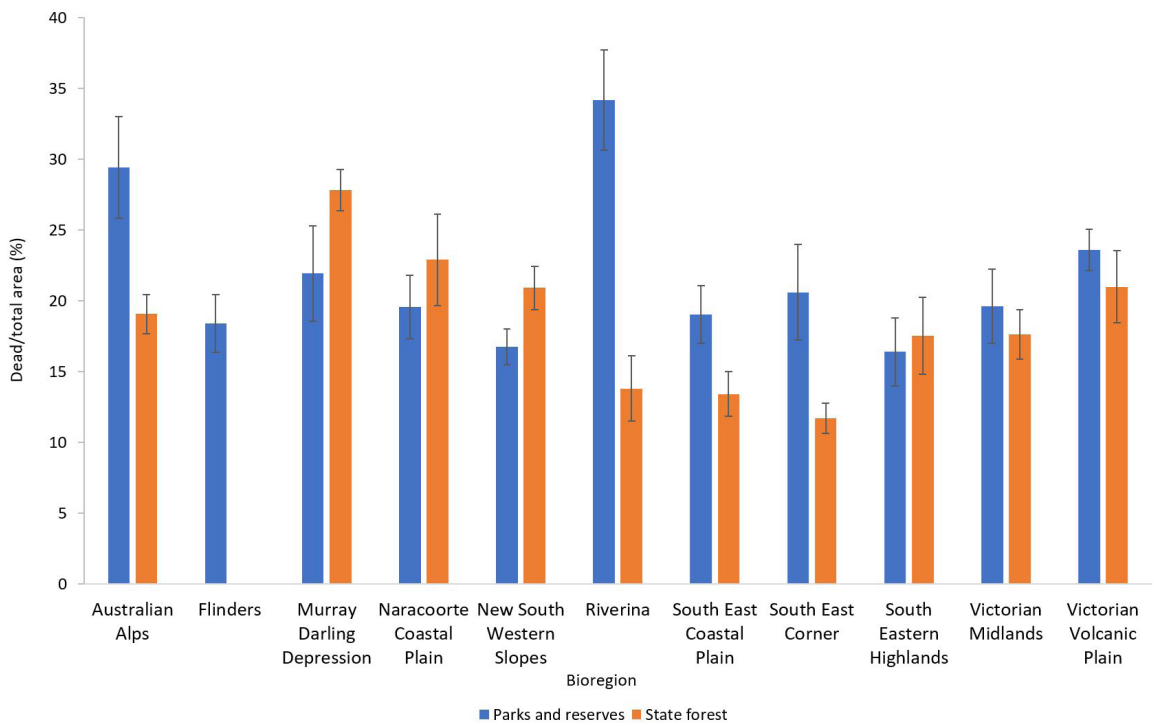


Figure Fo.19 Average canopy dieback and defoliation rates for measured plots by bioregion

Note: Number of plots by bioregion is described in Table Fo.1.

(Data source: DELWP, 2018)

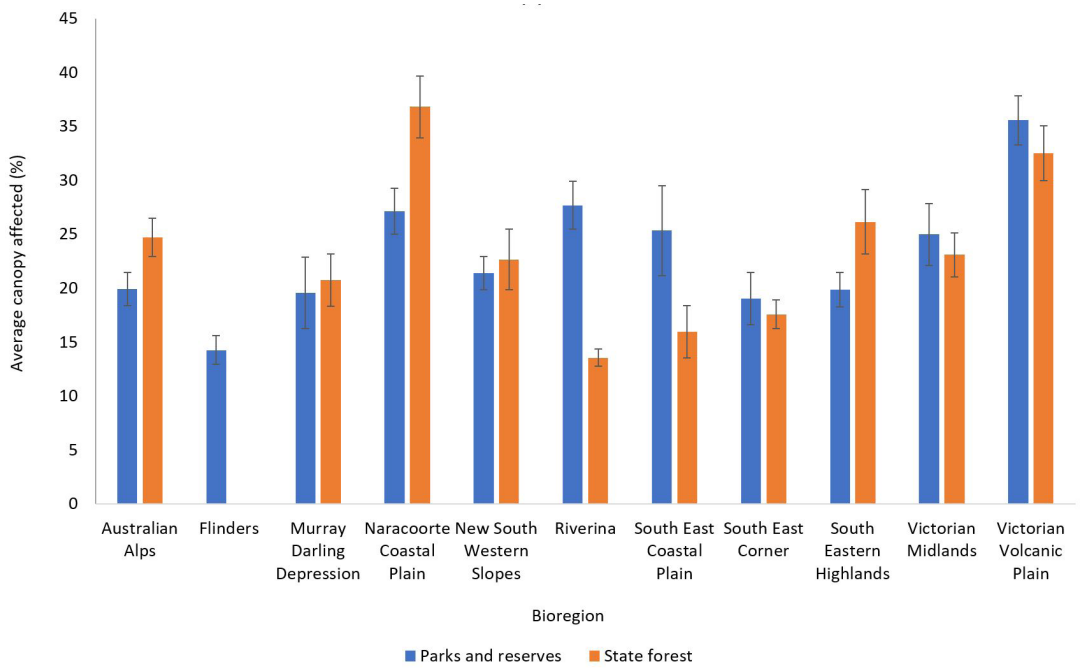


Figure Fo.20 Canopy health as characterised through discolouration and defoliation, by bioregion

(Data source: DELWP, 2018)

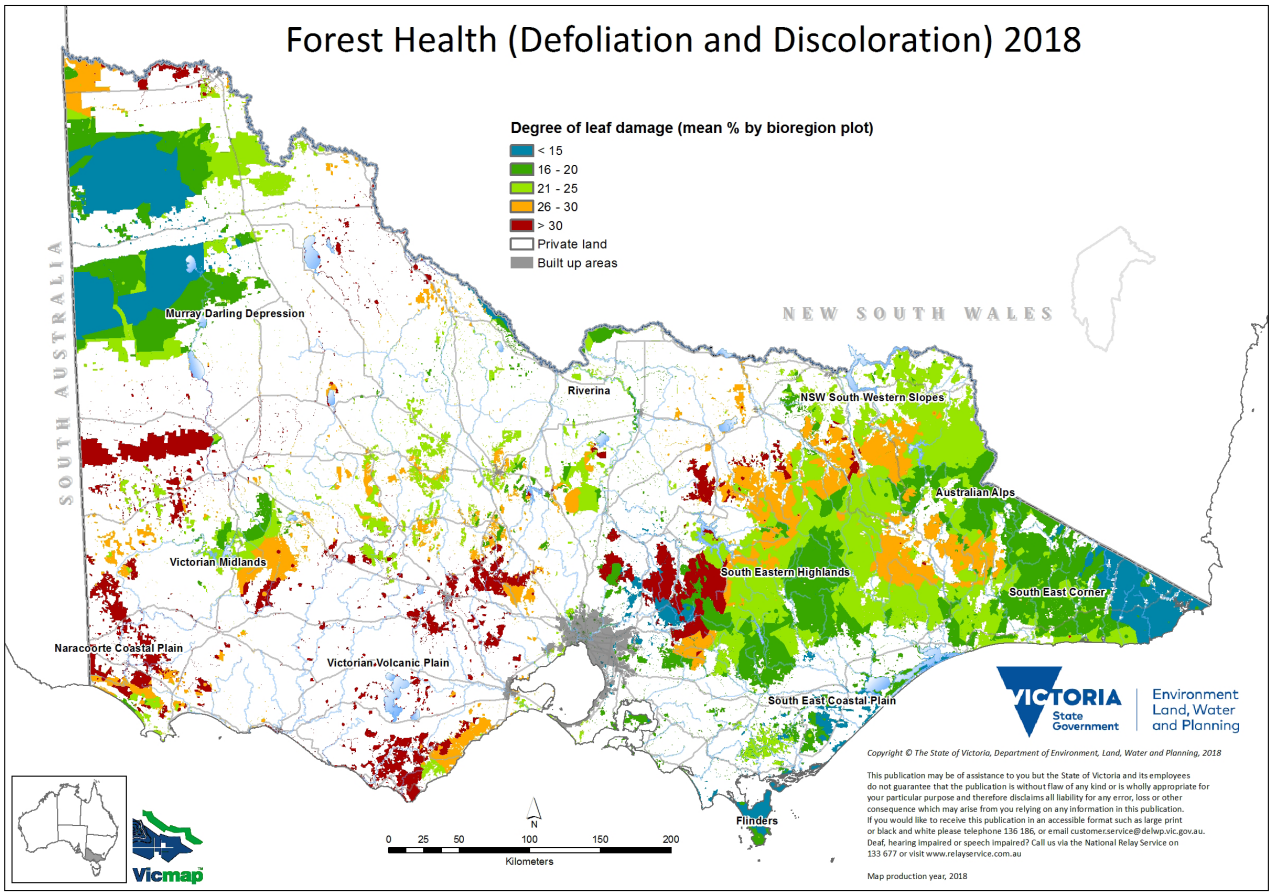


Figure Fo.21 Canopy health (defoliation and discolouration), 2018

(Data source: DELWP, 2018)

	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
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.

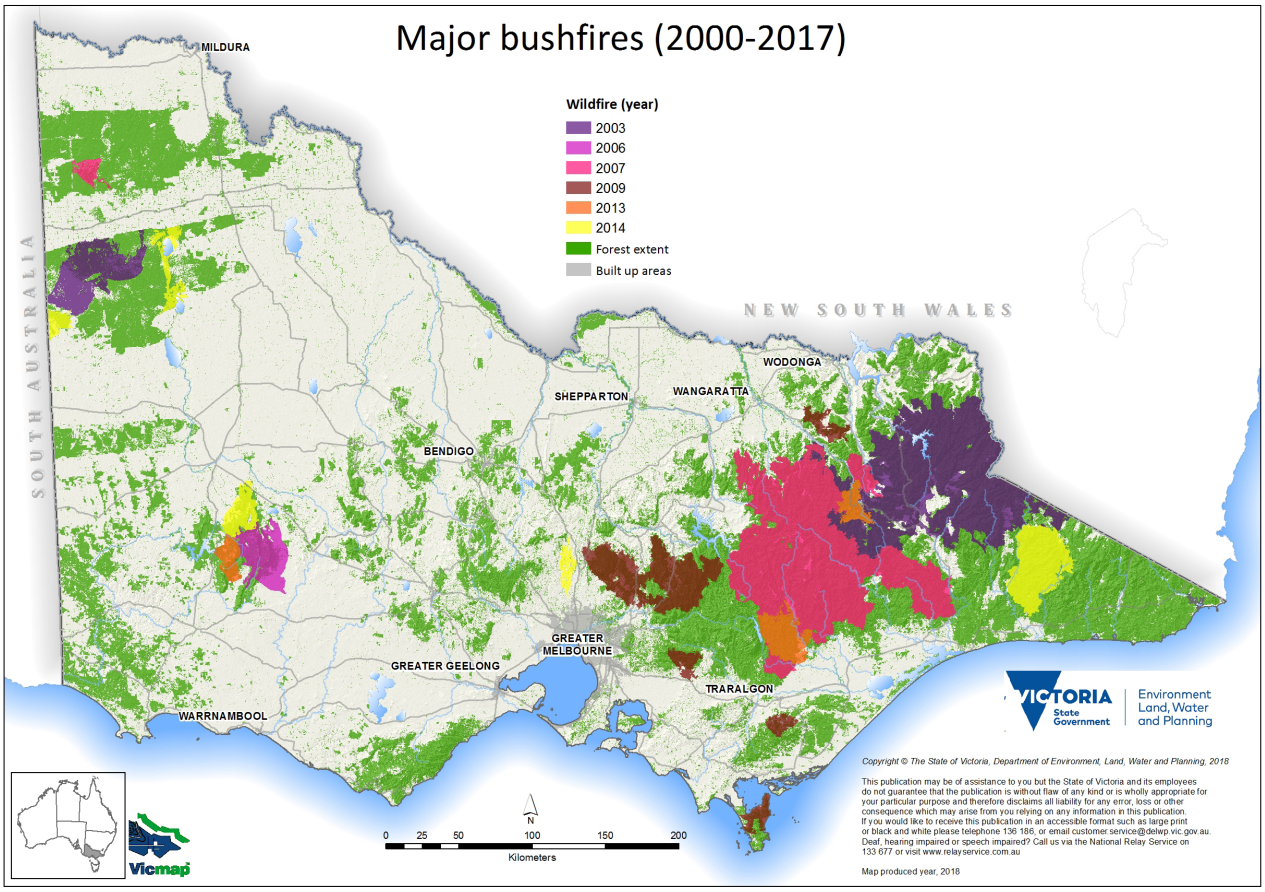


Figure Fo.22 Major bushfires in Victoria, 2000–17

(Data source: DELWP, 2018)

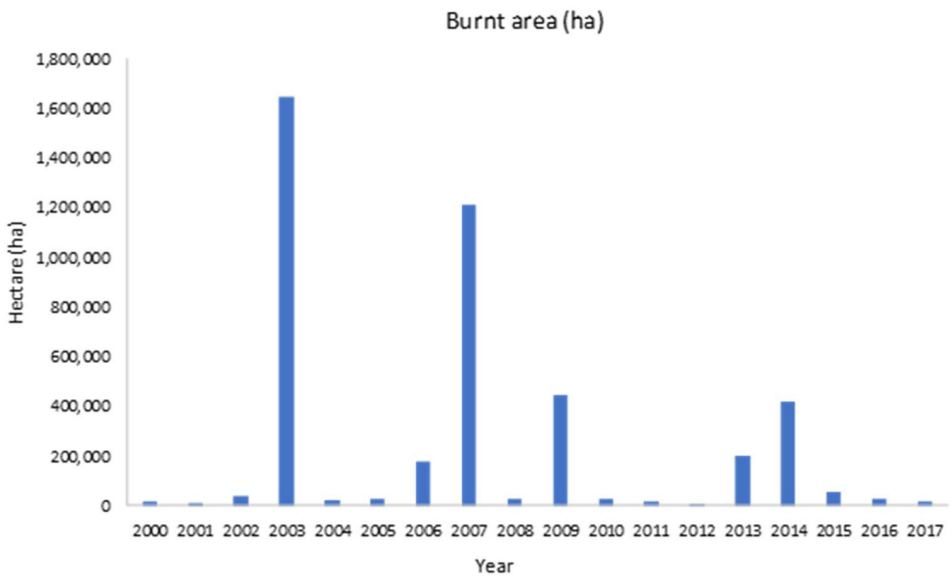


Figure Fo.23 Total area affected by bushfires, 2000–17

(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.

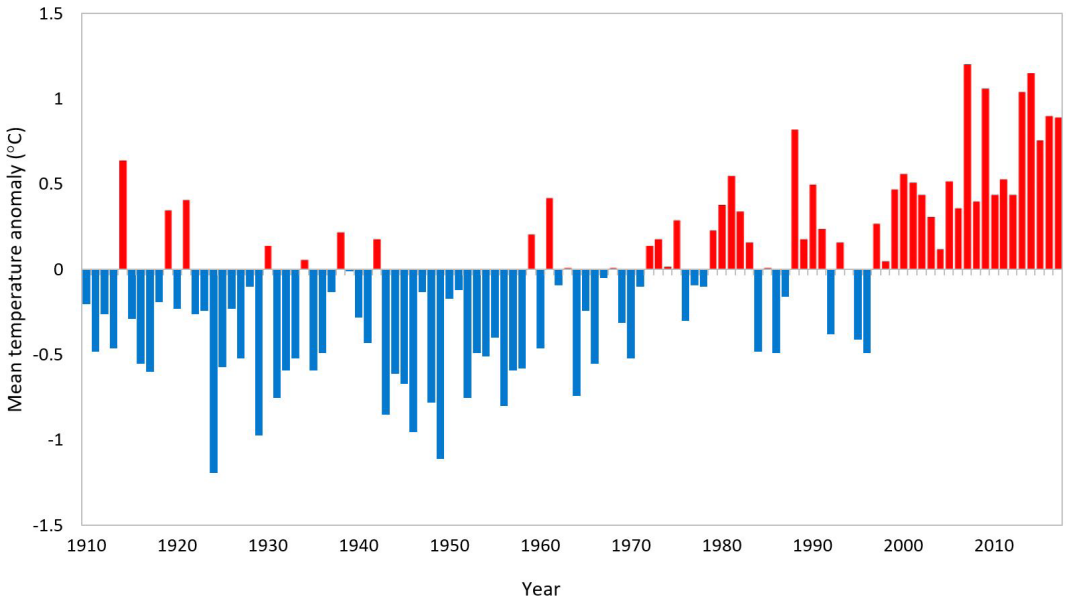


Figure Fo.24 Mean temperature anomaly in Victoria, 1910–2017

(Data source: BoM, 2018[91])

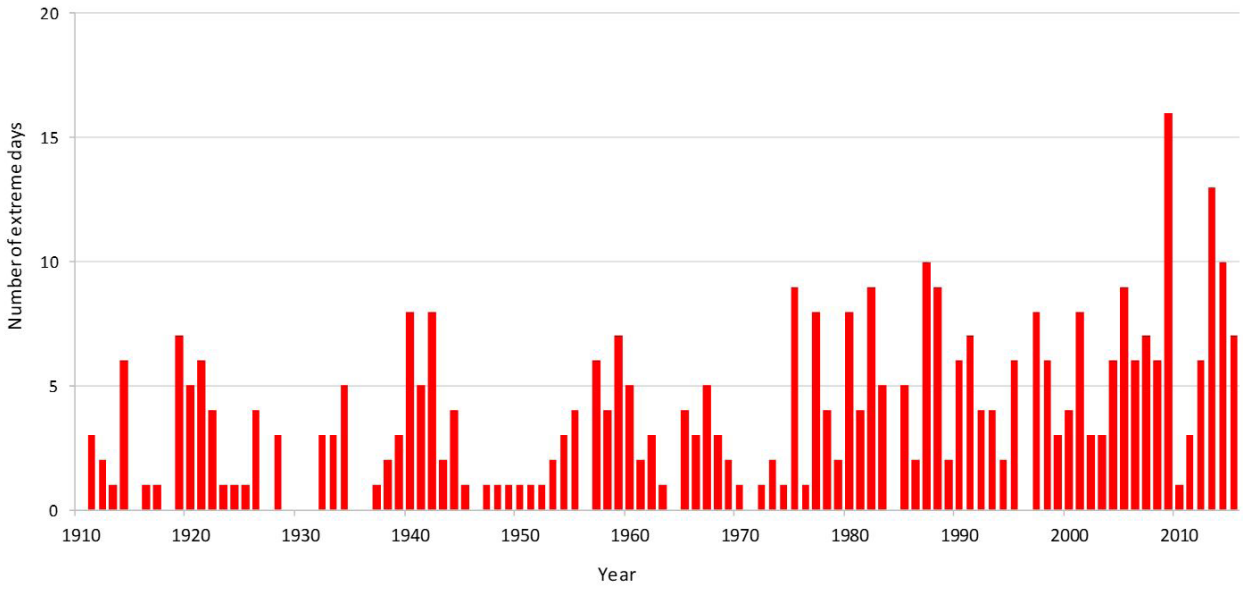


Figure Fo.25 Number of days annually when the Victorian area-averaged daily mean temperature is 'unusually warm', 1910–2015

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	○ ○ ● ○	?	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)

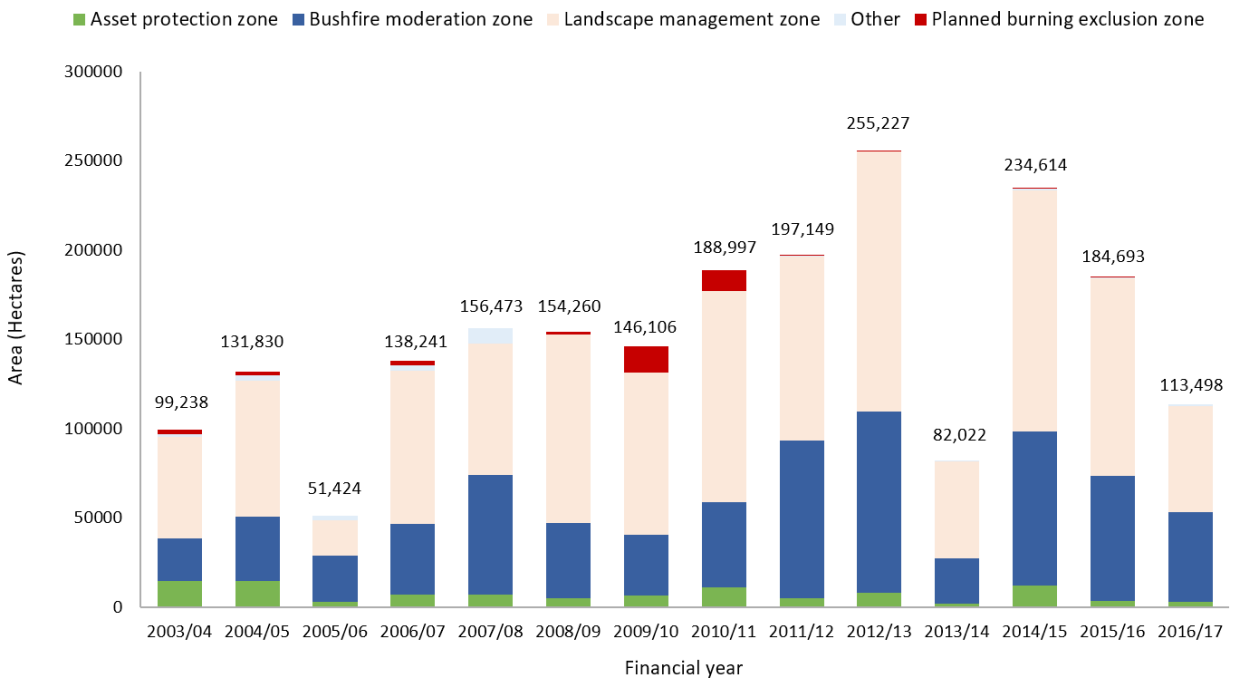


Figure Fo.26 Annual area of planned burns on public land, by fire management zone, 2003–04 to 2016–17

(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.

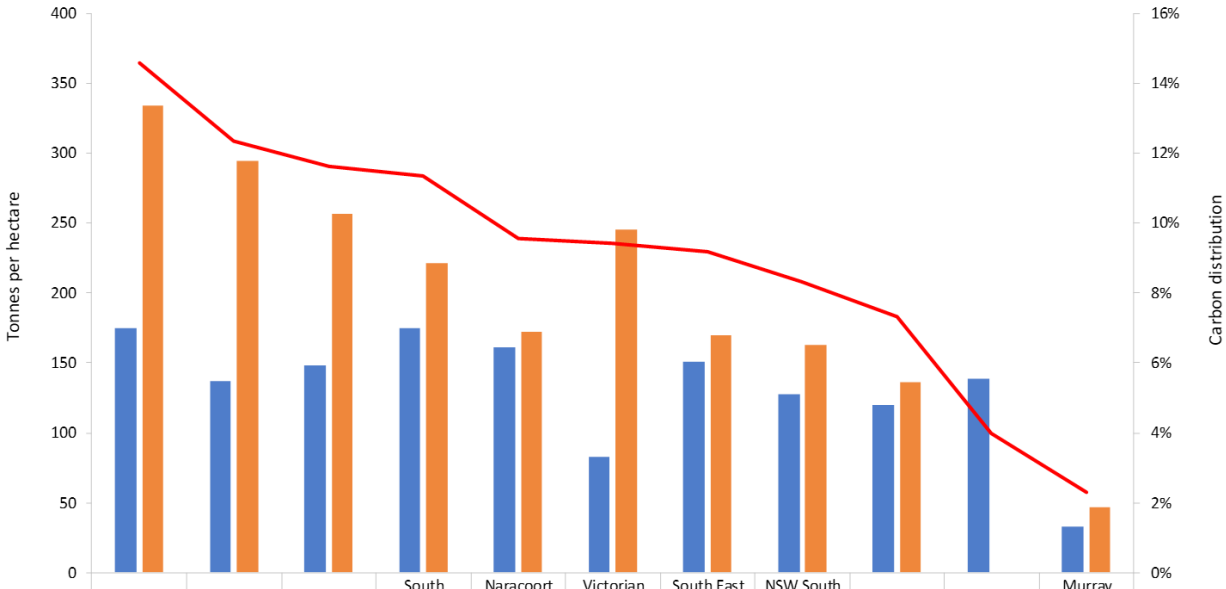
Existing data shows that across all Victorian public forests, the average C and biomass per hectare is 166.2 and 332.3 tonnes per hectare, respectively. The Murray–Darling Depression[101] has the lowest average C and biomass per hectare, with 39.9 and 79.9 tonnes per hectare, respectively.

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.



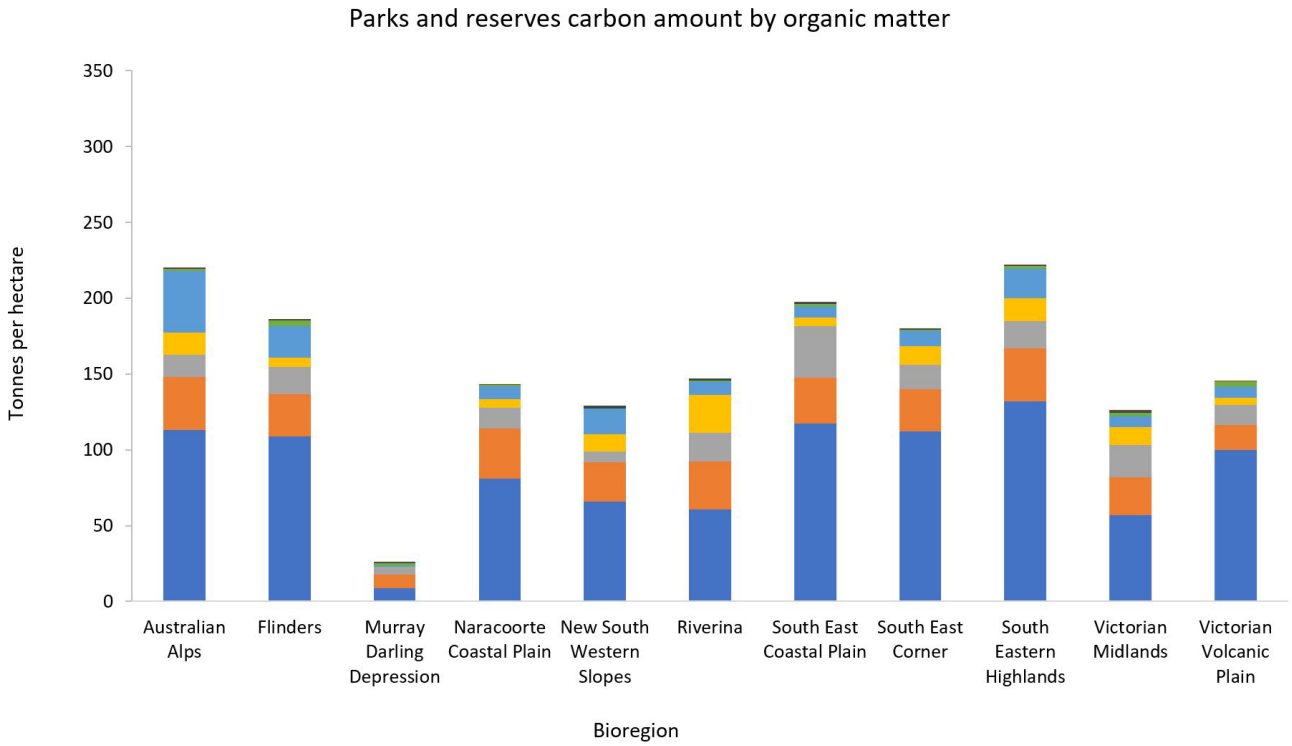
	Australian Alps	South East Corner	Riverina	South Eastern Highlands	Naracoorte Coastal Plain	Victorian Volcanic Plain	South East Coastal Plain	NSW South Western Slopes	Victorian Midlands	Flinders	Murray Darling Depression
Park/Reserve	175.0	137.1	148.1	174.6	161.4	83.3	151.1	127.7	119.7	138.8	33.0
State 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%

Bioregion

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)



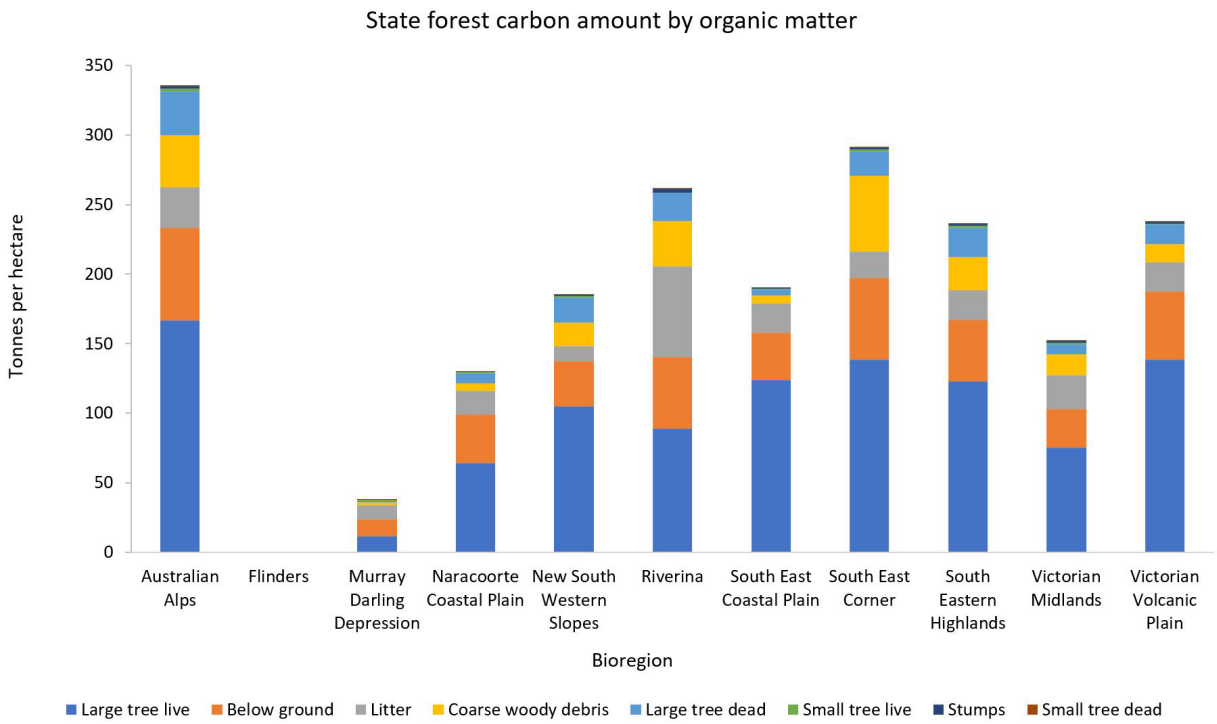


Figure Fo.28 Carbon stores by pool and bioregion in Victoria's public forests (state forests and parks/reserves)

(Data source: DELWP, 2018)

	Status UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
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.

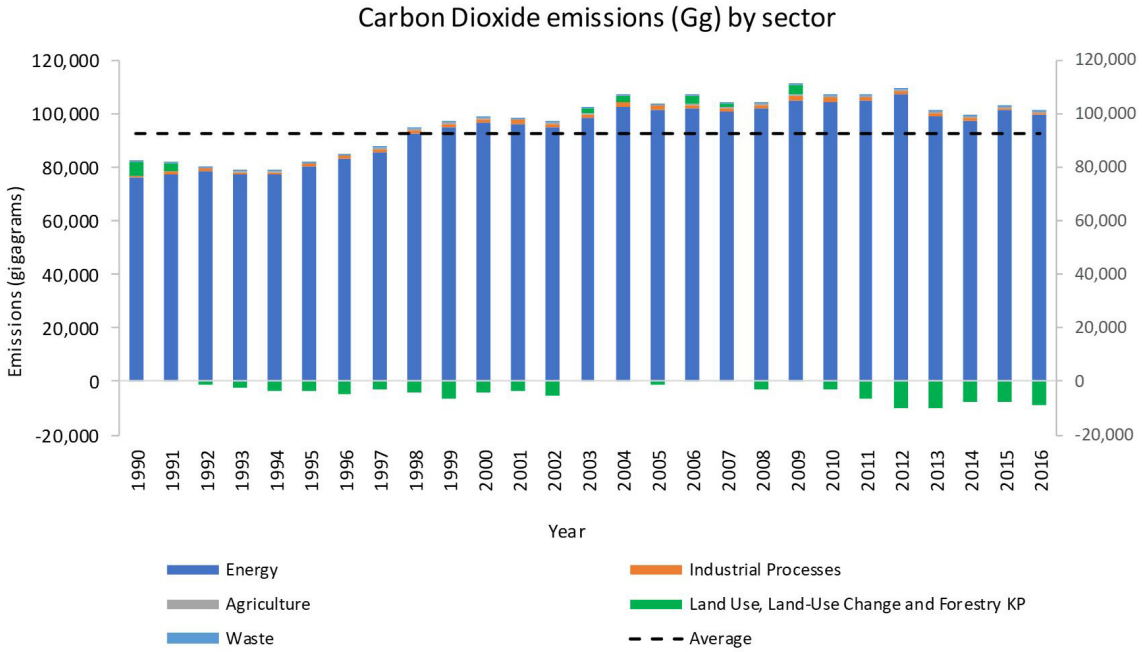


Figure Fo.29 GHG inventory (carbon dioxide) trend by sector in Victoria, 1990–2016

(Data source: Australian Government, Australian Greenhouse Emissions Information System, 2018)

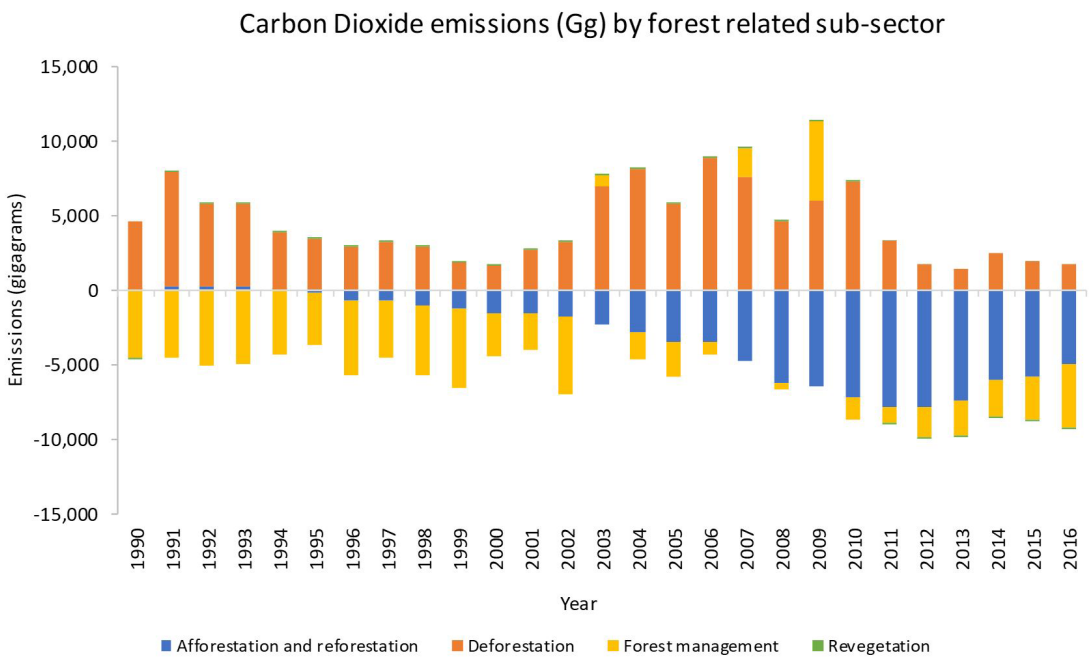


Figure Fo.30 GHG inventory (carbon dioxide) trend by subsector in Victoria, 1990–2016

(Data source: Australian Government, Australian Greenhouse Emissions Information System, 2018)

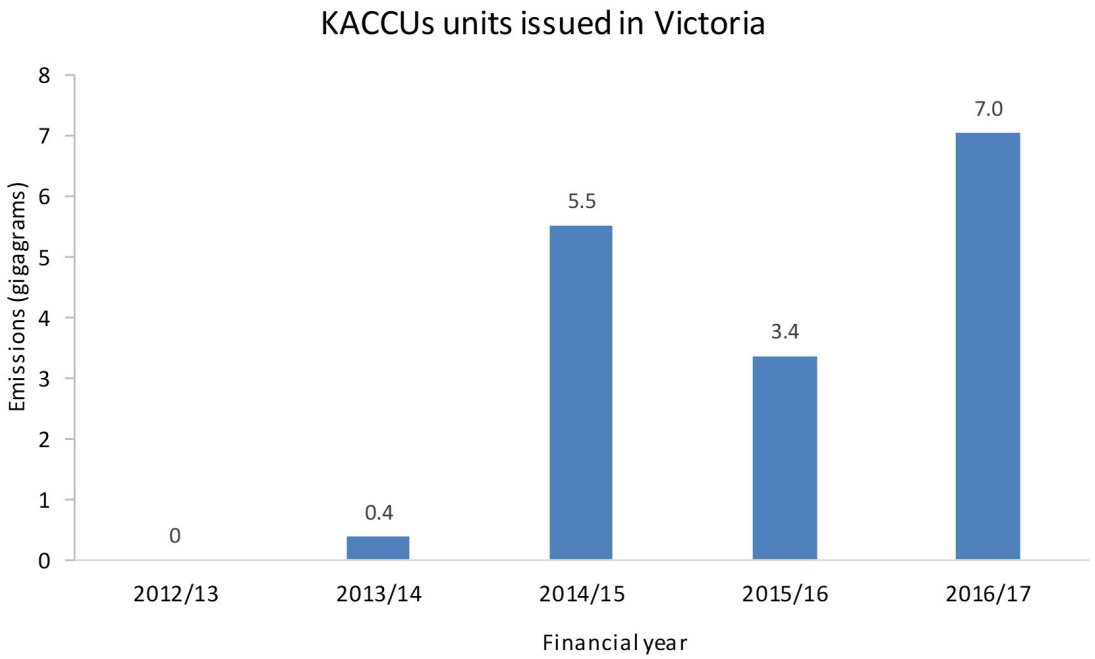


Figure Fo.31 Kyoto Australian Carbon Credit Units (KACCUs) using the 'vegetation method'

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

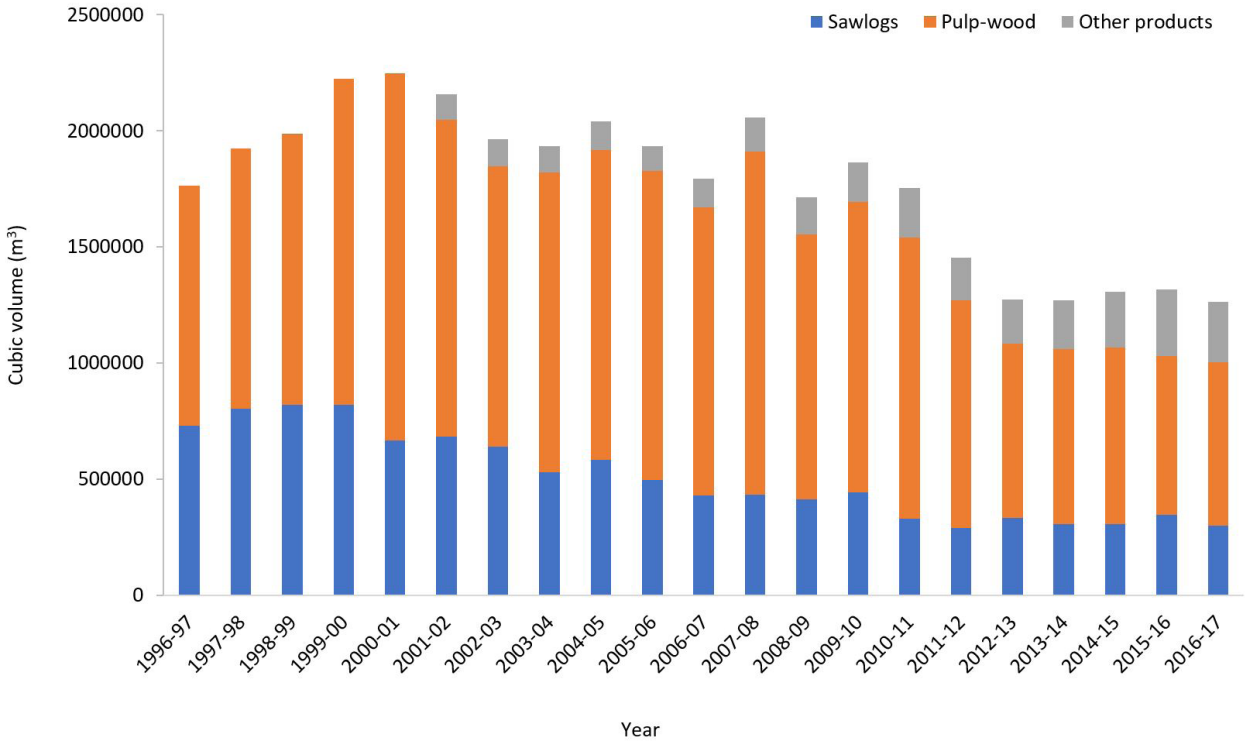


Figure Fo.32 Annual production of wood products from state forests by sawlogs, pulpwood and other products, 1996–97 and 2016–17

(Data source: VicForests, 2018)

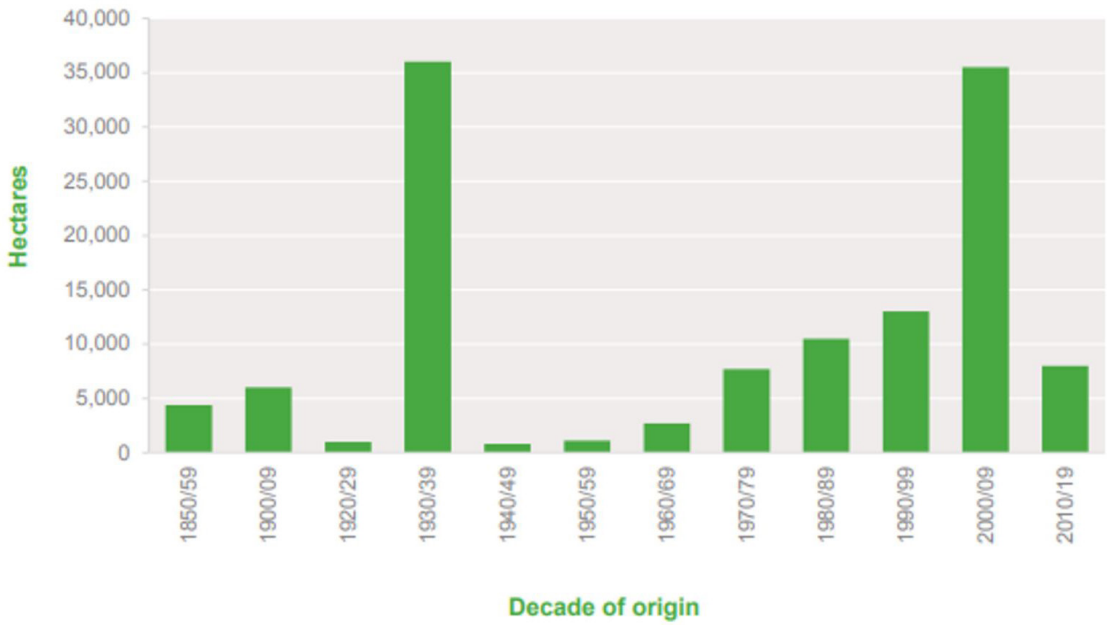


Figure Fo.33 Age class distribution of ash forests

(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				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:18 Extent to which the economic framework supports the conservation and sustainable management of forests	○	○	●	○	?	DATA QUALITY Fair

Data custodian DELWP

This indicator assesses whether the current economic framework supports sustainable forest management. It lists the economic framework elements considered important for supporting conservation and sustainable management of both public and private forests. The indicator includes assessment of new policies and key developments.

This indicator is assessed using the best available state and national data – but note that state-scale datasets are extremely limited. This makes assessment of this indicator, including comparison of past and present economic frameworks, difficult.

A recent report from Forest and Wood Products Australia indicates that the forest industry contributed about $7.3 billion to the Victorian economy in 2017–18.[147] This consisted of $1.9 billion in direct sales of wood and fibre and $5.4 billion in flow-on effects from other industries involving forest products (socio-economic activities).

Since SoE 2013, several state and federal government investments have contributed to progress for Victorian native forests. As part of Victoria's Regional Tourism Strategy from 2013 to 2016, the 2013–14 state budget committed $13 million to improve tourism in national parks, state forests and on public land.[148] This facilitated upgrades and continual management of Victorian regions containing forests, such as Gippsland, the Macedon Ranges and Daylesford.[149] (A drawback of this is the potential for ecological damage from the removal of prohibitions against private-sector development in national parks. While sustainable environmental outcomes are encouraged in the tourism development guidelines,[150] there are no current assessments for ecological affects due to private-sector development.)

In 2013–14, DEDJTR made grants of $620,000 to a number of wood processing enterprises, as a part of the Regional Growth Fund.[151] However, limited benchmarks and targets meantthe only quantifiable outcomes were in relation to financial returns or employment.[152]

From 2014 to 2017, the Australian Government provided $3 million to enhance the environmental and cultural values of the Dandenong Ranges.[153] The initiative, delivered through the National Landcare Program, funded community groups to undertake activities to strengthen wildlife habitat, regulate weeds and decrease bushfire fuel-loads. As this was a sub-program, outcomes of the fund have not been examined in detail, but will be reviewed as part of the National Landcare Program.[154]

147. Forest & Wood Products Australia 2018, 'Media release: Forest industry adds 7.3 billion to Victorian economy: research', https://www.fwpa.com.au/news/1632-forest-industry-adds-7-3-billion-to-victorian-economy-research.html Accessed 4 December 2018.
148. State Government Victoria 2013, 'Victoria's regional tourism strategy 2013-2016', Melbourne, Victoria https://corp.rdp.tourismnortheast.com.au/wp-content/uploads/sites/54/6588_victoria_-regional_tourism_strategy_2013-16_WEB-1.pdf Accessed 4 December 2018.
149. Ibid
150. DELWP 2015, 'Tourism lease in National Parks: guidance note', Melbourne, Victoria https://www.ecotourism.org.au/assets/Resources-Hub-Protected-Area-Management/tourism-leases-in-national-parks.pdf Accessed 4 December 2018.
151. Department of State Development Business and Innovation 2014, 'Annual report 2013-14', Melbourne, Victoria https://web.archive.org/web/20150301094836/http:/dsdbi.vic.gov.au/__data/assets/pdf_file/0018/1006353/DSDBI-ANNUAL-REPORT-2013-14-FINAL_web.pdf Accessed 4 December 2018.
152. VAGO 2015, 'Regional growth fund: outcomes and learnings', Melbourne, Victoria https://www.audit.vic.gov.au/report/regional-growth-fund-outcomes-and-learnings Accessed 4 December 2018.
153. Australian Government, 'Dandenong Ranges', Canberra, Australia http://www.nrm.gov.au/national/local/dandenong-ranges Accessed 4 December 2018.
154. Australian Department of the Environment and Energy and Australian Department of Agriculture and Water Resources 2017, 'Report on the review of the national landcare program', Canberra, Australia http://www.nrm.gov.au/system/files/resources/fb8af1b3-f8fc-4b07-9334-4ae013da9188/files/nlp-review-final-report.pdf Accessed 4 December 2018.

Information to evaluate this indicator is scant. However, a regional set of environmental–economic accounts for the Central Highlands[155, 156] has been developed to assess ecosystem assets and their benefits for human wellbeing, including a framework to measure conservation and sustainable forest management. This assessment of native forest management uses the United Nations System of Environmental and Economic Accounting (SEEA) framework, which has been adopted in more than 45 countries.[157] In the Central Highlands, the results show that the economic value of water, tourism and plantation industries on private land is greater than the economic value of the native timber harvesting industry. (This excludes 2009–10, due to the 2009 Black Saturday bushfires.) The value of plantation forestry was found to be greater than that for native forestry, even though the size of the area managed for plantations is only 14% of the area of native forest available for harvest.[158]

Results from the trade-off analysis show that cesasing native forest timber harvesting could increase the economic value of ecosystem assets such as carbon. This trade-off analysis provides an opportunity to systematically and regularly assess the costs and benefits of changing ecosystem assets and services. However, the analysis in this study focuses only on the Central Highlands and does not include a state-scale assessment. A rigorous and scientific state-scale approach to assess the economic framework for sustainable forest management, following the international SEEA standard, is critical for policy development and implementation. This environmental–economic accounts approach has been discussed in Fo:23 (Value ($) of forest derived ecosystem services).

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 UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
Fo:19 Capacity to conduct and apply research and development aimed at improving forest management, including development of scientific understanding of forest ecosystem Data custodian DELWP				●	→	DATA QUALITY Good

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	FAIR	→	DATA QUALITY: Good

Data custodian DELWP

Effective sustainable forest management relies on adequate investment and expenditure. This ensures that infrastructure, facilities, forest health and conservation values are maintained.

This indicator measures trends in forest management expenditure, reported as Victorian Government expenditure on forest-management-related activities. This includes expenditure on state forests, and parks and reserves, as well as VicForests's expenditure on forest management.

There are two main investment components: forest and fire management, and conservation and recreation.

The agency responsible for managing natural resources, including state forests, in Victoria has changed several times during the reporting period. In April 2013, the Department of Sustainability and Environment merged with the Department of Primary Industries to form the Department of Environment and Primary Industries (DEPI). In January 2015, DELWP, which has broad responsibility for Victoria's natural environments (including forest management, and fire and emergency management), was created following a government restructure. Together with Parks Victoria and VicForests, DELWP is responsible for managing Victoria's parks and reserves, and state forests. VicForests is a separate government-owned business responsible for the harvest, commercial sale and regrowing of wood from Victoria's state forests.

Table Fo.28 shows expenditure on managing Victoria's forests, parks and public land between 2012–13 and 2016–17. Expenditure has steadily increased over the five-year period. Forest and fire expenditure has remained comparatively steady, with a slight decrease in 2016–17 mainly attributed to a less-severe fire season. Expenditure on conservation and recreation increased significantly in 2013–14 and continued to increase during the period. The changes over five years may indicate that the Victorian Government has increased focus on and investment in conservation and recreational values in state forests, parks and reserves.

Table Fo.29 shows the forest management expenditure on general maintenance, capital roading and capital bridge works between 2012–13 and 2016–17. Total expenditure decreased across the period, particularly on maintenance work. This was mainly due to decreasing timber production and available production areas, which reduced the maintenance works required for state forests, and parks and reserves.

Table Fo.28 Victorian Government expenditure on forest management, 2012–13 to 2016–17

	Expenditure ($ millions)				
Expenditure category	**2012–13**	**2013–14**	**2014–15**	**2015–16**	**2016–17**
Forest and fire management	383.5	382.3	347.8	396.5	372.3
Conservation and recreation	199.0	199.3	298.9	328.2	369.8
Total	582.5	581.6	646.7	724.7	742.1

(Data source: DELWP, 2018)

Table Fo.29 Victorian Government forest management expenditure on maintenance, capital roading and capital bridges, 2012–13 to 2016–17

	Expenditure ($ millions)				
Expenditure category	**2012–13**	**2013–14**	**2014–15**	**2015–16**	**2016–17**
Maintenance	16.0	16.8	12.6	9.0	7.9
Capital roading	0.2	0.7	0.4	0.3	0.2
Capital bridges	2.2	2.4	2.6	3.2	1.4
Total	18.3	19.9	15.5	12.5	9.5

(Data source: DELWP, 2018)

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fo:21 Value ($) of forest derived ecosystem services			●		?	DATA QUALITY Fair

Data custodian DELWP

Environmental/economic accounting provides a framework for valuing the economic benefit of ecosystem services to the economy and society. The contribution forests make to the economy is partly captured in the System of National Accounts (SNA), which accounts for goods and services from forests, such as timber and tourism, when they are produced and consumed in the economy. The System of Environmental Economic Accountng (SEEA) extends the SNA by including forests environmental assets, and the natural inputs and ecosystem services forests produce.

Forest ecosystems provide a suite of ecosystem services, including climate regulation, carbon sequestration, water supply and filtration, and habitat. The management and condition of forests determines the level and extent of these services and, in turn, the benefits to the economy and community. A qualitative example of forest ecosystem accounting – from asset to benefits – is set out in Table Fo.30.

Table Fo.30 Qualitative example of ecosystem accounting for Victorian forests

Asset extent	Asset condition	Ecosystem services	Benefits
Forests can be classified into different assets using EVCs or production forest classes	Condition assessment must be linked to the impact on asset's ability to provide ecosystem services Size of habitat	Examples include: • habitat • water supply and filtration • climate regulation (carbon sequestration • temperature regulation • nourishment for bees • opportunities for recreation and tourism • opportunities for cultural connection • landscape	Examples include: • water consumption by humans and animals • timber • avoided impacts from climate change • urban cooling • apiculture (pollination or crops and honey) • recreation and tourism • avoided health impacts • cultural connection • visual amenity

(Data source: DELWP, 2018)

Ecosystem accounting has increasingly been applied to forest areas in Australia and around the world. In 2015, Parks Victoria and DELWP accounted for forest ecosystem assets in parks as part of an assessment of benefits from ecosystem services provided by Victorian parks.[167] The analysis estimates that Victorian parks contribute about $1 billion in gross value and 14,000 jobs. The park-based apiary sector was estimated to contribute between $3.4 million and $4.6 million per annum (between $0.6 million and $1 million per annum, respectively).

At the regional scale, the Australian National University has published ecosystem accounts for the Central Highlands across state forests and parks, focusing on water provisioning, timber provisioning, tourism and carbon sequestration.[168] The key findings show that the value of ecosystem services for agriculture production has the greatest value ($121 million) – because of pollination services as an ecosystem service – followed by the water provisioning service ($101 million). By contrast, the native timber provisioning service was valued at just $19 million. The tourism sector in the Central Highlands is estimated to produce benefits of $71.1 million as direct and indirect gross value added, with corresponding increases in employment of 470 direct jobs and 280 indirect jobs after 10 years of investment in the tourism industry.[169]

Forests provide a key natural input that is priced in the economy: timber. Once harvested, timber is accounted for in the SNA. Environmental/economic accounts can record the stock of native forest and plantation forest assets over time, which can increase due to natural growth or decrease due to timber harvesting or other events such as bushfires. The Australian Bureau of Statistics produces accounts on native and plantation timber resources for the whole of Australia, and reported a net value of $11.6 billion in 2016–17, or $471.6 per person. Of this, $9.9 billion is plantation timber and $1.7 billion is native timber.

Currently there is no state-scale approach to quantifying the dollar-value of forest-derived ecosystem services in Victoria. Environmental/economic accounting provides a consistent framework for assessing the range of natural inputs and ecosystem services provided by forests, and the benefits each of these deliver to the economy and community. This type of information, presented in a consistent and comparable format, can help to improve understanding of the different benefits forests provide, and can be used to inform land use and forest management trade-offs and decision-making.

167. Varcoe T, Betts O'Shea H, Contreras Z 2015, 'Valuing Victoria's parks: Accounting for ecosystems and valuing their benefits', DELWP and PV, Melbourne, Victoria https://parkweb.vic.gov.au/__data/assets/pdf_file/0010/695764/Valuing-Victorias-Parks-Report-Accounting-for-ecosystems-and-valuing-their-benefits.pdf Accessed 4 December 2018.
168. Keith H, Vardon M, Stein JA, Stein J, Lindenmayer DB 2017, 'Experimental Ecosystem Accounts for the Central Highlands of Victoria', The Australian National University and the Threatened Species Recovery Hub, Canberra, Australia.
169. Nous Group 2017, 'Great forests national park: economic contribution of park establishment, park management, and visitor expenditure: The Wilderness Society', Melbourne, Victoria http://www.greatforestnationalpark.com.au/uploads/1/5/5/7/15574924/nous_gfnp_economic_contribution_study_3_february_2017.pdf Accessed 4 December 2018.

Future Focus

Understand the impacts of forest fragmentation on biodiversity and improve assessment of protected areas

A systematic approach to understanding the status and future trends of Victorian public forests is critical. DELWP developed the Victorian Forest Monitoring Program (VFMP) in 2011. The VFMP completed its first full cycle of field measurements in 2015 and is expected to complete its second cycle by 2020. It is critical that minimal changes to the VFMP data-collection methods occur following the completion of the second full cycle of data retrieval. Consistency in methodology, with only essential amendments, would allow the identification of underlying trends and improve the utility of the evidence base. Any changes to data collection and analysis methods to achieve more accurate data must not disrupt comparative analysis with existing datasets or future trend analyses.

Furthermore, although the VFMP maps forest fragmentation at the state scale (including private forests), it does not provide a complete assessment of forest fragmentation and its impacts on biodiversity in native forests. Long-term monitoring and detailed spatial research have been conducted to explore impacts of fragmentation on native forests and forest-dependent species at the regional scale (such as mountain ash forests in the Central Highlands) and this research has demonstrated that forest fragmentation is becoming intensified, and its impact on threatened species has been increasing.[170, 171, 172, 173, 174] The study of biodiversity impacts from forest fragmentation is also impeded by the lack of an authoritative list of Victorian forest-dependent species.

Further research is critical as a complement to VFMP mapping and to understand the impact of forest fragmentation on biodiversity at the state scale. This research program would also assist in the establishment and management of protected areas. The International Union for Conservation of Nature (IUCN) protected areas in Victoria increased by 140,000 hectares between 2004 and 2016. However, there is little evidence of the level of long-term species protection provided by the classification of these areas. A viability analysis, for example, would provide risk assessment and management options to better protect target species in protected areas. Such analysis would also provide an indication of species conservation benefits if an increase in protected areas was to occur.

Recommendation 8: That DELWP maintain their commitment to resourcing and maintaining the VFMP and enhance it to (i) improve statewide understanding of the impacts of forest fragmentation on forest-dependent species (including the development of an authoritative list of Victorian forest-dependent species) and (ii) improve assessment of protected areas by conducting detailed research to identify the benefits of various types of IUCN-protected areas for target species. Any amendments to the VFMP must not disrupt future trend analyses.

170. Lindenmayer DB, Blair D, McBurney L, Banks S 2015, 'Mountain Ash: Fire, logging and the future of Victoria's giant forests', CSIRO Publishing, Melbourne.
171. Blair D, McBurney L, Lindenmayer DB, Banks S, Blanchard W 2017, 'The Leadbeater's Possum review', The Australian National University, Canberra.
172. Blair D, McBurney L, Lindenmayer DB 2018, 'Failing to conserve Leadbeater's Possum and its Mountain Ash forest habitat', Australian Zoologist, 39(3), 442-448. Doi:https://doi.org/10.7882/AZ.2018.008.
173. Lindenmayer DB, Blanchard W, Blair D, McBurney L 2018, 'The road to oblivion – quantifying pathways in the decline of large old trees', Forest Ecology and Management, In re-review.
174. Meney B, Cunningham S, Weston MA, Whisson DA 2018, 'Woodland birds and rural towns: artificial clutch survival in fragmented Box-Ironbark forests', The Royal Society of Victoria, 130, 7-17.

Accounting for the Environment

Environmental/economic accounting provides a framework for linking forests (a type of land account) to the natural inputs and ecosystem services they produce that benefit the economy and society. The contribution forests make to the economy is partly captured in the SNA, which accounts for goods and services from forests, such as timber and tourism, when they are produced and consumed in the economy. The SEEA extends the SNA by including forests environmental assets and the natural inputs and ecosystem services they produce.

See indicator Fo.23 (Value ($) of forest-derived ecosystem services) for further analysis.

Case Study: A pilot approach to estimating the potential for forests to provide habitat services

A key service provided by forest ecosystems is habitat for species. Fauna and flora species have different habitat requirements. They need a place to live and reproduce. They also need to tolerate changes in the weather as well as flood and fire disturbances. Because of these different needs, species are found in different locations across the landscape. Some species have highly specific habitat requirements (such as hollow-dependent arboreal marsupials that are present only in limited parts of mountain ash and alpine ash forests that support hollow-bearing trees), while other species can thrive in many different habitat types.

Habitat distribution models (HDMs) have been developed for all rare or threatened Victorian species where sufficient data is available. For this assessment, 1,750 HDMs were used. HDMs collect and compare information on where a species has been recorded and relate that data to environmental variables, such as soil, prevailing climate and topography. Sophisticated statistical and mathematical processes are then used to estimate the distribution of a species's habitat. The HDMs do not predict whether or not a species currently occupies the habitat at a particular location. Many factors can influence whether a species is present in the habitat at any given time, including: biogeography; size of the habitat patch and distance from other suitable habitat; the condition of the habitat; natural disturbance cycles; historical catastrophes; the impact of predators or disease; and seasonal factors.[175]

A pilot approach to estimating the potential for forests to provide habitat services is to examine the links between the distribution of important Victorian species to the extent of forest cover in Victoria. This approach describes the relative importance of forests in providing potential habitat for species. However, as HDMs do not predict whether or not a species occupies the habitat at a particular location, this approach does not reveal whether forest assets are actually providing habitat services. Forest-cover extent is used as a proxy for potential habitat, and this approach does not incorporate the condition of forest ecosystem assets, which is a key factor in providing habitat. In 2015, this approach was used to account for the habitat services provided by Victorian parks.[176] Approaches to measuring the flow of habitat services provided by ecosystem assets is a complex area that can be refined in the lead-up to a systematic approach to accounting for the environment (see Recommendation 19).

Figure Fo.34 and Table Fo.31 show the extent of forest cover within the intersection of bioregions[177] and natural resource management[178] (NRM) regions across Victoria. Figure Fo.36 is an intersection between bioregion/NRM region and the 1,750 HDMs. It represents the number of HDMs that intersect with each bioregion/NRM class, which indicates the potential for these areas to provide habitat services.

175. DELWP 2017 'Biodiversity information explanatory document: measuring value when removing or offsetting native vegetation', Melbourne, Victoria https://www.environment.vic.gov.au/__data/assets/pdf_file/0025/91267/Biodiversity-information-explanatory-document-Measuring-value-when-removing-or-.pdf Accessed 4 December 2018.
176. Varcoe T, Betts O'Shea H, Contreras Z 2015, 'Valuing Victoria's parks: Accounting for ecosystems and valuing their benefits', DELWP and PV, Melbourne, Victoria https://www.forestsandreserves.vic.gov.au/__data/assets/pdf_file/0027/57177/Valuing-Victorias-Parks-Report-Accounting-for-ecosystems-and-valuing-their-benefits.pdf Accessed 4 December 2018.
177. Australian Department of the Environment and Energy, 'Interim Biogeographic Regionalisation for Australia (IBRA7) codes', Canberra, Australia http://www.environment.gov.au/land/nrs/science/ibra/ibra7-codes Accessed 4 December 2018.
178. CSIRO 'Impacts and adaptation information for Australia's NRM regions', Climate Change in Australia: projections for Australia's NRM regions, Canberra, Australia https://www.climatechangeinaustralia.gov.au/en/impacts-and-adaptation/nrm-regions/ Accessed 4 December 2018.

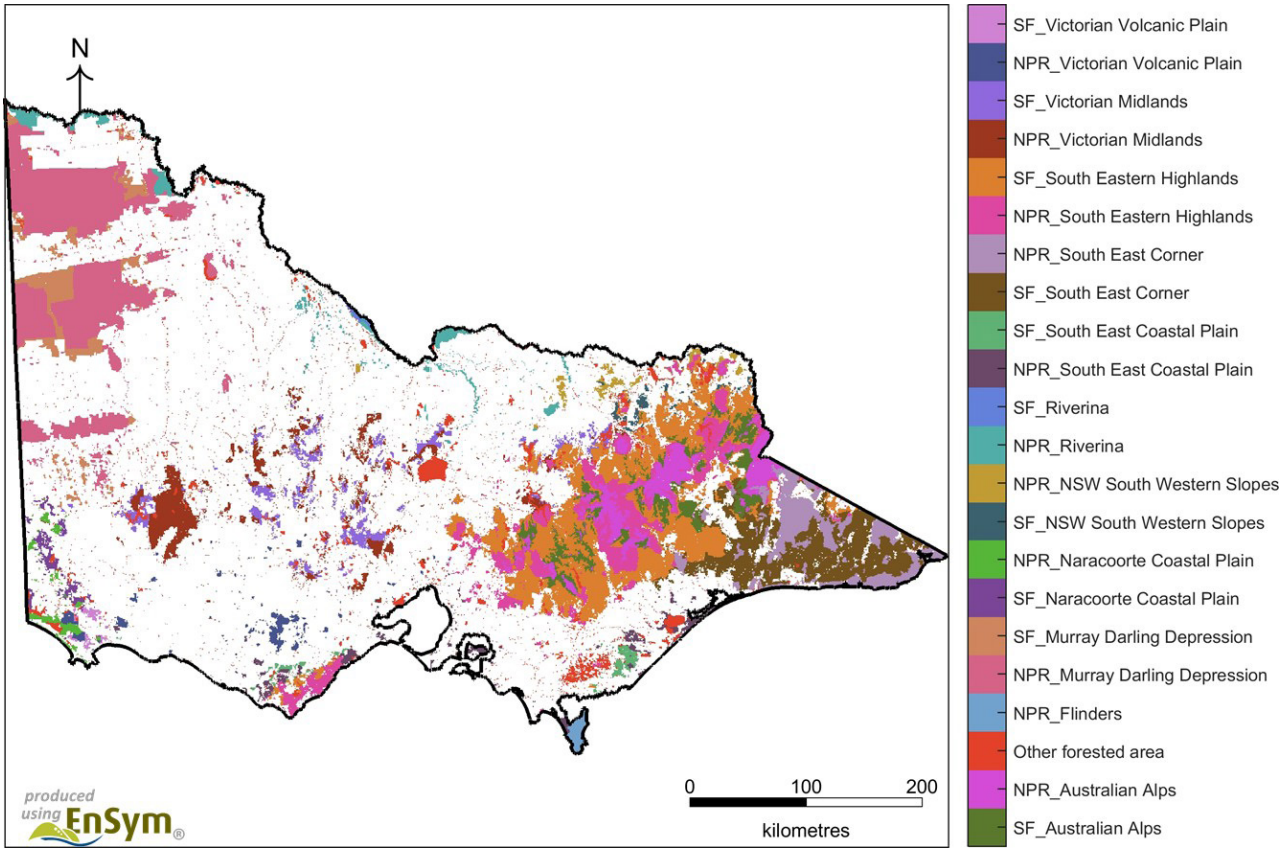


Figure Fo.34 Forest cover by bioregion/NRM class in Victoria

(Data source: DELWP, 2018)

Table Fo.31 Forested area in each bioregion/NRM class (per cent)

Bioregion	NRM Region	Area (ha)	Forest (%)
Australian Alps	Murray Basin	370,412	5
Flinders	Murray Basin	40,141	1
Murray–Darling Depression	Murray Basin	1,476,822	19
Naracoorte Coastal Plain	Murray Basin	67,847	1
NSW South Western Slopes	Murray Basin	68,926	1
Riverina	Murray Basin	211,861	3
South East Coastal Plain	Murray Basin	156,420	2
South East Corner	Murray Basin	429,514	5
South Eastern Highlands	Murray Basin	684,825	9
Victorian Midlands	Murray Basin	420,261	5
Victorian Volcanic Plain	Murray Basin	96,739	1
Australian Alps	Southern Slopes	336,865	4
Murray–Darling Depression	Southern Slopes	302,859	4
Naracoorte Coastal Plain	Southern Slopes	71,981	1
NSW South Western Slopes	Southern Slopes	43,108	1
Riverina	Southern Slopes	11,688	0
South East Coastal Plain	Southern Slopes	51,924	1
South East Corner	Southern Slopes	696,317	9
South Eastern Highlands	Southern Slopes	1,373,900	17
Victorian Midlands	Southern Slopes	284,708	4
Victorian Volcanic Plain	Southern Slopes	23,838	0
Other forested area	Southern Slopes	641,911	8
Total		**7,862,867**	**100**

(Data source: DELWP, 2018)

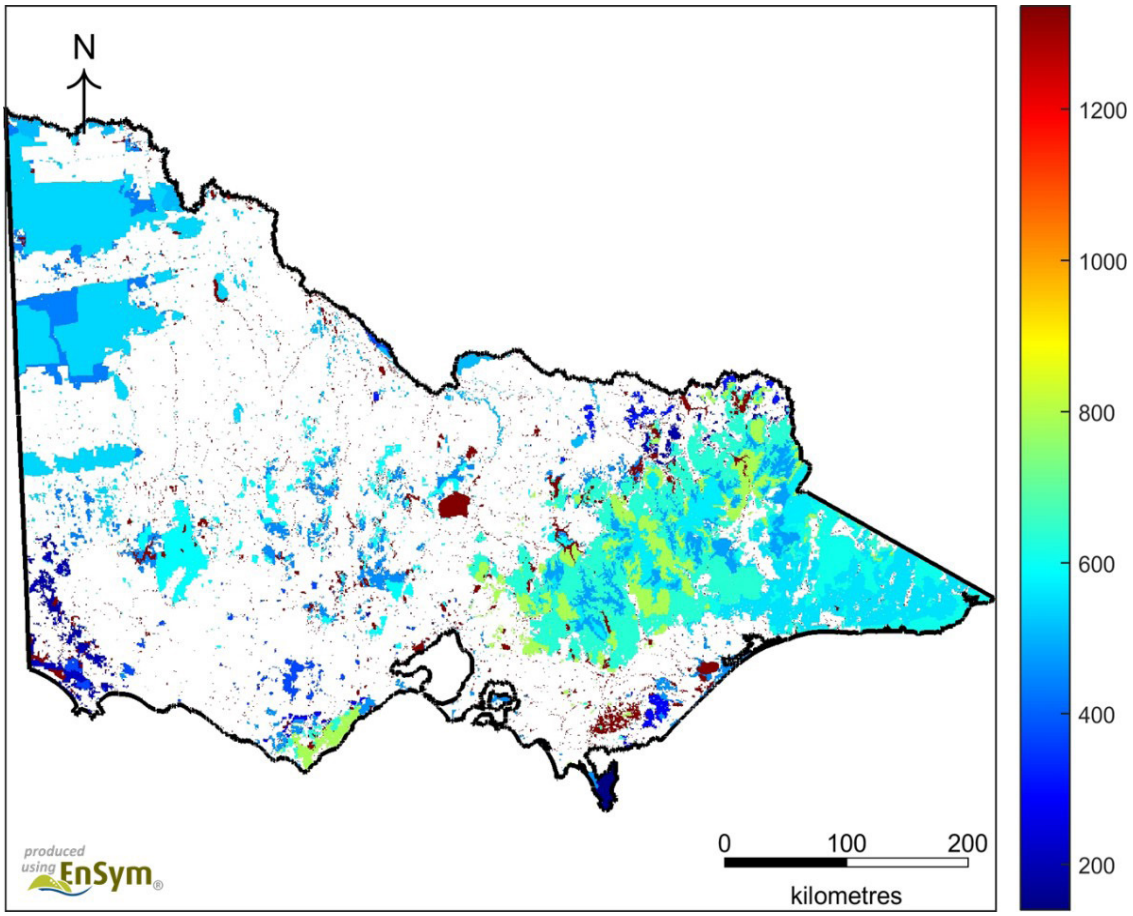


Figure Fo.35 Number of HDMs in each bioregion/NRM class in Victoria

(Data source: DELWP, 2018)

Figure Fo.36 is the same as Figure Fo.35, but with data classified for easier viewing. Note that there are large areas that intersect with more than 500 HDMs, suggesting that these forest areas may potentially provide valuable habitat services.

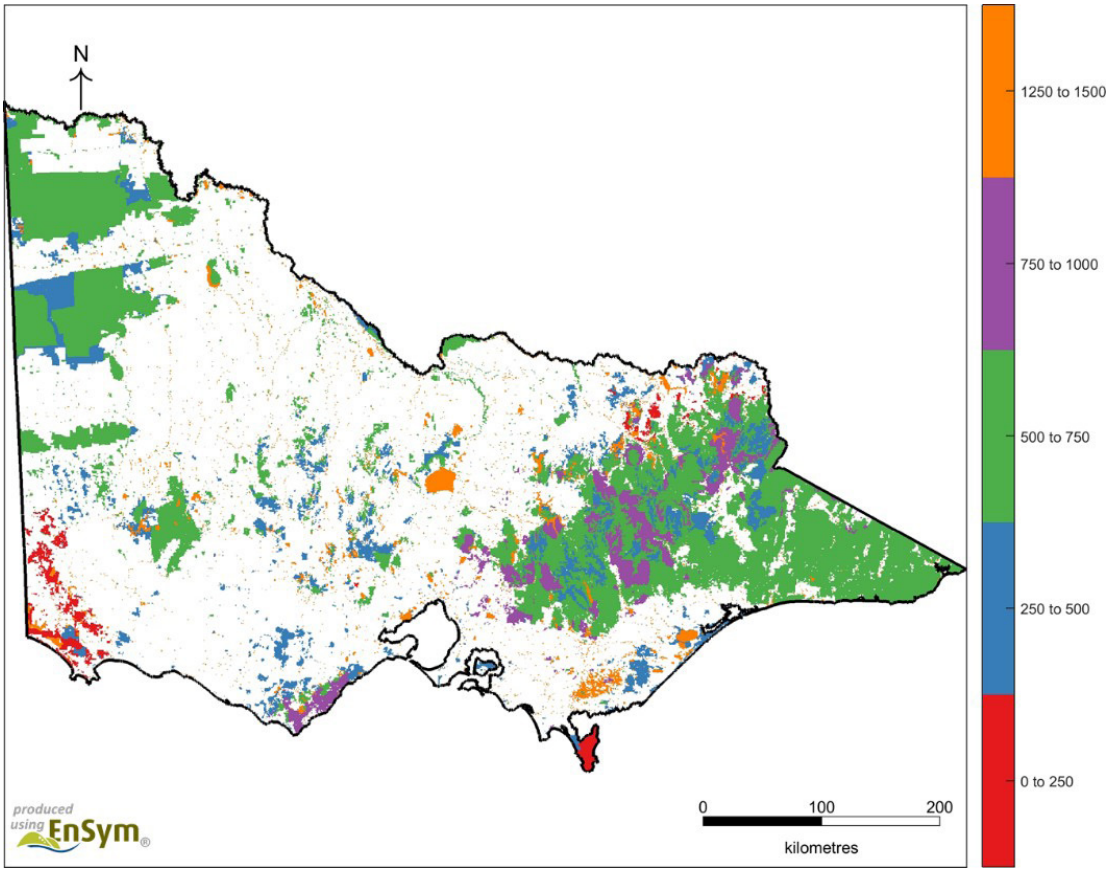


Figure Fo.36 Number of HDMs in each bioregion/NRM class in Victoria – grouped by count

(Data source: DELWP, 2018)

Table Fo.32 shows the potential species habitat presence for each bioregion/NRM class, out of the 1,750 species for which habitat distribution has been modelled. 9 out of 22 classes have potential habitat for species presence of greater than 500 species based on the HDMs. These nine bioregion/NRM classes represent 80% of the bioregion area. Note that the larger areas are expected to have an intersection with more species HDMs. Further work would be required to disaggregate the larger areas into specific management areas (for example, into regions and coupes) to gain a more accurate representation of the links to HDMs.

Table Fo.32 Number of HDMs for species within bioregion/NRM classes in Victoria

Bioregion	NRM region	Number of species HDM				
		Low		Medium		High
		0–250	250–500	500–750	750–1,000	1,250–1,500
Australian Alps	Murray Basin			✓		
Flinders	Murray Basin	✓				
Murray–Darling Depression	Murray Basin			✓		
Naracoorte Coastal Plain	Murray Basin	✓				
NSW South Western Slopes	Murray Basin		✓			
Riverina	Murray Basin			✓		
South East Coastal Plain	Murray Basin		✓			
South East Corner	Murray Basin			✓		
South Eastern Highlands	Murray Basin				✓	
Victorian Midlands	Murray Basin			✓		
Victorian Volcanic Plain	Murray Basin		✓			
Australian Alps	Southern Slopes		✓			
Murray–Darling Depression	Southern Slopes		✓			
Naracoorte Coastal Plain	Southern Slopes	✓				
NSW South Western Slopes	Southern Slopes	✓				
Riverina	Southern Slopes		✓			
South East Coastal Plain	Southern Slopes		✓			
South East Corner	Southern Slopes			✓		
South Eastern Highlands	Southern Slopes			✓		
Victorian Midlands	Southern Slopes		✓			
Victorian Volcanic Plain	Southern Slopes	✓				
Other forested area	Southern Slopes					✓
Total		**5**	**8**	**7**	**1**	**1**

(Data source: DELWP, 2018)

Table Fo.33 and Table Fo.34 show potential species habitat presence for each bioregion/NRM class, specifically for endangered and vulnerable species.

Table Fo.33 shows the potential endangered species habitat presence for each bioregion/NRM class. 6 classes have potential endangered species habitat presence of greater than 100 species, based on the HDMs. 10 bioregions have potential endangered species habitat presence of 50 to 100; 6 bioregions have potential endangered species habitat presence of less than 50.

Table Fo.33 Number HDMs for endangered species within bioregions/NRM classes in Victoria

Bioregion	NRM region	Number of endangered species HDM			
		0–50	50–100	100–150	250–300
Australian Alps	Murray Basin		P		
Flinders	Murray Basin	✓			
Murray–Darling Depression	Murray Basin			✓	
Naracoorte Coastal Plain	Murray Basin	✓			
NSW South Western Slopes	Murray Basin		✓		
Riverina	Murray Basin			P	
South East Coastal Plain	Murray Basin		✓		
South East Corner	Murray Basin		✓		
South Eastern Highlands	Murray Basin			✓	
Victorian Midlands	Murray Basin			✓	
Victorian Volcanic Plain	Murray Basin		✓		
Australian Alps	Southern Slopes	✓			
Murray–Darling Depression	Southern Slopes		✓		
Naracoorte Coastal Plain	Southern Slopes	✓			
NSW South Western Slopes	Southern Slopes	P			
Riverina	Southern Slopes		P		
South East Coastal Plain	Southern Slopes	P			
South East Corner	Southern Slopes		P		
South Eastern Highlands	Southern Slopes		P		
Victorian Midlands	Southern Slopes			P	
Victorian Volcanic Plain	Southern Slopes		P		
Other forested area	Southern Slopes				P
Total		**6**	**10**	**5**	**1**

(Data source: DELWP, 2018)

Table Fo.34 shows the potential vulnerable species habitat presence for each forest class. 10 forest classes have potential vulnerable species habitat presence of greater than 150 species, based on the HDMs. 6 forest classes have potential vulnerable species habitat presence of 100 to 150; 6 forest classes have potential vulnerable species habitat presence of less than 50.

Table Fo.34 Number of HDMs for vulnerable species within bioregions/NRM classes in Victoria

Bioregion	NRM region	Number of species HDM				
		50–100	100–150	150–200	200–250	400–450
Australian Alps	Murray Basin			✓		
Flinders	Murray Basin	✓				
Murray–Darling Depression	Murray Basin			✓		
Naracoorte Coastal Plain	Murray Basin	✓				
NSW South Western Slopes	Murray Basin		✓			
Riverina	Murray Basin			✓		
South East Coastal Plain	Murray Basin		✓			
South East Corner	Murray Basin			✓		
South Eastern Highlands	Murray Basin				✓	
Victorian Midlands	Murray Basin			✓		
Victorian Volcanic Plain	Murray Basin		✓			
Australian Alps	Southern Slopes		✓			
Murray–Darling Depression	Southern Slopes			✓		
Naracoorte Coastal Plain	Southern Slopes	✓				
NSW South Western Slopes	Southern Slopes	✓				
Riverina	Southern Slopes		✓			
South East Coastal Plain	Southern Slopes	✓				
South East Corner	Southern Slopes			✓		
South Eastern Highlands	Southern Slopes			✓		
Victorian Midlands	Southern Slopes		✓			
Victorian Volcanic Plain	Southern Slopes	✓				
Other forested area	Southern Slopes					✓
Total		**6**	**6**	**8**	**1**	**1**

(Data source: DELWP, 2018)

Case Study: accounting for water supply from forests

This case study shows how an environmental/economic accounting framework can be applied – both conceptually and quantitatively – to forest ecosystems to demonstrate the link between biophysical information and socio-economic benefits.

Asset extent and condition

As shown in Table Fo.35, and illustrated in Figure Fo.36, there are 3,499,602 hectares of forest across the prescribed water supply catchment (PWSC) areas that contain ash forest in Victoria. Of this, 459,393 hectares (or 13%) are eucalypt ash forest of mountain ash (*Eucalyptus regnans*) and alpine ash (*Eucalyptus delegatensis*). The largest extent of forest assets are in the catchment areas of Lake Hume, Mitchell River, Ovens River, Upper Goulburn and Tambo River. The largest extent of ash forest assets are in the catchment areas of Mitchell River, Lake Hume, Upper Goulburn and Upper Yarra.

Table Fo.35 Extent of forest assets by catchment area

PWSC with ash forest	Ash forest (ha)	Other forest (ha)	Other land cover (ha)	Total area (ha)
Armstrong Creek	2,039	2,074	73	4,186
Barham River	3,566	1,591	1,198	6,355
Bemm River	2,009	88,592	2,647	93,248
Britannia Creek	1,580	239	-	1,819
Brodribb River (Orbost)	455	91,903	1,247	93,605
Buchan River (Buchan)	10,930	67,629	3,072	81,631
Buckland River	6,414	25,520	446	32,380
Buffalo River (Lake Buffalo)	9,697	101,633	4,283	115,613
Bunyip River	3,084	859	32	3,975
Cann River	241	59,039	3,075	62,355
Cement Creek	808	0	0	808
Deep Creek & Loch River (Noojee)	6,686	4,691	517	11,894
Drouin	309	1,081	36	1,426
Gellibrand River	3,086	36,122	10,121	49,329
Gellibrand River (South Otway)	1,971	11,526	3,131	16,628
Glenmaggie	18,753	155,843	15,546	190,142
Kilmore	1,186	1,952	141	3,279
King River (Lake William Hovell)	8,469	24,303	258	33,030
Kinglake	5,006	5,913	89	11,008
Lake Hume	44,058	211,065	65,756	320,879
Lake Hume Northern Section	55,617	434,098	197,642	687,357
Lorne	1,001	1,651	28	2,680
Maroondah	13,605	4,135	197	17,937
McCraes Creek	192	353	0	545
McMahons Creek	3,689	728	8	4,425
Merrimans Creek (Seaspray)	27	31,748	21,896	53,671
Micks Creek	29	325	129	483
Mitchell River	58,553	315,098	17,349	391,000
Nicholson River	724	45,386	1,587	47,697
Ovens River (Bright)	7,503	25,088	2,070	34,661
Ovens River (Wangaratta)	5,153	148,930	143,344	297,427
Starvation Creek	3,532	88	25	3,645
Tambo River	18,476	202,815	49,227	270,518
Tanjil River	13,168	29,297	8,221	50,686
Tarago River	7,818	905	2,342	11,065

PWSC with ash forest	Ash forest (ha)	Other forest (ha)	Other land cover (ha)	Total area (ha)
Tarra River	391	2,201	237	2,829
Thomson River (stage 3)	5,540	8,886	738	15,164
Thomson River (stages 1,1a,2)	15,693	17,310	182	33,185
Tomahawk Creek (Gembrook)	287	30	0	317
Tyers River	7,039	22,085	2,834	31,958
Upper Barwon	1,475	12,608	1,210	15,293
Upper Goulburn	49,679	178,606	50,711	278,996
Upper Goulburn (Upper Delatite)	4,876	12,270	6,741	23,887
Upper Kiewa	15,435	17,717	7,549	40,701
Upper Kiewa (East Kiewa U2)	1,627	75	0	1,702
Upper Yarra	37,915	9,395	871	48,181
Total	**459,391**	**2,413,403**	**626,806**	**3,499,600**

(Data source: DELWP, 2018)

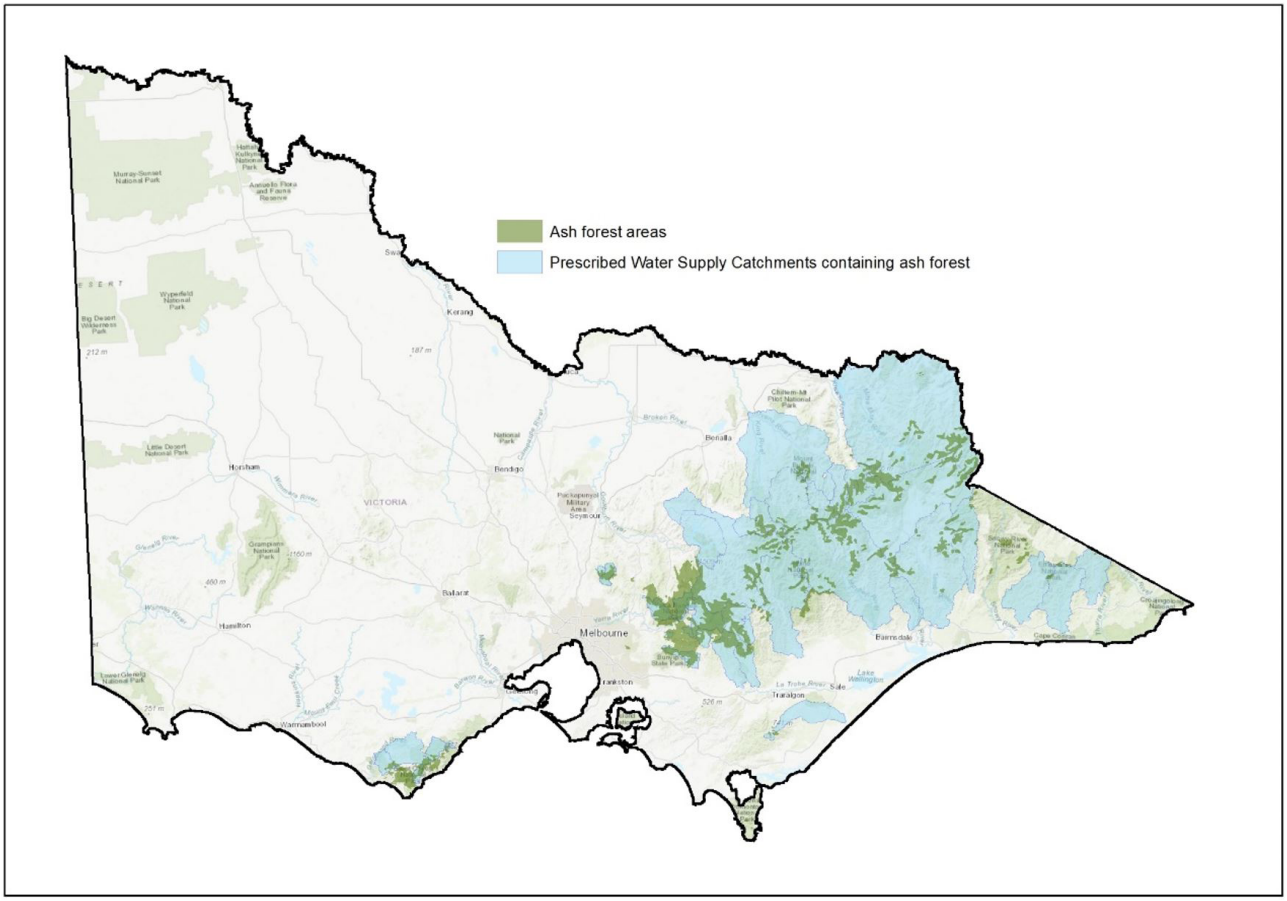


Figure Fo.37 Prescribed water supply catchments and ash forest extent in Victoria

(Data source: DELWP, 2018)

Ecosystem services and benefits

Forest assets provide a range of ecosystem services, as outlined in Figure Fo.39. This case study focuses on quantifying the water supply services provided by forest assets in the Kilmore, Mitchell River and Nicholson River catchment areas. Due to stream flow data limitations, absolute yearly flows could not be determined for other catchment areas listed in Figure Fo.39, including the Melbourne water catchments.

Asset extent

422,899 hectares of forest across Kilmore, Mitchell and Nicholson catchments:

- 60,463 hectares of ash forest
- 362,436 hectares of other forest

Condition

63 per cent of ash forest across Kilmore, Mitchell and Nicholson catchments has been disurbed since 1989, comprising:

- 62 per cent of ash forest disturbed by fire
- 1 percent of ash forest disturbed by logging

Services

Habitat

Water supply and filtration

Climate regulation (carbon sequestration)

Temperature regulation

Nourishment for bees

Opportunities for recreation and tourism

Opportunities for cultural connection

Landscape

Benefits

Water

Climate change mitigation

Timber resources

Pollination services

Recreation and tourism

Figure Fo.38 Forests in an environmental / economic accounting framework

(Data source: DELWP, 2018)

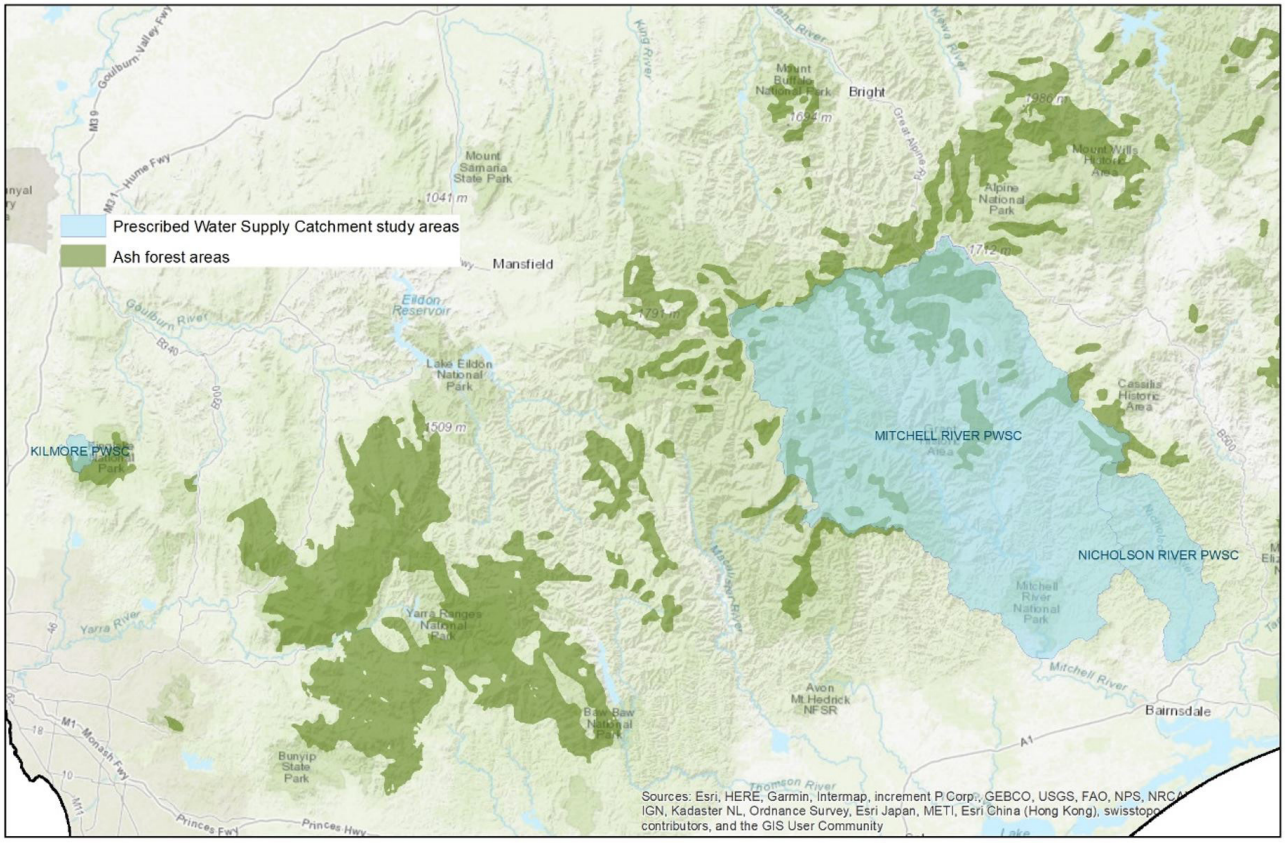


Figure Fo.39 Case study catchment areas

(Data source: DELWP, 2018)

The extent of forest ecosystem assets and yearly flow of water supply services for the three catchment areas is presented in Table Fo.37 and Table Fo.37. In 2017, the Kilmore PWSC area supplied 1,646 ML of water, the Mitchell River PWSC area supplied 504,098 ML of water, and the Nicholson River PWSC area supplied 4,979 ML of water.[179]

Table Fo.36 Forest ecosystem asset extent across three catchments

Forest type	Kilmore (ha)	Mitchell (ha)	Nicholson (ha)	Total (ha)
Ash forests	1,186	58,553	724	60,463
Other forests	1,952	315,098	45,386	362,436
Other land cover	141	17,349	1,587	19,077
Total	**3,279**	**391,000**	**47,697**	**441,976**

(Data source: DELWP, 2018)

Table Fo.37 Ecosystem-service flow – water supply – for three catchments, 2013-17

Catchment	Recorded annual flow (ML) – actual				
	2013	2014	2015	2016	2017
Kilmore	3,767	2,891	1,570	2,245	1,646
Mitchell River	841,139	519,979	486,647	1,125,627	504,098
Nicholson River	37,303	38,891	51,950	62,492	4,979
Total	**882,209**	**561,761**	**540,167**	**1,190,364**	**505,744**

(Data source: DELWP, 2018)

Table Fo.37 shows the annual flow of water-supply ecosystem services. However, to understand and value the benefit for the economy and society, the relevant agencies must develop an understanding of water-use.

An example in the context of the Mitchell River is useful. The largest remaining river system in Victoria that is not dammed, it provides valuable irrigation water to Lindenow Valley farmers in East Gippsland, as well as supplying urban water users. The Mitchell River supplies water to Bairnsdale and Paynesville, and to towns in adjacent river basins including Bruthen, Nicholson, Nowa Nowa, Johnsonville, Swan Reach, Metung and Lakes Entrance. It also supplies environmental flows to the Gippsland Lakes.

The Mitchell River underpins a substantial economic base in the region, including irrigated agricultural production, tourism, a growing number of small businesses and manufacturers, and an increasing population. The Gippsland Lakes are important environmental assets and are partially dependent on water from the environmental water reserve in the Mitchell Basin. The lakes are listed as internationally significant wetlands under the Ramsar Convention and rely on freshwater inputs from the Mitchell Basin to function ecologically. Other environmental assets that rely on the environmental water reserve include heritage river reaches, fish populations (Australian grayling, black bream), waterbirds (great egret) and botanical values (yellowwood).

179. Stream gauge data sourced from the Victorian Water Measurement Information System (WMIS) http://data.water.vic.gov.au/monitoring.htm Accessed 4 December 2018.

Diversions take out a relatively small proportion of total inflows, varying from approximately 1.5% during wetter years to 4.5% during drier years.[180] Applying these proportions to the amount of water supplied annually from forest assets gives the volumes outlined in Table Fo.38. In 2017, water supply that can be attributed to diversion for use was estimated at 7,561 ML to 22,684 ML.

Table Fo.38 Water supply to Mitchell River – diversions (ML), 2013-17

	2013	2014	2015	2016	2017
Lower bound (1.5%)	12,617	7,800	7,300	16,884	7,561
Upper bound (4.5%)	37,851	23,399	21,899	50,653	22,684
Total	**50,468**	**31,199**	**29,199**	**67,537**	**7,561**

(Data source: DELWP, 2018)

For the forest assets supplying regional and rural Victoria, water supply can be valued for agricultural users and regional townships using current entitlement prices.[181] This valuation approach is conservative, because the value of water to households is likely to be higher than for irrigated agriculture in many situations.

The value of water yields flowing to regulated rivers can be calculated using average high-reliability entitlement prices ($1,350/ML) across Victorian-regulated trading zones. This approach reflects the fact that the water is callable from water storages, and high-reliability entitlements are, therefore, the appropriate valuation basis.

The value of water yields flowing to unregulated rivers can be calculated using low-reliability entitlement prices ($190/ML) across Victorian unregulated trading zones. For unregulated flows outside trading zones (such as flows to Bass Strait), a zero value can be assumed, as these are likely non-consumptive uses. This approach yields conservative valuation estimates.

As the Mitchell River is an unregulated (undammed) river, applying the second value to the proportion of annual water supply from forest assets that is expected to be diverted gives an estimated value of the benefit from ecosystem services of between $1.4 million and $4.3 million in 2017. There are also additional benefits from environmental flows which have not been estimated.

180. Southern Rural Water 2014, 'Local Management Plan: Mitchell River Basin', Maffra, Victoria http://www.srw.com.au/files/Local_management_rules/Mitchell_River_Basin_LMP_January_2014.pdf Accessed 4 December 2018.

181. This valuation approach was used in Varcoe T, Betts O'Shea H, Contreras Z 2015, 'Valuing Victoria's parks: Accounting for ecosystems and valuing their benefits', DELWP and PV, Melbourne, Victoria https://parkweb.vic.gov.au/__data/assets/pdf_file/0010/695764/Valuing-Victorias-Parks-Report-Accounting-for-ecosystems-and-valuing-their-benefits.pdf Accessed 4 December 2018.

Impact of ash forest disturbance on water-supply services

Major disturbance to ash forests, and subsequent seed-bed regeneration, causes major reductions in water yield for up to 100 years, peaking at approximately 33 years post-disturbance with approximately 50% reductions in flow.[182] Post-1989 disturbance in the Kilmore, Mitchell River and Nicholson River catchment area is illustrated in Table Fo.39.[183] Theoretical maximum water yield from these catchments has been modelled and is reported in Table Fo.40. Theoretical maximum water yield has been calculated using the 3PG+ model within the EnSym[184] framework, assuming no forest disturbance since the 1939 'Black Friday' bushfires. This will create a conservative maximum yield estimate, as the water-yield impact of the 1939 Black Friday bushfires are still being experienced and will not return to normal until the middle of this century.

The difference between actual recorded flows and theoretical maximum flows is reported in Table Fo.40. For instance, if there was no ash forest disturbance post-1939 in the Mitchell River catchment area, there would have been an additional 18,503 ML of water supply in 2017. This type of analysis can help to assess the potential impacts of fire, fire management and forest harvesting on forest assets and the ecosystem services they provide.

Table Fo.39 Forest ecosystem asset condition across three catchments, since 1989

	Kilmore (ha)	**Mitchell** (ha)	**Nicholson** (ha)	**Total** (ha)
Ash disturbed by fire since 1989 (%)	87	61	54	62
Ash disturbed by logging since 1989 (%)	5	1	4	1
Total ash disturbed since 1989 (%)	92	62	58	63

(Data source: DELWP, 2018)

182. Kuczera G 1987, 'Prediction of water yield reductions following a bushfire in ash-mixed species eucalypt forest', Journal of Hydrology, 94(3-4), pp. 215-236.
183. CRCSI, '4.104 LandFor: Landsat for forests – a monitoring and forecasting framework for the sustainable management of SE Australian forests at the large area scale', Docklands, Victoria http://www.crcsi.com.au/research/4-1-agriculture-natural-resources-and-climate-change/4-104-landfor-landsat-for-forests/ Accessed 4 December 2018.
184. DELWP, 'EnSym native vegetation regulations tool', Melbourne, Victoria https://ensym.biodiversity.vic.gov.au/cms/ Accessed 4 December 2018.

Table Fo.40 Ecosystem-service flow – theoretical maximum water supply from forest assets in three catchments, 2013-17

Catchment	Theoretical maximum annual flow with no post-1939 ash forest disturbance (ML)				
	2013	2014	2015	2016	2017
Kilmore	6,511	4,776	2,732	3,567	2,853
Mitchell River	857,006	535,634	506,186	1,144,856	522,601
Nicholson River	38,234	39,823	52,749	63,525	5,301
Total	**895,240**	**575,457**	**558,935**	**1,208,381**	**522,601**

(Data source: DELWP, 2018)

Table Fo.41 Ecosystem-service flow – theoretical loss of water supply due to disturbance in three catchments, 2013-17

Catchment	Theoretical additional recorded annual flow (ML) under a no post-1939 ash forest disturbance, compared to actual recorded flow				
	2013	2014	2015	2016	2017
Kilmore	2,744	1,885	1,161	1,322	1,207
Mitchell River	15,867	15,655	19,539	19,228	18,503
Nicholson River	931	932	799	1,033	322
Total	**16,798**	**16,587**	**20,338**	**20,261**	**18,825**

(Data source: DELWP, 2018)