FIRE (Fi)

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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Fire

The Fire chapter has four indicators that discuss the impacts of bushfire and planned burns on humans, property and biodiversity. This chapter does not provide comprehensive discussions about fire ignition control, which includes aerial attack capability and the overall likely impact of climate change on the Victorian community. Instead, this chapter focuses on the link between climate change and fire. In addition, this chapter does not provide detailed information and interpretation of each threatened fauna species in relation to fire, but demonstrates a need for a dual-scale (state and regional) approach for successful biodiversity monitoring in response to fire in Victoria.

Background

Fire regimes play a vital, yet complex role in Victorian ecosystems, which provide habitat for a diverse range of fire-adapted native flora and fauna species, with some plant species only germinating after stimulation by heat or smoke. The beneficial effects of fire on ecosystem processes are well researched. Locally, fire catalyses plant nutrient cycles by decomposing organic materials into available nutrients that provide fertile soil conditions. At the landscape level, fire assists key processes such as tree decay, tree collapse and stand tree germination.[1, 2, 3, 4] However, unanticipated or inappropriate fire regimes will impact dangerously on the survival of threatened flora and fauna species. These ecological complexities highlight another important aspect of optimising fire management in Victoria.

1. Lindenmayer DB, Blanchard W, Blair D, McBurney L 2018, 'The road to oblivion – quantifying pathways in the decline of large old trees', Forest Ecology and Management, 430, pp. 259-264.
2. Lindenmayer DB, Blanchard W, Blair D, McBurney L, Banks SC 2018, 'Empirical relationships between tree fall and landscape-level amounts of logging and fire', PLOS One, 13(2), e0193132.
3. Lindenmayer DB, Blanchard W, McBurney L, Blair D, Banks S, Likens GE, Franklin JF, Stein J, Gibbons P 2012, 'Interacting factors driving a major loss of large trees with cavities in an iconic forest ecosystem', PLOS One, 7, e41864.
4. Smith AL, Blair D, McBurney L, Banks SC, Barton PS, Blanchard W, Driscoll DA, Gill AM, Lindenmayer DB 2014, 'Dominant drivers of seedling establishment in a fire-dependent obligate seeder: climate or fire regimes?' Ecosystems, 17, pp. 258-270.

Compounded by population growth and residential incursion into previously uninhabited forest areas, the risk of fire to people and property has increased. It is estimated that about $8.5 billion (or 1.15%) of Australia's gross domestic product accounts for the total annual cost of fires in Australia.[5] In Victoria, the economic cost of the 2009 Black Saturday fires was evaluated as $4.4 billion.[6]

Fire managers and communities must plan for more frequent and extreme bushfire events.[7, 8] It is predicted that Victoria will encounter more dangerous conditions than other states.[9] Climate change predictions show the likely impact on biodiversity, with some effects being noticed already – such as changes in plant growth rates, fuel loads and moisture content, as a result of longer periods of weather associated with high fire risk.[10] Although many native Australian flora and fauna species are tolerant of individual fires, an increase in fire intensity and frequency may impose a variety of negative impacts on biodiversity. Some habitats and species are more likely to be adversely influenced than others.[11] In addition, the *Flora and Fauna Guarantee Act 1988* listed inappropriate fire regimes and high-frequency fires as potentially threatening processes to the survival of flora and fauna in Victoria.

5. Ashe B, Mc Aneney KJ, Pitman AJ 2009, 'Total cost of fire in Australia' Journal of Risk Research, 12, pp. 121-136.
6. Teague B, McLeod R, Pascoe S 2010, '2009 Victorian Bushfires Royal Commission Final Report', 2009 Victorian Bushfires Royal Commission, Parliament of Victoria, Melbourne, Victoria http://royalcommission.vic.gov.au/finaldocuments/summary/PF/VBRC_Summary_PF.pdf Accessed 4 December 2018.
7. Hughes L 2003, 'Climate changes and Australia: trends, projections and impacts', *Austral Ecology*, 28, pp. 423-443.
8. Downie C 2006, 'Heating up: bushfires and climate change'. The Australia Institute, Manuka, ACT. http://www.tai.org.au/sites/defualt/files/WP92_8.pdf Accessed 4 December 2018.
9. Dowdy JA 2018 'Climatological variability of fire weather in Australia', Journal of Applied Meteorology and Climatology, 57, pp. 221-234.
10. Enright NJ, Fontaine JB, Bowman DMJS, Bradstock R, Williams RJ 2015, 'Interval squeeze: altered fire regimes and demographic responses interact to threaten woody species persistence as climate changes', Frontiers in Ecology and the Environment, 13, pp. 265-272.
11. Williams D, Bowman D, Little J 2014, 'Climate Change, Fire and Terrestrial Biodiversity: information sheet six', James Cook University, Townsville, Queensland http://nccarf.jcu.edu.au/terrestrialbiodiversity/documents/information_sheet_6_fire_final.pdf Accessed 4 December 2018.

Smoke from fires (planned burns and bushfires) has health implications for surrounding communities. In some cases, the area of effect can expand to 50 km from the source of the fire.[12] Particulate matter and noxious gases associated with smoke can reduce air quality in rural and urban areas and may affect people's health.[13] In addition, smoke can also have economic impacts – tainting grapes, for example,[14] or forcing road closures that prevent or delay transportation of goods and services,[15] and hinder emergency transport. The critical challenges facing Victoria's bushfire management now and in the future include:

- minimising the impact of major bushfires on human life, communities, essential and community infrastructure, industries, the economy and the environment
- monitoring responses of biodiversity (flora and fauna) to both planned burns and bushfires on regional and state scales
- maintaining or improving the resilience of natural ecosystems and their ability to deliver services such as biodiversity, water, carbon storage and forest products[16]
- maintaining the persistence of key fire-response species to increasing fire frequency and intensity
- increasing community awareness and establishing effective emergency management systems, especially in peri-urban areas
- developing a structured framework for analysing the impacts of bushfires on human life and property
- protecting human health from more frequent smoke exposure.

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12. Goodrick SL, Achtemeier GL, Larkin NK, Liu Y, Strand TM 2013, 'Modelling smoke transport from wildland fires: a review', International Journal of Wildland Fire, 22, pp. 83-94.
13. Health Victoria, 'Bushfire smoke and planned burns', Melbourne, Victoria. https://www2.health.vic.gov.au/public-health/environmental-health/climate-weather-and-public-health/bushfires-and-public-health/bushfire-smoke-and-planned-burns Accessed 4 December 2018.
14. Whiting J, Krstic M 2007, 'Understanding the sensitivity to timing and management options to mitigate the negative impacts of bush fire smoke on grape and wine quality-scoping study', Project report (MIS No. 06958 and CMI No. 101284), Victorian Department of Primary Industries, Knoxfield, Victoria https://www.wineaustralia.com/getmedia/7e0159f4-037c-42e5-a642-05585f07be9e/200707_Understanding-impacts-of-bush-fire-smoke.pdf Accessed 4 December 2018.
15. Stephenson C 2010, 'A literature review on the economic, social and environmental impacts of severe bushfires in south-eastern Australia', Fire and adaptive management Report no.87, Bushfire CRC, East Melbourne, Victoria https://www.ffm.vic.gov.au/__data/assets/pdf_file/0009/21114/Report-87-A-Lit.Rvw-On-The-Economic,-Social-and-Envtal-Impacts-of-Severe-Bushfires-In-SE-Aust..pdf Accessed 4 December 2018.
16. DSE 2012, 'Code of practice for bushfire management on public land', Melbourne, Victoria https://www.ffm.vic.gov.au/__data/assets/pdf_file/0006/21300/Code-of-Practice-for-Bushfire-Management-on-Public-Land.pdf Accessed 4 December 2018.

Current Victorian Government Settings: Legislation, Policy, Programs

The Victorian Government published *Safer Together: A New Approach to Reducing the Risk of Bushfire in Victoria* in 2015 based on recommendations from the Inspector-General for Emergency Management (IGEM). *Safer Together* adopts a risk reduction target, replacing the previous hectare target approach to bushfire fuel management on public land. This approach enables the government to act more strategically, by planning and implementing risk-reduction activities in areas that will derive the greatest benefit. The government has committed to maintaining residual bushfire risk at or below 70%. In addition, the Department of Environment, Land, Water and Planning (DELWP), along with the Country Fire Authority (CFA) and Forest Fire Victoria, now involves local communities in prioritising fuel management activities and identifying opportunities to reduce risk across all land tenures.

Since the new approach was initiated, IGEM has published two monitoring reports that review DELWP's progress in response to the recommendations.[17] These recommendations are to reform bushfire risk management since the 2015 review and investigation. All of four recommendations are being implemented as part of *Safer Together*. The recommendations will be continually monitored as part of ongoing assurance activities, including breaches of planned burn control lines.

Underpinning the government's efforts to reduce risk of bushfires is the Code of Practice for Bushfire Management on Public Land. The code was adapted from its 2006 iteration, following the 2009 Victorian Bushfires Royal Commission. Risk-based planning, where human life is afforded the highest priority, is a fundamental part of the code; however, it also recognises the impacts of fire on the natural environment and thereby considers risk to human life, infrastructure and ecological assets within its approach.

17. Inspector-General for Emergency Management Victoria 2017, 'Annual report: implementation of recommendations on bushfire fuel management', Melbourne, Victoria https://www.igem.vic.gov.au/sites/default/files/embridge_cache/emshare/original/public/2018/01/6d/d7d449083/Annual_Report_Implementation_of_bushfire_fuel_management_recommendations_2017.pdf Accessed 4 December 2018.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fi:01 Area of native vegetation burnt in planned fires and bushfires		●			↘	DATA QUALITY Good
Data custodian DELWP						

Until 2015–16, the Victorian Government had an annual planned-burning target. Prior to 2010–11, the annual target was 130,000 hectares. This increased to 200,000 hectares in 2010–11, 225,000 hectares in 2011–12 and 250,000 hectares in 2012–13. These increases were responses to recommendations from inquiries into large fires since 2002, including the 2009 Victorian Bushfires Royal Commission, which recommended an annual planned-burning target of 390,000 hectares (from 1.3% to 5% of public land).[18] The annual planned-burning targets aimed to reduce risks to life and property.

Planned burns are always dependent on weather and fuel conditions. Burning is not possible when conditions are too hot and dry, nor when conditions are too wet. Weather conditions therefore dictate the amount of burning carried out in a given year to meet planned-burning targets, and account for much of the annual fluctuations.

In order to meet the targets each year, the Victorian Government progressively increased the annual planned-burning area until 2012–13. The following year (2013–14) provided very few days that permitted planned burns. Regular showers and unstable weather conditions, especially in the Far South West, Otways and Midlands districts, limited burning opportunities. As a result, DELWP was only able to treat 82,022 hectares through planned burns. The subsequent years also had few days when planned burns could be conducted, resulting in burning of less than the annual target of 390,000 hectares until 2015–16.

In 2016–17, the annual burn area target was abolished, based on the recommendations from IGEM, and replaced by a risk-reduction target. In response to the recommendations, DELWP initiated the Safer Together program,[19] which is in development and will be fully functional for forest fuel management by 2020.

Between 2003–04 and 2016–17, just over 2 million hectares of native vegetation was burnt in planned fires in Victoria (Figure Fi.1). Much of the ecological and fuel-reduction burns were concentrated on the eastern part of Victoria (Figure Fi.2). The majority of planned burns (86%) were carried out for fire suppression purposes by reducing fuel levels. While the area of the fuel-reduction burn has been decreasing from a maximum of 94% in 2006–07 to 76% in 2016–17 (Figure Fi.1), ecological-burn activities have proportionally increased from 3% to 22% over the same period. The increase in planned-burning area since 2009–10 was a response to recommendations by royal commissions[18] that opportunities for planned burns should be maximised where possible to reduce fuel loads in Victorian forests. However, such recommendations do not adequately address aspects of forest ecosystem health, such as the risk of extinction in a range of native species. Biodiversity in the Mallee shrublands and in the woodlands of north-western Victoria is particularly at risk.[20]

18. State of Victoria 2012, 'Bushfire Royal Commission Implementation Monitor: Final report 2012', State of Victoria, Melbourne, Victoria https://www.igem.vic.gov.au/sites/default/files/embridge_cache/emshare/original/public/2017/07/01/d8b8a164d/Publication%20-%20brcim_final_report_July%202012.PDF Accessed 4 December 2018.

19. DELWP 2015, 'Safer Together: A new approach to reducing the risk of bushfire in Victoria', Melbourne, Victoria http://www.delwp.vic.gov.au/__data/assets/pdf_file/0004/319531/DELWP_SaferTogether_FINAL_17Nov15.pdf Accessed 4 December 2018.

20. Giljohann KM, McCarthy MA, Regan TJ 2015, 'Choice of biodiversity index drives optimal fire management decisions', Ecological Applications, 25(1), pp. 264-277.

Since 2015–16, the hectare-based target has shifted from a hectare-based approach to a risk-based approach for fire management. The new risk-based approach focuses on strategic areas near housing and infrastructure where there is a high chance of fire impacting on people and property. This shift is also in-line with research that demonstrates that fuel treatments close to property will more effectively mitigate impacts from bushfires in peri-urban communities than standard (hectare-based approaches).[21] But significant risk of human loss from bushfires still remains, depending on the rate of fuel treatment.[22] More information can be found in the indicator Fi:04 Bushfire risk.

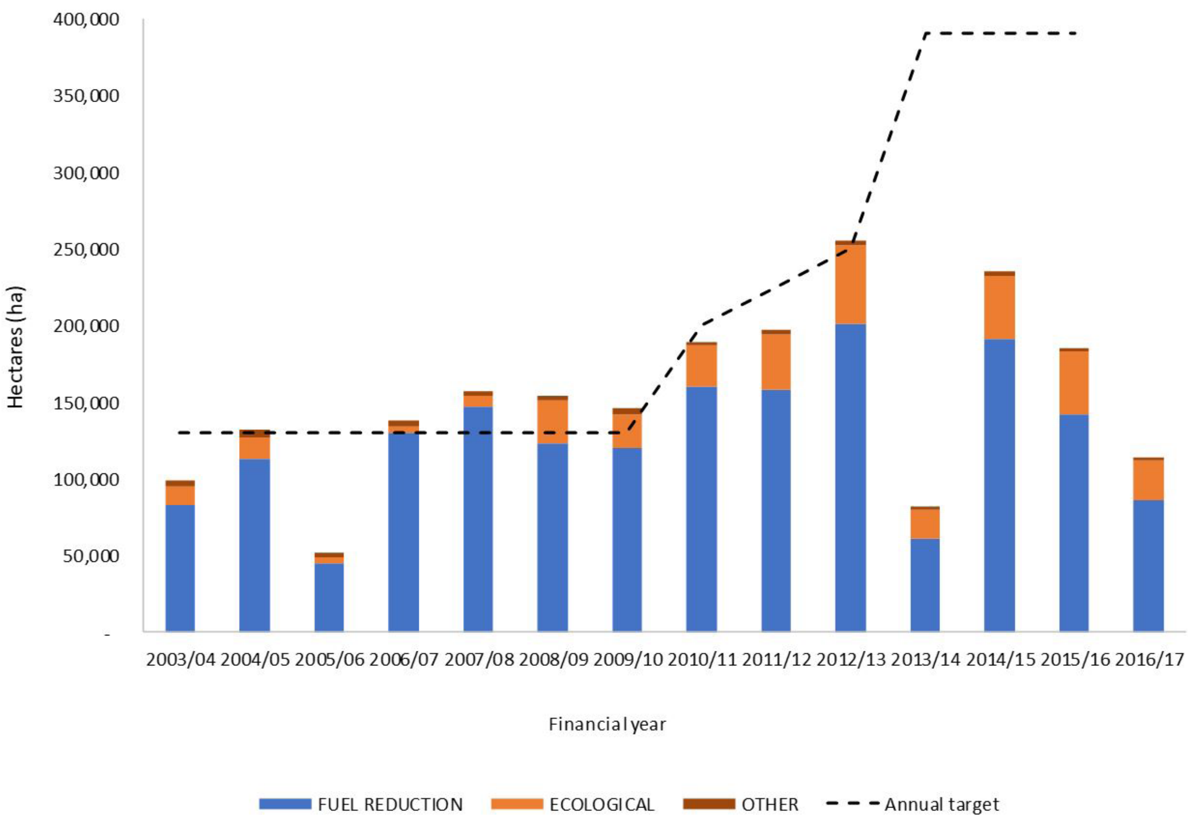

Figure Fi.1 Area of planned burns by type, 2003–04 to 2016–17

(Data source: DELWP, 2018)

21. Gippsons P, van Bommel L, Gill AM, Cary GJ, Driscoll DA, Ross A, Bradstock RA, Knight E, Moritz MA, Stephens SL, Lindenmayer DB 2012, 'Land management practices associated with house loss in wildfires'. PLOS One, 7, e29212.
22. Bradstock RA, Cary GJ, Lindenmayer, Price OF, Williams RJ 2012, 'Wildfires, fuel treatment and risk mitigation in Australian eucalypt forests: insights from landscape-scale simulation', Journal of Environmental Management, 105, pp. 66-75.

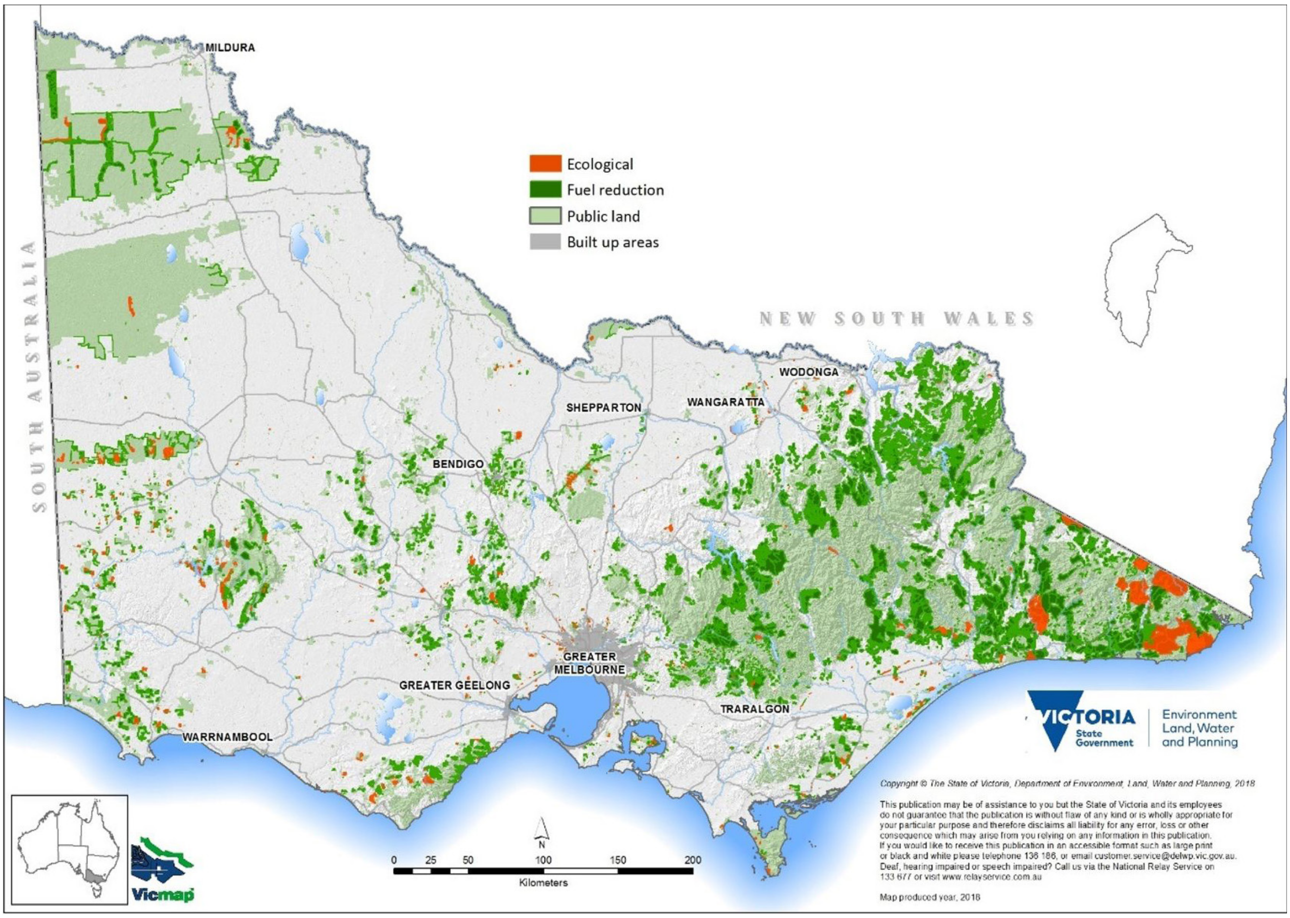

Figure Fi.2 Map of planned-burn areas in Victoria, 2000–2017

(Data source: DELWP, 2018)

Area of Planned Burns by Region and Fire District

DELWP applies fire management plans throughout six Victorian regions: Hume, Gippsland, Port Phillip, Grampians, Loddon Mallee and Barwon South West. Each region is comprised of several districts. The Gippsland region accounted for the largest area of planned burns between 2003–04 and 2016–17, with 829,000 hectares or 39% of the total planned-burning area. The Hume region was the second-largest area, with 621,000 hectares or 29% of the total planned-burning area. The high proportion of the state's planned burns in Gippsland and Hume (Figure Fi.3) is explained by the extent of public land close to assets in these regions, which has remained relatively consistent over time. The Snowy district in the Gippsland region was subject to extensive planned burns over the period, accounting for 19% (403,000 hectares). Upper Murray, in the Hume region, and Tambo, also in the Gippsland region, had 14% (293,000 hectares) and 12% (250,000 hectares) of the total area burnt over the period respectively (Figure Fi.4).

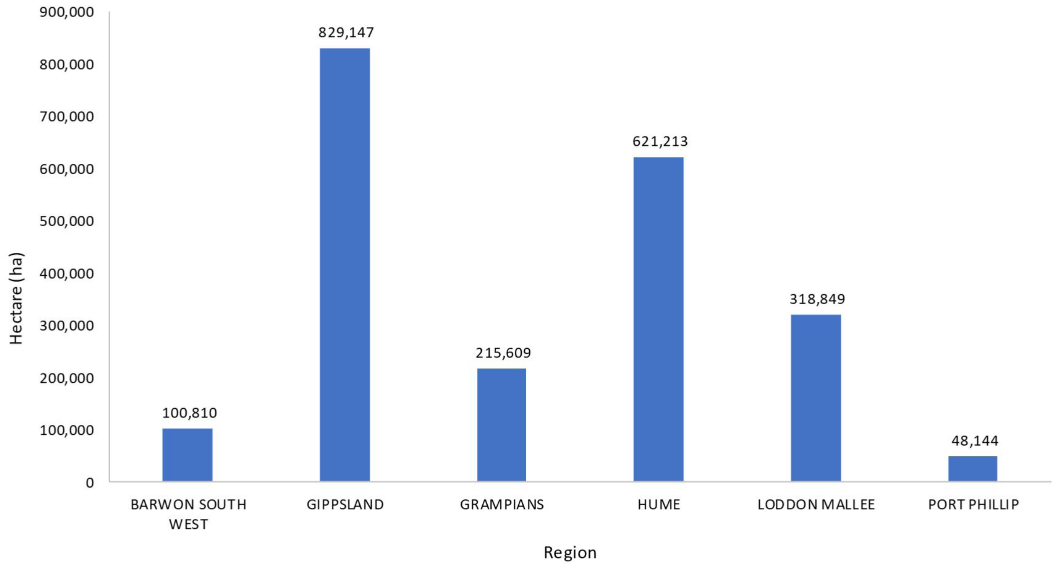

Figure Fi.3 Cumulated planned-burning area in Victoria by region, 2003–04 to 2016–17

(Data source: DELWP, 2018)

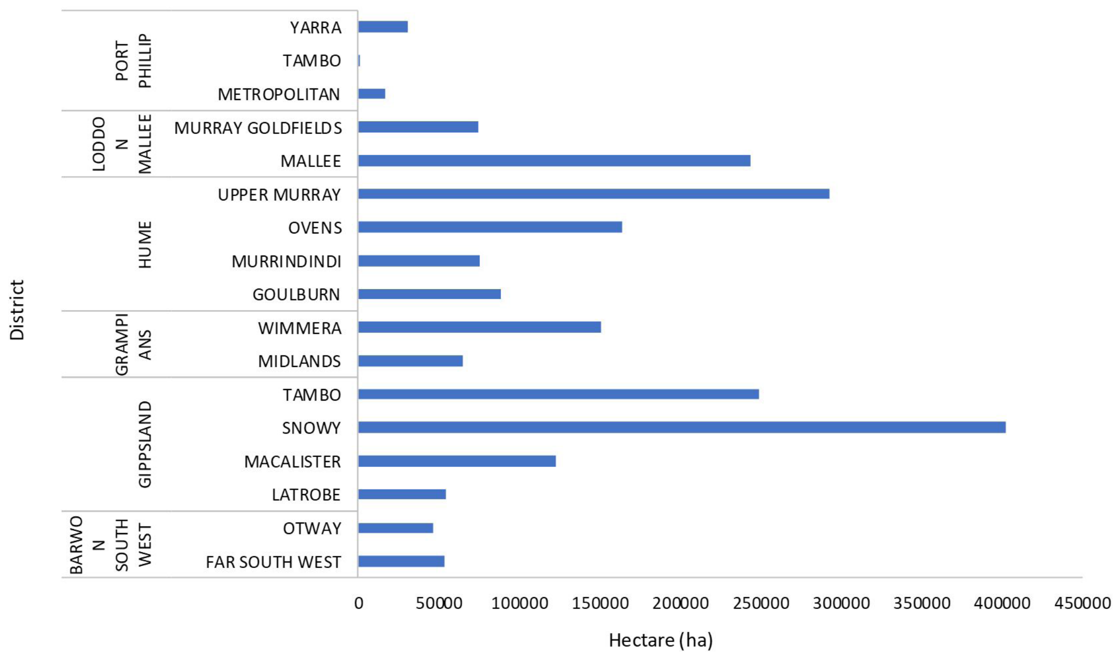

Figure Fi.4 Cumulated planned-burning area in Victoria by fire district, 2003–4 to 2016–17

(Data source: DELWP, 2018)

Area Burnt by Bushfire

More than 85% of the area burnt by bushfire in Victoria between 2003–04 and 2016–17 was burnt in four extensive bushfires between 2003 and 2017: 2003 (1.6 million hectares), 2007 (1.2 million hectares), 2009 (446,000 hectares) and 2014 (415,000 hectares). The 2003, 2007 and 2009 bushfires occurred during the millennium drought of 1996 to 2010, which increased the frequency and severity of large bushfires (Figure Fi.5 and Figure Fi.6).

In 2013–14, Victoria experienced its most significant fire season since 2008–09, challenging both emergency services and Victorian communities. Across the season, Victoria had 19 days of 'extreme' and 'severe' fire danger rating, and 16 days of 'total fire ban'. More than 463,000 hectares of public and private land was burnt, and 80 residences were destroyed.[23] The respective land management and fire agencies (including the CFA and DELWP, and their Networked Emergency Management partners – Parks Victoria, VicForests and Melbourne Water (DEPI/NEO) – and the Metropolitan Fire Brigade) responded to more than 4,600 bushfires and grassfires over a five-month period.

The Hazelwood mine fire also occurred in 2014, releasing significant amounts of smoke and ash that settled on the adjacent township of Morwell.[24] Following the fire, IGEM identified issues around the initial availability of air-quality monitoring, health-monitoring data, decision-making protocols and community information. These issues were addressed through two inquiries into the fire and the EPA inquiry, and their recommendations are now being implemented are now being implemented, as discussed in indicator A:09 (Health impacts of air pollution).[25]

Subsequent years up to 2017 have seen relatively low fire activity.

23. Emergency Management Victoria 2014, 'Post season operations review: Fire danger period 2013/14', Melbourne, Victoria https://www.emv.vic.gov.au/publications/post-season-operations-review-2013-14 Accessed 4 December 2018.
24. Environmental Protection Australia Victoria 2015, 'Summarising the air monitoring and conditions during the Hazelwood mine fire, 9 February to 31 March 2014', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1598.pdf Accessed 4 December 2018.
25. Hazelwood Mine Fire Inquiry 2014, 'Hazelwood Mine Fire Inquiry Report', Melbourne, Victoria http://report.hazelwoodinquiry.vic.gov.au/wp-content/uploads/2014/08/Hazelwood_Mine_Inquiry_Report_Intro_PF.pdf Accessed 4 December 2018

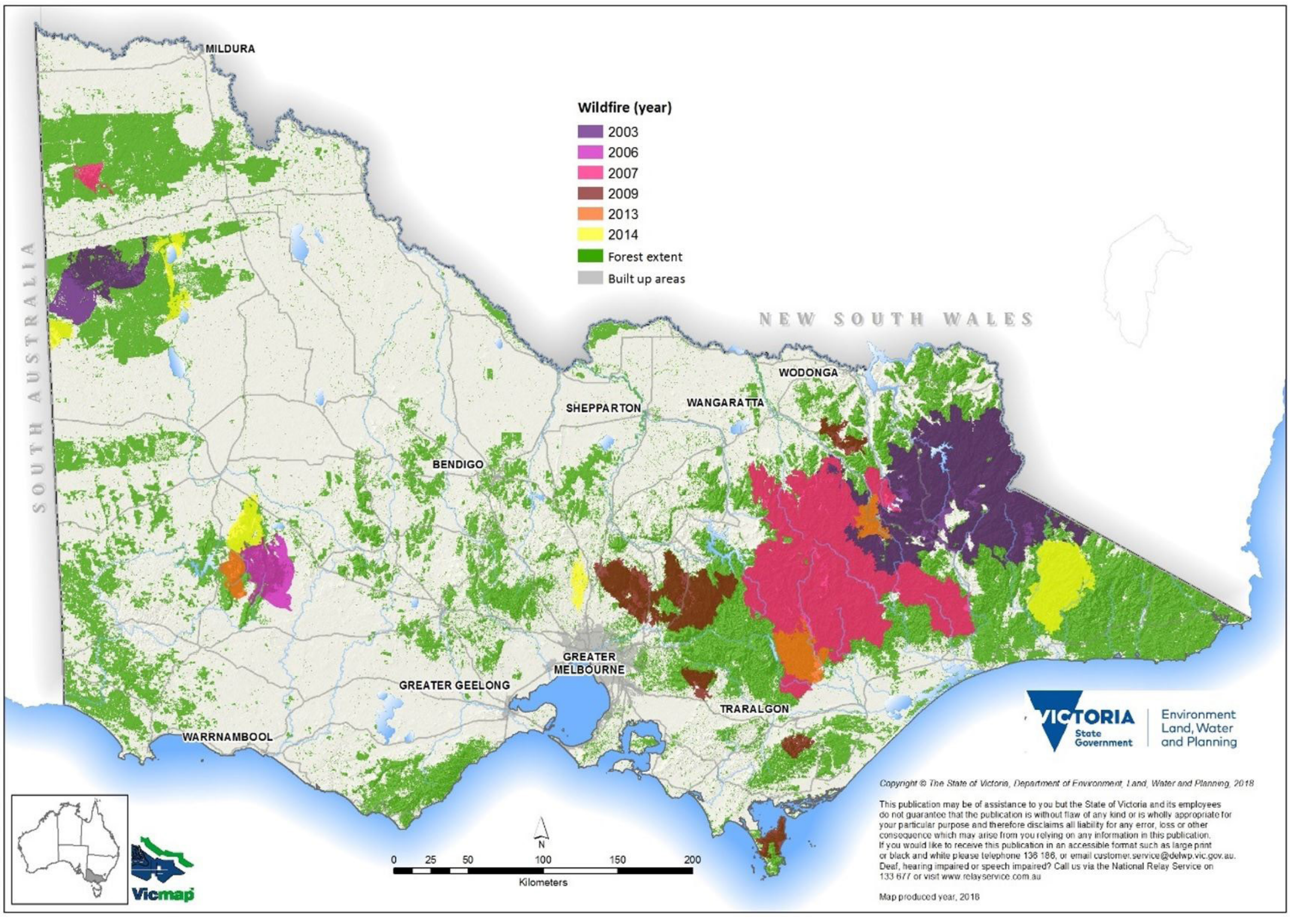

Figure Fi.5 Major bushfires in Victoria, 2000–2017

(Data source: DELWP, 2018)

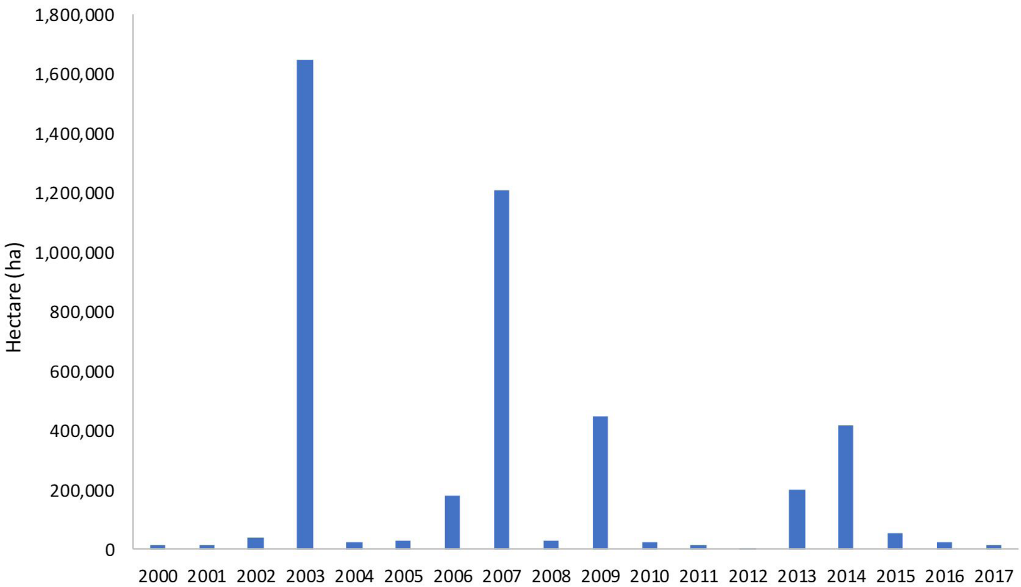

Figure Fi.6 Total area in Victoria affected by bushfires, 2000–2017

(Data source: DELWP, 2018)

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fi:02 Impacts of bushfires		●			?	DATA QUALITY Poor
Data Custodian None						

The Victorian Government's highest priority is to protect people, property and infrastructure. It is therefore extremely important to monitor and evaluate the cumulative impacts on society of bushfires.

Given the cost of fire responses, the drain on water resources, and the devastating impact of bushfires on biodiversity and communities, it is critical to identify data custodians responsible for collating information on the impacts of fire on essential community infrastructure (i.e. hospitals, power supplies), businesses, water resources, biodiversity and the cost of fire responses.

Previously, the Bushfire Cooperative Research Centre was the leading agency collating evidence on the economic, social and environmental impacts of bushfires in Victoria, with funding provided by the Victorian Government.[26, 27] Since 2013, the only information that was identified to be held by emergency management agencies was property loss from bushfires over the past three years (Table Fi.1).

During major emergencies, the Department of Health and Human Services (DHHS) is responsible for:

- overseeing and coordinating the health system's response, including understanding the impacts on the community, the health sector, and the department's clients and services, and working with EPA Victoria where there may be significant impacts on, or risks to, public health
- coordinating regional relief and recovery, the social recovery environment and the following services:
  - emergency shelter, housing and accommodation
  - emergency financial assistance
  - health, medical assistance and first aid
  - psychosocial support.

No specific bushfire-related information was available from DHHS for this report. DHHS referred to its annual reports,[28] which aggregate data from all emergency events, such as flooding, storms and thunderstorm asthma events.

Impact of bushfire on biodiversity is discussed in the next indicator (Fi:03 Actual fire regimes compared to optimal fire regimes).

Table Fi.1 Available property-loss data from bushfires, 2015–16 to 2017–18

Year	Property loss
2015–16	148 (116, from Wye River bushfire)
2016–17	1
2017–18	27 (26, South West Complex; 1, Carrum Downs fire)

(Data source: Emergency Management Victoria, 2018)

26. Stephenson C 2010, 'A literature review on the economic, social and environmental impacts of severe bushfires in south-eastern Australia', Fire and adaptive management Report no.87, Bushfire CRC, East Melbourne, Victoria https://www.ffm.vic.gov.au/__data/assets/pdf_file/0009/21114/Report-87-A-Lit.Rvw-On-The-Economic,-Social-and-Envtal-Impacts-of-Severe-Bushfires-In-SE-Aust..pdf Accessed 4 December 2018.
27. Stephenson C 2010, 'The impacts, losses and benefits sustained from five severe bushfires in south-eastern Australia'. Fire and adaptive management Report no. 88, Bushfire CRC, Melbourne, Victoria https://www.ffm.vic.gov.au/__data/assets/pdf_file/0010/21115/Report-88-The-Impacts-Losses-and-Benefits-Sustained-from-Five-Severe-Bushfires-in-SE-Aust..pdf Accessed 4 December 2018
28. DHHS 2017, 'Annual report 2016-17', Melbourne, Victoria https://dhhs.vic.gov.au/dhhs-annual-report-2016-17-pdf Accessed 4 December 2018.

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fi:03 Actual fire regimes compared to optimal fire regimes			●		↘	DATA QUALITY Good
Data custodian DELWP						

A fire regime is a combination of factors including frequency, intensity, size, pattern, season, interval and severity. Inappropriate fire regimes can cause disruption to sustainable ecosystems and result in a loss of biodiversity by changing the structure of plant communities and the composition of fauna communities.

Fires impact on the habitat extent of some fauna species. For example, sugar glider (*Petaurus breviceps*) and Leadbeater's possum (*Gymnobelideus leadbeateri*) are subject to high-severity bushfire.[29] Landscape-level fire severity was found to have strong effects on bird species richness and the detection frequency of the majority of bird species after the 'Black Saturday' bushfire event in 2009.[30] For any given plant community, the suitable fire interval to maintain species composition is dictated by the life-history attributes of the plant species in that community, particularly the time required for species to mature and set seed, as well as their time to mortality in the absence of fire. The tolerable fire interval for a vegetation community is defined by the minimum and maximum intervals between fires of the species in that community that are most sensitive to fire. These are denoted as 'key fire response species (KFRS)'.[31] If fire frequency is above or below minimum fire tolerance intervals, KFRS may not be able to reproduce and repopulate and thus the vegetation community may change. Information on the vital attributes of plants that define their KFRS status is collated and subject to regular updating by DELWP, but is not published publicly and if requested, the status of KFRS is available. This information is regularly updated from ongoing field-monitoring activities. The KFRS is created based on the life-history characteristics or 'vital attributes' of flora species. The vital attributes of plants will dictate the response of a plant population to a particular disturbance.[32] At a minimum, three vital attributes of plants are required to determine their response to fire and tolerable fire intervals:

1. Method of persistence
2. Conditions for establishment
3. Relative longevity of each life stage.

Once the vital attributes of a species are identified, the sensitivity of a species to repeated fire can be determined. The purpose of defining the vital attributes of individual species is to ensure the viability of all species at a given location. However, it is impractical to manage all individual species at all locations across the landscape. Mapping of vegetation using floristic information is conducted at the community level. Thus, the viability of the community can be defined to a large extent by the viability of the individual species in the community. By identifying the plant species within each plant community which will be either significantly reduced in abundance by too frequent fire or by fire exclusion for long periods. These species are the key fire response species for the community. Once these KFRS have been identified, these species can be monitored regularly to see if they are developed to survive from next fire.

29. Lindenmayer DB, Blanchard W, McBurney L, Blair D, Banks SC, Driscoll D, Smith AL, Gill AM 2013, 'Fire severity and landscape context effects on arboreal marsupials', Biological Conservation, 167, pp. 137-148.
30. Lindenmayer DB, Blanchard W, McBurney L, Blair D, Banks SC, Driscoll DA, Smith A, Gill AM 2014, 'Complex responses of birds to landscape-level fire extent, fire severity and environmental drivers', Diversity and Distributions, 20, pp. 467-477.
31. Cheal D 2010, 'Growth stages and tolerable fire intervals for Victoria's native vegetation data sets', Fire and adaptive management Report no.84, Bushfire CRC, Melbourne, Victoria https://www.ffm.vic.gov.au/__data/assets/pdf_file/0009/21114/Report-87-A-Lit.Rvw-On-The-Economic,-Social-and-Envtal-Impacts-of-Severe-Bushfires-In-SE-Aust..pdf Accessed 4 December 2018.
32. Noble IR, Slatyer RO 1981, 'Concepts and models of succession in vascular plant communities subject to recurrent fire', In '*Fire and the Australian biota*', Eds Gill Am, Groves RH, Noble IR, pp. 311-335, Australian Academy of Science, Canberra, ACT.

At a landscape level, the Victorian Government uses Tolerable Fire Interval (TFI) as a metric to determine the current resilience condition of ecosystems. TFI thresholds provide minimum and maximum fire intervals to ensure ecosystem resilience. Currently, TFIs are determined based on expert elicitation, which uses a combination of published knowledge of plant vital attributes and information derived from experts on the responses of plants and plant communities to fire[33]. To complete the database of vital attributes for Victorian flora species, extensive and labour-intensive field measurements are needed. This requires field-surveys and long-term monitoring of plant communities. This could be a fundamental caveat of the system as the database is incomplete currently. However DELWP regularly updates the vital attributes dataset to establish TFIs on the basis of field-collected data.

Vegetation types in Victoria are classified by ecological vegetation classes (EVC).[34] EVCs are described through a combination of ecological characteristics, lifeforms and floristics. In order to use the EVC system in fire management for general monitoring, evaluation and reporting (MER) process, an Ecological Vegetation Division system was developed so that EVC data is grouped into larger ecological vegetation divisions (EVD) map units, based on EVC groups that have similar ecological characteristics. In addition, EVC data is attributed using an Ecological Fire Group (EFG) attribute field that provides specific fire-response information for particular (subsets of) EVCs. The interval since the last fire for each EFG has been estimated based on the mapped history of bushfires and planned burning in Victoria over recent decades. TFI analysis provides an opportunity for detecting the potential of vegetation to undergo fundamental ecological changes related to the extinction of KFRS in the event of a recurrence or absence of fire.

The proportion of public land below minimum TFI is representative of the total area that is younger than that recommended for the recurrence of fire. For example, if a recommended minimum TFI is 15 years for a given vegetation, and it was last burnt 10 years ago, the land is now below the minimum TFI and will continue to be for another five years. By contrast, the proportion of public land above maximum TFI is the percentage that remained unburnt longer than the recommended interval. The proportion of public land with no fire history is the percentage for which no identifiable record was found – or the percentage of land with vegetation that does not have a recommended TFI.

Figure Fi.7 (a) demonstrates that in 2017, 54% (4,119,000 hectares) of native vegetation was found to be below minimum TFI, with only 2% (163,000 hectares) above the maximum TFI. This means that more than half of Victoria's native vegetation is in a state where another fire would threaten the persistence of that vegetation type on that site, because, for example, many key plant species will not have set seed to replace themselves. Only 20% of native vegetation assessed was found to be within the required TFI to successfully maintain vegetation communities in 2017. The trend over the past decades to maintain their condition has been slightly deteriorating for Victorian vegetation. Figure Fi.7 (b) demonstrates that areas below minimum TFI increased by 5% (443,815 hectares) between 2007 and 2017, while areas within the TFI threshold decreased by 2% (107,914 hectare). The area below minimum TFI reflects a large number of extensive fires over that period.

33. Cheal D 2010, 'Growth stages and tolerable fire intervals for Victoria's native vegetation data sets', Fire and adaptive management Report no.84, Bushfire CRC, Melbourne, Victoria https://www.ffm.vic.gov.au/__data/assets/pdf_file/0009/21114/Report-87-A-Lit.Rvw-On-The-Economic,-Social-and-Envtal-Impacts-of-Severe-Bushfires-In-SE-Aust..pdf Accessed 4 December 2018.
34. Ibid

This index is a warning sign that future subsequent fires before minimum TFI is reached may have a large ecological impact, with the potential to drive localised extinction of some plant species. When a subsequent fire occurs in young forest at an immature stage, and where there is an absence of mature vegetation, the area dominated by young forest has potential to preclude the development of new cohorts of old-growth forest,[35] with corresponding negative impacts on the persistence of biodiversity.[36] Many bushfire-affected vegetation types have relatively long minimum TFIs (between 15 and 80 years), so the reported increases in areas below minimum TFI can remain for a considerable time.

Between 2007 and 2017, areas with no fire history reduced by 11% (834,000 hectares). This is partly a consequence of areas with no recorded history of fire being impacted by bushfires. Some of these areas are long-unburnt habitats, which could potentially impact on biodiversity. An extensive report on suitable growth stages for different habitat types observed that early growth stages 'can be created far more easily than can late (mature) stages'.[37] Recently burnt vegetation can be created in a single season. Some important habitat features occur only in mature to senescent vegetation and thus take decades, or even centuries, to develop. The decrease of long-unburnt area is a great concern as these habitats are very hard to re-establish once lost.

Long-unburnt areas provide an essential habitat: hollow-bearing trees. There is scant monitoring of bushfire impact on critical habitat structures, especially tree hollows, hollow logs and coarse woody debris on the ground, which are critically important to threatened species in Victoria.

'Hollow tree' is defined as 'a cavity in tree >20 mm diameter that appears to extend beyond the surface of bark/wood (i.e. has some 'depth', such that it could shelter a bird or mammal), or fissure extending beyond outer surface into interior of tree'.[38] Several peer-reviewed studies have indicated the importance of maintaining or improving the presence of a large range of tree hollows in the landscape.[39, 40, 41] Frequent fires can damage these important structural components of forests and woodlands.

A study by DELWP also demonstrates that planned burns in Gippsland significantly increase the risk of collapse of hollow-bearing trees, which is likely to result in loss of habitat for fauna species that rely on hollows for survival, such as Great gliders (*Petauroides volans*).[42] Thus, planned burns, which typically utilise low-intensity prescription burns, may cause some destruction of hollow-bearing trees.[43]

35. Lindenmayer DB, Hobbs RJ, Likens GE, Krebs C, Banks S 2011, 'Newly discovered landscape traps produce regime shifts in wet forests', Proceedings of the National Academy of Sciences, 108, pp. 15887-15891.
36. Todd CR, Lindenmayer DB, Stamation K, Acevedo-Catteneo S, Smith S, Lumsden LF 2016, 'Assessing reserve effectiveness: application to a threatened species in a dynamic fire prone forest landscape', Ecological Modelling, 338, pp. 90-100.
37. Cheal D 2010, 'Growth stages and tolerable fire intervals for Victoria's native vegetation data sets', Fire and adaptive management report no.84, Bushfire CRC, Melbourne, Victoria https://www.ffm.vic.gov.au/__data/assets/pdf_file/0009/21114/Report-87-A-Lit.Rvw-On-The-Economic,-Social-and-Envtal-Impacts-of-Severe-Bushfires-In-SE-Aust..pdf Accessed 4 December 2018.
38. Clarke M, personal communication dated 25/08/2018 (Leonard S, Haslem A, Bennett A, Clarke M 2018, 'Guidelines for ecosystem resilience monitoring, evaluation and reporting within the Victorian Bushfire Monitoring Program: scientifically-based monitoring project – final report', Latrobe University, Melbourne, Victoria).
39. Stares MG, Collins L, Law B, French K 2018, 'Long-term effect of prescribed burning regimes and logging on coarse woody debris in South-Eastern Australia', Forests, 9(5), pp. 242.
40. Lindenmayer DB 2009, 'Forest pattern and ecological process: a synthesis of 25 years of research'. CSIRO Publishing, Collingwood, Victoria.
41. Lindenmayer DB, Cunningham RB, Tanton MT, Smith AP 1990, 'The conservation of arboreal marsupials in the montane ash forests of the Central Highlands of Victoria, southeast Australia: II. The loss of trees with hollows and its implications for the conservation of Leadbeater's possum *Gymnobelideus leadbeateri* McCoy (Marsupialia: Petauridae)'. *Biological Conservation*, 54, pp. 133-145.
42. Bluff L 2016, 'Reducing the effect of planned burns on hollow-bearing trees'. Fire and adaptive management report no. 95, DELWP, Melbourne, Victoria https://www.ffm.vic.gov.au/__data/assets/pdf_file/0006/21120/Report-95-Reducing-the-effect-of-planned-burns-on-hollow-bearing-trees-2016.pdf Accessed 4 December 2018.
43. Parnaby H, Lunney D, Ian S, Fleming M 2010, 'Collapse rates of hollow-bearing trees following low intensity prescription burns in the Pilliga forests, New South Wales', Pacific Conservation Biology, 16(3), pp. 209-220.

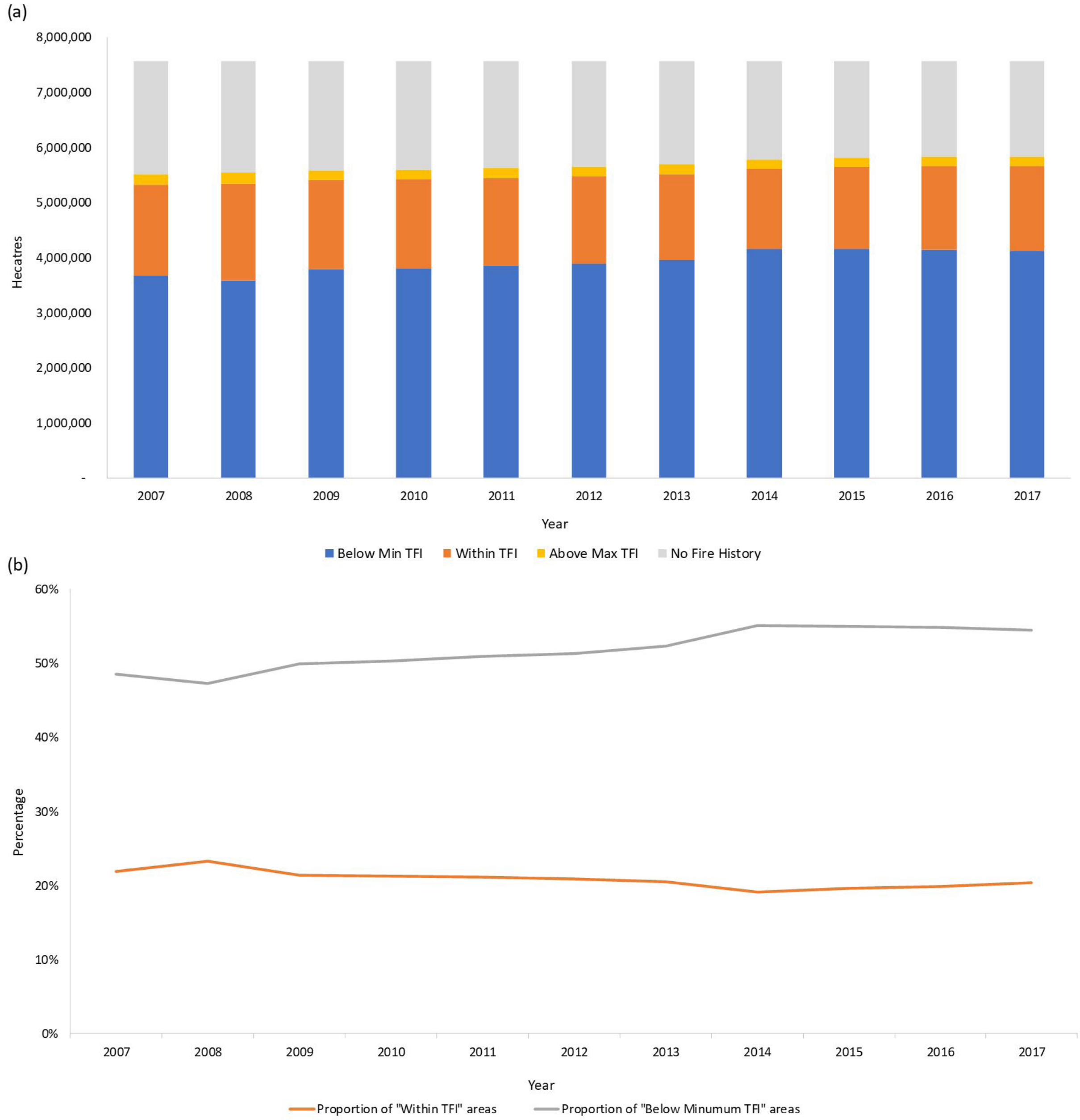

Figure Fi.7 Tolerable fire interval status on Victoria's public land

Graph (a) Area of native vegetation on Victoria's public land by TFI status, 2007–2017

Graph (b) Proportion of areas 'Within TFI' and 'Below minimum TFI', 2007-2017

(Data source: DELWP, 2018)

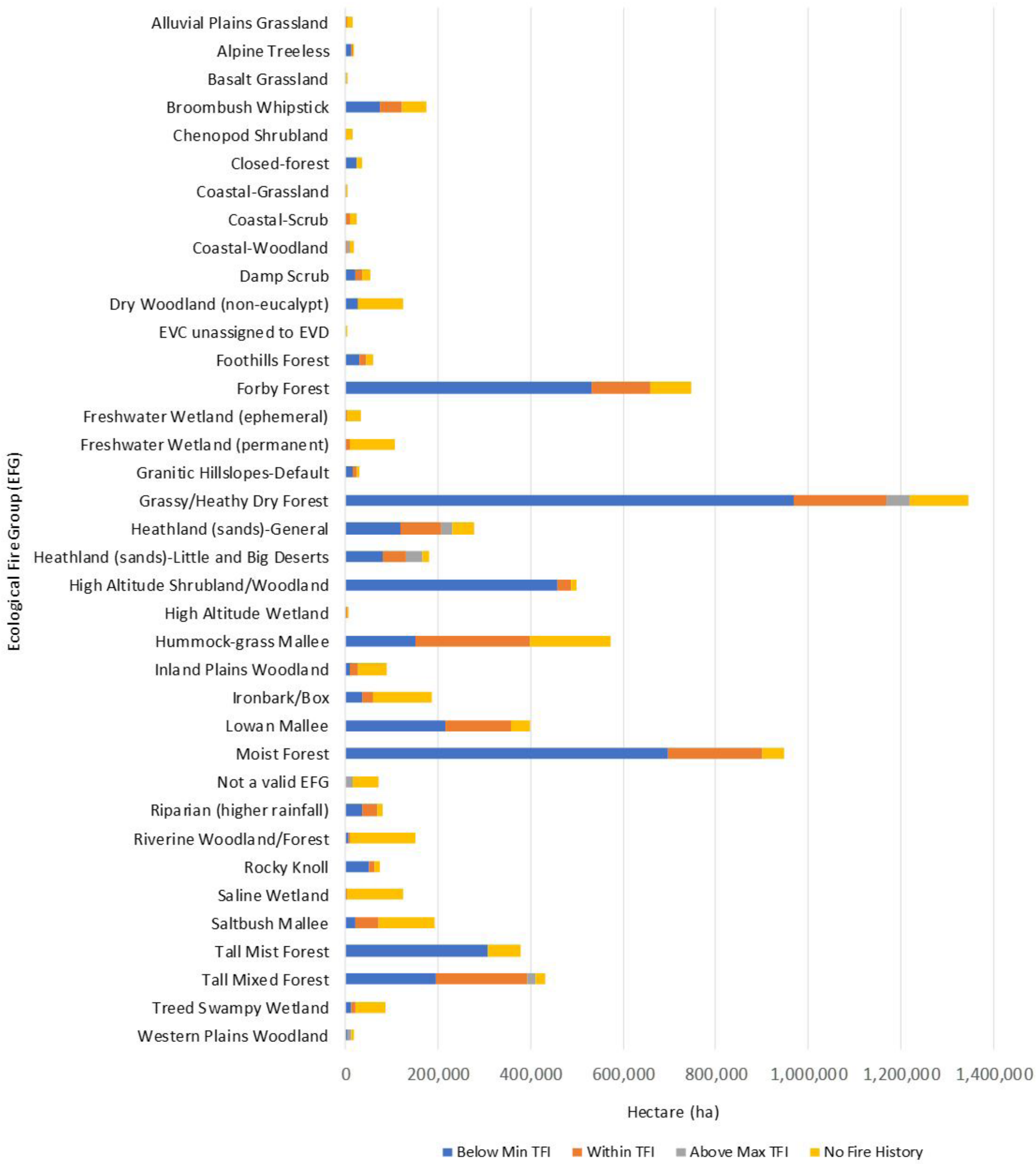

Figure Fi.8 Area of below minimum TFI, within TFI, above maximum TFI with no fire history in each EFG, 2016–17

(Data source: DELWP, 2018)

When Victorian public land is categorised by Ecological Fire Group (EFG), only 12 of 37 ecological groups have more than 25% of land that meets the required TFI standard. More than half (19) have more than 25% of land below the minimum TFI standard.

Hummock-grass Mallee and Tall Mixed Forest have the highest area within TFI, with 43% and 46% respectively. Three EFGs have more than 75% of the area below minimum TFI: Alpine Treeless, High Altitude Shrubland/Woodland, and Tall Mist Forest. Data for these fire groups is a warning that subsequent fires may impose more local or regional extinction risk on key threatened species. Detailed assessment of impacts on threatened vegetation community and/or species is an important process to ensure successful management of the Victorian environment.

Figure Fi.9 Proportional distribution of below minimum TFI, within TFI and above maximum TFI in EFGs, 2016–17

(Data source: DELWP, 2018)

Vegetation growth stage structure (GSS) is used to indicate ecosystem resilience at a landscape level, as well as TFI. GSS is a mix of different age stages: juvenile, adolescent, mature and old. A vegetation's GSS depends on when it was last burnt or otherwise disturbed.

Figure Fi.10 shows changes in GSS for Victorian public land between 2007 and 2017 and demonstrates that overall, vegetation on public land has aged. There has been a 9% decrease in vegetation (724,400 hectares) in the juvenile growth stage, but a 10% increase in the adolescent growth stage (779,500 hectares) and a 4% increase in the mature growth stage (20,000 hectares). Areas that have no fire history were decreased by approximately 325,000 hectares within the same period, similar to Figure Fi.7 (a). This potentially means that some areas experienced an ongoing reduction in long-unburnt habitats as they succumbed to recent bushfires.

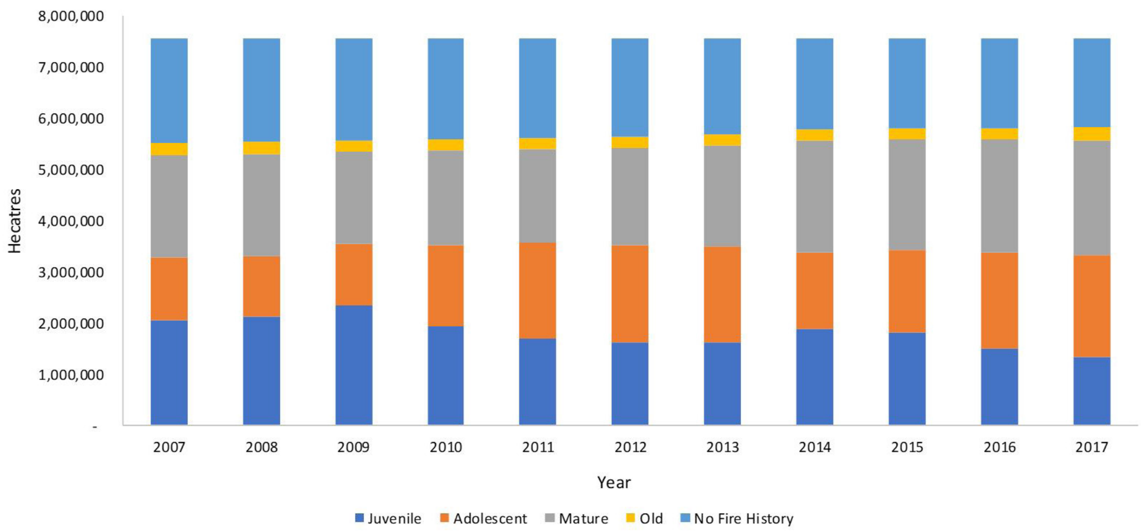

Figure Fi.10 Area of vegetation growth stage on Victoria's public land, 2007–2017

(Data source: DELWP, 2018)

	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
Fi:04 Bushfire risk			●		↘	DATA QUALITY Poor
Data custodian DELWP, BoM						

Bushfire risk is composed of two variables: the likelihood of a fire starting, and its impact on communities and the environment. Planned burns are the main tool used to reduce bushfire risk globally.

Planned burns aim to reduce fuel loads at target locations to hinder fire intensity and spread rate. They are also used to provide benefits to key native fauna and flora species by providing heterogeneous landscape in nature. However, planned burns could harm biodiversity, including homogenised landscapes, if their impact is not properly assessed.[44]

As explained above, the Victorian Government set an annual burn-area target until 2015–16, which increased from 130,000 hectares to 390,000 hectares between 2003–04 and 2015–16 (Figure Fi.1). The government then shifted from a hectare-based approach to a risk-based approach for fire management. The new risk-based approach focuses on strategic areas near housing and infrastructure where there is a high chance of fire impacting on people and property.

To achieve this, the Victorian Government has adopted a fire-behaviour simulation program, PHOENIX RapidFire. The program provides a method to estimate bushfire risk by comparing the predicted difference in house loss in a maximum-risk scenario with maximum fuel load, with a scenario with fuel loads after a planned burn on public land.[45] The difference between the two scenarios is known as 'residual risk'. Residual risk can be expressed as a ratio of the average property impact from a modified risk scenario following planned burning, to the average impact of the maximum risk scenario, reported as a percentage.

The government's goal is to keep residual risk below 70%. DELWP estimated that residual risk in Victoria in 2018 was 63%[46] (Figure Fi.11). The figure below also indicates how dramatically residual risk fell after major bushfire events, such as the 'Ash Wednesday' fires in 1983, and the Black Saturday fires in 2009, and the comparatively higher-impact bushfires have had on residual risk than planned burns as those 1983 and 2009 bushfires dropped residual risk sharply.

44. Holland GJ, Clarke MF, Bennett AF 2017, 'Prescribed burning consumes key forest structural components: implications for landscape heterogeneity'. Ecological Applications, 27(3), pp. 845-858.

45. DELWP 2015, 'Measuring bushfire risk in Victoria', Melbourne, Victoria http://www.delwp.vic.gov.au/__data/assets/pdf_file/0009/318879/DELWP0017_BushfireRiskProfiles_rebrand_v5.pdf Accessed 4 December 2018.

46. DELWP 2015, 'Safer Together: a new approach to reducing the risk of bushfire in Victoria', Melbourne Victoria http://www.delwp.vic.gov.au/__data/assets/pdf_file/0004/319531/DELWP_SaferTogether_FINAL_17Nov15.pdf Accessed 4 December 2018.

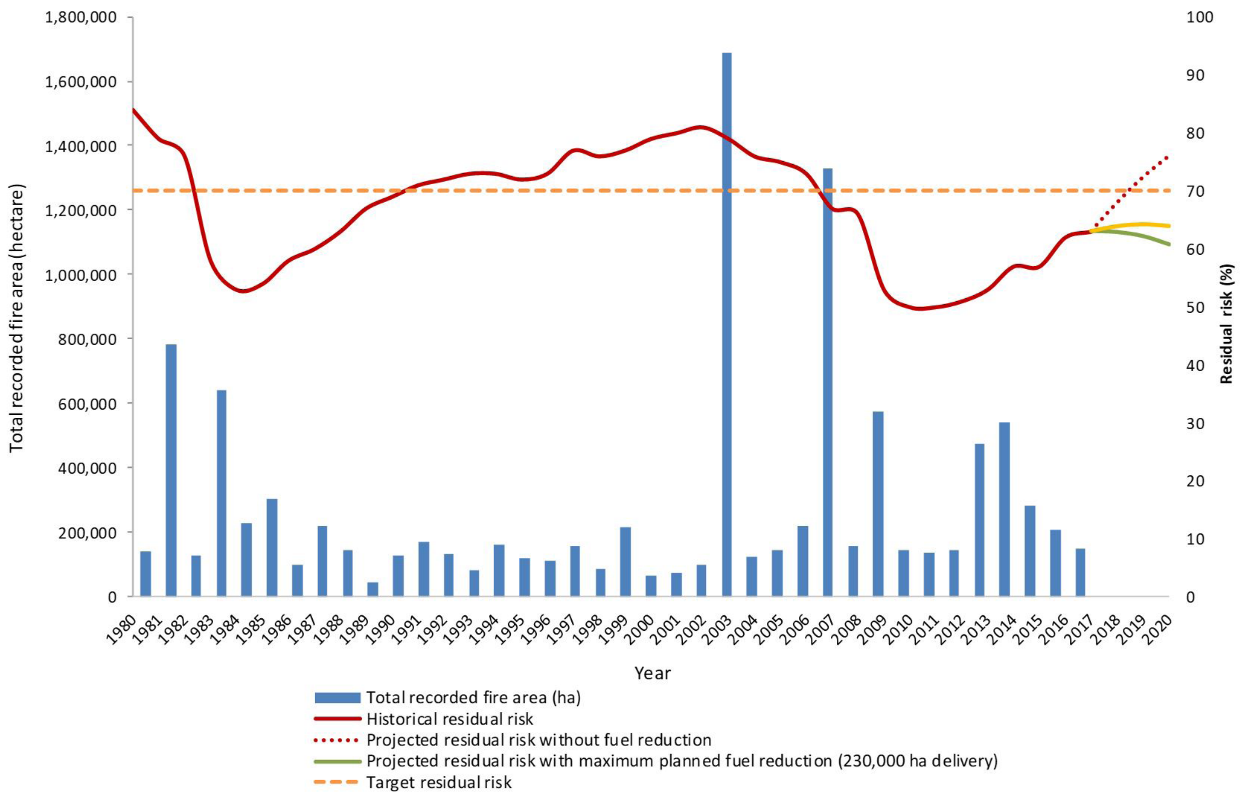

Figure Fi.11 Residual risk profile in Victoria, 1980–2020

(Data source: DELWP[47])

One criticism levelled at forest fire management agencies was that the previous hectare-based approach to planned burns did not adequately address potential harm to Victorian ecosystems.[48, 49] A similar concern may be raised regarding the current approach under the Safer Together program. However, Safer Together provides a framework for assessing the new burning approach in relation to ecological resilience and biodiversity. Although it has been in an establishment phase over the past two years, it has yet to incorporate the risk to biodiversity in the residual risk calculations. Therefore, data quality for biodiversity is assessed as 'poor' while that for life and property is assessed as 'good'.

It is important to note that after disturbances such as logging or fire, forests are prone to subsequent high-severity fires (typically crown-scorching fires). A 2018 study found that in tall, wet forests dominated by ash-type eucalypts, post-disturbance stands of trees could be more than eight times as likely to burn than mature stands.[50] In some areas, especially the alps areas, areas below minimum TFI may be more prone to subsequent high-severity fires, resulting in forest degradation and loss of the original formation of forests.

While the use of planned burns may still be necessary for the management of some native species, variability of subsequent high-severity fires must be considered in risk assessment.

47. Ibid.
48. Ingamells P 2012, 'Statewide fuel reduction target threatens biodiversity', Park Watch, 249, pp. 16-17.
49. Kelly L, Giljohann K, McCarthy M 2015, 'Burning issues: state-wide percentage targets for planned burning are blunt tools that don't work', Decision Point, 88, pp. 4-5.

50. Zylstra PJ 2018, 'Flammability dynamics in the Australian Alps', Austral Ecology, 43, pp. 578-591.

Climate Change

The impact of climate change on weather conducive to fire is well understood by researchers and land managers.[51, 52] There is a trend towards more dangerous weather conditions for bushfires in south-east Australia, including significant increases in the frequency and magnitude of extreme conditions in some regions.

The figures provided are for the Forest Fire Danger Index (FFDI), which is configured from temperature, rainfall, humidity and wind speed, and used throughout Victoria by fire agencies. Fire weather is monitored with FFDI in Australia. FFDI patterns have changed in recent decades, with the strongest increases to the index generally in summer and spring. This upward trend in FFDI is due to increasing temperatures and drying conditions.[53] Changes to the springtime pattern indicate a shift towards an earlier start to the fire season (Figure Fi.12). These recent changes are attributable, at least in part, to anthropogenic (human-related) climate change, including increasing temperatures.

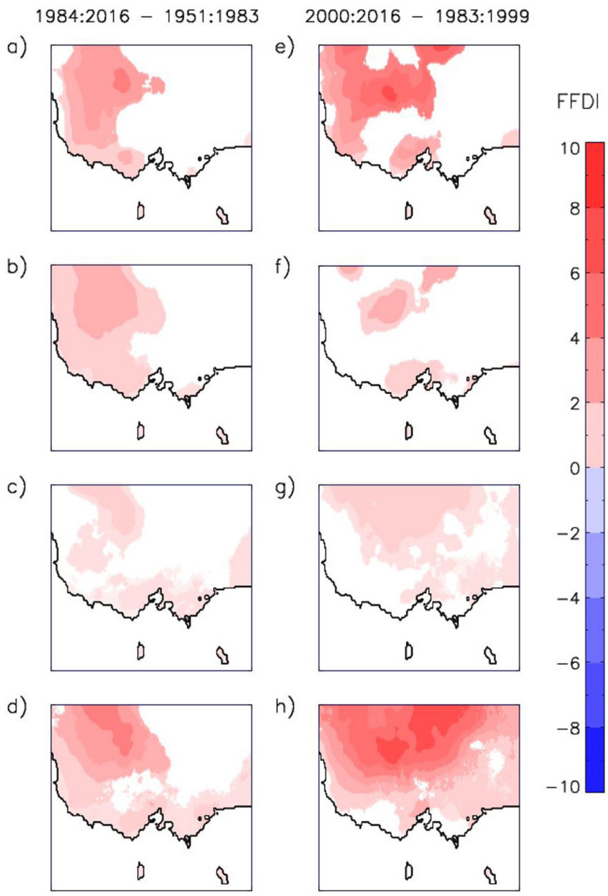

Figure Fi.12 Long-term changes in seasonal mean FFDI values

Note: This is shown for the change from the first half (1951–83) to the second half (1984–2016) of the study period during (a) December–February, (b) March–May, (c) June–August and (d) September–November. This is also shown for the change from 1983–1999 period to 2000–2016 period during the same four seasons mentioned above for (e), (f), (g) and (h) respectively. The coloured regions represent locations where the magnitude of the change is significant at the 95% confidence level.[54] (Figure (a) – (h) are modified by the author).

(Data source: Dowdy[55])

51. Hennessy, K, Lucas C, Nicholls N, Bathols J, Suppiah R, Ricketts J 2005, 'Climate change impacts on fire-weather in south-east Australia'. CSIRO, Aspendale, Victoria http://www.cmar.csiro.au/e-print/open/hennessykj_2005b.pdf Accessed 4 December 2018.
52. Clarke H, Evans JP 2018, 'Exploring the future change space for fire weather in southeast Australia', Theoretical and Applied Climatology, pp. 1-15.
53. CSIRO and Bureau of Meteorology 2016, 'State of the Climate 2016'. http://www.bom.gov.au/state-of-the-climate/State-of-the-Climate-2016.pdf Accessed 4 December 2018.
54. Dowdy AJ 2018, 'Climatological variability of fire weather in Australia', American Meteorological Society, 57, pp. 221-234.
55. Ibid.

Fire authorities use the Southern Australia Seasonal Bushfire Outlook for making strategic decisions on resource planning and prescribed fire management. Each year, the outlook is developed at an annual workshop attended by relevant expert practitioners, and convened by the Bushfire & Natural Hazards CRC and Australian Fire and Emergency Services Authorities Council Limited (AFAC). Throughout the workshop, stakeholders discuss fire weather, landscape conditions and potential areas where above-normal or below-normal fire season may occur in Australia in the upcoming fire season.

The most recent outlook through to the end of 2018 in Victoria demonstrates that much of East Gippsland will have above normal fire potential due to two consecutive years of record low rainfall during autumn and winter, leading to forests in East Gippsland being more flammable than normal (Figure Fi.13).[56] The outlook also stated that there is extensive and historically unprecedented dryness across the majority of southern Australia, due to the combination of increasing temperatures and drying conditions.

Given the intensifying impacts of climate change, addressing the risks and impacts of climate change that are facing the emergency management sector, including fire, is an urgent and significant challenge for fire management agencies. The agencies have been working collaboratively to identify key risks and priorities for action.[57] In response to this, the Emergency Management Climate Change Program was initiated in 2017, led by Emergency Management Victoria. The program will work with the emergency management sector to tackle potential risks to the Victorian environment, community and economy.

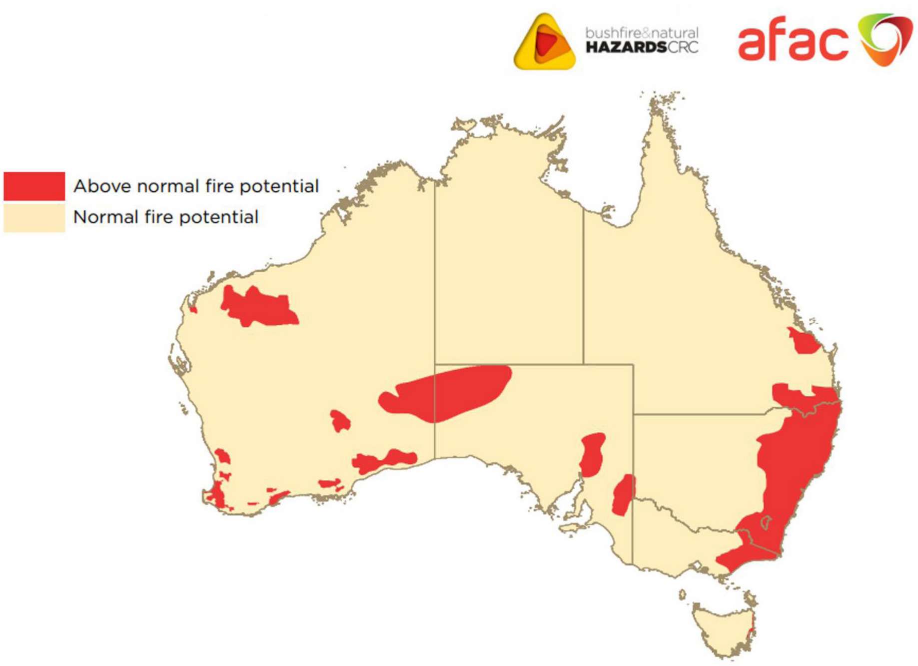

Figure Fi.13 Areas where higher and normal fire potential exist in Australia through to the end of 2018

(Data source: Bushfire & National Hazards CRC, 2018)

56. Bushfire & Natural Hazards CRC and Australian Fire and Emergency Services Authorities Council Limited 2018, 'Southern Australia seasonal bushfire outlook 2018', Hazard Note Issue 51, Bushfire & Natural Hazards CRC, Melbourne, Victoria https://www.bnhcrc.com.au/hazardnotes/51 Accessed 4 December 2018.
57. Australian Fire and Emergency Services Authorities Council Limited 2018, 'Climate change and the emergency management sector: discussion paper version 1.0', Australian Fire and Emergency Services Authorities Council Limited, East Melbourne, Victoria https://files-em.em.vic.gov.au/public/EMV-web/AFAC-Climate-Change-Discussion-3July2018FINAL.pdf Accessed 4 December 2018.

Future Focus

Understand fire impacts on the environment statewide using a structured, integrated framework

Ecological values are not currently included in the DELWP residual risk prediction program (PHOENIX RapidFire) used to inform the risk-based approach to forest fire management, Safer Together.[58] To address this and assess the impact of current fire management strategies on Victoria's native species and ecosystems, as recommended by the 2009 Victorian Bushfires Royal Commission,[59] DELWP, in partnership with La Trobe University, developed an ecosystem resilience monitoring program in 2017–18 to collect, analyse and interpret comprehensive data on how bushfire and fire management activities affect plants, animals and their habitats in the landscape.

This program is described in the *Guidelines for Ecosystem Resilience Monitoring, Evaluation and Reporting within the Victorian Bushfire Monitoring Program: Scientifically-based Monitoring Project – Final Report*. The ecosystem-resilience monitoring program has been piloted and includes recommendations for deployment. It is structured around a dual-scale approach to monitoring: regional and statewide. Regional monitoring activities focus on the immediate and short-term effects of fuel-management actions (primarily planned burns) on species of local interest and/or significance (such as the impact of planned burns on the greater glider by causing the loss of hollow-bearing trees in Alpine-North East). The statewide program would examine the effects at a broader scale and the long-term relationships between plants and animals, and fire, at sites across the landscape with a varied fire history.

The full implementation of this program would help establish a science-based, state-scale approach to the monitoring, evaluation and reporting framework for ecosystem resilience on public land in Victoria. An approach that includes both flora and fauna species at the state scale has never been implemented before.

Conserving flora and fauna species in fire-prone landscapes in Victoria requires an evidence-based approach to identify how fires affect ecosystems that can be modified by cumulative threats. There are two contemporary fire management paradigms: fire mosaic paradigm and functional types paradigm.[60] Current fire management has adopted the functional types paradigm, which focuses on plant responses to recurrent fires. This paradigm is guided by life-history traits of plants such as the Tolerable Fire Interval (TFI), and aims for temporal variation within acceptable fire intervals. By contrast, the fire mosaic paradigm focuses on animal responses to fire events, aiming to create spatially diverse fire mosaics for promoting biodiversity and assisting the persistence of isolated, localised species.

Research indicates[61] that both paradigms need to be integrated in evidence-based monitoring for fire management for biodiversity conservation, as animals and plants are interdependent and influenced by the spatial and temporal dimensions of fire regimes. The new ecosystem-resilience program will provide an opportunity to integrate these two paradigms to better evaluate and report on the effectiveness of bushfire for maintaining resilient and biodiverse ecosystems.

Recommendation 9: That the Victorian Government establish a structured framework based on the findings of the dual-scale ecosystem-resilience monitoring program, piloted by DELWP in 2017–18, and undertake a detailed analysis of the persistence of key fire-response species to increased fire frequency in Victoria, particularly in areas where below-minimum TFI exists.

58. DELWP 2015, 'Measuring bushfire risk in Victoria', Melbourne, Victoria http://www.delwp.vic.gov.au/__data/assets/pdf_file/0009/318879/DELWP0017_BushfireRiskProfiles_rebrand_v5.pdf Accessed at 5 December 2018.
59. Teague B, McLeod R, Pascoe S 2010, 2009 'Victorian Bushfires Royal Commission Final Report', Parliament of Victoria, Melbourne, Victoria.
60. Kelly LT, Brotons L, Giljohann KM, McCarthy MA, Pausas JG, Smith AL. 2018, 'Bridging the divide: integrating animal and plant paradigms to secure the future of biodiversity in fire-prone ecosystems', Fire, 29, 1-8.
61. Ibid

Accounting for the Environment

Forest and grass fires impact on both built and natural assets, affecting the production of goods and services, that benefits the economy and society.

The impact of fire on the economy is partly captured in the System of National Accounts (SNA) through changes to stock of built assets and the flow of goods and services. However, the SNA does not capture the impact of fire on the environment, and the ecosystem services that flow from the environment to the economy. The System of Environmental-Economic Accounting (SEEA) provides a framework for measuring the impact of fire on the environment (ecosystem assets including wetlands, rivers and ecological vegetation) and the connection between this and the economy and society.

When fire burns an area of land, it can affect both the extent and condition of different types of vegetation (different ecosystem assets). Most Victorian plant communities are fire tolerant and exhibit some form of recovery after fire. However, under certain circumstances fire can change the mix of environmental assets in an area by killing one type of vegetation, which is then replaced by another. Depending on the ecological vegetation type and the severity and frequency of fire, fire can increase or reduce the extent and condition of ecosystem assets.

Fire can impact on the ecosystem services produced by ecosystem assets. For example, fire can increase the habitat services provided by ecosystems, as some flora species depend on fire or smoke for seed germination. However, fire can reduce the timber resources available from native or plantation forests, as well as reduce carbon storage, water filtration and soil stabilisation services. For example, when fire burns plants that stabilise soil, water runoff can carry increased amounts of soils and nutrients into rivers and water storages. This reduces the quality of water for human and animal consumption. The risk of landslides can increase, potentially impacting on other ecosystem assets or built assets such as roads or buildings. For example, in 2003, the Australian Capital Territory was significantly affected by fire. In the aftermath, storm events resulted in sediment entering Canberra's water storages, and the closure of these storages for water supply.[62] This illustrates the connection between fire and water supply and quality accounts (discussed further in the Water Resources, Water Quality, and Forests chapters).

62. Daniell T, White I 2005, 'Bushfires and their implications for management of future water supplies in the Australian Capital Territory', Climatic and Anthropogenic Impacts on the Variability of Water Resources, HydroSciences Montpellier, pp. 1-15 http://www.bom.gov.au/water/about/waterResearch/document/Daniell_and_White_Montpellier_2005.pdf Accessed 4 December 2018.

Case Study: Accounting for the Impact of Fire on Ash Eucalypt Vegetation

This case study draws on the numerous studies on the ash-reseeding.[63, 64, 65, 66, 67, 68]

In the past 15 years, bushfires have burnt large areas of forest in the alpine area of Victoria, with major fires in 2003 (Alpine fires), 2006–07 (Great Divide fires), 2009 (Black Saturday fires) and 2013 (Harrietville, Tomahawk and Aberfeldy fires). Although most Victorian plant communities are well adapted to fire, the eucalypt ash forests of mountain ash (*Eucalyptus regnans*) and alpine ash (*Eucalyptus delegatensis*) are particularly vulnerable to increased fire frequency and intensity.[69] Ash eucalypt species are vulnerable to demographic collapse if their life cycles become de-synchronised with the fire regimes to which they are adapted.[70]

Data is available on the area of public and private land burnt by bushfire, including the area of ash eucalypt species burnt, and the proportion of this that is burnt immature ash regrowth. That is, ash that had already been burnt prior to reaching sexual maturity. Mature ash eucalypt forests can recover from a single high-intensity fire through mass seed regeneration. But if the regenerated forest is subject to another high-intensity fire prior to setting seed, management intervention (revegetation) is needed for the ecosystem asset to be maintained. After major fires in the Victorian alpine areas, DELWP, VicForests and Parks Victoria intervened to maintain ash ecosystem assets, through aerial sowing (via helicopter) and planting seedlings.

Available data has been used to construct account tables for each of the major fires (see from Table Fi.2 to Table Fi.5).[71] Each account shows an opening stock of assets burnt, the loss of ash forest due to fire (where immature ash forest was burnt), and additions to ash forest. Additions are either from human activity (aerial sowing or planting seedlings) or additions to other forest type as the composition of ecosystem assets changes where areas of burnt immature ash have not been revegetated (termed ‘reclassifications’ under SEEA).

Overlap of areas burnt in each fire event has resulted in increasing losses of ash eucalypt species relative to the size of the fires. For example, Table Fi.5 shows that the total area of the 2013 fires (126,002 hectares) was much smaller than the area burnt in previous years; however, 5,537 hectares of immature ash was still killed in 2013. The areas of immature ash killed in 2013 included some areas of triple-burnt ash stands – that is, areas that were burnt three times between 2003 and 2013.

63. Fagg P, Lutze M, Slijkerman C, Ryan M, Bassett O 2013, ‘Silvicultural recovery in ash forests following three large bushfires in Victoria’. Australian Forestry, 76(3-4), pp. 140-155.
64. Jewell C, Lutze M, Fagg P, Ryan M 2008 ‘Bushfire recovery - forest values (silviculture). 2007 regeneration report’, Department of Sustainability and Environment, Melbourne, Victoria.
65. Slijkerman C, Lutze M, Fagg P 2010, ‘2006/07 great divide fire recovery (forest values) 2008 regeneration report’, Department of Sustainability and Environment, Melbourne, Victoria (internal report).
66. Slijkerman C, Fagg P, Lutze M, Notman W, Patrick R, Cleaver J, Harper E, Doherty K 2011, ‘Bushfire recovery silviculture report-2009 Black Saturday fires’, Department of Sustainability and Environment, Melbourne, Victoria (internal report).
67. Stabb T 2013, ‘Alpine fires - north east Victoria & Gippsland bushfire recovery plan’, Department of Environment and Primary Industries (internal report), Melbourne, Victoria. Spreadsheet ‘Sowing summary_area_kg_fire-ln20-20130705.xls’ as supplied by Carolyn Slijkerman
68. Slijkerman et al (2010) 2006/2007 Great Divide Fire recovery (Forest Values) 2008 Silviculture Report. Department of Sustainability and Environment, Victoria (internal report)
69. Williams RJ, Bradstock RA, Cary GJ, Enright NJ, Gill AM, Liedloff AC, Lucas C, Whelan RJ, Andersen AN, Bowman DJMS, Clarke PJ, Cook GD, Hennessy KJ, York A 2009, ‘Interactions between climate change, fire regimes and biodiversity in Australia: A preliminary assessment’, Australian Department of Climate Change and Department of the Environment, Water, Heritage and the Arts, Canberra, ACT.
70. Keeley JE 1986, ‘Resilience of Mediterranean shrub communities to fires. In: Resilience in Mediterranean-type ecosystems’, pp 95-112, Springer, Netherlands.
71. Re-seeding data sourced from numerous DELWP internal fire recovery documents and associated reports, each listed at the end of this chapter.

Table Fi.2 Change in stock of assets burnt in 2003 Alpine fires (hectares)

	State forest and other public land		Private land	Total
	Ash eucalypt species	**Other species (a)**		
	ha	**ha**	**ha**	**ha**
Opening stock of assets	81,000	923,000	96,000	1,100,000
Reductions in stock				
Losses due to natural events	3,550			
Total reductions in stock	*3,550*	-	-	-
Additions to stock				
Improvements due to human activity – aerial seeding	2,000			
Reclassifications		1,550		
Total additions to stock	*2,000*	*1,550*	-	-
Closing stock of assets	**79,450**	**924,550**	**96,000**	**1,100,000**

(a) Other species are fire tolerant, so while they were burnt, this does not necessarily change the ecosystem type

(Data source: DELWP, 2018)

Table Fi.3 Change in stock of assets burnt in 2006–07 Great Divide fires (hectares)

	State forest and other public land		Private land	Total
	Ash eucalypt species	**Other species**		
	ha	**ha**	**ha**	**ha**
Opening stock of assets	65,000	1,020,000	105,000	1,190,000
Reductions in stock				
Losses due to natural events	15,000			
Total reductions in stock	*15,000*	-	-	-
Additions to stock				
Improvements due to human activity – aerial seeding	5,880			
Improvements due to human activity – seedling planting	376			
Reclassifications		8,744		
Total additions to stock	*6,256*	*8,744*	-	-
Closing stock of assets	**56,256**	**1,028,744**	**105,000**	**1,190,000**

(Data source: DELWP, 2018)

Table Fi.4 Change in stock of assets burnt in 2009 Black Saturday fires (hectares)

	State forest and other public land		Private land	Total
	Ash eucalypt species	Other species		
	ha	ha	ha	ha
Opening stock of assets	43,000	244,000	119,000	406,000
Reductions in stock				
Losses due to natural events	4,500			
Total reductions in stock	*4,500*	-	-	-
Additions to stock				
Improvements due to human activity – aerial seeding	3,965			
Improvements due to human activity – seedling planting	102			
Reclassifications		433		
Total additions to stock	*4,067*	*433*	-	-
Closing stock of assets	**42,567**	**244,433**	**119,000**	**406,000**

(Data source: DELWP, 2018)

Table Fi.5 Change in stock of assets burnt in 2013 Harrietville, Tomahawk and Aberfeldy fires (hectares)

	State forest and other public land		Private land	Total
	Ash eucalypt species	Other species		
	ha	ha	ha	ha
Opening stock of assets	7,800	105,332	12,870	126,002
Reductions in stock				
Losses due to natural events	5,537			
Total reductions in stock	*5,537*	-	-	-
Additions to stock				
Improvements due to human activity – aerial seeding	2,425			
Improvements due to human activity – seedling planting	-			
Reclassifications		3,112		
Total additions to stock	*2,425*	*3,112*	-	-
Closing stock of assets	**4,688**	**108,444**	**12,870**	**126,002**

(Data source: DELWP, 2018)

Cost data associated with management intervention – revegetation of ash forest – is available (see Table Fi.6). If information on the ecosystem services provided under different scenarios (for example, revegetation or no revegetation) was available, this could be assessed against management intervention to help determine where management interventions are likely to deliver greatest benefits for the community.

Table Fi.6 Cost of additions to stock from human activity (revegetation of ash forest)

	Aerial sowing $	Seedling planting $	Total $
2003 Alpine fires	899,600	-	899,600
2006–07 Great Divide fires	1,813,578	793,020	2,606,598
2009 Black Saturday fires	1,615,060	249,000	1,864,060
2013 Harrietville, Tomahawk and Aberfeldy fires	787,445	-	787,445

(Data source: DELWP, 2018)