Assessment of the impacts of large, severe and intense bushfires across South East Australia

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Contents

1 Introduction

The author considers that current fire management approaches across SE Australia landscapes are failing and, in many cases, have failed.

The current state and federal fire interval approaches focus on individual species, a large number of listed threatened flora and fauna species and communities, reduced fire return frequencies and inadequate assessment of the consequences of not burning.

As an example, across NSW, prescribed burning of forested areas has an average of 0.6 % of forests per year over the last seven years.

Prescribed burning in most states is at low levels, except for WA. The graphs in the link article below highlight the value of prescribed burning in reducing bushfire extent across Australian states, the data is over 60 years.

https://arr.news/2022/05/18/review-of-prescribed-burning-and-wildfire-burning-across-australia-john-odonnell/

The adopted fire regimes and approaches result in widespread high intensity bushfires in these same areas where low intensity fires are restricted, and often result in major bushfire impacts, social and safety impacts, environmental impacts and economic impacts.

It is essential that all the impacts and costs of failed and failing fire regimes in SE Australia and associated intense bushfires are assessed to adequately understand the scale of bushfire impacts, social and safety impacts, environmental impacts and economic impacts. This has been undertaken in this review.

2 Bushfire disaster impacts across SE Australia, including from intense and severe bushfires

Bushfire disaster impacts across SE Australia, including from intense and severe bushfires, are outlined in Sections 2.1 to 2.5.

2.1 Ongoing impacts from the loss of Aboriginal burning and open forest

It is essential to gain an understanding of the changes and impacts since Aboriginal burning stopped.

Jurskis (2011) outlines the pivotal role that human fires have in Australia's ecological history:

Human fires have had a pivotal role in Australia's ecological history (e.g. Pyne 1991; Bowman 2003; Gammage 2011; Jurskis 2011). About the time Aboriginal people occupied Australia, climate was relatively stable but there was a peak in charcoal production and mesic vegetation retreated whilst eucalypts and grasses became dominant indicating that human fires were primarily driving vegetation change (Kershaw et al. 2002). Consequently browsing megafauna with specialized diets gave way to less specialized grazers (Miller et al. 2005; Prideaux et al. 2007). Subsequently charcoal production or biomass burning declined and then remained at relatively low levels for about 20 ka until the time of European settlement (Mooney et al. 2010). Woody thickening, loss of ground layers and associated fauna, pest outbreaks, eucalypt decline and extensive conflagrations occurred when Aboriginal fire management was displaced by European settlers (Mitchell 1848; Curr 1883; Howitt 1891). Charcoal production peaked once more, then declined from the mid-20th Century as broadscale prescribed burning including aerial ignition reduced the frequency and extent of wildfires (Jurskis et al. 2003; Boer et al. 2009; Mooney et al. 2010). There has been a resurgence in eucalypt decline, extensive wildfires and loss of species over recent decades with expansion of unmanaged conservation reserves and reduced prescribed burning (Jurskis 2005, 2011; Adams and Attiwill 2011).

Jurskis (2021 a) provides valuable detail in relation to the reinstate resilient, healthy and safe landscapes

Mild burning of anthropogenic landscapes consumes relatively little biomass and produces relatively little charcoal. Although burning by people has typically been regarded as an ecological disturbance, the historical evidence, together with traditional Aboriginal knowledge, suggests that it is actually maintenance, essential to sustain our natural environment. People can reinstate resilient, healthy and safe landscapes irrespective of climate change.

Burrows et al. (2013) review Jarrah forest fire history from stem analysis and anthropological evidence

Fire frequencies before and after European settlement were compared by studying stem sections from large, old jarrah (Eucalyptus marginata)trees for fire injury and by relating this to the documented historical evidence. The resilience of jarrah to injury by fire and the limitations of ring counting as an ageing technique, prevented an accurate and definitive reconstruction of the fire frequency prior to European settlement. However, the chronological pattern of fire-caused bole injury supports historical descriptions of fire history and can be explained by broad eras of human activity in the forest. Prior to European settlement, the incidence of fire injury was very low with the average interval between injurious fires being about 81 years. Following European settlement, the frequency of fire injuries increased and the average interval between injuries decreased to about 17 years. The pre-European fire regime in the drier jarrah forest and the forest margin was probably one of frequent, non-injurious, low intensity fires set mainly in summer and autumn, with occasional long intervals between fires ending in high intensity, injurious fires. The increase in fire injury to trees immediately following European settlement and up to the 1950s is probably due to the higher frequency of intense wildfires associated with increased fuel levels resulting from logging and long periods of fire exclusion.

Laming et al. (2022) note:

We identify a shift in fire activity in the late 1960s to early 1970s (age-depth model error range), from relatively low macroscopic charcoal input to both an increase in the amount of charcoal into the site and an increase in the variability of charcoal input. These changes reflect both an increase in the amount of burning of woody fuels (which produce larger charcoal fragments [101]) and a shift to a *more variable fire regime (Figure 6c,f). This is followed by an increase in the proportion of vegetation comprised of woody fuels (trees and shrubs) in the late 1970s (Figure 6a) and a further increase in the variability of burning, with higher peaks and lower troughs in charcoal deposition (Figure 6e,f). Indeed, the most severe burning events recorded at the site occur following a doubling of tree and shrub pollen in the sequence, signalling significant increases in vegetation density (Figure 6). These events were severe enough to completely incinerate vegetation cover and expose soils to removal by erosion [106,116,134,135] (Figure 6a,b). In sum, the data presented display a shift from a consistent high frequency-low intensity fire regime (i.e., cultural burning/settler mimicry) within an open grass and herb-rich forest, to a lower frequency-higher intensity fire regime (i.e., infrequent catastrophic fires) (Figure 6d) in response to the banning of settler mimicry burning under the Land Conservation Act of 1970—a wilderness-inspired act of legislation aimed at promoting and protecting peoplefree nature. The absence of a discrete charcoal peak in the upper most section of the sediment core reflecting the early 2020 "Black Summer" bushfires that burnt the region likely reflects the time-averaged nature of charcoal deposition into wetland sediments [101]. This results in a large part of the charcoal signal delivered into wetlands being washed in during the years subsequent to discrete fire events.*

and:

The direct implication of wilderness-inspired conservation legislation on the local environment around Buchan on Gunaikurnai Country was profound. Prior to ca. 1970, biomass (i.e., fuel load) was predominantly herbs and grasses that fostered a broadly stable low-intensity fire regime (Figure 6a,d). Local Gippsland settlers state that their intent for frequently firing the land around Buchan was to mimic the management style they witnessed Aboriginal people practicing [47]. These settler mimicry fires were often different in frequency, intensity and seasons of burning, yet they were still able to maintain some semblance of pre-existing fire regimes (Figure 6). Buchan locals made note that the Gunaikurnai enacted frequent, cool, slow-burning fires that maintained open vegetation and low biomass [87].

and:

In Victoria, from the late-1950s through to the mid-1970s the government set to create and enforce legislation as part of a conservation movement (Figure 2) that was not aimed at fuel reduction or fire prevention (largely ignoring fuel reduction), but rather fire suppression [140]. The direct impacts of these Acts can be seen in our data from Buchan, with:
(1) a change in fire activity to more variable and severe fires;
(2) a marked increase in woody and more flammable plants favoured by a lengthening of the fire-return interval and;
(3) the onset of post-fire erosion events commencing after ca. 1970 and the establishment of the Land Conservation Council that implemented the prohibition of settler mimicry burning locally around Buchan and more broadly across Victoria (Figure 6) [76,89].

Professor Simon Haberle an Australian National University Professor of Natural History. Professor Haberle has undertaken sediment, sampling at a very fine resolution, which paints a picture of the landscape around the Bega Swamp in freeze frames of every 20 years, stretching back over 15,000 years. "The results show that the number of samples including charcoal has increased since European settlement, confirming other studies that big fires have occurred more frequently than during the time of Aboriginal land tenure in the Australian high country," Professor Haberle said. "It also shows that in the past mega fires only occurred very rarely, once every 4000 years, and that the current situation of big and intense fires is unusual in the long-term history of the region." "You see big changes in fire management, because you can look at the charcoal and see what burning regime took place," he said. "It was a regular regime, Aboriginal people knew how to keep fuel loads lower." According to Professor Haberle's research from Tasmania to the Kimberley, big fire events are becoming more common, fires are starting sooner and problematic trends are forming. "Big disastrous fires used to be rare, but are more common now," he said. "The difference now is the regular burning doesn't occur anymore, so we don't know what will happen in the future. "Things that happened in the past can be beneficial, and regular small scale burning in the forest may be a reason for less big fires."

Ellis et al (2021) provide valuable detail in relation to people shaping most of terrestrial nature for at least 12,000 years:

Human societies have been shaping and sustaining diverse cultural natures across most of the terrestrial biosphere for more than 12,000 y. Areas under Indigenous management today are recognized as some of the most biodiverse areas remaining on the planet (51, 61), and landscapes under traditional low-intensity use are generally much more biodiverse than those governed by high-intensity agricultural and industrial economies (62, 63). Although some societies practicing low-intensity land use contributed to extinctions in the past, the cultural shaping and use of ecosystems and landscapes is not, in itself, the primary cause of the current extinction crisis, and neither is the conversion of untouched wildlands, which were nearly as rare 10,000 y ago as they are today. The primary cause of declining biodiversity, at least in recent times, is the appropriation, colonization, and intensifying use of lands already inhabited, used, and reshaped by current and prior societies. Depicting human use of nature largely as a recent and negative disturbance of an otherwise human-free natural world is not only incorrect but has profound implications for both science and policy. Across the vast majority of this planet, traditional, Indigenous, and contemporary cultural natures, together with their interwoven peoples and histories, and not areas free from human influence, are essential for understanding and sustaining terrestrial nature, including its biodiversity and contributions to people (2, 24, 47, 49–51, 64). Effective, sustainable, and equitable conservation of biodiversity and nature's contributions to people recognizes and empowers Indigenous, traditional, and local peoples and their cultural heritage of sustainable ecosystem management through rights and responsibilities as an essential basis for conservation strategies and priorities around the world (17, 23, 51, 65, 66). Efforts to achieve ambitious global conservation and restoration agendas (11, 15) will not succeed without more explicitly recognizing, embracing, and restoring these deep cultural and societal connections with the biodiversity they aim to sustain.

2.2 Large area megafires and long fire runs/ due to large contiguous fuel loads across landscapes

Under current approaches and fire regimes, large bushfire disasters will continue and often have very long fire runs across landscapes and often affecting large numbers of towns, cities, fire fighters and ecosystems will continue to be impacted by bushfires.

The fires burnt an estimated 24.3 million hectares (243,000 square kilometres), destroyed over 3,000 buildings (including 2779 homes), and killed at least 34 people. Wikipedia 2019–20 Australian bushfire season, accessed 28 April 2025.

As an example, Map 22.1: Fire extent and severity mapping, highlights the extent of the 2019–20 NSW Black Summer bushfires across NSW (Refer mapping within NSW SOE Fire 2021).

The intense bushfires kill large numbers of trees and markedly reduce the health of remaining trees for 10 years plus, the impacts are that high.

The Gosper's Mountain bushfire was the biggest ever individual bushfire in the world during 2019/ 20 bushfires. And there were many other disastrous bushfires in the Greater Blue Mountains World Heritage Areas.

As an example as highlighted in O'Donnell (2025 a), The NSW Alps 5 years after the 2019/2020 bushfires, the impacts and area of the 2019/ 20 bushfire were large.

Kiandra to Adaminaby, a stark scene resulting from the 2019/ 20 bushfires in KNP, the carbon loss was obviously huge from tree mortality and lost growth. Dense understorey fuels with dead timber fuels represent a major fire hazard for the next bushfire. Fuel will now contain a high proportion of woody material and for many years subsequent bushfires will have a longer burnout period and be more damaging to any regenerating trees. Note the absence of live hollow bearing trees.

Cabramurra to Khancoban, above Tumut Pond Dam view resulting from the 2019/ 20 bushfires in KNP, the carbon loss was obviously huge from tree mortality and lost growth. Dense

understorey fuels and dead timber fuels represent a major current and ongoing fire hazard for the next bushfire. Fuel will now contain a high proportion of woody material and for many years subsequent bushfires will have a longer burnout period and be more damaging to the regenerating trees. Note the absence of live hollow bearing trees.

Cabramurra to Khancoban. Large areas of single age 5-year-old snow gums (technically older where there are live lignotubers present below the ground) resulting from the 2019/ 20 bushfires in KNP, the carbon loss was obviously huge from tree mortality and lost growth. Fuel will now contain a high proportion of woody material and for many years subsequent bushfires will have a longer burnout period and be more damaging to the regenerating trees.

January 2020 satellite imagery below demonstrate the highly active and intense bushfires in a large area of southern NSW, including KNP, the two fires being the Dunns Rd fire and the Green Valley fire. I understand that both fires started from lightning in late December 2019. The weather, long drought. Low prescribed burning rates and high fuel loading all contributed to these bushfires.

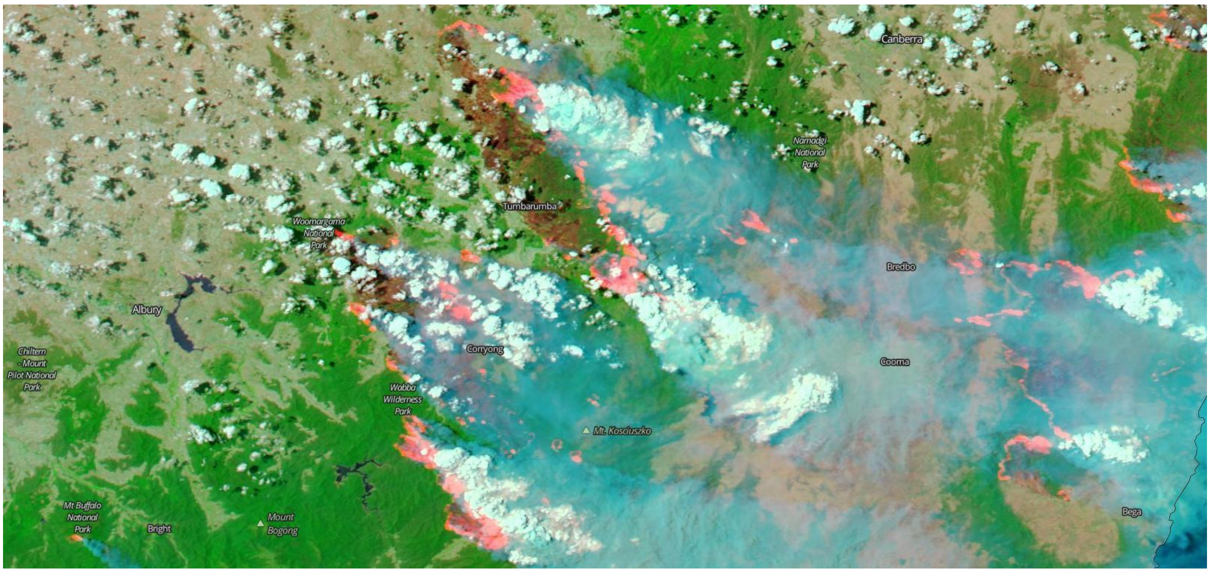


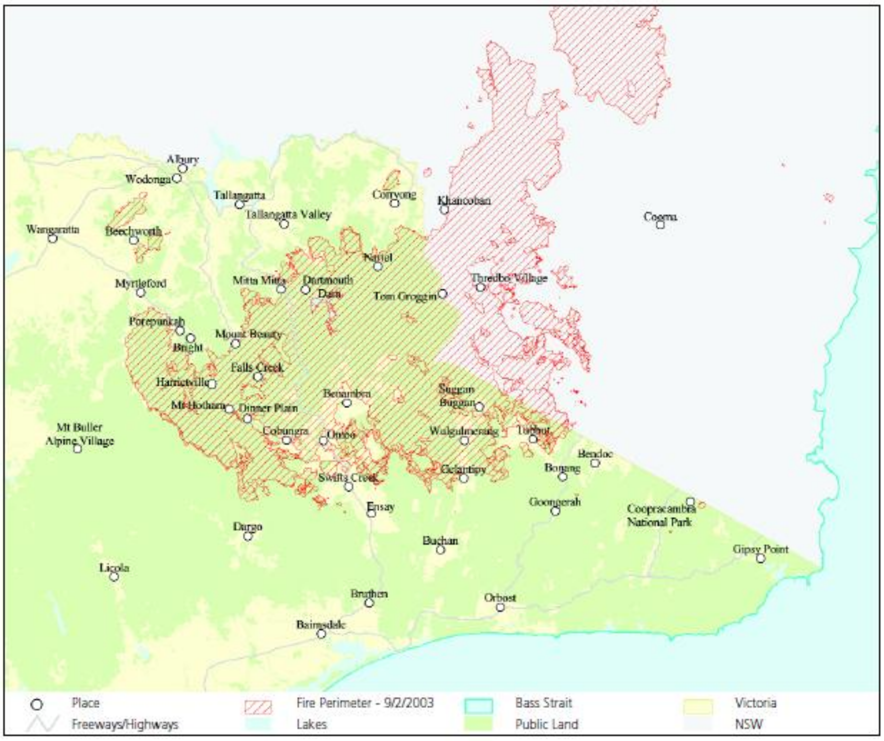
Figure. This is a satellite image of 4 January 2020 which indicates very hot fires associated with the Dunns Road and Green Valley fires. EOS Worldview Aqua Modis Corrected reflectance bands 7 2 1.

In the image, about 65 % across from the left and 40 % down from the top, there are two (then smaller) individual bushfires moving very fast to the SE, north of the Selwyn area of KNP. 3 pm (3.22 pm) weather data for 4 January 2020 at Cabramurra highlights strong winds at 35 km WNW (with maximum wind speed up to 128 km W); RH at 15 and Temperature at 32 degrees C. These two bushfires and other bushfires would have likely been influencing the high wind speeds.

Further mapping of the 2003 bushfires includes NSW, Victoria and the ACT, on two days 18 January 2003 and 9 February 2003. The extent of the bushfires in the alpine areas were huge, let alone the other bushfires in Victoria and the ACT.

Figure 4.4: Geographic Areas Affected by Fires Day 11, 18 January 2003

Figure 4.8: Geographic Areas Affected by Fires Day 33, 9 February 2003



Figures above mapping the 2003 bushfires. Extracted from Report of Inquiry into the 2002-3 Victorian Bushfires, Victorian State Government. 2003.

In relation to these 2003 bushfires, on January 8, 2003, a major storm passed over the mountains and lightning strikes ignited 185 fires in Victoria, NSW and ACT. 555,000 hectares of Park Service managed lands affected by fire, including 522,000 hectares (71%) of Kosciuszko National Park and 18,000 hectares (94%) of Brindabella National Park. Extracted from Australian Alps National Park Education Resource. As noted by Worboys (2003) in “A Brief Report on the 2003 Australian Alps Bushfires In the summer of 2003”, the Australian Alps experienced their largest bushfires in over 60 years, with an estimated 1.73 million hectares burning. The bushfires burnt across Victoria, New South Wales (NSW), and the Australian Capital Territory (ACT) during a drought that ranks as one of the worst in 103 years of official Australian weather records.

And as well, there are repeat huge megafires in Kosciuszko National Park (KNP). Refer to the following links that provide additional detail in relation to the 2003 and 2019/ 20 bushfires:

- https://www.fireandbiodiversity.org.au/images/publications/conference-2006/Fire_Management_in_the_alpine_region.pdf
- https://fridayoffcuts.com/dsp_article.cfm?id=1109&date={ts%20%272025-04-24%2000:00:00%27}&aid=14403 The NSW Alps 5 years after the 2019/2020 bushfires

And there’s more large bushfires in other conservation areas:

- There are repeat megafires in the Grampians NP, these were huge in 2024 and 2025.
- There are repeat megafires in the Little Desert conservation area, these were huge in 2024 and 2025.
- The same applies to the Flinders Ranges.

Large intense bushfires are going to continue, unless prescribed burning rates in SE Australia increase from the minimal 0.6 % per year over the last 7 years (in NSW), to around 8 % per year. The author cannot see this happening any time soon.

Hislop et al (2020) study the effectiveness of fuel reduction burning for wildfire mitigation in sclerophyll forests:

ABSTRACT

The wildfires in south-eastern Australia in the 2019–20 fire season were some of the worst in recent memory. The effectiveness of fuel-reduction burning as a risk mitigation strategy is, once again, being scrutinised. Some argue that more fuel-reduction burning is needed, while others suggest that it is of limited use in such extreme fires. In this study, we tested the effectiveness of fuel-reduction burning at a landscape scale in terms of its ability to reduce the severity of subsequent wildfire. To achieve this, we selected all the recent (2015–2019) fuel-reduction burns undertaken in New South Wales and Victoria that intersected with the extent of the 2019–20 wildfires and evaluated whether the fire severity was significantly different in the recently treated areas to that of similar untreated areas in the vicinity. To determine fire severity, Sentinel 2 satellite imagery and the change in normalised burn ratio (a common metric used for rapid and broadscale fire severity mapping) was used. Our results showed that 48% of the 307 recent fuel-reduction burns resulted in statistically significant decreased fire severity. Our results also indicated that more recent fuel-reduction burns had a greater impact, with 66% of burns undertaken in 2019 significantly reducing severity, compared with 42% from 2015. We also analysed each fuel-reduction burn in the context of a range of metrics, including location, elevation, slope, aspect and forest heterogeneity, to assess whether these factors influenced the likelihood that a burn would be effective. Location and, to a lesser degree, forest heterogeneity were found to be significant factors. Our results support the view that recent fuel-reduction burns reduce fire severity. It is unclear, however, whether the differences would be operationally significant under extreme conditions, when wildfires are driven largely by weather, irrespective of fuel loads.

2.3 Bushfire suppression difficulty impact

As noted in the US, minimising prescribed burning and adaptive management can increase suppression time considerably, equipment needs, personnel risks and costs of bushfire suppression. In relation to the US 2021 Dixie Fire at Chester, this was readily apparent, they noted that they spent nearly $700 million on the Dixie Fire, we could have spent a fraction of that to thin and burn and tend land around Quincy, Greenville and Chester.

Boer et al (2009) in Western Australia highlight that prescribed burning pronouncedly changed the spatial distribution of fuel age in the study area and has significantly reduced the incidence and extent of unplanned bushfires.

2.4 Repeat intense bushfires and repeat bushfire cycle impacts

Repeat intense bushfires can result in significant ecosystem changes and ecological damage, high-intensity fires not only kill trees but also sterilize soil, incinerate seed banks, and convert tall forests into shrublands and also change grassy forests to non-grassy forms. Repeat intense bushfires also have long-term impacts on wildlife habitats and the availability of live hollow bearing trees. There is more discussion in relation to this in Section 4.

There is useful other information on repeat bushfires in alpine ash with the KNP, issued by NSW National Parks and Wildlife Service (2024) in the Ecological Health Performance Scorecard report for Kosciuszko National Park 2022–23:

- Alpine ash dominated forests occupy 77,050 ha in KNP, representing 76% of the NSW extent;
- In 2003, 64% of the total area of alpine ash in KNP was burnt;
- In 2020, 33% of the total area of alpine ash was burnt; and
- The area burnt by both fires was 19,295 ha, allowing a 17-year recovery time for the species such as alpine ash.

The big risk here is repeat intense/ large area bushfires in the years after intense bushfires in regrowth alpine ash to around Year 15 for this obligate tree species.

The author believes that there is a cycle of repeat intense bushfires set up within much of SE Australia forests, with regular large area intense bushfires over landscapes due to mimimal low intensity prescribed burning, very long fire return intervals, even for low intensity fire, and previous severe bushfires. These repeat bushfires are having large impacts on ecosystems.

van Wagtendonk et al. (2012) assess factors associated with the severity of intersecting fires in Yosemite National Park, California, USA:

The severity of fires in the Illilouette Creek basin was associated with the fire return interval departure, the years since last burned, the severity of the previous fire, the number of times an area had burned, the weather conditions at the time of reburning, and the pre-fire vegetation type. The factors that were associated with reburn severity worked in combination with each factor, influencing some aspect of severity.

Barker and Price (2018) consider the positive severity feedback between consecutive fires in dry eucalypt forests of southern Australia:

Abstract

Fire regimes have long-term effects on ecosystems which can be subtle, requiring study at a large spatial scale and temporal scale to fully appreciate. The way in which multiple fires interact to create a fire regime is poorly understood, and the relationship between the severities of consecutive fires has not been studied in Australia. By overlaying remotely sensed severity maps, our study investigated how the severity of a fire is influenced by previous fire severity. This was done by sampling points at 500-m spacing across 53 fires in dry eucalypt forests of southeast Australia, over a range of time since fire spanning every major fire season for 30 yr. Generalized additive models were used to determine the influence of previous severity on the probability of crown fire and understory fire, controlling for differences in time since fire, topography, and weather. ***We found that a crown fire is more than twice as likely after a previous crown fire than previous understory fire, and understory fire is more likely after previous understory fire****. Our findings are in line with the results of studies from North America and suggest that severe fire promotes further fire. This may be evidence of a runaway positive feedback, which can drive ecological change, and lead to a mosaic of divergent vegetation, but research into more than two consecutive fires is needed to explore this. Our results also suggest that a low-severity prescribed fire may be a useful management option for breaking a cycle of crown fires.*

and:

Discussion

The effect of previous severity

The likelihood of very high/extreme severity was low compared to low severity, but it was significantly more likely after previous very high/extreme severity. Conversely, the probability of fire restricted to the understory decreased with increasing severity in the previous fire.

These findings are not unique, it does not surprise the author in relation to a crown fire is more than twice as likely after a previous crown fire than previous understory fire.

The author provides further interpretation in relation to this:

- past crown fires usually produce a dense new understorey;
- combustible species may be favoured following intense bushfires;
- in some cases grassy forest types may be replaced by shrubby forest types, increasing fuel loads and strata;
- there is a lot of dead wood present on the ground and standing;
- post intense crown fire, fuel loads are high and fuel strata provides a bushfire avenue to tree crowns and in many cases there may be contiguous fuel loads across landscapes;
- in addition, the range of tree/ vegetation heights would be reduced from the previous times;
- these factors result in increasing bushfire intensity, severity and duration in the next bushfire; and
- in many cases a cycle of intense, severe and long duration bushfires is established.

2.5 Changes in feedback between past fires and future fires and changes in flammability

Kasel et al. (2024) highlights major concerns in relation to severe wildfires with short fire return intervals and the massive ecosystem impacts of this:

Conclusion

Clear shifts in plant diversity in extant vegetation and soil seed banks, including a decline in alpha diversity and changes in species composition and functional trait associations, provide strong evidence for changes in plant diversity with emerging fire regimes. The largely consistent changes in plant diversity in both forest types, despite contrasting historical fire regimes, suggests that ***severe wildfires with short fire return intervals are pushing ecosystems beyond their historical range of variability, with the realization of a previously hidden resilience debt. Shifts in species composition, including the potential for an increased flammability of these forests and positive feedback between past fires and future fires*** *[120,134,135], point to a likely increase in extent in areas burnt at even higher frequencies, with some areas in southeastern Australia already being burnt four to five times since 1995 [136].*

Barker et al. (2021) assess high severity fire that promotes a more flammable eucalypt forest structure:

Abstract

Recent landscape-scale wildfires in eastern Australia have made apparent the need for a greater understanding of the flammability dynamics of forested ecosystems. Fire severity is a measure of the impact of a fire on vegetation, but little is known about the landscape-scale response of the fire-prone dry sclerophyll forests of eastern Australia to different levels of fire severity. Species in these forests have multiple responses to fire, which can be dependent on the fire severity. In this study, we aimed to determine the effect of fire severity on the vegetation structure, and therefore flammability, of these forests. We addressed two hypotheses that 1) High severity fire would result in a denser understory than low severity fire after 5 years and that 2) High severity fire would reduce the vertical separation between understory and canopy after 5 years. Field surveys of 38 forest sites with differing fire severity but standardised time since fire and forest type, in Sydney region of New South Wales, Australia, were used to test these hypotheses. ***We found lower canopy cover and greater understory cover (0.5–4 m height) after high severity fire compared with sites which burnt at low severity. Vertical separation was less between the canopy and understory at sites after high severity fire than after low severity fire. The greater quantity of understory fuel and greater vertical continuity in fuel structure observed suggests a potential increase in forest flammability after high severity fire compared with lower severity fires in these forest types.***

3 Social and safety bushfire impacts across SE Australia, including from intense and severe bushfires

Social and safety bushfire impacts across SE Australia, including from intense and severe bushfires, are outlined in Sections 3.1 to 3.7.

3.1 Fire fighter impacts and safety exposure

Davey and Sarre (2020) outline key facts in relation to the 2019/ 20 bushfires:

"Thirty-three deaths occurred as a result of these fires, 25 of them in New South Wales. Nine firefighting personnel died, comprising three American aircrew and three Rural Fire Service volunteer firefighters in New South Wales and three members of Forest Fire Management Victoria. Fires destroyed 3100 homes."

It is the author's belief that many of the forested fire grounds across south eastern Australia are way too dangerous to fight bushfires and for firefighter safety due to past intense bushfires, minimal prescribed burning and long fire interval policies. To be frank, we as a society have learnt very little following the 2019/20 bushfires and bushfires before that, especially in regards to bushfire mitigation and fire fighter and community safety.

The author has identified 21 main areas of concern in relation to bushfire firefighter safety in forested areas with minimal rates of prescribed burning, these are outlined below across a number of heading areas. The 21 concerns are outlined in the link below:

https://arr.news/2023/11/16/inadequate-firefighter-safety-in-south-east-australian-forests-john-odonnell/

Dense understorey fuels and dead timber fuels represent a major current and ongoing fire hazard across large number of areas across SE Australia. Future bushfires dense fuel loads and strata under bad weather and drought conditions will likely be of high intensity, high severity and in many long combustion durations, depending on the forest type, history, fuel load and weather on the day. This makes firefighting incredibly difficult and puts their safety at risk.

This is much worse than could be imagined, as the 2019/ 20 bushfire impacts occurred over extremely large contiguous areas, so repeat long burnfire runs will very likely occur again in the near future where dense regeneration and a lot of dead timber present.

Large dead trees at firefighting locations are often very dangerous, including at locations where trees alight are falling down around fire fighters. Firefighting in such situations is going to be very very difficult with these understorey fuels, standing trees above and a large number of logs on the ground. Worse still, is when key accesses are blocked by fallen trees, restricting access, egress or retreat.

The Bushfire Front (2025 web) document "Impacts of Bushfires" also outlines firefighter considerations in relation to bushfire safety.

3.2 Community impacts and safety exposure

Davey and Sarre (2020) noted community deaths above in relation to the 2019/ 20 bushfires.

2019–20 Australian bushfire season impacts are highlighted in the Wikipedia 2019–20 Australian bushfire season link below (date 29 April, 2025):

The fires burnt an estimated 24.3 million hectares (243,000 square kilometres), destroyed over 3,000 buildings (including 2779 homes), and killed at least 34 people. According to the University of Tasmania's Menzies Institute, bushfire smoke was responsible for more than 400 deaths, reported by the Medical Journal of Australia.

Deaths and household impacts from past Australian bushfires is highlighted in the Wikipedia Bushfires in Australia link below (date 29 April, 2025):

https://en.wikipedia.org/wiki/Bushfires_in_Australia

Deaths and impacts from bushfires is also covered in the Victorian link below:

https://www.ffm.vic.gov.au/history-and-incidents/past-bushfires

Impacts to towns in Australia impacted by the 2019/ 20 bushfires is outlined in Wikipedia (2025) Impact to towns of the 2019–20 Australian bushfire season. The list is extensive, but likely not complete.

Community impacts from bushfires for a number of major Australian bushfires is outlined in the Bushfire Front document in the link below:

https://www.bushfirefront.org.au/home/fire-facts/impacts-of-bushfires/#:~:text=Public%20infrastructure%20also%20suffers%20in,reduced%20economic%20performance%20by%20industry.

Stephenson (2010) assesses the impacts-of-severe-bushfires-in-SE-Australia on property from a number of bushfires pre 2010.

Stephenson (2010) also assesses the impacts-of-severe-bushfires-in-SE-Australia on social impacts and government services considering a number of bushfires pre 2010.

In relation to bushfire safety of adjacent neighbours and communities, the author believes that under current circumstances with long return fire intervals in place, huge fuel loads across contiguous areas, past intense bushfires, dense understories, large amounts of dead fuel, firefighting will have limited effectiveness in protecting communities in difficult bushfire conditions.

3.3 Public air quality and health impacts

The 2019/ 20 bushfire season commenced in early August 2019 at Grafton/ Casino and continued to February 2020. Poor air quality conditions during long duration major bushfires such as 2019/ 20 are made worse by heavy fuels, dead tree fuel, dense understories, long fire runs and long bushfire durations. This increases the difficulties and health impacts on firefighters.

Department of Environment and Heritage (2025, web 1 June 2025) outline extreme air pollution details in NSW during the 2019/ 20 bushfires:

Extreme air pollution levels

All regions across the NSW Air Quality Monitoring Network recorded extended periods of poor air quality due to smoke and dust, during spring–summer 2019–20. The extreme air pollution levels are summarised below, in comparison with air quality benchmarks and long-term records:

- *Air pollution levels were above benchmarks for poor air quality on 134 days (74% of spring–summer days) across the standard monitoring network, compared to 83 days (46%) in spring–summer 2018–19. The percentage of days above benchmarks across regions in the Network in spring-summer 2019–20 ranged from 22% in the Central Coast to 47% in the Newcastle Local region.*
- *The percentage of hours affected by smoke across our rural and bushfire indicative air quality monitoring stations ranged from 8% in western NSW to 45% at Ulladulla in south-eastern NSW.*
- *Daily PM2.5 levels were above the benchmark across the standard monitoring network on 99 days (54% of spring–summer days), mainly due to bushfire smoke, compared to 4 days in spring–summer 2018–19. Bushfire emergency monitoring stations recorded 46 days above the benchmark, including 10 days not recorded by the standard monitoring network.*
- *Daily PM10 levels were above the benchmark across the standard monitoring network on 140 days (77% of spring–summer days), due to dust and bushfire smoke, compared to 78 days in spring–summer 2018–19. Bushfire emergency monitoring stations recorded 43 days above the benchmark, including four days not recorded by the standard monitoring network.*

- *Hourly NEPH (visibility) levels were above the benchmark across the standard monitoring network on 115 days (63% of spring–summer days), mainly due to bushfire smoke, compared to 13 days in spring-summer 2018-19. Bushfire emergency monitoring stations recorded 66 days above the benchmark, including 15 days not recorded by the standard monitoring network.*
- *Ozone levels were above either the one-hour or four-hour average benchmarks on 32 days (18% of spring–summer days), compared to 13 days in spring–summer 2018–19. Bushfire emergency monitoring stations recorded two days above the benchmark.*
- *The hourly NO2 level was above the benchmark on one day within the standard monitoring network. This event was the first day over the benchmark since 1998.*
- *The 8-hour CO level was above the benchmark on two days at a bushfire emergency monitoring station, the first event over the benchmark since 2013.*

Australian Institute of Health and Welfare (2020) provide a detailed exploration of the short-term health impacts of the Australian bushfires 2019–20:

Key findings

What impact did the 2019–20 bushfires have on respiratory health?

Hospital emergency department data for New South Wales analysed for this report show a clear increase in presentations for respiratory problems during the bushfire season compared with data for the previous year. Data for smaller geographical areas below the state level—Statistical Area Level 4 (SA4)—show strong impacts in this regard in regions where bushfires burned nearby. For example, for people residing in the Riverina SA4 where the Dunns Road megafire burned at Emergency Warning level near Batlow for several days, respiratory-related presentations to an emergency department increased by 86% for the week beginning 5 January 2020 when compared with presentations for the same week in the previous year.

Sales data from pharmacies showed large increases in sales of inhalers for shortness of breath corresponding with the spread of bushfires throughout the bushfire season when compared with the same weeks in the previous year. For example, in the Mid North Coast SA4, inhaler sales increased by 144% for the week beginning 10 November 2019, when several fires were burning at Emergency Warning level in the area.

Pharmaceutical Benefits Scheme (PBS) data for scripts dispensed for salbutamol (commonly marketed as Ventolin or Asmol and used for the relief of respiratory symptoms) also show changes that coincide with bushfire activity. In south-eastern New South Wales in the week beginning 29 December 2019, salbutamol prescriptions increased by 63% in the Capital Region SA4 (which includes towns such as Batemans Bay) compared with the same week in the previous year. There was a 73% increase the following week, beginning 5 January 2020. Dispensing rates for salbutamol prescriptions remained high in this SA4 up until the last week of January.

Compared with the same weeks in the previous year, salbutamol scripts dispensed in the Hume SA4 in Victoria increased by 74% and 30%, respectively, in the weeks beginning 5 January 2020 and 12 January 2020 as 3 fires burned on the New South Wales and Victoria border.

How did the bushfires affect mental health?

Biddle and colleagues (2020) estimated that directly after the 2019–20 bushfires more than half of Australian adults felt anxious or worried about them. Bushfire-related calls to the Lifeline crisis support hotline increased, resulting in the introduction of a telephone line for people affected by the bushfires (Lifeline 2020).

Additional Medicare items to allow people whose mental health was adversely affected by the 2019–20 bushfires to access mental health and wellbeing services were introduced in January 2020. From 19 January to 11 October 2020 there was an average of 498 services claimed, per week, across Australia. Although emergency department data for New South Wales show little impact of the bushfires on presentations for mental health, they capture only one means by which people may seek *help for their mental health. Further, many people would have found it more difficult to physically access a hospital during the bushfires. More will be known about this topic as other data become available.*

Other effects on health

There is evidence to suggest cardiovascular and cerebrovascular health are affected by bushfire smoke (see, for example, Haikerwal et al. 2015 and Finlay et al. 2012); however, this was not apparent in data analysed for this report on presentations to emergency departments in New South Wales. This may be at least partly due to people in the community heeding public health advice to stay indoors and reduce their exposure to smoke. Similarly, there was little change in presentations to emergency departments in New South Wales for dehydration.

During peaks in the bushfires, the number of people visiting a general practitioner (GP) dropped. The largest decreases in claims for GP attendances were seen in affected regions during weeks when air quality was recorded as particularly poor, including the Capital Region, Riverina and Southern Highlands and Shoalhaven SA4s in New South Wales; this drop in attendance may also have been influenced by health advice to stay indoors, which could likely have encouraged people to delay GP visits for minor health reasons.

Deaths are the most extreme health impact of the bushfires; 33 people tragically lost their lives during the 2019–20 bushfire season (Parliament of Australia 2020). Analysis of data for deaths certified by a doctor showed no change during the 2019–20 bushfire season compared with data for previous years. Deaths referred to a coroner (coroner certified deaths) account for around 10% of deaths and these data are not yet available—the total number of deaths for this period will change with their inclusion (ABS 2020).

Riley et al. (2022) outline PM2.5 exposures observed during the 2019-20 bushfire season:

PM2.5 exposure observed during the 2019-20 bushfire season was unprecedented and premature deaths from PM2.5 exposure were estimated at 219 individuals and there were more than 2300 hospital admissions or emergency department visits (Borchers Arriagada et al., 2020).

and:

Figure 4 highlights daily average PM2.5 during the study period, showing elevated levels during summer 2019/20 bushfires compared with lower levels during La Nina summer of 2020/21.

Stephenson (2010) also assesses the impacts-of-severe-bushfires-in-SE-Australia on health impacts and government services considering a number of bushfires pre 2010.

In regards to air quality and wildfires, the air quality readings during the 2019/ 20 fire season are extremely high PM 2.5/ 10 microns and Total Suspended Particles and provide a data set over a long period that has greatly impacted people and communities. The fire season has dragged on and the impact on human health has been large. The news has focussed on Sydney, but country NSW suffered as well. Refer to the Lismore, Grafton, Coffs Harbour, Port Macquarie data that Department of Planning and Environment has, monitoring set up in light of the wildfire crisis.

Personally, there were two days I had trouble breathing due to the wildfires:

- One day in Grafton where from memory the PM 2.5 got over 500 microns, sometime in November 2019.
- One day near Whiporie in mid-August 2019 when I was travelling north on the Summerland Way.

Hazardous smoke conditions in the Tumbarumba on 5 January 2020, in this case during bushfire mopping up. These conditions were common during that period, common for firefighters and emergency personnel.

Riley et al. (2022) outline tropospheric ozone measurements at the rural town of Gunnedah in New South Wales:

The effect of these three distinct summer periods is evident in the time series of daily maximum 1-h ozone (Fig. 5). Ozone peaked during the Black Summer bushfires, was elevated during the hot summer of 2018/19 and was reduced during the La Nina summer of 2020/21.

and:

During the peak of the smoke impacts in December and early January ozone concentrations at Gunnedah were significantly higher than at other times during this study. The maximum 1-h and 8-h concentrations at this site were both observed on 20 December 2019 and at 94 ppb and 87 ppb respectively were significantly higher than at any other time outside of the bushfire period ….

NOAA Research (2024) highlight early-season 2023 wildfires generated record-breaking surface ozone in the USA Upper Midwest on November 26:

Wildfires produce large quantities of carbon monoxide, carbon dioxide, fine particulates (PM2.5) and a variety of other gaseous compounds, including reactive nitrogen oxides and volatile organic compounds – which are the photochemical precursors of ozone. These compounds quickly react in sunlight to form ozone in the fire plume and can be transported far downwind with the smoke.

Ozone and PM2.5 both impair lung and cardiovascular function. Recent studies suggest that exposure to wildfire smoke containing both elevated ozone and PM2.5 can have more severe health impacts than exposure to either pollutant alone.

and:

A new analysis by NOAA's Chemical Sciences Laboratory (CSL) found that ozone pollution readings in the Upper Midwest caused by these massive fires were the worst in decades.

"We were watching the Environmental Protection Agency's air quality indices, and all across the Upper Midwest they were showing ozone exceedances," said Owen Cooper, a research physical scientist at CSL. "On June 3, 2023, every ozone monitor in Iowa, about a dozen of them, exceeded the ozone standard of 70 parts-per-billion. It was unbelievable. Then it happened again on June 20th."

3.4 Evacuation route impacts

Just one example of a major bushfire evacuation route closure during the 2019/ 20 bushfires is provided by Nema (undated) at Mallacoota:

https://knowledge.aidr.org.au/resources/black-summer-bushfires-vic-2019-20/

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

and:

On 4 February, the Princes Highway was re-opened from Orbost to the NSW border, although with reduced speed limits in some areas. The Mallacoota-Genoa Road was re-opened and Mallacoota reconnected to the main power grid on 8 February.

Underwood (2020) looks at bushfire evacuation issues in relation to the 2019/ 20 bushfires:

Once the fires got going, there were other factors that made things worse, or more confused, such as the lack of coordination across state borders and the attempted evacuation of whole towns, the residents of which were totally unprepared, and the evacuation routes uncertain. We also observed that emergency services and national parks agencies these days will often "watch and wait", rather than pounce aggressively on a fire when it is small. And there seems to be a reluctance to fight fires at night when, traditionally, control is easiest. Reading about a fire in a national park that was left untended for three weeks before control was attempted left me speechless with disbelief.

Haynes et al. (2010) explore trends in relation to the 'Prepare, stay and defend or leave early' policy, including late evacuation issues:

Our study has focussed on fatalities and so has not been able to include comparative figures of successful defence of a property compared to all those that failed. However, it is clear that prior to the Black Saturday 2009 fires, most bushfire fatalities have resulted from late evacuations or, in the case of males, defending property outside. Only one out of the 46 known fatalities that occurred inside a defendable property (the third most common activity of bushfire victims at the time of death) while actively defending, and this person died of a heart attack. In terms of awareness and capacity to respond, the ranking of numbers of fatalities were as follows: the majority were aware of the fire and carrying out a plan in the open (mostly males); second were those aware of the fires but having either no plan or having a plan that was not followed and that in turn usually resulted in late evacuation (mostly females). Thirdly were those unaware of the fire and children following the decisions of adults (and whose bodies were found in cars or outside with adults).

It is essential to note that there have been significant overseas evacuation issues and impacts in recent times associated with major bushfires. Evacuation and access route lessons and insights include:

- The undertaking of annual assessment of safety of town/ city evacuation and bushfire access routes in the event of a bushfire/ s and undertaking the required actions;
- For towns and cities with single evacuation routes, optimising the safety of these routes and plan other options for evacuation such as by sea, beaches and water;
- It is important to review all potential evacuation choke points and consider options and opportunities;
- Also the need to assess densely populated and narrow roadways which can hinder evacuation and fire fighter movement during suppression (as well as evacuation and rescue) efforts;

- Planning for alternate evacuation and access routes is also critical.

3.5 Infrastructure impacts

Bushfires impact infrastructure by damaging or destroying roads, bridges, power lines, telecommunications networks, schools, hospitals, buildings, fencing, and other essential services such as fencing. This damage can disrupt communication, electricity supply, transport, and economic activity, requiring considerable resources for repair and restoration.

Resilience Rising (2020) outline the whole system impact of the Australian 2019/ 20 bushfire impacts on energy, transport and supply chains, water, biodiversity and emergency response

https://resiliencerisingglobal.org/bushfires-resilience/#:~:text=If%20water%20is%20contaminated%20with,in%20more%20than%20a%20decade .

Resilience Shift (2020) also highlight 2019/20 bushfire infrastructure impacts in a separate document:

https://www.slideshare.net/resilienceshift/the-damaging-impact-of-bushfires-on-infrastructure-and-supply-chains

This later document raised the issue of more resilient infrastructure in future, an important issue.

The Bushfire Front (2025 web) document also outlines infrastructure impacts from bushfires:

Public infrastructure also suffers in major wildfires, Bridges may be burnt, powerlines damaged and industrial plants destroyed. All these lead to diversion of Government resources to repair them, or to reduced economic performance by industry. Apart from the inconvenience of interrupted access, lack of electrical power and economic activity, job losses are frequently added to human woes.

As an example of infrastructure losses, after the 2016 Yarloop fire, in which over 160 homes were destroyed, Western Power estimated that the cost of restoring the electricity network at $26 million. Where does the finance for this come from? Probably from our pockets as Western Power recovers its losses through its tariffs.

Stephenson (2010) assesses the impacts-of-severe-bushfires-in-SE-Australia on infrastructure and notes the costs associated with repairing or replacing these assets, particularly during a large-scale fire, can therefore become very expensive, with the economic impacts stretching out for months to years.

Refer to road infrastructure 2019/ 20 bushfire impacts throughout the state, including the Gwydir Highway, south coast, many highways and roads.

There were large losses of important pine and hardwood plantations in the Batlow/ Tumbarumba area (50,000 hectares), Whiporie and other areas of Australia resulting from the 2019/ 20 bushfires.

Ecos (2022) highlights the importance of resilient infrastructure::

"Yet, in the rush to deliver infrastructure, it is critical that we consider resilience in our infrastructure choices, design, and business case assessments. (Disaster resilience – CSIRO)

"There is now substantial evidence demonstrating that the benefits of resilient infrastructure – even if more expensive upfront – greatly outweigh the repair and restoration costs of rebuilding."

Research from the Global Center on Adaptation has shown that resilient infrastructure could deliver up to $12 for every dollar invested. And closer to home, the QRA has demonstrated over the last decade a return (avoided reconstruction cost) of $3 to every $1 invested in resilient infrastructure Queensland Betterment Funds | Queensland Reconstruction Authority (qra.qld.gov.au) .

To unlock these benefits, however, we must properly value and account for resilience in our decision making.

From the Pathway to Infrastructure Resilience research project, Infrastructure Australia delivered two papers in relation to infrastructure resilience:

- Advisory Paper 1: Opportunities for systemic change– identifies 10 directions for transformational and systemic change in infrastructure planning to achieve infrastructure for resilience; and
- Advisory Paper 2: Guidance for asset owners and operators in the short term- identifies a series short-term actions for asset owners and operators as the first steps towards this change.

As outlined in Infrastructure Australia, (2021) Pathway to Infrastructure Resilience Advisory Paper 1:

Their vision is that future Australian communities be able to anticipate, resist, absorb, recover, transform and thrive in response to shocks and stresses, to realise positive economic, social and environmental outcomes.

A major finding of this research is that achieving resilience requires a shift in focus from the resilience of assets themselves, to the contribution of assets to the resilience of the system – what we call infrastructure for resilience. This approach requires consideration not only of how to strengthen the asset, network and sector, but also how to strengthen the place, precinct, city, and region that the infrastructure operates within. It requires considering the role of each asset within the broader network and/or system and a shift from individual to shared responsibility.

The paper outlines best practice guidance suggested as an embarkation point for investigation by each owner and operator specific to their own circumstances. In applying the guidance, asset owners and operators will need to develop their own implementation plan.

The author has a number of concerns in regards to infrastructure protection and bushfires, including:

1. In summary, the Infrastructure Australia approach maybe an opportunity for infrastructure sectors and forestry/ plantations to work together, but I believe there are serious limitations on infrastructure outcomes under current bushfire approaches in NSW and southern Australia on the ground, bureaucratic bushfire systems, inadequate annual bushfire review systems and very low levels of landscape prescribed burning in southern Australia. The fuel loads across landscapes are extremely high. My concerns with bushfire management in NSW are outlined further below, and infrastructure isn't safe in southern Australia.
2. I suggest that if we don't get the higher level state/ local government basic bushfire systems and approaches right to address bushfire risks and complete adequate ecological maintenance burning across landscapes, achieving the aims of these two documents isn't going to work effectively. Just look at the level of fuel loads in southern Australia, miniscule ecological maintenance burning and declining forest health and more giga fires to come.
3. The assets can work together, sure, but the State and Federal systems need to be optimal in regards to bushfire management for the proposed approach in these documents to work.
4. Under the proposed approach, I suggest that there will be serious gaps in strengthening asset resilience, some areas may strengthen bushfire resilience, but areas may be to the north south east and west will likely not and a landscape bushfire will undo any good work in one or two smaller areas. A landscape approach to bushfire management is critical for the success of the approaches in these two documents. Refer to the information below in regards to bushfire spread of two bushfires, one in 2009 and one in 2020.
5. Development of community bushfire protection plans is a better way to go, at least as a first step. Approaches like Fire Adapted Communities learning Network, 2016, Fire Adapted Communities, FAC Self-Assessment Tool (FAC SAT), USA Ready Set Go Firewise, Fire Safe Councils and other US initiatives to reduce bushfire risk, the Canadian FireSmart program (community awareness and education) and use of a Community Wildfire Protection Plan as in many towns and cities in the USA. Australia has small programs such as Fire Safe WA. Town and city safety is addressed in fairly generic Local Bushfire Risk Management Plans with limited community involvement.

3.6 Aboriginal heritage impacts

Bushfires have had considerable impact on Aboriginal heritage sites in many cases, especially intense bushfires.

Stephenson (2010) assesses the impacts-of-severe-bushfires-in-SE-Australia on Aboriginal heritage:

In the event of a severe bushfire, tangible forms of cultural heritage are impacted, and for those linked to Aboriginal culture, the level of damage can vary. Some destructive impacts include the complete burning of scar trees, sooty covering and blackening of artefacts, movement of small artefacts down a slope through erosive processes and loss of rock art as a result of exfoliation of granite rock that has been subjected to intense heat (Australian Alps Liaison Committee 2003). Following the 2003 Alpine Fires, the DSE and PV commissioned Freslov (2004) to conduct an archaeological survey of 14 fire-affected sites in search of Aboriginal cultural heritage values. The survey located a total of 325 sites with Aboriginal significance, ranging from areas burnt by high intensity fires to areas left untouched by the fire. The report found that severe fires aided in locating sites, firstly by defoliating vegetation to enable better line of sight and exposing the soil, and secondly by triggering erosion, which in some cases washed the overlying soil away (Freslov 2004). In other cases, the complete defoliation enabled the researchers to discover and record artefacts and sites not previously known. In terms of severe fire impacts on physical objects, Freslov (2004) found very minimal damage to artefact A literature review on the economic, social and environmental impacts of severe bushfires in south-eastern Australia 3 scatters, grinding grooves, rock shelters and quarry sites, citing sooty deposits as the main impact.

Stephenson (2010) also notes:

From the little information that could be sourced on the topic of cultural heritage, the impact of severe fires on certain aspects of cultural heritage can be extensive. The International Council on Monuments and Sites (ICOMOS) provides good background information on cultural heritage. Freslov (2004) gives readers an appreciation of the impacts of bushfires on Aboriginal values, while reports by the Ministerial Taskforce on Bushfire Recovery (2003) and DSE and PV (2008) detail the loss of European settler structures from the 2003 Alpine Fires and 2006–07 Great Divide Fires respectively.

Gill et al. (2004) outline European heritage impacts in the Australlan Alps from the 2003 bushfires:

As 70% of the Kosciuszko and Brindabella National Parks (with 580 recorded Aboriginal sites) were affected by the fires and suppression operations, a significant number of Aboriginal objects and sites may have been impacted. As no condition assessment, reporting or monitoring programs had been established previously for the National Parks to monitor and manage the Aboriginal sites within them, a project has commenced to establish a field sampling strategy in association with NSW Department of Environment and Conservation and Aboriginal community representatives (see Appendix 1). An important objective of this project is to develop strategies and recommendations associated with the management of Aboriginal objects and sites prior to, during, and after, unplanned fire events in the future.

Similarly, indigenous cultural heritage values were significantly affected by the fires and associated fire suppression activities in the North East and

Gippsland regions of Victoria. As only 1% of this area had been previously surveyed, a major project has been undertaken to survey and assess the nature and extent of the damage to Aboriginal heritage values on public land, including those areas which constitute a significant landscape or spiritual place or those that have some historic connection with Indigenous people. The increased visibility occasioned by the fires presented enhanced opportunities for effective survey. The survey, undertaken in 15 study areas, recorded 270 new sites, some of which are 2-3 kms in extent with millions of artefacts.

In the ACT, advantage was taken of the increased visibility following the fire to survey 46 remote locations in Namadgi National Park. All locations revealed Aboriginal sites and objects. The survey of Rotten Swamp revealed a massive open scatter site where previously only 2 artefacts had been recorded.

The results of these studies and surveys should be integrated so that there is a bioregional perspective on the distribution of Aboriginal sites as revealed by the fires.

Allam (2020) outlines the grave fears held for thousands of rock art sites after bushfires. An important rock art site in northern New South Wales has been discovered after being irretrievably damaged by bushfire, with grave fears held for thousands of other sites. An intense bushfire burned right up to the edge of the boulder, shearing off enormous slabs of granite. The shearing – known as spalling – was probably caused by a rapid temperature change rather than prolonged heat exposure, he said. What's left: an ochre painting of a plains turkey and its tracks, part of an important Anaiwan creation story. Last week the team discovered a second, unrecorded panel on a neighbouring boulder where the face of the rock, along with the images that may have been there, had already been sheared away.

3.7 European heritage impacts

Bushfires have had considerable impact on European heritage sites in many cases.

Stephenson (2010) assesses the impacts-of-severe-bushfires-in-SE-Australia on European heritage:

Early European cultural resources have been affected during the recent Victorian fires. In the 2003 Alpine Fires, the Ministerial Taskforce on Bushfire Recovery (2003) conveyed that approximately 270 known nonindigenous archaeological sites were located within the fire boundary, including old mining sites, early European settlement areas and pastoral properties. Some sites were saved; however, 32 historic Alpine huts and several mining complexes suffered some degree of damage (Ministerial Taskforce on Bushfire Recovery 2003). Furthermore, 245 historic places were recorded within the 2006–07 Great Divide Fires boundary according to DSE and PV (2008), with eight huts being burnt during this fire. One very significant cultural icon destroyed during the fire was Craig's Hut, which was constructed for the set of the iconic film The Man from Snowy River. These sites, especially those in relatively accessible locations, are significant tourism and recreational attractions. Therefore, damage to or destruction of these sites have large ongoing economic and social implications for tourism operators and the wider community, especially since the fire-affected areas rely heavily on tourism for their economic stability (DSE and PV 2008).

Gill et al. (2004) outline European heritage impacts in the Australlan Alps from the 2003 bushfires:

Table 1. Alps cultural heritage values affected by fire 2 and responses to fire, 2003

VALUE FIRE AFFECTS

Pastoralism Loss of huts - Victoria 46 lost out of 81; Kosciuszko 21 out of 260; ACT-Mt Franklin Chalet, most brumby yards, most ACT boundary survey markers and 3 homesteads complexes.

Mining Loss of historic sites and Glen Wills Historic Reserve - 4 sites in Vic

Timber getting Historic mill sites (Vic); earlier features revealed -logging tracks, landings etc.

Recreation Loss of cross country facilities - huts, trails etc.

Walker (2020) outlines the impacts of the Kosciuszko 2019/ 20 bushfires on European heritage:

The 2019-20 bushfire season is the most widespread and extreme that NSW has ever experienced. More than 5.4 million hectares burnt across NSW, including 2.7 million hectares of national park estate (up until 3 February 2020). In some regions, over 50% of the national park estate has been impacted.

Within Kosciuszko National Park, just over 231,000 ha, or 33.5% of the national park has burnt. The Adaminaby complex (which originated out of the Green Valley fire) and Pilot Lookout fires were finally declared extinguished on 16 February 2020.

The following report comes from The Resort Roundup (available here), published by the State of NSW and Department of Planning, Industry and Environment.

According to the Resort Roundup:

“Heavy losses to assets occurred during the fires including the destruction of most buildings within the Selwyn snow resort, and loss of buildings at historic Kiandra including the Kiandra Courthouse. The courthouse was originally built as a police station in 1890. It was one of the last reminders of the Kiandra village which housed up to 10,000 people in the 1860s gold rush.

The town of Cabramurra was also badly impacted, with the loss of many buildings including the former school and the historic ski rope tow.

Nine historic huts were destroyed and several others significantly damaged. Huts destroyed were Bradley’s, Brooks, Delaneys, Four Mile, Happy’s, Pattersons, Round Mountain, Wolgals and Sawyers Huts.

Incredibly, Yarrongobilly Caves House was saved during the fires due to work by just 6 NPWS staff undertaking dramatic back burning operations and setting up sprinkler systems around the buildings as the fire storm approached, before they retreated to the safety of the caves as the fire storm passed through. Currango homesteads were also saved during the fires.

Another European heritage impact from the 2019/ 20 bushfires occurred in Catherine Hill Bay in the Lake Macquarie region, the historic Wallarah House was destroyed by fire. Formerly the mine manager’s residence dating from the 1880s, and one of the oldest buildings in the Lake Macquarie area, the house was a powerful reminder of late 19th-century coal mining in the district. It was a landmark, an historical site and a place of significant local heritage.

4 Environmental bushfire impacts across SE Australia, including from intense and severe bushfires

Environmental bushfire impacts across SE Australia, including from intense and severe bushfires, are outlined in Sections 4.1 to 4.15.

4.1 Major intense bushfire impacts on forest ecosystems

As a result of minimal low intensity prescribed burning and very long adopted fire return intervals (even for low intensity fire), intense, severe and long duration bushfires and megafires are occurring across Australia.

As noted by Jurskis et al. (2003), current policies and regulations in NSW exclude low intensity burning from much of the landscape including wilderness, old growth, rare ecosystems, habitats of rare plants or animals, and drainage lines. This approach focusses on individuals, target species and fire frequency, this policy environment reinforces the shift towards more widespread high intensity fire regimes.

As highted below in images below, the long term impacts of such high intensity bushfires are severe and long term.

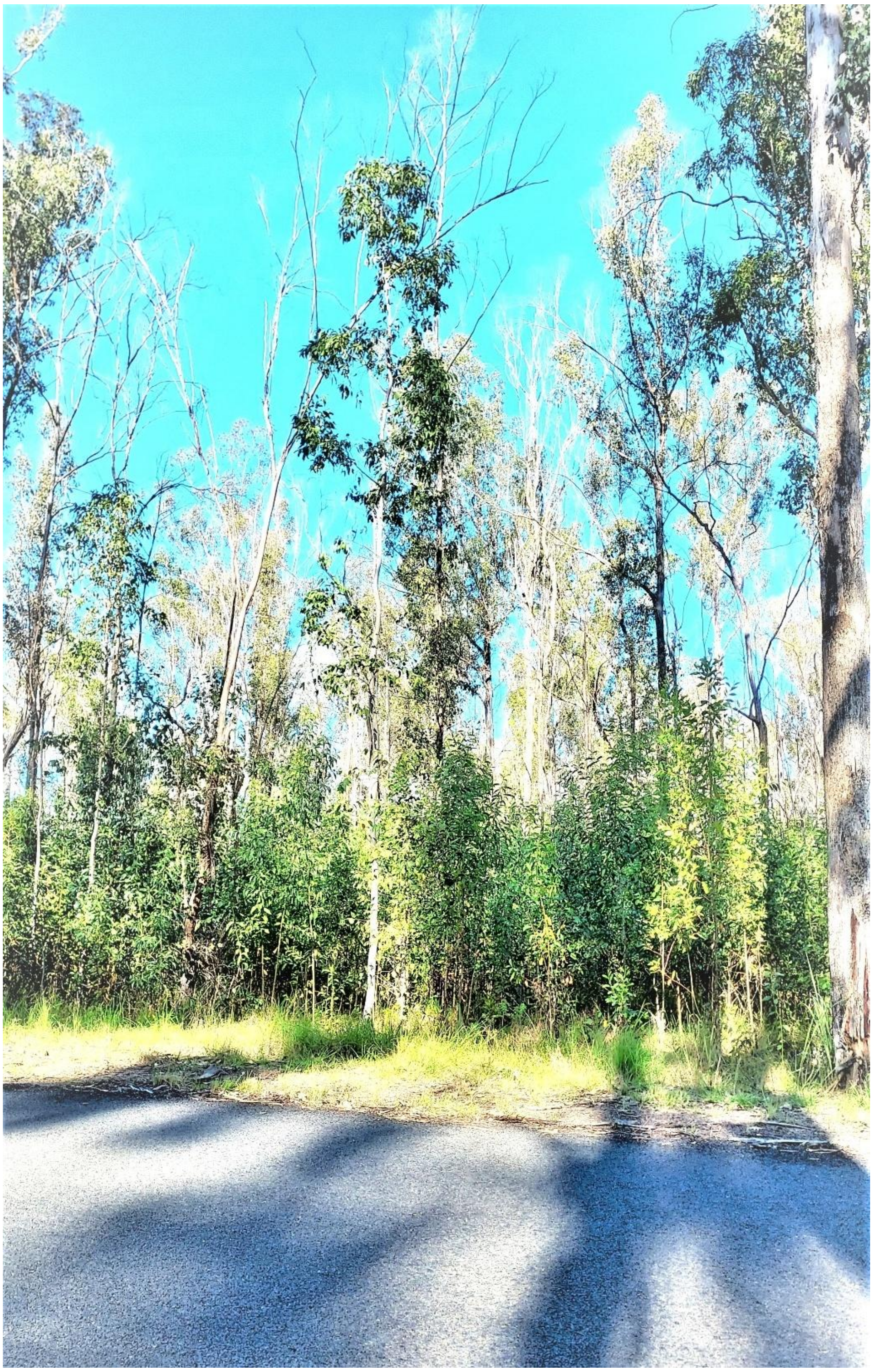
Kiandra to Adaminaby, two stark scenes from the 2019/ 20 bushfires within Kosciuszko National Park (KNP) as of March 2025, just over 5 years after these bushfires. Dense understorey fuels with dead timber fuels represent a major fire hazard. Fuels now contain a high proportion of woody material and for many years subsequent bushfires will have a longer burnout period and will be more damaging to the regenerating trees. Note the absence of live hollow bearing trees.

As highlighted by the author above and in a number of photos, many areas of vegetation of different age classes-in KNP have been narrowed to one new age class aged 5 years (in 2025) across large large contiguous areas of forests from the 2019/ 2020 bushfires, not the aimed for multi age succession progression by the managers. The author considers that current inadequate low intensity fire management is not good for the alpine ecosystems generally.

4.2 Dense regrowth following intense and severe bushfires

Following large intense bushfires across SE Australia during the 2019/ 20 bushfires, there are large areas of dense understorey regrowth, much of which is highly flammable and a lot of dead vegetation. This is highlighted in a number of images below.

Two images above of the severe impacts on ecosystems in the Blue Mountains area, 4 years after the 2019/ 20 bushfires. Note the dense understorey, including in the lower photo and the large amount of dead timber.



Major impact on an ecosystem in N NSW nearly 3 years after the 2019/ 20 bushfires. Note the impacted overstory with many dead trees and the dense understorey, a recipe for return "knife through butter" bushfires.

Such areas with large amounts of dense regrowth and dead timber provide perfect conditions for the next high intensity, high severity and long duration bushfires.

With more and more of these intense bushfires, more and more dense understorey fuels with dead timber will be present across SE Australia, for the next intense, severe and long duration bushfires.

4.3 Vegetation association impacts

It is noted in Table 22.2 of the SOE Fire report 2021 that large proportions of some vegetation associations were burnt in the NSW 2019/ 20 bushfire firegrounds, including:

- 51.24 % of Wet Sclerophyll (grassy sub formation); and
- 48.81 % of Wet Sclerophyll (shrubby sub formation).

These proportions were considerably higher than other vegetation associations outlined in Table 22.2 of the report.

A major factor in the high proportions of these associations that were burnt in 2019/ 20 bushfires would likely be:

- Very long fire intervals used for prescribed burning and bushfires;
- Minimal prescribed burning;
- The broad category threshold approach to fire management used across NSW;
- The increasing presence of eucalypt decline and declining crowns/ increasing understories; and
- Consequent high fuel loads and strata across continguous landscapes and difficulty of bushfire suppression.

Considering fire thresholds across NSW, there are very large areas of so called "within threshold forests" across eastern NSW, these are very large is size and not assisting with mosaic fire approaches that reduce risks and improve biodiversity. Consequently, prescribed burning in these areas is very small, yet they will not have been prescribed burnt for very very long periods.

Questions in relation to these thresholds include:

1. What fuel ages are within threshold, including what fuel age for each vegetation association?;
2. Are fuel ages up to 40-60 years for differing associations within threshold; and
3. If the fuel age is beyond 3 to 6 years, how can this be within sound thresholds to protect forests and ecosystems, communities, infrastructure and firefighters.

KNP intense bushfire example

As an example, large areas of Wet Sclerophyll grassy in KNP (and most other associations) are getting too many intense bushfires. Many of these locations aren't grassy anymore, including following the 2019/ 20 and earlier bushfires and it is unclear whether they will ever return to that grassy association under the current very long fire intervals being used in NSW.

Fire intervals provided for in KNP are outlined in NPWS (2024), including Figure 71, Wet Sclerophyll grassy, the desired fire interval is 15 to 50 years, this association is present over very large areas of the park. Under these intervals, fuel loads and strata build up to very high levels and the inevitable intense bushfires occur in these areas.

Northern NSW example

Jurskis et al. (2003) outline the process of decline, loss of grassy associations and increased shrubbiness with inadequate low intensity fire usage:

An example of the impact of this change in policy was provided by reassessment of some flora survey plots in northern NSW during 2002. The initial survey in 1992 used 77, 0.1 hectare plots covering the full range of forest types and logging histories in State Forests' Urbenville Management Area (Binns 1995). In 1992, Binns (1995) classified ten plots as a group typified by grassy understories and a frequent fire regime. He suggested that some areas of dry forest should remain unburnt for longer periods of ten to fifteen years or more. When these formerly grassy and frequently burnt plots were reassessed in 2002 (State Forests unpublished data), they had all remained unburnt since the previous assessment. Four of the plots had developed denser shrub understories and were classified in different floristic groups compared to the original survey. Two of these plots were heavily infested by lantana. The eucalypts in the four shrubby plots were in moderate to severe decline.

It is no wonder the vegetation association impacts from intense bushfires are so high, consider the factors below:

- There is little to no consideration of different growth and fuel load accumulation rates in each of the vegetation associations, moist/ wet forests have rapid fuel accumulation but then very long fire intervals;
- There is no consideration of fire behaviour nor difficulty of bushfire suppression in the mostly long to very long fire intervals between burning;
- There is little to no consideration that fire regimes are now vastly different to regular Aboriginal burning practices across landscapes; and
- Current policies and regulations in NSW exclude low intensity burning from much of the landscape including by fire intervals, wilderness, old growth, rare ecosystems, habitats of rare plants or animals and drainage lines as outlined in Section 3.4.

Jurskis et al. (2003 provide the answers to tackle the problems.

4.4 Worsening forest fire resilience due to intense bushfires

Forestry Australia (2023) highlight the importance of enhancing the resilience of forest and rangeland ecosystems within the Forest Fire Management Position Statement:

CONTEXT Fire has been part of the Australian environment for millions of years; it is an essential element and can't be removed without ecological consequences. Aboriginal people developed appropriate fire management practices to maintain their culture and Country. Australia has experienced an increased occurrence of severe bushfires, that result in substantial impacts on life, property, forest biodiversity, water quality and quantity, forest products and uses as well as on the health and resilience of forest ecosystems. Australia's knowledge and systems of forest fire management are based on decades of bushfire research and lessons from previous bushfire inquiries. The COAG-endorsed National Bushfire Management Policy Statement for Forests and Rangelands brings this knowledge together to provide appropriate goals and strategies for reducing the occurrence, severity, and impacts of bushfires as well as for enhancing the resilience of forest and rangeland ecosystems.

Important words in relation loss of resilience and biodiversity from megafires is outlined by Jurskis (2021 b):

Real science and the knowledge of experienced pastoralists and foresters align perfectly with Aboriginal tradition. Steffensen talks of upside-down country – thin on top and thick underneath. Also – sick trees with lazy roots in damp soils.

Fairdinkum science confirms that frequent mild burning is essential to recycle dead grass, leaves, bark and twigs and maintain healthy soils and roots. When trees get sick, understorey booms as do pests, parasites and diseases. Dense scrub or thick mulch won't burn in mild weather but explode in firestorms when inevitably ignited by lightning, arson or accident in extreme conditions.

Megafires are one side of the coin, loss of resilience and biodiversity the other. Academics, bureaucrats and fire chiefs apply the Climate Cop-Out to both.

We need a coalition of traditional knowledge; black, white and brindle, with fairdinkum science to restore sustainable management across the landscape. It would save heaps of money and reduce the massive emissions from megafires which aren't brought to account because it doesn't suit our Lock It Up and Let It Burn 'conservation' paradigm.

The author considers the biggest risks to Australian ecosystems are related to the minimal prescribed burning programs underway in SE Australia and removal of active/ adaptive management from landscapes. The consequent outcomes are intense severe bushfires, often across these same landscapes.

When the intense bushfires occur, the severe outcomes are described throughout this document

A good example of reducing the impacts of intense, hot season bushfire to smaller, patchier, less severe fire patterns is outlined by Sheppard Brennand (2023), who notes:

Fire management aims to shift landscape-scale fire patterns from intense, hot season wildfire to smaller, patchier, less severe fire patterns. Analysis collated by the Indigenous Desert Alliance-led 10 Deserts Project, in partnership with AWC, the Central Land Council, Kanyirninpa Jukurrpa, Bush Heritage and Desert Support Services, indicates that effective fire management is altering desert fire patterns, shifting fire seasonality towards the cooler months, reducing burnt-patch size and increasing fire age diversity. At Newhaven, AWC's Fire Management Program has seen wildfire extent and severity reduced by 9% and 47% respectively since 2007.

Parks et al. (2025) recently released a paper which raises concerns in relation to the resilience of North American forests and the potential for more severe wildfires in the future. Their results indicate that while the area burned by wildfires has increased in recent decades, it remains relatively low compared to historical prevalence. The authors highlight a significant fire deficit in many North American ecoregions, suggesting that the rate of burning at NAFSN sites has been much lower than historical rates across most of the continent. This finding is attributed to aggressive fire suppression treatments, particularly in the southern Appalachian Mountains. The authors also note that contemporary wildfires are characterized by increased severity, contrasting with historical fire regimes that were more frequent and of lower intensity. This shift in fire behavior raises concerns about the resilience of our forests and the potential for more severe wildfires in the future.

The US Forest Service released the important document Confronting the Wildfire Crisis A Strategy for Protecting Communities and Improving Resilience in America's Forests FS-1187a (https://www.fs.usda.gov/sites/default/files/Confronting-Wildfire-Crisis.pdf) and associated documents in mid-January 2022. This is the new wildfire reality facing much of the West (US): it is nothing less than a forest health crisis. A healthy forest is resilient— capable of self-renewal following drought, wildfire, beetle outbreaks, and other forest stresses and disturbances. There is firm commitment to this through Confronting the Wildfire Crisis A Strategy for Protecting Communities and Improving Resilience in America's Forests and also the earlier National Cohesive Wildland Fire Management Strategy in place.

In Australia, large wildfires are common, the wildfire situation is not good and as time goes by is getting worse. Forest health and resilience is also declining. There is limited funding and strategy for protecting communities and improving health resilience in Australia's forests. This also is affecting forest resilience for bushfires.

There is another issue at play in Australia, here is increasing eucalypt decline across Australia and influence on forest structure, including increasing forest understories and changes in flora and fauna habitat. There are a considerable number of research papers and authors who have identified exclusion of low intensity mild fire as the major cause of eucalypt decline across a number of Australian native forests and woodlands. Key research authors in relation to establishing root cause of eucalypt decline relating to soil changes associated with inadequate low intensity fire include Turner, Lambert, Jurskis, Horton, Landsberg and Ellis. Other useful contributions have been made by Ishaq, Jones, Davidson, Close, Dijkstra and Adams. Howitt also identified eucalypt decline as linked to a reduction in burning in his legendary 1890 paper. There are 66 papers identified in the "key references used for this review" list and an additional 39 other references in the Section 7 list.

Jurskis et al. (2003) outline the process of decline and increased shrubbiness with inadequate low **intensity fire. This is a factor contributing to intense bushfires**

4.5 Hollow bearing tree impacts

Intense bushfires result in large losses of live and dead hollow bearing trees.

A photo below highlights an intense bushfire result in large losses of live hollow bearing trees. Some of these dead trees will have hollows, but many of these trees will continue to fall over time and drop with heavy show falls. Some may stay and have new hollows.

However, it is going to be a very long time before there are new replacement hollow bearing trees and most trees will fall over or be burnt in the next bushfire. And more than likely, many of the new trees will be killed/ setback in the next bushfire.

Kiandra to Adaminaby. After the 2019/ 20 Dunns Road bushfire. Note the absence of live hollow bearing trees. Some hollows may form in the larger dead hollow bearing trees, maybe prior to the next bushfire.

Salmona (2018) considers the effects of fire history on hollow-bearing tree abundance in montane and subalpine eucalypt forests in southeastern Australia:

Hollow-bearing trees provide critical habitat resources for forest fauna, yet there is evidence of a ubiquitous decline in the large, old trees most likely to provide this resource. Fire can influence the formation and persistence of tree hollows. In this study, we investigated the effects of stand-level fire history and individual tree attributes on tree hollow abundance in two forest types in Namadgi National Park in the Australian Capital Territory: subalpine woodlands dominated by Eucalyptus pauciflora Sieber ex Spreng (snow gum); and tall-open E. delegatensis R.T.Baker (alpine ash) montane forest. These forests can be differentiated by their distinct response to fire; E. pauciflora resprouts following fire and E. delegatensis reproduces exclusively via seed. We employed a ground-based approach to measure 1044 trees across 36 sites selected by forest type and fire history as recorded since 1920. For both species, hollow abundance decreased with total fire count at stand level and increased for E. delegatensis in response to an extensive wildfire that occurred in the study area in 2003. The probability of a tree containing a hollow increased with tree diameter and if the tree was dead. Our results show that fire frequency and severity have strong implications for tree hollow abundance in montane and subalpine eucalypt forests.

It would be very interesting to assess the same 1044 trees for hollows, if present, following the 2019/ 20 bushfires, in the large areas where there is overlap between the 2003 and 2019/ 20 bushfires.

4.6 Tree flowering and fruiting impacts

Bushfires have large ongoing impacts on the flowering and fruiting capacity of eucalypts and the insect, birds and mammals that are dependent on flowering eucalypts for their survival.

This is evident within images included in Section 4 of this review, and in many cases is a long term impact on flowering and fruiting.

A good example of this long term flowering and fruiting impact is highlighted in a WA paper by Dixon et al. (2023)

Abstract

Plant phenology describes the timing of reproductive events including flowering and fruiting, which for many species are affected by fire disturbance. Understanding phenological responses to fire provides insights into how forest demographics and resources may shift alongside increasing fire frequency and intensity driven by climate change. However, isolating the direct effects of fire on a species' phenology and excluding potential confounders (e.g. climate, soil) has been difficult due to the logistical challenges of monitoring species-specific phenological events across myriad fire and environmental conditions. Here, we use CubeSat-derived crown-scale flowering data to estimate the effects of fire history (time since fire and fire severity over a 15-year time span) on flowering of the eucalypt Corymbia calophylla across a Mediterranean-climate forest (814 km2) in southwest Australia. We found that fire reduced the proportion of flowering trees at the landscape-scale, and flowering recovered at a rate of 0.15 % (SE) per year. Further, this negative effect was significant due to high crown scorch fires (20% canopy scorch), yet there was no significant effect from understory burns.

and Conclusion:

This research estimates the effect of fire history (15-years) on flowering of the eucalypt species Corymbia calophylla. We found that time since fire had a significant reducing effect on the proportion of flowering tree crowns across the Jarrah Forest of southwest Australia. Importantly, this effect was greatest due to high crown scorch fires, yet there was no significant effect from low severity understory burns.

The Editor (2022) Peter Rutherford response, ARRN 16 December that shows the value of prescribed burning to flowering after bushfires:

Prescribed burning reduces the impacts on native vegetation and assists flowering. The image below shows an area fuel reduced three years before the 4 January 2020 run of the Border Fire. Photo taken in April 2021 shows one of a number of red bloodwoods (Corymbia. gummifera) in full flower. The fire intensity was reduced sufficiently to ensure there was no crown scorch to the canopies of the regrowth and mature trees within the fuel reduced area.

An area fuel reduced three years before the 4 January 2020 run of the Border Fire. Photo taken in April 2021 shows one of a number of red bloodwoods (Corymbia. gummifera) in full flower. The fire intensity was reduced sufficiently to ensure there was no crown scorch to the canopies of the regrowth and mature trees within the fuel reduced area. Photo: Peter Rutherford.

4.7 Direct fauna impacts from intense bushfires

Fauna impact detail is provided in relation to Australian 2019/ 2020 and 2003 megafires.

<u>Fauna impacts of the 2019/ 20 bushfires</u>

In summary of the fauna impacts of the 2019/ 20 bushfires, of the order of 5.5 million hectares in NSW and over 18 million hectares over Australia were burnt, with over 1 billion animal deaths in NSW and 3 billion nationally. The loss of fauna over these fires has been huge. Fauna kills have been huge in pretty well all major bushfires in Australia.

As noted by Elsworthy (2020), over a billion animals and "hundreds of billions" of insects have been killed in bushfires throughout New South Wales this season, according to leading wildlife experts. The figure has more than doubled from an original estimate of 480 million animals lost, as the hectares razed by out-of-control fires increased from 3 million to now almost 5 million in NSW. Ecologist Chris Dickman from the University of Sydney said: "for some species we're looking at imminent extinction". "There will almost certainly be species of all geographical ranges and populations that are cooked before we've even had the chance to discover that they exist," Professor Dickman said. Wildlife is threatened by more than just flames in a bushfire crisis, says David Lindenmayer, a professor of forest ecology and management at Australian National University. "Australian wildlife has to deal with four things: the incredibly fragile overheated periods before fires, the fire itself, the lack of habitat and food after the fire, and the fourth thing is the invasion of foxes and cats in these burnt areas," he said.

As noted in WWF (2020), in total, they estimate that almost 3 billion native vertebrates across Australia are likely to have been present within the 2019-20 bushfire areas. Their estimate comprises approximately: • 143 million mammals • 2.46 billion reptiles • 181 million birds • 51 million frogs. As outlined Perkins P (2020), almost three billion animals may have been killed or displaced during last summer's bushfire season, which experts say was "one of the worst wildlife disasters in modern history".

Cox (2021) considers invertebrate species lost habitat in Black Summer bushfires:

Major extracts:

- *Australia has 111,233 described terrestrial and freshwater invertebrate species. Though they receive less attention than Australia's unique mammals and birds, they perform important roles in the ecosystem, such as pollination or as a food source for larger animals. Others are detritivores that break down ecosystem debris – such as leaf litter – which cycles nutrients back into the soil, fostering plant growth and reducing fuel loads for fire.*
- *More than 14,000 species of invertebrate lost habitat during Australia's 2019-20 bushfires, according to a post-fire analysis that has recommended a doubling of the number of species listed as threatened. The scientists found that 14,159 – roughly half of those species - had at least some habitat burnt by the fires, with 1,209 having had either 50% of their known range burnt by fires of any severity or 30% by fires of high severity. very little public attention." Of those 1,209, the scientists had enough data to recommend the government add 60 species to Australia's list of nationally threatened invertebrates, which currently totals 63.*
- *The research, prepared for the federal government by scientists with the national environmental science program (NESP), found the number of insects, spiders, worms and other invertebrates affected by the disaster was much greater than the tally of vertebrates impacted.*
- *The NESP study warns the true figure is likely to be far higher than 14,000 because so many Australian invertebrates are either undescribed or have no data available through which to measure declines.*
- *At least one animal, the Banksia montana mealybug in Western Australia, is considered likely extinct as a result of Black Summer fires in that state.*
- *"If you look at the most affected animals by the fires, about 95% of them are invertebrates," said John Woinarski, a professor at Charles Darwin University and one of the authors of the research. "And it has had Jess Marsh, a scientist on Kangaroo Island and co-author of the research, said the 60 they had recommended for listing were "just the ones we know about" – meaning there was enough data available to make them eligible for an assessment by the threatened species scientific committee.*

Dorey et al. (2021) note:

The 2019–2020 Australian Black Summer wildfires demonstrated that single events can have widespread and catastrophic impacts on biodiversity, causing a sudden and marked reduction in population size for many species…….. Using publicly available collection and GIS datasets, combined with life-history data, we modelled the extinction risk from the 2019–2020 catastrophic Australian wildfires for 553 Australian native bee species (33% of all described Australian bee taxa). We suggest that two species are now eligible for listing as Endangered and nine are eligible for listing as Vulnerable under IUCN criteria, on the basis of fire overlap, intensity, frequency, and life-history traits: this tally far exceeds the three Australian bee species listed as threatened prior to the wildfire.

Fauna impact information in relation to Greater Blue Mountains World Heritage Area impacts from the 2019/ 20 bushfires is highlighted below:

GBMWHA Burnt

GBMWHA Burnt	Area (Ha)	Burnt (Ha)	% Burnt
Wollemi NP	502,600	380,826	76
Blue Mountains NP	269,200	196,381	73
Yengo NP	167,600	155,927	93
Kangangra-Boyd NP	71,600	62,646	87
Nattai NP	50,660	43,467	86
Gardens of Stone NP	15,120	12,693	84
Jenolan KCR	3,142	3,078	98
Thirlmere Lakes NP	662	292	44
Total GBMWHA	**1,080,588**	**855,310**	**79**

GBMWHA Native Fauna Impacted

Fauna	Number Impacted by GBMWHA Fire
Mammals (Excl. bats)	15.0 million
Birds	17.7 million
Reptiles	110.4 million
Total GBMWHA	**143.1 million**

[* Density of mammals, birds and reptiles in NSW is based on C. Johnson, H. Cogger, C. Dickman and H. Ford (2007), *Impacts of Landclearing: The Impacts of Approved Clearing of Native Vegetation on Australian Wildlife in New South Wales*, WWF-Australia, Sydney.]

https://bluemountains.org.au/bushfires.shtml

Ward *et al.*(2020) review the impact of 2019–2020 mega-fires on Australian fauna habitat:

Australia's 2019–2020 mega-fires were exacerbated by drought, anthropogenic climate change and existing land-use management. Here, using a combination of remotely sensed data and species distribution models, we found these fires burnt ~97,000 km^2 of vegetation across southern and eastern Australia, which is considered habitat for 832 species of native vertebrate fauna. Seventy taxa had a substantial proportion (>30%) of habitat impacted; 21 of these were already listed as threatened with extinction.

KNP and Snowies fauna impacts in the 2003 bushfires

Worboys (2003) reports on the 2003 Australian Alps Bushfires In the summer of 2003, noting two endangered animal species, the Corroboree frog and the mountain pygmy possum, were the 2 species thought to be most affected by the Kosciuszko National Park fires. Most of the Corroboree frog's habitat had been burnt, and it may be in real danger of extinction in the wild. Areas of mountain pygmy possum habitat at one of its more important locations, Mount Blue Cow, had been burnt.

Mitchell (2005) note that Keith McDougall, of the NSW Environment Department, and Neville Walsh, of the National Herbarium of Victoria, report that some plant cover was wiped out and that bog vegetation, known as sphagnum moss, home of the rare frog, was burnt down to the peat layer. The tiny yellow-and-black-striped frog, which grows to about 25 millimetres, is only found in the 400 square kilometres of snow gum woodlands and sphagnum bogs in Kosciuszko National Park, and the Brindabella Range, near Canberra. "As a result of the fire, the frogs have vanished from more than half the sites being monitored by the National Parks and Wildlife Service," Opposition environment spokesman Michael Richardson said. He said the report predicted "the likely extinction of this species from the wild in the near future". The tiny mountain pygmy possum lives in the Snowy Mountains of NSW and Victoria. In the bushfire, 75 to 80 per cent of its Mount Blue Cow habitat was severely damaged and its slow recovery has caused concern for the 500 possums still in existence. "The possum's primary habitat is a dwarf conifer known as the mountain plum pine which was burnt so badly that many have died," Mr Richardson said. "Some of the shrubs were more than 200 years old and it will take generations for them to recover - if they ever do.

Sanecki and Green (2005) review small mammals post-fire (2003) in Kosciuszko National Park:

The small mammal fauna of the Australian Alps does not only consist of the iconic Mountain Pygmy-possum Burramys parvus, but several other species that remain active throughout the year including winter during which they spend most of their time in the space that forms between the ground and the base of the snow-pack, the subnivean space.

The most common of these above the snowline include the bush rat, Rattus fuscipes, dusky antechinus, Antechinus swainsonii and the threatened broad-toothed rat, Mastacomys fuscus. Of these species R. fuscipes and A. swainsonii are the most commonly occurring small mammals in the Alps. Research and monitoring of these species, (especially M. fuscus) has been undertaken for some time in Kosciuszko National Park, the Smiggin Holes trapping grid being monitored since 1978. Prior to the fires, eight grids were being monitored during December, February and April each year. Augmenting this, a landscape scale transect had been established in the subalpine zone to investigate and monitor the distribution of small mammals in relation to snow cover and the development of the subnivean space.

Recent research in particular, demonstrated the importance of habitat structure in the development and maintenance of the subnivean space; in particular shrub structural complexity and microtopographic relief.

The 2003 fire had a number of effects on small mammals. In the first instance there was a significant reduction in the population of each species at burnt grids. A second reduction occurred following the next winter when small mammal numbers on highly burnt grids fell to zero. A similar effect was also observed at the landscape scale with small mammals absent from burnt sites on the subalpine transect. We attributed this to the loss of the subnivean space which was almost non-existent at burnt sites.

Two years after the fire small mammals are being detecting in small numbers on burnt trapping grids and at pre-fire levels on unburnt grids. At the landscape scale small mammals are still not being detected at burnt sites. We expect that small mammal recovery will be closely linked to the recovery of the subnivean space which is coupled to the regeneration of heathlands.

<u>ACT fauna impacts in the 2003 bushfires</u>

Evans and Webb (2005) outline post-fire (2003) recovery of small mammals in the ACT

The 2003 bushfires in the ACT were extremely hot (almost all areas burnt were classed as moderate to very high severity) and widespread (90% of Namadgi National Park affected). Such conditions have the potential to severely affect populations of small mammals and even cause localised extinction. Environment ACT began monitoring of a range of fauna, including small ground mammals, within 6 weeks post-fire. Small mammal trapping was conducted in a range fire severity classes and vegetation communities, including Montane (Snow Gum) Woodland, Montane Tall Moist Forest (Alpine Ash), Montane Moist Forest, Dry Woodland and Riparian Forest. Between 75 and 100 Elliot traps were placed at nine sites in autumn 2003, with retrapping conducted in autumn during 2004 and 2005. Where possible trapping was conducted at locations where previous (pre-fire) trapping surveys had been undertaken.

Three small ground-dwelling mammal species are known to occur in Namadgi NP, the Agile Antechinus, Antechinus agilis, Dusky Antechinus swainsonii and Bush Rat Rattus fuscepes. There was surprisingly high survival of all three native small ground mammal species within the first 2 months following fire. During two years following fire, trapping rates of both Antechinus species severely declined with one species apparently becoming locally extinct. Numbers of House Mice exploded in post-fire habitats in the second year.

Summary • There was surprisingly high survival of all three native small ground mammal species within the first 2 months following fire. • During two years following fire, trapping rates of both Antechinus species severely declined with one species apparently becoming locally extinct. • Numbers of House Mice exploded in post-fire habitats in the second year.

4.8 Ongoing fauna and threatened fauna species decline from intense bushfires and inadequate fuel management

Department of Planning, Industry and Environment (2020) outline the impacts of the 2019/ 20 bushfires on threatened fauna:

Of the 293 threatened animal species or populations with records in the RFS fire ground:

- *all 413 records of the yellow-bellied glider endangered population on Bago Plateau are within the fire ground and more than 55% of records are in areas where the canopy has been partially or fully affected*
- *four other species or populations have more than 80% of their records within the fire ground: ° the critically endangered long-nosed potoroo (97% of records, although fire severity has yet to be assessed in these areas) ° the endangered frog Philora pughi (85% of records) ° the greater glider endangered population in Eurobodalla (81% of records and more than 25% of records in areas where the canopy has been fully affected) ° the endangered Hastings River mouse (84% of records)*
- *99 species have more than 10% of their records within the f ire ground.*

Santos et al. (2022) consider beyond inappropriate fire regimes: A synthesis of fire-driven declines of threatened mammals in Australia:

Abstract
Fire can promote biodiversity, but changing patterns of fire threaten species worldwide. While scientific literature often describes "inappropriate fire regimes" as a significant threat to biodiversity, less attention has been paid to the characteristics that make a fire regime inappropriate. We go beyond this generic description and synthesize how inappropriate fire regimes contribute to declines of animal populations using threatened mammals as a case study. We developed a demographic framework for classifying mechanisms by which fire regimes cause population decline and applied the framework in a systematic review to identify fire characteristics and interacting threats associated with population declines in Australian threatened land mammals (n = 99). Inappropriate fire regimes threaten 88% of Australian threatened land mammals. ***Our review indicates that intense, large, and frequent fires are the primary cause of fire-related population declines, particularly through their influence on survival rates. However, several species are threatened by a lack of fire, and there is considerable uncertainty in the evidence base for fire-related declines.*** *Climate change and predation are documented or predicted to interact with fire to exacerbate mammalian declines. This demographic framework will help target conservation actions globally and will be enhanced by empirical studies of animal survival, movement, and reproduction.*

Onfray (2023) highlights a number of case studies as proof that species are declining in forests set up to protect them, including in relation to fire management:

https://arr.news/2023/05/05/proof-that-species-are-declining-in-our-forests-set-up-to-protect-them-robert-onfray/

It is widely known in New South Wales that there has been a decline in biodiversity in national parks. The New South Wales National Parks and Wildlife Service (NPWS) admitted this in their 2021 zero extinctions report.

In response, NPWS announced, in October last year, the establishment of a network of seven feral predator-free areas across the state as part of a rewilding exercise. They aim to have 65,000 hectares free from feral predators. However, considering they manage over 7.5 million hectares, ensuring less than one per cent of the land they manage is free from ferals is hardly an achievement.

NPWS have been forced to do this work because private enterprise has achieved much better results in dealing with feral predators. For example, the Australian Wildlife Conservancy is a not-for-profit private landowner and land manager of nearly 13 million hectares. In just 30 years, they have successfully established an active reserve management program focussing on two things NPWS doesn't – feral animal control and fire management.

Even a similar program on state forest managed by Forestry Corporation of NSW in southern New South Wales has out-trumped NPWS. A careful and successful pest baiting program in state forests around Eden has reduced predator numbers. The program had led to increases in populations of several small mammals including the endangered southern brown bandicoot (Isoodon obesulus obesulus) and long-nosed potoroos (Potorous tridactylus).

Onfray (2023) also discusses the corroboree frog and the 2019/ 20 bushfires:

Just before Christmas in 2019, 115 corroboree frogs were laboratory-reared at the University of Wollongong as part of a breeding program to save the dwindling numbers from extinction. They were helicoptered into Kosciuszko National Park, where they were delicately and individually introduced into custom-built enclosures to protect them from the chytrid fungus that had decimated numbers in the past. Weeks later, fierce bushfires bore down on the fledgling colonies. Two fronts converged on the remote and inaccessible sphagnum bogs. By not actively managing the surrounding fuel loads, the corroboree frog was nearly extirpated from a park that was supposed to protect it.

Instead of being proactive and implementing fuel reduction cool burns across the whole park to minimise the risk of massive conflagrations, NPWS made sure we bore witness to the virtual loss of a beautiful frog species. The fact they spent so much on a carefully orchestrated breeding program and exposed the frogs to a brutal death by not protecting its habitat from fire at the end of a prolonged drought, says much about their lack of priorities and competence as land managers.

Thankfully, after the fires, 40 frogs survived, so there is still hope. However, we can only sit back and anxiously wait for something to be done to reduce the likelihood of large conflagrations in Kosciuszko National Park in the future.

Critical breeding habitats for the frog are sphagnum bogs, and many were burnt. For example, marshes near McNamara's Hut at Dinner Plain and south-west of Kiandra near Mount Selwyn were destroyed and allowed to burn to bare earth through neglect. This truly is an unprecedented event in terms of fauna (mis)management. Human stupidity allowed the unnecessary cremation of hundreds of hectares of the vitally essential sphagnum bogs and virtually kill off the last remaining populations of the corroboree frogs.

In March 2023, it was reported that another 100 corroboree frogs were again released into the park in "disease-free, purpose-built enclosures". The department had the gall the claim the "success of this long-term project". I guess if you ignore allowing just about every fire-sensitive sphagnum bog in the park, a vital habitat for the frog, to be forever destroyed, then you might be able to get away with calling it a success. Time will tell how the frog survives without its critical habitat.

Onfray (2023) also considers the greater gliders and the 2019/ 20 bushfires:

It is not just at Booderee where the greater gliders are disappearing. Eighty-four per cent of the glider's habitat was burnt in the 2019-20 wildfires in the Greater Blue Mountains World Heritage Area. Consequently, monitoring has revealed a steep decline in subpopulations within the park. Even scarier is that these recent declines suggest that many unmonitored subpopulations of the greater glider are likely to be declining.

Management of the Blue Mountains area has been a problem for decades. At an event in the Blue Mountains, the former New South Wales Environment Minister, Matt Kean, told the media it was necessary "to leave our planet to our kids better than we found it". However, less than a week later, the International Union for Conservation of Nature (IUCN), the official adviser to the United Nations Educational, Scientific and Cultural Organisation (UNESCO), downgraded its rating of the Greater Blue Mountains World Heritage Site to "significant concern". In just 20 years, the site has gone from one with outstanding universal value to the second lowest rating there is. It is hardly the performance that gives confidence to our kids that they are inheriting an environment in better condition.

4.9 Ongoing flora and threatened flora species decline from intense bushfires and inadequate fuel management

Godfree et al. (2021) report on the impacts of these fires on vascular plant species and communities across Australia:

Australia's 2019–2020 'Black Summer' bushfires burnt more than 8 million hectares of vegetation across the south-east of the continent, an event unprecedented in the last 200 years. Here we report the impacts of these fires on vascular plant species and communities. Using a map of the fires generated from remotely sensed hotspot data we show that, across 11 Australian bioregions, 17 major native vegetation groups were severely burnt, and up to 67–83% of globally significant rainforests and eucalypt forests and woodlands. Based on geocoded species occurrence data we estimate that >50% of known populations or ranges of 816 native vascular plant species were burnt during the fires, including more than 100 species with geographic ranges more than 500 km across. Habitat and fire response data show that most affected species are resilient to fire. However, the massive biogeographic, demographic and taxonomic breadth of impacts of the 2019–2020 fires may leave some ecosystems, particularly relictual Gondwanan rainforests, susceptible to regeneration failure and landscape-scale decline.

Department of Planning, Industry and Environment (2020) outline the impacts of the 2019/ 20 bushfires on threatened flora in NSW:

Threatened plants of the 680 threatened plant species with sighting records within the RFS fire ground (Figure 9):

- *61 species have more than 80% of their records within the f ire ground, including 19 with more than 30% of records in areas where the canopy has been fully affected*
- *37 species have 50–80% of records within the fire ground.*
- *42 species have 30–50% of records within the fire ground.*

and:

NSW assessment of Biodiversity indicators: post 2019/ 20 bushfire fire analysis

Within the RFS fire ground, ecological condition has decreased from 72% in 2013 to 44% in 2020, representing a 39% reduction. This assessment reflects the immediate effects post-fire on vegetation condition. The effects of regeneration and regrowth will be captured in future assessments.

and:

Within the RFS fire ground, ecological carrying capacity decreased from 62% in 2013 to 38% in 2020, representing a 39% reduction. This assessment reflects the immediate effects post-fire on ecological carrying capacity. The effects of regeneration and regrowth will be captured in future assessments.

and:

The persistence of ecosystems indicator reflects the expected persistence of species diversity based on the proportion of habitat remaining in ecosystems, using a classification representing known and undiscovered species. This indicator is a metric for diversity across ecosystems, species and genetics. Plant species are used as a surrogate for all biodiversity.

In 2013, 84% of the original diversity of NSW plants were estimated as likely to persist. In 2020, this decreased to 82%.

In areas within the fire ground, the diversity of NSW plants likely to persist was reduced by 4%. This decline represents a loss of unique diversity. This is not equivalent to extinction of individual plant species. Field studies have demonstrated that floristic diversity can increase in a post-fire environment.

Onfray R (2023) considers three critically endangered plant species only found in the far south-east of New South Wales near the eastern summit of Mount Imlay:

There are three critically endangered plant species only found in the far south-east of New South Wales near the eastern summit of Mount Imlay, at 800 metres altitude. They are the Mount Imlay *mallee (*Eucalyptus imlayensis*), Connie's guinea flower (*Hibbertia circinata*) and the Imlay boronia (*Boronia imlayensis*).*

And adds additional information in relating to after the 2019/ 20 bushfires and impacts on the Imlay Mallee:

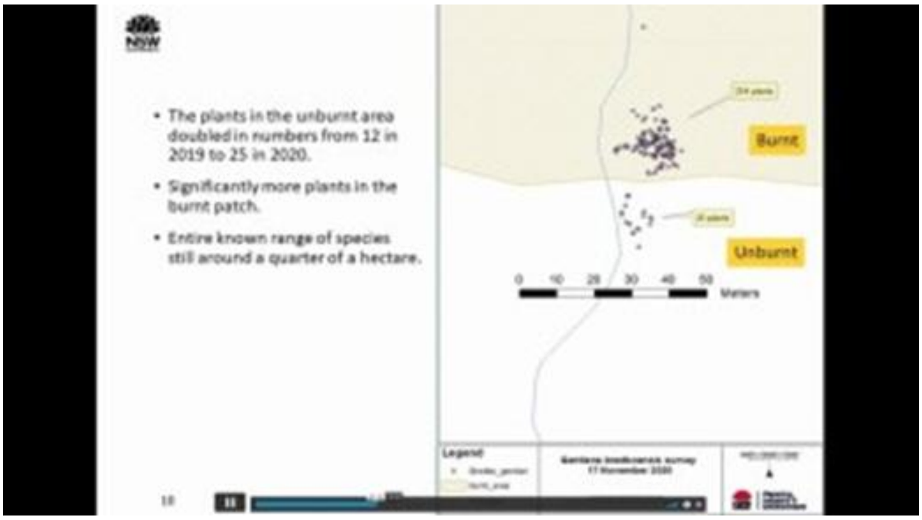
A 2020-21 report card by the New South Wales Government claimed there was good regeneration of the mallee (Imlay Mallee) *after the fire, but they acknowledge that it will take at least a decade for any tree to produce seed. There are now many seedlings of silvertop ash (Eucalyptus sieberi) which was previously rare on the mountain, and tea tree (Leptospermum scoparium) that will have to be thinned "in the coming years". Given the lack of appropriate active management on other reserves in the country, and the total lack of any active management on Mount Imlay in 50 years, I am not confident NPWS will carry out this work. Time will tell.*

SETA (2022 a) documents further concerns in relation to Eucalyptus imlayensis (Imlay Mallee).

The Editor (2022) Peter Rutherford response, ARRN 16 December adds other flora species to the mix suffering from inadequate low intensity fire and the impacts of intense bushfires.

As the per hectare tonnage of ground fuels increase, high intensity bushfires have more time to heat the soil and kill any remaining dormant orchid tubers.

In low site quality eucalypt forests, with low fuel layers, NSW conservation agencies have reported an increase in the number of individuals of rare orchids and other threatened species post the 2019-20 fire season. The example below refers to the critically endangered Bredbo Gentian.



Slide courtesy of the NSW Department of Planning, Industry and Environment.

4.10 Ongoing biodiversity decline impacts

Environment and Heritage (web) note a decline in biodiversity and note changes in fire regimes as a threat:

However, there is evidence that the overall decline in biodiversity in New South Wales is occurring even in the national park estate. Key threats affecting threatened species populations in national parks include:

- *feral predators and other feral animals*
- *invasive weeds*
- *changed fire regimes*
- *a range of impacts associated with climate change.*

The author suggests that intense and severe bushfires is a massive threat.
National Parks and Wildlife Service Threatened Species Framework (web) outlines a series of actions designed to secure and restore threatened species populations in national parks. They have several objectives for threatened species conservation in NSW national parks.

Our commitments
By 30 June 2026:

- *Stabilise or improve the on-park trajectory of at least 300 threatened species (measured by reference to metrics appropriate to the relevant species).*
- *No extinctions on the national park estate (that is, no loss of threatened species from the national park estate as a whole).*

By 30 June 2030:

- *Stabilise or improve the on-park trajectory of all threatened species.*
- *No extinctions on the national park estate.*
- *Remove # species (target to be determined by 30 June 2026) from the threatened species list as a result of on-park conservation measures.*

In addition, NSW National Parks and Wildlife Service (web) Threatened Species Framework annual report 2021–22 and 2022–23 outlines:

In New South Wales there are currently 928 plants and animals listed as critically endangered, endangered or vulnerable under Schedule 1 of the Biodiversity Conservation Act 2016 (NSW) (BC Act), excluding marine mammals, invertebrates and fungi. Just over 84% of threatened plant and animal species are represented on NSW national parks, which cover 10.4% (8.3 million ha) of land in the state. This concentration of threatened species and their habitat in the reserve system highlights the critical role of the NPWS in threatened species conservation.

and:

The first iteration of the NPWS threatened species inventory has been established. Of the 928 threatened plants and animals listed in NSW, 780 (84%) have been recorded in NSW national parks.

OK, but the threat of intense bushfires and repeat intense bushfires doesn't seem to get the attention deserved from the Service.

Kasel et al. (2024) highlights major concerns in relation to severe wildfires with short fire return intervals and massive ecosystem and biodiversity impacts of this it is understood for SE Australia:

Abstract
Many plant species are well-adapted to historical fire regimes. An increase in the severity, frequency, and extent of wildfires could compromise the regenerative capacity of species, resulting in permanent shifts in plant diversity. ***We surveyed extant vegetation and soil seed banks across two forest types with contrasting historical fire regimes—Shrubby Dry Forest (fire return interval: 10–20 years) and Sub-Alpine Woodland (50–100 years). Over the past 20 years, both forests have been subject to repeated, high-severity wildfires at intervals significantly shorter than their historical return intervals.*** *We examined the soil seed bank response to fire-cued germination, and whether the plant diversity in soil seed banks and extant vegetation demonstrated similar responses to short-interval, high-severity wildfires. The soil seed bank demonstrated a positive response to heat in combination with smoke, and for the Sub-Alpine Woodland, this was limited to sites more frequently burnt by fire. With an increase in fire frequency, there was a decline in species richness and Shannon's Diversity and a shift in species composition in both extant vegetation and the soil seed bank. The fire frequency effects on the relative richness of trait associations were restricted to the Shrubby Dry Forest, and included an increase in short-lived obligate seeders, wind-dispersed species, and ant-dispersed shrubs in burnt relative to long unburnt sites in both extant vegetation and the soil seed bank. Graminoids were the most abundant component of the soil seed banks of Sub-Alpine Woodlands, and this increased with more frequent fire, with a similar trend (p = 0.06) in extant vegetation. Clear shifts in plant diversity in both soil seed banks and extant vegetation in forest types with contrasting historical fire regimes suggest that emerging fire regimes are pushing ecosystems*

beyond their historical range of variability, including potentially more flammable states and a decline in the buffering capacity of soil seed banks.

Conclusion
Clear shifts in plant diversity in extant vegetation and soil seed banks, including a decline in alpha diversity and changes in species composition and functional trait associations, provide strong evidence for changes in plant diversity with emerging fire regimes. The largely consistent changes in plant diversity in both forest types, despite contrasting historical fire regimes, ***suggests that severe wildfires with short fire return intervals are pushing ecosystems beyond their historical range of variability, with the realization of a previously hidden resilience debt.*** *Shifts in species composition, including the potential for an increased flammability of these forests and positive feedback between past fires and future fires [120,134,135], point to a likely increase in extent in areas burnt at even higher frequencies, with some areas in southeastern Australia already being burnt four to five times since 1995 [136]. The erosion in the buffering capacity of soil seed banks points to an increase in the reliance on post-fire resprouting, clonal spread, or long-distance dispersal from fire refugia for maintaining plant diversity, particularly in extensively burnt areas such as those in southeastern Australia.*

Verrall and Pickering (2019) consider recovery and structure of subalpine grasslands 15 years after landscape level fires:

Abstract
As conditions warm, previously rare landscape level fires are more likely to affect vegetation in the Australian Alps including in subalpine grasslands. The recovery of this community was assessed using paired unburnt and burnt plots (30 × 20 m) at 10 sites 15 years after largescale fires that burnt >70% of the subalpine zone in Kosciuszko National Park. There were few significant differences found: higher cover of shrubs (17.8% burnt vs 11.3% unburnt plots), and taller vegetation (22.6 vs 19 cm). However, vegetation cover (97%), species richness (38 taxa), composition and limited presence of invasive plants (10 species, 8.5% cover) were not significantly different. This differs from results six weeks and one year post-fire, when there were clear differences in the cover and composition of vegetation. These results indicate that subalpine grasslands recover from single fires, but with warmer and drier conditions becoming more common, and repeat fires in some areas, the distribution, structure and composition of this and other communities in the Australian Alps will change.

The author considers that it is a major concern changed fire regimes is listed as a key threat affecting threatened species populations in national parks, but there is minimal action to address very low rates of prescribed burning across NSW and national parks, indeed, the rates of prescribed burning in forest areas across NSW averages 0.6 % over the last 7 years. It is the author's belief that changed fire regimes is certainly a key threat affecting threatened species populations in national parks. That threat is a fire deficit of inadequate low intensity fire usage and massive fuel load build up and intense, severe long duration bushfires.

This inaction approach will do nothing to stop intense bushfires across the same landscapes with minimal prescribed burning. And very long fire runs.

SETA (2022 b) outlines why current bushfire mitigation levels must be increased across landscapes to reduce the scale and impact of high intensity bushfires on biodiversity and human lives and assets.

4.11 Sediment, waterway, water quality and water catchment impacts

Department of Sustainability, Environment, Water, Population and Communities (2012) consider bushfires and water quality impacts:

The extent to which water quality is affected by fire depends on factors such as: the size and extent of the fire; the type of surrounding vegetation, soil and erosion; the geographical features and size of the catchment; and the time period between the last fire and a significant rainfall event.

High intensity fires can cause enormous damage to water catchments by destroying ground-cover and changing hydrology, as well as altering the structure, behaviour and erosion of soil. Furthermore, the chemical reactions triggered by fire can release nutrients, metals and other toxicants stored in vegetation and soil. Post-fire rainfall has significant impacts on water quality as it often washes these contaminants into waterways and reservoirs. When this occurs, water may be unsafe for agriculture or *human consumption without additional treatment or alternative sources of water. Poor water quality and loss of amenity can therefore have substantial financial implications.*

The entire local food chain may be adversely affected by the loss of riparian vegetation after fire as it can lead to increased light availability, higher water temperatures, loss of habitat, and reduced protection from predators for in-stream biota. When combined with increased contaminant loading, the increased water temperature can trigger greater breakdown of organic matter by bacteria, which may deplete oxygen levels in the water. Fish suffocation is a common after-effect of fires as a result of this sudden depletion of dissolved oxygen.

Leitch et al. (2013) study erosion and nutrient loss impacts resulting from Ash Wednesday (February 1983) wildfires in a case study:

Summary

A wildfire on Ash Wednesday (16 February 1983) near Warburton in the Victorian Central Highlands left large areas of burnt forest in a highly erodible state and, in one particular locality, an intense thunderstorm of short duration six days after the fire caused gross erosion of catchment slopes and gullies. Limited sampling and measurement were undertaken in a 35 ha study area to indicate the causes and extent of erosion and to estimate quantities of nutrients lost during and following the wildfire. Recognising the imprecision of the data due to restricted sampling, it was estimated that in the order of 800 t of ash plus loose soil were washed from the study area (equivalent to about 22 t ha−1), and that this eroded material contained about 2 900 kg of nitrogen and 220 kg of phosphorus. Losses of nitrogen and phosphorus through erosion together with volatilisation and convective transfer of ash were each estimated at approximately one-third of the total quantity of these nutrients held in the above-ground biomass. Soils in the study area were observed to be hydrophobic for more than three months following the wildlife. It is concluded that burnt forests can remain in a highly erosive state for protracted periods until the soils lose their hydrophobicity and revegetation commences.

An article by Gorman (2020) highlights negative impact images of the Dunns Road bushfire on water quality in Mannus Creek in southern NSW, refer to the reference link in references.

MacKenzie (2019) highlights negative impact images of bushfires on water quality near Tenterfield in northern NSW, refer to the reference link in references.

Stephenson (2010) assesses the impacts-of-severe-bushfires-in-SE-Australia on aquatic fauna.

Jurskis et al. (2003) analyses the lesser impacts of prescribed burning as opposed to bushfires:

Catling's (1991) theoretical analysis of contrasting fire regimes didn't consider impacts such as water pollution and siltation that may affect off site biodiversity. These have received little attention in fire ecology compared to their prominence in other aspects of land management. Good (1981) cited a study showing a thousandfold increase in soil erosion over more than a year as a result of wildfire. Birk and Bridges (1989) found that five times more fine fuels remained unburnt by prescribed fires in a blackbutt forest compared to a wildfire. Thus there was much less protection for the soil following wildfire. It is likely that a low intensity fire regime will generate less soil erosion, siltation and water pollution than a high intensity regime.

Readfearn (2020) outlines the impacts of bushfires on sediment and fish:

- Thompson (Professor Ross Thompson, a freshwater ecologist at the University of Canberra's Institute for Applied Ecology) has studied the impacts of previous droughts and bushfires on freshwater systems. When the millennium drought broke, Thompson said, the downpours acted as "another disturbance" to species, rather than a welcome relief. "Floods that come after droughts have really big impacts on aquatic biota," he said. But with this summer's addition of the extensive bushfires in river catchments, "we have a triple whammy this time". He said a study around the Murrumbidgee river after Canberra's fires of 2003 had shown just how much sediment could be released into rivers from burnt catchments. "There were pools in that river that were 5m deep that got completely filled in," he said. Sediment tended to smother food sources that were on the river beds. Thompson was particularly concerned about species such as the stocky galaxias – the subject of a rescue effort in the Kosciuszko national park – and the endangered Macquarie perch. He said a broader concern was that rivers might not get the 30 or 40 years they needed to recover before the next big disturbance.

- On the Macleay river, near Kempsey, hundreds of thousands of fish died after heavy rain upstream flushed ash and debris into the river, turning it into what one local described as “runny cake mix”. One ecologist said it could take decades for the Macleay river to recover from the event.
- Prof Fran Sheldon, of the Australian Rivers Institute, said adding so much ash and sediment into the rivers turned them into the aquatic equivalent of “deserts” because the bacteria sucked the oxygen from the water. “Most organisms can’t survive so they just disappear.”
- Prof Max Finlayson, of the Institute for Land, Water and Society at Charles Sturt University, told Guardian Australia that while the individual impacts on rivers such as floods, droughts and bushfires were “not new phenomena”, it was the combination of impacts – together with the scale of the fires – that was “the big difference”.

The Bushfire Front (2025 web) document Impacts of bushfires on water catchment impacts:

In the large Perth Hills bush fire of 2005, monitoring of a Water Corporation experimental catchment showed that water yield increased by a factor of 2.2 times in the first year, but then returned to normal afterward, However, over 350 cubic metres of soil were deposited in the stream bed, silting up the stream and small pools. Large amounts of silt and ash passed through into the Mundaring Weir. A survey by the Department of Environment and Conservation found that aquatic diversity was significantly impaired in the wild fire area. Invertebrates in the wildfire area were also much less diverse than those from areas that had been covered by a low intensity fuel reduction burn.

As noted above, sediment and ash impact on waterways after wildfires has happened before. It is important to learn the lessons and reduce the impacts of intense bushfires.

Australia State of Environment (2021) outlines a case study of bushfire impacts on freshwater habitats and provides detailed information in relation to impacts:

Brendan Ebner, Centre for Tropical Water and Aquatic Ecosystem Research, James Cook University

The 2019–20 bushfires followed a period of prolonged drought but were followed by a period of above-average rainfall. This combination has exacerbated the impact of the fires on the catchments burned, as pre-bushfire populations of some species were already fragmented and isolated in drying streams; the fires themselves removed bankside vegetation and shading; and postfire erosion and run-off reduced water quality, with sediment loads rich in ash, nutrients, organics and metals.

An assessment of the Upper Murray catchment in south-eastern New South Wales and north-eastern Victoria found that nearly one-third of forested and rural regions were burned, resulting in high loads of sediment and ash entering the Murray River and Lake Hume. Sediment delivery to Lake Hume was 7 times that of the previous year, at 600,000 tonnes per month. High levels of suspended sediment caused local mortality of fish, reduced hatching success of key crustacean food sources and high mortality of freshwater snails (Joehnk et al. 2020).

Deaths were recorded in at least 27 species of fish and 4 crustacean species across 15 waterways in New South Wales and Victoria, including 11 obligate estuarine species – the first global record of bushfire impacts on water quality extending into estuaries (Silva et al. 2020). Some species were especially badly affected – in Victoria, East Gippsland galaxias (Galaxias aequipinnis) had 100% of potential habitat burnt; Yalmy galaxias (Galaxias sp. ‘Yalmy’) had 95% of its habitat within the fire extent; and roundsnout galaxias (Galaxias terenasus) had 38% of potential habitat extent burned (DELWP 2020).

Salvage collection of fish and crayfish from the wild was attempted in several jurisdictions to create captive, insurance populations. River blackfish (Gadopsis marmoratus), mountain galaxias (Galaxias olidus) and spiny crayfish (Euastacus sulcatus) were collected in the Queensland headwaters of the Darling River in late 2019 and early 2020 (Ebner et al. 2020).

4.12 Greenhouse gas and air quality impacts

Raison (2024) outlines changes to carbon stocks in Australian native forests are driven much more by extensive wildfire than by harvesting.

First, wildfires can have major impacts on forest C stocks that can persist for centuries. Second, under sustained severe fire weather, all forests across a landscape will burn at high intensity and severity, resulting in large C emissions, irrespective of whether they have a history of harvesting. Third, management of fire will be more challenging in the future under a predicted warmer and drier climate in southeastern Australia – both the area burnt and the number of megafires (>1 million ha burnt) have increased in Australia in recent decades (Morgan et al. 2020; Canadell et al. 2021). Unless ways can be found to mitigate escalating bushfires, C storage in all native forests (irrespective of management intent) is clearly threatened, and C stocks will almost certainly decline in the future.

In my opinion, the threat from wildfire to any C emissions abatement benefit derived from forests is likely to be greater under a non-harvest management scenario, which relies on the protection of forest C stocks over a long time into the future. Harvested forests managed on rotations of 80–100 years provide more opportunities for any benefits related to the use of harvested wood to be 'banked' progressively over time before wildfires intervene.

Kasel et al. (2024) highlight major concerns in relation to severe wildfires with short fire return intervals and the massive ecosystem impacts of this, including changes in species and increased flammability:

Conclusion
Clear shifts in plant diversity in extant vegetation and soil seed banks, including a decline in alpha diversity and changes in species composition and functional trait associations, provide strong evidence for changes in plant diversity with emerging fire regimes. The largely consistent changes in plant diversity in both forest types, despite contrasting historical fire regimes, suggests that severe wildfires with short fire return intervals are pushing ecosystems beyond their historical range of variability, with the realization of a previously hidden resilience debt. Shifts in species composition, including the potential for an increased flammability of these forests and positive feedback between past fires and future fires [120,134,135], point to a likely increase in extent in areas burnt at even higher frequencies, with some areas in southeastern Australia already being burnt four to five times since 1995 [136].

A consequence of changes in fuel and forest structure, changes in suppression and increased severity bushfires is also highlighted by Hurteau and Brooks (2011), no different to Australia:

Forests sequester carbon from the atmosphere, and in so doing can mitigate the effects of climate change. Fire is a natural disturbance process in many forest systems that releases carbon back to the atmosphere. In dry temperate forests, fires historically burned with greater frequency and lower severity than they do today. Frequent fires consumed fuels on the forest floor and maintained open stand structures. Fire suppression has resulted in increased understory fuel loads and tree density; a change in structure that has caused a shift from low- to high-severity fires. More severe fires, resulting in greater tree mortality, have caused a decrease in forest carbon stability. Fire management actions can mitigate the risk of high-severity fires, but these actions often require a trade-off between maximizing carbon stocks and carbon stability. We discuss the effects of fire on forest carbon stocks and recommend that managing forests on the basis of their specific ecologies should be the foremost goal, with carbon sequestration being an ancillary benefit.

Further information is outlined in a paper referenced below from Hollis et al. (2013) in relation to the effect of fire line intensity on woody fuel consumption in southern Australian eucalypt forest fires:

The results of this research suggest that predicted changes to fire regimes and fire intensity associated with climate change in southern Australia could result in greater woody fuel consumption and carbon release during bushfires and a reduction in woody fuel loads in dry eucalypt forests. Use of low-intensity prescribed fires may provide a practical way of managing woody fuel stocks to achieve particular land management objectives.

As noted in Bushfires in Australia Wikipedia 15 Feb 2020:

In January 2020, the British Met Office said Australia's bushfires in 2019-2020 were expected to contribute 2% to the increase in the atmospheric concentration of major greenhouse gases which are forecast to hit 417 parts per million, one of the largest annual increases in atmospheric carbon dioxide on record. Interesting, the author checked the NOAA CO2 daily/ weekly/ monthly means at Mauna

Loa. There is definitely a rise in CO_2 to around 416 ppm but this peak was present last year as well. The CO_2 data drops to around 408 ppm in the southern winter/ cooler months, the data is quite cyclic.

Due to minimal prescribed burning and high fuel loads, the inevitable intense bushfires kill large numbers of trees and markedly reduce the health of remaining trees for around 10 years plus, the impacts are that high. This further reduces carbon storage and carbon capture in reduced health trees.

In relation to the disastrous impacts of the 2019/ 20 bushfires on carbon emissions, there are many papers in relation to this in relation to the bushfire extent, severity and duration impacts.

One example is the 2019/ 20 Gosper's Mountain bushfire, the biggest ever individual bushfire in the world. And the many other disastrous bushfires in the Greater Blue Mountains World Heritage Areas.

And another are the repeat huge megafires in Kosciuszko National Park (KNP), detail in relation to this is outlined O'Donnell (2025 a). As highlighted in the review, the NSW Alps 5 years after the 2019/2020 bushfires, it is readily apparent to anyone that the greenhouse impacts are huge.

Kiandra to Adaminaby, a stark scene resulting from the 2019/ 20 bushfires in KNP replicated across much of the landscape, the carbon loss was obviously huge from tree mortality and lost growth. Dense understorey fuels with dead timber fuels represent a major fire hazard for the next bushfire. Fuel will now contain a high proportion of woody material and for many years subsequent bushfires will have a longer burnout period and be more damaging to any regenerating trees.

Cabramurra to Khancoban, above Tumut Pond Dam view resulting from the 2019/ 20 bushfires in KNP, the carbon loss was obviously huge from tree mortality and lost growth across ridges. Dense understorey fuels and dead timber fuels represent a major current and ongoing fire hazard for the next bushfire. Fuel will now contain a high proportion of woody material and for many years subsequent bushfires will have a longer burnout period and be more damaging to the regenerating trees. Note the absence of live hollow bearing trees.

Cabramurra to Khancoban. Large areas of single age 5-year-old snow gums (technically older where there are live lignotubers present below the ground) resulting from the 2019/ 20

bushfires in KNP, the carbon loss was obviously huge from tree mortality and lost growth. Fuel will now contain a high proportion of woody material and for many years subsequent bushfires will have a longer burnout period and be more damaging to the regenerating trees.

Intense bushfires and large greenhouse impacts are going to continue, unless prescribed burning rates in NSW increase from the minimal 0.6 % per year over the last 7 years, to around 8 % per year. The author cannot see this happening any time soon.

And there's more large bushfires and consequent greenhouse impacts, including in "protected" conservation areas:

- There are repeat megafires in the Grampians NP, these were huge in 2024 and 2025.
- There are repeat megafires in the Little Desert conservation area, these were huge in 2024 and 2025.
- The same applies to the Flinders Ranges.

Basically, conservation areas receive minimal low intensity bushfires and pay back/ feedback time soon comes around with repeat megafires, generating huge greenhouse gas emissions.

It is perverse that low intensity fire is used as a carbon credit in Northern Australia where prescribed burning is used, yet in southern Australia credits could be claimed for lock up, involving no adaptive management and miniscule prescribed burning, under current procedures being considered for carbon methods in NSW.

There is an opportunity to use prescribed burning to reduce climate change impacts from massive bushfires and megafires.

4.13 Bushfires and Pacific impacts

NASA Earth Observatory (2020a) outline the impacts of Australian fires fuelling ocean looms:

The catastrophic wildfires that scorched eucalyptus forests in southern and eastern Australia in the summer of 2019-2020 were unprecedented in their scale and intensity. Started in October 2019 and burning through January 2020, they scorched millions of hectares and killed or displaced an estimated 3 billion animals. The fires emitted vast amounts of carbon dioxide and lofted smoke plumes to record heights.

That smoky summer also affected marine ecosystems thousands of kilometers away, according to new research that combined satellite data and surface measurements. From December 2019 to March 2020, the deposition of aerosols emitted by the fires triggered phytoplankton blooms in the normally iron-limited waters of the South Pacific and Southern Ocean. Together the surface area of those blooms exceeded the size of Australia.

and:

It is important to understand the effects of such fires, not just on local ecosystems but on distant ones as well, noted marine biogeochemist Weiyi Tang of Princeton and biogeochemist Nicolas Cassar of Duke University, lead authors of the . "The fact that both the fires and the blooms were unprecedented in the satellite record initially gave us an inkling that they might be connected," Cassar said.

To quantify the aerosols emitted by the fires, the team examined aerosol optical depth (AOD)data from the Copernicus Atmosphere Monitoring Service (CAMS), which is based partly on measurements from the (MODIS) on NASA's and satellites. In the visible spectrum, AOD provides a measure of the amount of desert dust, sea salt, sulfate, organic matter, and black carbon in a column of air. The researchers looked specifically at black carbon AOD as a proxy for wildfire aerosols. Tang, Cassar, and colleagues found that black carbon emissions emanated mainly from wildfires in southern and eastern Australia and blew out to the broad South Pacific within a few days.

and:

The team also examined chlorophyll concentrations recorded by the European Space Agency's Ocean Color Climate Change Initiative. OCCI merges data from the Medium Resolution Imaging Spectrometer(MERIS) on Envisat, Terra MODIS, the Visible Infrared Imaging Radiometer Suit(VIIRS), and the Sea Viewing Wild Field of View Sensor (SeaWiFS).

The maps above show the monthly aerosol levels (left) and chlorophyll anomalies (right)from November 2019 to February 2020. The researchers identified two regions south and east of Australia where chlorophyll concentrations were double the normal seasonal levels—values never before observed in the 22-year satellite record. Those chlorophyll anomalies occurred within a few days to weeks after the peaks in black carbon aerosols. In those two regions, black carbon aerosol values were also 300 percent higher than normal, a level unprecedented in the 17-year aerosol record.

As the wildfire plumes streamed off the Australian continent, they passed over an air sampling station on the summit of Mount Wellington in Tasmania. Analyses of airborne aerosol samples collected there revealed the presence of iron and a saccharide molecule called levoglucosan that forms when cellulose burns—direct evidence that the aerosols came from the wildfires. Downwind, Argo floats in the ocean also detected elevated levels of chlorophyll in the bloom areas, affirming that the satellite chlorophyll signal was real.

The connection between the smoke aerosols and the bloom was also corroborated by a model that computed the trajectories of the air parcels leaving the fire. "The aerosol optical depth and the modeled air mass trajectories confirmed that the algal blooms were in the path of the aerosols from the wildfires," Cassar said.

The team even considered whether natural variability in the ocean—such as the Indian Ocean Dipole, the Southern Annular Mode, or El Niño-Southern Oscillation—could explain the influx of nutrients fueling the bloom. "There was nothing that could explain the observations that we had," Tang said. "It turns out that natural variability was relatively small compared to what we observed."

More information in relation to blooms is included in Tang et al. (2021) and Van der Velde et al. (2021).

NASA Earth Observatory (2020) outlines useful detail in relation to 2019/ 20 Carbon Monoxide impacts in the air and stratosphere:

Bushfires have raged in Victoria and New South Wales since November 2019, yielding startling satellite images of smoke plumes streaming from southeastern Australia on a near daily basis. The images got even more eye-popping in January 2020 when unusually hot weather and strong winds supercharged the fires.

Narrow streams of smoke widened into a thick gray and tan pall that filled the skies on January 4, 2020. Several pyrocumulus clouds rose from the smoke, and the towering clouds functioned like elevators, lifting huge quantities of gas and particles well over 10 kilometers (6 miles) above the surface—high enough to put smoke into the stratosphere.

During the past few weeks, satellite sensors have collected data that is even more stunning than the images. The Microwave Limb Sounder (MLS) on NASA's Aura satellite has collected preliminary data that suggests the Australian fires injected more carbon monoxide into the stratosphere in the month of January than any other event the sensor has observed outside of the tropics during its 15-year mission. The fires appear to have produced about three times as much of the poisonous, colorless gas as major fires in British Columbia in 2017 and Australia in 2009. (Fires in Indonesia in 2015-16 may have delivered as much or more, but those fires happened over a longer period.)

The map above shows the locations and dates of carbon monoxide observations that MLS made in January 2020. The highest values were observed in early January as smoke crossed the Pacific Ocean. "All of the carbon monoxide in the stratosphere will be converted into carbon dioxide over a few weeks," explained Hugh Pumphrey, an atmospheric scientist at University of Edinburgh. "But the amount of carbon dioxide will not be significant for the climate. The important thing about these carbon monoxide observations is that they are a big flag being waved that point to just how unusual these fires were at the surface."

The Australian smoke is also proving to be an outlier in measurements made by the NASA/CNES CALIPSO satellite, which carries a sensor that scientists use to track the height of the smoke plume. On January 6, 2020, a few days after the most explosive fire activity, CALIPSO measured smoke between 15 and 19 kilometers (9 and 12 miles) above the surface.

Within two weeks, the top of the plume had risen as high as 25 kilometers, making this the highest wildfire-caused plume ever tracked by CALIPSO. "The plume is rising because of the radiative heating of soot particles within the smoke by the Sun," explained Jean-Paul Vernier, a scientist from the National Institute of Aerospace at NASA Langley Research Center and the lead of a NASA disasters team responding to the fires.

A similar process caused the smoke plume from the 2017 fires in Canada to rise from its initial injection height of 12 kilometers to 23 kilometers over a two-month period. In that case, satellites detected the smoke for eight months before it dissipated.

"One of the great things about MLS and CALIPSO is that they give complementary altitude information about gases and aerosols in the atmosphere," said Vernier. "Most satellite sensors provide a two-dimensional view of the atmosphere, but MLS and CALIPSO together offer a pretty ***detailed three-dimensional picture."***

4.14 Climate impacts following intense bushfires

A recent paper by Fasullo et al. (2023) highlights feedback loops from the bushfires and influence on post bushfire La Niña events:

The climate response to biomass burning emissions from the 2019–2020 Australian wildfire season is estimated from two 30-member ensembles using CESM2: one of which incorporates observed wildfire emissions and one that does not. In response to the fires, an increase in biomass aerosol burdens across the southern hemisphere is simulated through late 2019 and early 2020, accompanied by an enhancement of cloud albedo, particularly in the southeastern subtropical Pacific Ocean. In turn, the surface cools, the boundary layer dries, and the moist static energy of the low-level flow into the equatorial Pacific is reduced. In response, the intertropical convergence zone migrates northward and sea surface temperature in the Niño3.4 region cools, with coupled feedbacks amplifying the cooling. A subsequent multiyear ensemble mean cooling of the tropical Pacific is simulated through the end of 2021, suggesting an important contribution to the 2020–2022 strong La Niña events.

Put simply in relation to this research, the author considers that a vicious cycle of bushfires and floods is underway:

- Major bushfires/ megafires occur with large greenhouse and other emissions occur, such as the 2019/ 20 bushfires
- Then Pacific cooling and consequent increased rainfall impacts in E Australia making La Nina's worse for Eastern Australia and increasing vegetation growth such as in 2020 to 2022.
- Consequent increased bushfire risks when an El Nino strikes such as in late 2023, with large areas of increased vegetation over Australia.
- The cycle continues.

This research needs to be considered and actioned, there are obvious solutions in markedly increased prescribed burning across south eastern Australia and an increased focus on adaptive management, reducing both bushfire insurance costs and flood costs and better protecting communities and the environment.

4.15 Ozone hole impacts

Humphries (2022) provides detail in relation to damage to the ozone layer from the 2019/ 20 bushfires:

UK researchers have revealed Australia's Black Summer bushfires likely damaged the ozone layer and caused the highest temperatures in the stratosphere in 30 years.

The fires scorched more than 24 million hectares, killed 33 people directly, and almost 450 more lost their lives from the effects of smoke inhalation.

A study published Thursday in the journal Scientific Reports revealed the temperature in the stratosphere rose by 0.7 degrees Celsius. Above Australia, it rose by 3C.

The study's co-author, atmospheric science professor Jim Haywood, said the findings were statistically significant and worrying.

"The implications might be quite alarming, because the future climate is predicted to get warmer and drier and we're expecting higher frequencies of wildfires and we're also expecting them to be at greater intensity," he said.

The University of Exeter researchers also discovered the bushfires appeared to have depleted the Earth's ozone layer and led to "a very large, deep and long-lived ozone hole".

The ozone layer has managed to make some recovery since the 1980s as a result of a landmark multilateral agreement, the Montreal Protocol, phasing out the use of some chemicals.

The stratosphere, which contains the ozone layer, is around 12 to 50 km above the Earth's surface.

It doesn't usually vary much in temperature, except in events like volcanic eruptions or extreme prolonged bushfire events.

Professor Hayward said global efforts to restore the ozone layer could be rapidly be put at risk.

5 Economic bushfire impacts across SE Australia, including from intense and severe bushfires

Economic bushfire impacts across SE Australia, including from intense and severe bushfires, are outlined in Sections 5.1 to 5.5.

5.1 Disaster impacts and costs, including repeat disasters

The 2019/ 20 bushfires were very costly, estimated by AccWeather to be $110 billion in terms of total damage and economic loss. https://www.accuweather.com/en/business/australia-wildfire-economic-damages-and-losses-to-reach-110-billion/657235 The estimate is based on an analysis incorporating independent methods to evaluate all direct and indirect impacts of the fires based on a variety of sources. It is noted that other estimates are lower than this, estimated damage from the bushfires in another case was estimated at a $20 billion impact to the Australian economy. Still, it is noted that the costs are huge.

The costs of repeat disasters of Australian bushfires are very costly. There are large numbers of repeat bushfire disasters across Australia, many intense and costly. Under current approaches, these are allowed to continue. In relation to flooding, Lismore and north coast flooding highlights other examples of repeat disasters, where broadscale mitigation is hardly actioned and the current mitigation problems and opportunities remain unaddressed.

Further information in relation to repeat bushfires is outlined in Section 2.4.

5.2 Bushfire suppression cost impacts of inadequate mitigation

There is inadequate funding of bushfire mitigation and a focus on bushfire suppression in Australia. As noted in a Deloitte Access Economics (2022) report:

"*Australia's disaster relief strategies are underpinned by a cycle of underinvestment in resilience and adaptation. It's been estimated by the Productivity Commission that 97 per cent of all-natural disaster funding in Australia is spent after an event, with just 3 per cent invested prior to an event to reduce the impact of future disasters."*

There are huge costs in bushfire control, resources on the ground, dozers, tankers, aircraft, large planes etc. Risk to planes and fire fighters are high.

And where there is limited fire mitigation, this results in longer and more difficult suppression operations.

O'Donnell (2025 b) outlines some examples where mitigation has assisted in suppression and lowered suppression costs:

Victoria Cann River and Mallacoota 1982-83

Some useful information is outlined in a document titled Cann River campaign fires – 1983 (Victorias Forests Bushfire Heritage (2025 web)).

It's reported that a heroic effort to light a backburn and hold the line at Stoney Peak on 9 March, in the face of 100 km/hr winds, together with a previous fuel reduction burn in 1979-80 probably saved Genoa, Gipsy Point and Mallacoota.

Linking areas which had been recently fuel reduced, together with aggressive first attack and backburning to build containment lines were important and effective control strategies in the very dry conditions.

Victoria Dimboola Fire 1980/ 81

Readily apparent. The fuel reduced area along the river effectively protected most of the town and relieved the pressure on suppression forces. This permitted a concentrated attack on the fire to the north of the town thereby reducing the area burnt following the south-westerly wind change. In consequence private property losses were minimised.

An effective attack on this sector would not have been possible because of the heavy fuels and access problems along the Wimmera River frontage. With many vacant blocks within the town covered in long dry grass the fire would have continued to spread and threaten more buildings. Under those circumstances it is likely that substantial property losses would have occurred.

NSW Blue Mountains 2019 and 2020 bushfires (Ruined Castle Fire)

The reasonably large hazard reduction burns were used as part of the containment strategy that successfully prevented asset impacts in villages, reduced firefighting requirements and decreased the risk to firefighters.

WA Preston fire 2023

The Preston fire, Fire 20, started in old fuels in Preston National Park, was a priority but could not be controlled, burning out a large area including Mandalay pine plantation.

Noting the 5 year old fuels on the eastern side, if this fire had been in older fuels it could potentially have reached Noggerup and Mumballup if older fuels were present.

Good consideration of bushfire resourcing. As noted "When hundreds of fires start in a lightning episode, resources are never enough hence priorities must be determined and many fires left for some time ("triaging")".

WA Perth 2018

Thanks to a number of these strategically located areas of reduced fuel age, the bushfire was contained to 4000 hectares when the headfire and southern flank of the bushfire ran into bush burnt within the last three years. Once it reached there it stopped abruptly and was able to be easily contained by ground crews.

WA Jarrahdale 2009

They found that the fire was burning in heavy fuels driven by a strong easterly breeze. The head-fire had already "crowned" (was burning through the tree-tops). There was nothing the crews could do about the head-fire, so they began work containing the flanks and tail-fire.

Fortunately the head-fire entered the area that had been commercially thinned and prescribe burned 18 months earlier. Starved of ground fuel the crown-fire could not sustain itself and within 50 metres of the boundary the fire dropped to the ground. Here it became a mild ground-fire and was easily and rapidly contained with a mineral-earth break made with the Cat and by the firefighters.

At the time the result did not surprise me as the fire intensity was reduced by about 90 percent due to the lighter fuels, allowing the head-fire to be contained.

WA Nornalup Road national park fire 1984

At mid-day the wind veered to southeast and freshened to 25-30 kph. The flank fire became a head fire, reaching a rate of spread of 500 m/hr within the dense ti-tree flats. At 1230 hours the fire crossed the Southwest Highway and entered the dense mixed Karri and Red Tingle (E. jacksonii) forest in this area of the National Park. These stands had not been burnt for 25 years.

At this stage the head fire rate of spread exceeded 300 m/hr and direct attack failed. The head fire was abruptly halted when it reached a one-month old prescribed burn at 1400 hours. This burn had been carried out to protect the Walpole townsite and adjoining farms. The flanks of the fire were contained by direct attack leaving a final fire size of 170 ha.

ACT Orroral Fire 2020

Incident Management Team staff noted that an area that had been fuel reduced nine months previously, halted the spread of the fire in that direction for five days. Although the fuel reduced area was ultimately outflanked as the fire grew, it offered tactical opportunities for containment that would otherwise not have been available. It is also probable that the final extent of the Orroral Fire was reduced as a consequence.

5.3 Economic and production impacts

Stephenson (2010) assesses the impacts of-severe bushfires in-SE Australia on economic production, in detail:

- Retail, Commercial and Industrial Sectors;
- Tourism;
- Forestry;
- Agriculture; and
- Horticulture.

Bishop et al. (2025 web) assess the impacts of the 2019-2020 bushfires on food and agricultures in Australia below:

This report provides a review and synthesis of the economic impacts of the 2019-2020 bushfires on agriculture and the wider food system. Of the more than 10 million hectares burnt in south-eastern Australia during the 2019-2020 fire season, around one-quarter was agricultural land. To assess this impact in economic terms, the researchers investigated the effects of the bushfires on farmland values and food output, as well as nonmarket impacts on farm and food workers, consumer prices and other cross-sectoral effects. The report also reviewed the value of bushfire recovery support to the food sector.

The report finds that the 2019-2020 bushfires caused an estimated $4-5 billion worth of economic losses to the Australian food system. There was also evidence of short-term increases in food prices and job losses in fire-affected areas, which added to the economic impact of the bushfires. Insurance pay-outs and government assistance compensated for only part of these costs. The report found that farmers and other food-related businesses received approximately 20% of economic recovery grants provided by governments. Despite shocks occurring one after another, Australian food producers and distributors have continued to supply quality products to consumers both at home and abroad. The long-term prospects for Australian food production are less clear.

Reiner et al. (2024) consider the economic impact of the tourism shutdown from Australia’s 2019-20 Black summer bushfires:

Tourism, including education-related travel, is one of Australia’s top exports and generates substantial economic stimulus from Australians travelling in their own country, attracting visitors to diverse areas including World Heritage rainforests, picturesque beachside villages, winery townships and endemic wildlife. The globally unprecedented 2019-20 bushfires burned worst in some of these pristine tourist areas. The fires resulted in tourism shutting down in many parts of the country over the peak tourist season leading up to Christmas and into the New Year, and tourism dropped in many areas not physically affected by the fires. Our research quantified the cost of the short-term shock from tourism losses across the entire supply chain using input-output (IO) analysis, which is the most common method for disaster analysis; to this end, we also developed a framework for disaggregating the direct fire damages in different tourism sectors from which to quantify the impacts, because after the fires, the economy was affected by COVID-19. We calculated losses of AU$2.8 billion in total output, $1.56 billion in final demand, $810 million in income and 7300 jobs. Our estimates suggest aviation shouldered the most losses in both consumption and wages/salaries, but that accommodation suffered the most employment losses. The comprehensive analysis highlighted impacts throughout the nation, which could be used for budgeting and rebuilding in community-and-industry hotspots that may be far from the burn scar.

5.4 Financial budget and reducing savings impacts

Key information in Menzies Research Centre (2020) in relation to strengthening resilience and managing natural disasters after the 2019-20 bushfire season, highlights the following:

- *Despite this relentless commitment to inquiries, in 2014, a report released by the Productivity Commission into Natural Disaster Funding Arrangements found that government natural disaster funding arrangements had been inefficient, inequitable and unsustainable. 'They are prone to cost shifting, ad hoc responses and short term political opportunism.' The Productivity Commission lamented that the funding mix was disproportionately recovery-based and did not promote mitigation. It observed that the political incentives for mitigation were weak, 'since mitigation provides public benefits that accrue over a long-time horizon,' and that over time this would create entitlement dependency and undermines individual responsibility for natural disaster risk management.' At that time, it said, mitigation funding amounted to* ***only three per cent of what is spent on post-disaster recovery*** *and recommended that the Australian Government should gradually increase the amount of annual mitigation funding it provides to state and territory governments to $200 million.*
- *A report by the Australian Business Roundtable for Disaster Resilience & Safer Communities suggests that a mitigation expenditure in the order of $5.3 billion over the period from 2020 to 2050 (in present value terms) could generate budget savings in the order of $12.2 billion for all levels of government, or $9.8 billion when looking at the Commonwealth government budget only. If successfully implemented, it could see Australian and State Government expenditure on natural disaster response fall by more than 50 per cent by 2050.*

Australian Government funding of $200 Million annual mitigation funding to state and territory governments, is in reality is extremely low, resulting in small scattered mitigation across different disaster types.

This approach is never going to resolve current mitigation inadequacies. It will never capture much budget savings, if in doubt, consider the extent of current disasters and repeat disasters and assess if much progress is being made over long periods.

The author considers that there should be a total revamp of disaster funding from a recovery focus to a mitigation focus reducing recovery needs; dramatically increasing funding for increased mitigation; accept the fact in most current disaster scenarios that mitigation benefits that accrue over a short-time horizon (considering the actual costs of disasters, repeat disasters and the efficiency benefits of disaster mitigation); and totally review current inadequate disaster risk based approaches.

Inadequate action by home owners results in increased bushfire impacts. Both the NFPA and IBHS have long stressed that homeowners and businesses must do two things to help make their buildings resilient: maintain defensible space and invest in home-hardening construction.

It is readily apparent that budget impacts of megafires will continue way into the future, unless governments start seriously addressing disaster funding and mitigation.
There are opportunities such as implementation of cost effective opportunities as identified by Deloitte Access Economics (2013). They note that building more resilient housing in high risk bushfire areas generates a Benefit to Cost Ratio (BCR) of around 1.4; improved vegetation management (around houses) a BCR of around 1.3, and undergrounding electricity wires results in a BCR of up to 3.1.

For example, many insurance companies in the US sponsor grants for the National Fire Protection Association's (NFPA) Firewise program, which supports communities and homeowners in preparing for wildfires.24 The industry also supports the Insurance Institute for Business and Home Safety (IBHS), which conducts educational outreach and in-depth research on wildfire-resilient construction and mitigation.25 Nine of the 10 largest insurance companies that write homeowners insurance in the U.S. are members of IBHS.26 Other resilience-focused organizations supported in part by the insurance industry include Build Strong America and the Federal Alliance for Safe Homes (FLASH).

5.5 Rising insurance cost and emergency services levy impacts

The costs of Australian insurance, emergency services levy (ESL) and stamp duty costs are rapidly rising as a result of increasing bushfire, flood and other disasters.

There are inadequate measures in place and limited accountability in relation to addressing rising bushfire and other disaster insurance costs across regions of Australia.

There is a need to urgently address high and rising bushfire (and flood) disaster insurance costs via increased preparedness and mitigation funding and actioning opportunities, as highlighted in this review.

Tax reform to improve affordability and increase uptake of insurance was a recommendation from Menzies Research Centre (2020).

Another opportunity area is addressing the increasing bushfire insurance costs and optimising insurance approaches, and hopefully reduce these costs. A 2019 USA example of an effective approach is outlined by the Insurance Information Institute (2019) and this outlines the following:

To help at-risk communities adapt to the new reality of catastrophic wildfires, insurers have been instrumental in leading resilience efforts in the following ways: Educating policyholders and communities about wildfire risks and tactics to increase resilience; Working to help create resilient communities in high-risk areas; Developing innovative insurance products and tools to help better underwrite, price and transfer wildfire risk.

6 The combination of all these bushfire impacts across SE Australia

The combined impacts across SE Australia of bushfire disaster impacts; social and safety impacts; environmental impacts and economic impacts are huge, especially considering intense and severe bushfires.

It is essential that action is taken to incorporate these intense bushfire impacts into risk management, policies, strategies, preparedness, mitigation, prescribed burning, adaptive management, funding and bushfire control.

It is important that governments at all levels commence adequately address these impact areas and utilise fire mitigation much better in scale, distribution and funding.

7 Failures of bushfire accountabilities and efficiency capture

O'Donnell (2025 c) outlines 12 key bushfire accountability issues that aren't currently being addressed properly in bushfire management:

Number 1. There are concerns in relation to Federal, State and local Governments and associated fire agency accountabilities for community and firefighter bushfire protection, including incorporating full and active accountability for setting sound bushfire policy, undertaking effective fire mitigation across landscapes, meeting minimum prescribed burning targets, establishing resilient landscapes, addressing high fuel loads, minimising large and intense bushfires, protecting communities and firefighters, rectifying large insurance rises and implementing effective disaster learning capture and sharing.

Number 2. The current bushfire expenditure distribution mix has a large focus on bushfire suppression, response and recovery focus, with limited fire mitigation. The approach needs to be much more focussed on bushfire prevention, mitigation and preparedness such as prescribed burning, adaptive mechanical treatment/ thinning of dense forests to reduce bushfire risks to communities and forests, combined with suppression. Fire mitigation and bushfire preparedness is inadequate and not effectively reducing suppression and recovery costs.

Number 3. Address failings of large centralised fire regime approaches that are costly to run and bureaucratic. Where possible establish regional/ local government fire bodies that manage fire mitigation effectively across landscapes, improve community and fire fighter safety, tackle the key fire issues that are not being adequately addressed and reduce insurance costs.

Number 4. Address failures of non-adoption of the science and experience in other jurisdictions that highlights the level of landscape burning needs to be 8-10% per annum if any significant bushfire risk reduction benefits are to be realised (e.g., refer to WA data including Boer et al. (2009) and other data on the WA Bushfire Front website). https://www.bushfirefront.org.au/prescribed-burning/why-prescribed-burning/

Number 5. Review why measures that make forest bushfire suppression easier, cheaper, quicker and safer (such as bushfire fighting and measures such as backburning) are not being adopted. Question why regular landscape prescribed burning and adaptive management are not being used adequately.

Number 6. There are inadequate measures, such as sound mitigation, preparedness and community protection, in place and limited accountability to address bushfire deaths and injuries including for fire fighters and communities and the huge costs of bushfire disasters. This is being borne out in Australia and overseas. Measures to reduce accountability failures include increased mitigation, fire resilience and sound community protection.

Number 7. There are inadequate measures in place and limited accountability in relation to addressing rising bushfire and other disaster insurance costs across regions of Australia. Urgently address high and rising bushfire (and flood) disaster insurance costs via increased preparedness and mitigation funding and actioning opportunities, as highlighted in this review. Establish firm government mitigation requirements where home insurances reach $5000 per year, it's time for governments to get serious about protecting affected communities and reducing insurance costs, emergency services levies and the like.

Number 8. There are inadequate measures in place and limited apparent accountability in relation to addressing rising Emergency Service Levy costs across many areas of Australia

Number 9. There are extensive barriers, restrictions, red tape, poor policy, inadequate legislation and over regulation in place in relation to bushfire management. The answer involves around removal of barriers, restrictions and over regulation is and fire mitigation, active management, 3-6 year fire intervals and total focus on community and fire fighter safety.

Number 10. Question why the full costs of bushfire disasters on communities and opportunities to reduce disaster costs are not being captured and information used effectively. There are many economic reform and productivity opportunities across the spectrum of mitigation, prevention, suppression and recovery, including in regard to bushfires. Some of these opportunities include implementing cost effective opportunities as identified by Deloitte Access Economics (2013) and Menzies Centre (2020) report: including Government funding should prioritise risk reduction which will reduce the need to spend on disaster recovery.

Number 11. Conservation policy and management is failing in Australia and across the world. Undertake a review of fire and fuel management and policies across all Australian conservation reserves, including fuel history and locations of mitigation undertaken over the last 40 years; intense bushfire history over the last 40 years; consequent dense regrowth resulting from intense bushfires; and history of bushfire impacts on surrounding communities and properties and close shaves. This review would need to consider the Gosper's Mountain Bushfire (reported as the largest individual bushfire in Australia's history); bushfires across the Blue Mountains; Kosciusko bushfires of 2003 and 2019/ 20 and before; Warrumbungle's (including 2013); Victorian alpine and other bushfires; Grampians bushfires, Little Desert and other bushfires as assessed.

Number 12. Consider the impact of Australian 30 by 30 approach (30 % nature conservation areas by 2030) on fire hazards, risks and threats to Australian communities, fire fighters, landholders/ neighbours and ecosystems, especially considering miniscule adaptive management that is often undertaken in nature conservation areas.

There are many failures in accountabilities, policies, barriers, red tape, expenditure mix, sound prescribed burning across landscapes, setting up fire resilient landscapes, suppression approaches, inadequate community and fire fighter safety and many other areas.

O'Donnell (2025 c) also identifies 9 bushfire disaster economic and efficiency lessons and insights from across Australia.

It is time to listen and turn this around to an improved landscape mitigation focus.

8 Conclusions

This assessment has assessed the impacts of large and intense bushfires across SE Australia.

Bushfire disaster impacts across SE Australia are outlined in Sections 2.1 to 2.5.

Social and safety bushfire impacts across SE Australia are outlined in Sections 3.1 to 3.7.

Environmental bushfire impacts across SE Australia are outlined in Sections 4.1 to 4.15.

Economic bushfire impacts across SE Australia are outlined in Sections 5.1 to 5.5.

The impacts are across 32 different impact areas, and intense and severe impacts for the majority of them.

The scale of the combined impacts are very large. It's time for effective action to reduce intense bushfires across SE Australia.

It is important that governments at all levels commence adequately addressing these impacts and utilise fire mitigation much better in scale, distribution and funding.

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