SUBMISSION

Royal Commission into Natural Disaster Arrangements

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Contents

Executive summary

We offer this submission as leading Australian experts in areas ranging from fire behaviour to ecology, ecophysiology, forestry and indigenous land management. Our submission addresses national standards on hazard reduction, and the use of traditional Aboriginal knowledge.

Recommendation 1: Increase transparency in decision-making

Government programs for bushfire hazard management should detail the science underpinning their programs to a sufficient level that decisions can be replicated. This should be available for public scrutiny so that it can be challenged through established legal processes in cases where decisions are inconsistent with sound science.

Recommendation 2: Move toward independent research funding

Ensure that research funding is provided from sources that do not have a vested interest in particular proceedings. For example, agencies that are tasked with implementing existing policies have a vested interest in attaining their KPIs. Researchers who receive funding from these agencies may be viewed more favourably if they assist the agency in reaching those KPIs, and less favourably if they call them into question or produce findings that could slow progress towards them.

Recommendation 3: Diversify research structures

The formation of 'official' research centres and hubs beyond the level of learning institutions such as universities creates ingroup – outgroup divisions where ideas are more likely to be accepted or rejected for social rather than scientific reasons. Such groups risk excluding scientists that legitimately challenge their ideas, instead providing false orthodoxy and authority to in-group ideas that may be less worthy. We recommend that funding previously directed to such groups instead be directed toward diversified models such as programs through the Australian Research Council, where it can be widely accessed by researchers with more diverse views.

Recommendation 4: Fund independent knowledge brokerage.

Scientific collaboration happens organically as ideas are discussed and gaps in knowledge identified. Knowledge brokers play a key role in collating and interpreting science to facilitate its adoption and identify needs. Where these are answerable to vested interests, they risk becoming gatekeepers with a focus on ideas that are consistent with the existing beliefs. When they are independent, there is greater likelihood that they will challenge existing structures and introduce new thinking.

Recommendation 5. Collate cultural knowledge

Funding for research into indigenous practices requires a focus on the collation of the underpinning related cultural traditions, subject to permission from the knowledge holders.

Recommendation 6: Build transparency into Government fire management practices that are claimed to be traditional

Indigenous people have felt in some cases that their traditional practices have been replaced by Government programs appropriating their cultures, with very different outcomes. To avoid this and allow this problem to be rectified where necessary, we recommend that Government fire management programs claiming to replicate indigenous management are required to document the underpinning traditions, their sources, and the reasoning used to translate these into fire regimes.

Recommendation 7. Ensure that Indigenous-based Government fire management programs are adaptive

Community consultation should continue after programs have begun. This should involve independent research to gauge the level of satisfaction in the community that the management reflects their intentions.

Preamble

We thank the Federal Government for the opportunity to contribute to this inquiry, and provide the following submission addressing the first and third terms of reference. We offer this as leading experts in areas of fire science ranging from fire behaviour to ecology, ecophysiology, forestry and indigenous land management.

In this submission, we address a series of repeated claims and widely-held beliefs that have become deeply embedded within fire management. It is our belief and concern that the future success or failure in the face of an undeniably increasing fire threat depends upon Australia's capacity to question such beliefs with sound science, and to develop an approach to fire management that is solidly grounded in reality.

Biographies

Adjunct Associate Professor Philip Zylstra BAppSc, PhD

Philip Zylstra is a fire behaviour scientist working in an adjunct role with Curtin University, and as an Honorary Fellow at the University of Wollongong. He has developed the only peer-reviewed modelling of fire behaviour for the majority of Australian ecosystems, and has globally pioneered techniques to mechanistically link fire behaviour to characteristics of the ecosystems burning. His work links plant traits and forest growth and health to fire behaviour, but also predicts the impacts that such behaviour will have on individual flora and fauna, and on soils. He has also pioneered methods for empirically measuring historical fire regimes that most effectively minimise landscape flammability. His work has been influenced by a background in fire management and remote-area firefighting, together with mentoring by Ngarragu and Wolgalu teachers in SE Australia.

Professor Stephen Hopper AC BSc PhD Hon DSc (UWA) Hon DSc (U Sussex)

Working as Professor of Biodiversity at UWA Albany since 2012, Steve has 45+ years as a conservation biologist and teacher, including 12 years leading Kings Park and Botanic Garden, Perth (1992-2004), and six years leading the Royal Botanic Gardens, Kew in London (2006-2012). An active field biologist, Steve's research focuses on sustainable living with biodiversity, especially through collaboration with Aboriginal elders. He has also described 300+ new species of plants, and is globally recognized for his research on granite outcrop plant life. He developed Ocbil theory, which explores the evolution, ecology and conservation of biological and cultural diversity on the world's oldest, climatically buffered and most infertile landscapes. These are found notably in 12 of the world's 35 Global Biodiversity Hotspots, mainly in the Southern Hemisphere. In 2012, Steve was awarded an AC (Companion of the Order of Australia), the nation's highest civilian honour, for his global leadership in science and conservation.

Emeritus Professor Don Bradshaw BSc (Hons) PhD, FAIBiol

Don Bradshaw is an ecophysiologist whose research has been concerned with how vertebrates living in seasonally or permanently-arid environments respond to stressors imposed by these inhospitable places and yet continue to reproduce, and thus survive as populations. An important aspect of his work has been to analyse water deprivation, electrolyte loading, heat stress and the hormonal mechanisms mediating the animals' responses in the field. The novelty of his approach lies in combining natural history, population ecology and measurements of the circulating levels of hormones mediating responses to environmental challenges. His work on the many endangered marsupials living on Barrow Island and his long-term study of the tiny nectarivorous Honey possum in the extreme southwest of WA have given new insights into the adaptive physiology of the Australian fauna. Since retirement, his focus has been on conservation of the many rare and endangered species in WA's threatened biodiversity hotspot and the threats posed by frequent fire. He is a Membre Correspondant du Muséum d'Histoire Naturelle in Paris, was elected a Scientific Fellow of the Zoological Society of London in 1985 and awarded the Kelvin Gold Medal of the Royal Society of Western Australia in 2010. In 2015, he was awarded a Special Commendation Whitley Award by the Royal Zoological Society of NSW … "for the promotion of knowledge and conservation of Australasian fauna through many outstanding publications over an extended time period."

Professor Kingsley Dixon FLS BSc (Hons), PhD, John Curtin Distinguished Professor
Kingsley Dixon is a biologist and Professor at Curtin University, Associate of the Missouri Botanical Garden and a Visiting Professor at Kings Park and Botanic Garden. He has specialised for 45 years in the conservation and restoration sciences with research programs involving community, industry and government through targeted research in seed science, landscape restoration, ex situ conservation and plant ecology. He was instrumental in discovering smoke for germination of Australian species and worked on the discovery of the chemicals in smoke responsible for promoting post-fire germination. He holds positions in national and international conservation and professional organisations and is the 2016 Scientist of the Year for Western Australia.

Professor David Lindenmayer BSc, DipEd, PhD, DSc, ARC Laureate Professor (2013 – 208), FAA, FESA, AO
Professor Lindenmayer is a world-leading expert in natural resource management, conservation science, and biodiversity conservation. His areas of expertise include integrating farm production and environmental management, terrestrial ecology, wildlife and habitat management, environmental monitoring, fire management, zoology and forestry sciences. David Lindenmayer has published more than 1240 scientific articles including over 780 peer-reviewed papers in international scientific journals and 47 books. He is an Australian Research Council Laureate Fellow (held from 2103-2018), a member of the Australian Academy of Science (elected 2008), Fellow of the Ecological Society of America (elected in 2019), and was appointed an Officer of the Order of Australia (AO) in 2014. His conservation and biodiversity research has been recognised through numerous awards, including the Eureka Science Prize (twice), Whitley Award (seven times), the Serventy Medal for Ornithology, and the Australian Natural History Medallion. In 2018, he was awarded the prestigious Whittaker Medal from the Ecological Society of America.

Terms of reference

In this submission, we will address terms of reference f (i.) and g:

f. ways in which Australia could achieve greater national coordination and accountability — through common national standards, rule-making, reporting and data-sharing — with respect to key preparedness and resilience responsibilities, including for the following:
 i. land management, including hazard reduction measures;

g. any ways in which the traditional land and fire management practices of Indigenous Australians could improve Australia's resilience to natural disasters.

TOR.F: National coordination in land management, with specific reference to hazard reduction measures

Australia is not yet equipped to operate a nationally coordinated approach to bushfire hazard reduction, because we do not yet have effective hazard reduction programs.

Australia's hazard reduction programs have many known costs to health, the environment and the economy, but have not yet been shown to reduce bushfire hazard, and in some cases may be increasing it. A nationally coordinated approach that enforces these deeply flawed programs would likely have disastrous consequences.

Here, we will examine the evidence for and against the efficacy of Australian attempts at hazard reduction, firstly with regard to prescribed burning, then to proposed forestry techniques such as tree thinning. Finally, we will summarise some of the associated costs.

The efficacy of prescribed burning

Any discussion of this season in the context of hazard reduction efforts must recognise that the season occurred at the peak of historic prescribed burning in NSW National Parks. According to NPWS mapped records (*1*), more prescribed burning has occurred in this past decade than in any before – more than twice the rate of the preceding decade (Fig. 1)(*2*). While it is correct that these totals were less than those recommended by some, it is apparent that the most extreme fire season coincided with the greatest amount of prescribed burning. The area of 'young' fuels (burnt within the past 6 years) approximately doubled over the past decade (Fig. 2). If landscape flammability is indeed related to the area of 'young' or recently burnt forests, then there should have been a decline in flammability over the past decade, rather than such an increase.

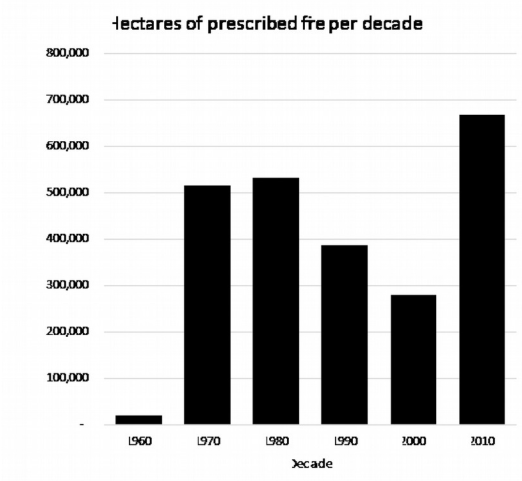

Figure 1 | Area of NSW National Park burnt by prescribed fire per decade.

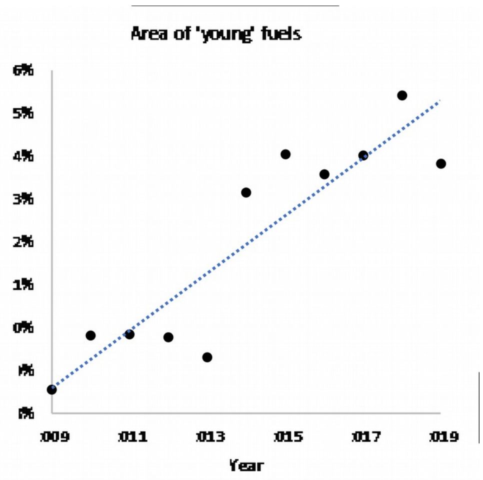

Figure 2 | Area of land burnt within the previous 6 years in NSW National Parks, 2009 - 2019

One response to this is the claim that there is a threshold percentage of land that must be treated before a prescribed burning program is effective, but observations from the current season call this into question.

Numerous firefighters have reported this season that prescribed burns have been ineffective; some describing the claim that more burning would have stopped the fires as "a running joke" (*3*). This was also true for areas recently burnt by wildfire. The Gospers Mtn fire north of Sydney, for example, ignited and grew to a very large fire in country that had been burnt six-years earlier. The main run of the Werri Berri fire near Bemboka passed unhindered through the area burnt in the winter of 2018 by the Yankees Gap wildfire (*Fig.* 3) – itself an escaped prescribed burn that destroyed houses in the area. An analysis of fire severity for NSW found that wildfires burned through almost all recent prescribed burns in the state, indicating that for the vast majority of cases, these provided no material assistance in containing fires (*4*) (*Fig. 4*).

The claim that more prescribed burning would have had a different effect must be considered in this context. If most individual burns were ineffective, then it is unlikely more of these ineffective treatments would have made an effective treatment program.

In many cases, prescribed burns can prove a hindrance to fire control operations. The western flank of the Green Wattle fire for example was at one stage bound by a 3yo prescribed burn. However, the edge burnt through this downhill and against the prevailing wind (*Fig.* 5). Another 1yo burn lay directly in its path and along a fire trail, yet fire crews were not prepared to trust in the efficacy of this burn, and chose instead to defend the trail using a backburn. This backburn again spread consistently down-slope through the 1yo fuels, with no observable reduction in the depth of the leading edge relative to the surrounding 22yo fuels. Had the burn proved more effective, it may have hampered the backburn.

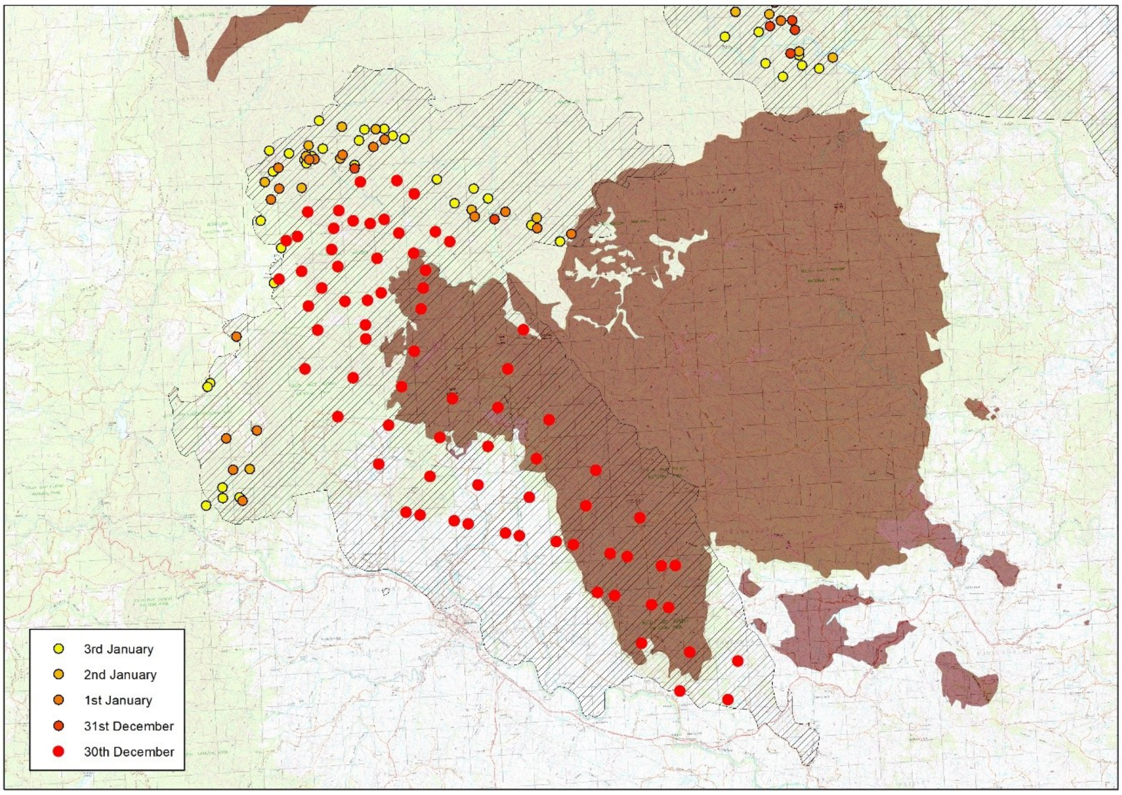

Figure 3 | RFS mapping of the Werri Berri fire (hatched area) and the 2018 Yankees Gap fire, overlaid with satellite-detected hotspots indicating the date of fire spread. The main fire run took place on the 30th December 2019 and spread to the south-east unhindered through the Yankees Gap burn scar. Fire spread on the northern edge occurred on subsequent days under mild weather, and largely halted at a fire trail. It is not possible to determine from this map whether that was due purely to fire suppression at the trail, a backburn lit from the trail, or whether the recently burnt forest provided assistance.

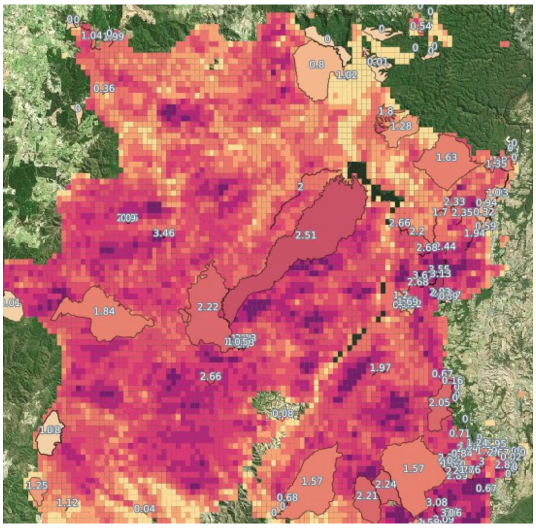

Figure 4 | Mapped fire severity for the Green Wattle fire, overlaid with areas of recent (up to 5 years) prescribed burns coloured and numbered by mean severity for the burn.

Figure 5 | Western edge of the Green Wattle fire spreading down-slope through a 4-year-old prescribed burn. A 1-year-old prescribed burn lies in its path, but no confidence has been placed in this, and a backburn has been lit from the trail at its centre. The backburn is spreading down-slope through the 1-year-old fuels, with no difference in depth of the flaming edge compared to the 22-year-old fuels at the top of the image.

Underpinning theory

The foundation of fire management in Australia is the assertion that rates of fire spread are directly proportional to 'fuel load' or the weight of fine dead materials on or close to the ground, so that fire risk can be minimised by burning forests to reduce those fuels (*5*). This theory is derived from a leaflet (*6*), presenting nine data points. Despite their critical importance to decisions affecting the survival of people, other species, and entire ecosystems; these data were never subjected to peer-review but have been accepted as presented in the leaflet. At the time, the author took pains to make clear that:

"many of my observations and comments are tentative and may be proved wrong or subject to drastic change as more data becomes available" (*7*).

Since McArthur's time, the relationship between fuel load and rate of spread has been formally tested in properly conducted scientific experiments. It has been demonstrated conclusively that this relationship *does not exist*, that altering the fuel load does not alter the rate of fire spread (*8*). Subsequent work showed that the drivers of fire spread and severity are the living plants. This was shown empirically for lower plant strata in *E. marginata* forests of SW Australia (*9*, *10*), then demonstrated mechanistically as a general process of fire spread validated for a range of forests and conditions in SE Australia (*11*, *12*). Plants affect flammability either by acting as fuels, or, if not burning, by creating a microclimate that reduces light and wind speed beneath their canopies. Whether plants accelerate fire by burning, or slow it by creating overstorey shelter, depends on the size of the gaps between the plants, the flammability of the donor (burning) plants, and the ignitability of the receiver plants, or those that may potentially ignite. To date, there is no peer-reviewed scientific work supporting the assumed relationship between fuel load and rate of spread, yet it continues to underpin Australian fire management at the expense of the actual science.

The two views have opposite implications for the ways in which fire should be managed. Under the traditional view, fuels accumulate, so that flammability is highest in long-unburnt forests. This imposes a single rule for fire management: frequent disturbance through burning or manual fuel removal. Under the scientific view, however, plants drive the flammability of a forest, so flammability varies according to plant dynamics. This has some very specific outcomes for flammability dynamics.

One of the central tenets of ecology is the law of self-thinning (*13*, *14*). Conditions at a site can support a finite quantity of biomass. As plants grow in individual biomass, less individuals can be supported at a site, and self-thinning occurs. The phenomenon of 'woody thickening' is a corollary of this. Woody thickening or the proliferation of dense shrub and sapling growth is specifically a response to disturbance (*15*). Disturbance by fire or clearing allows increased light access to the soil surface, and may add nutrient additions through ash. This increases the energy balance and, consequently the biomass that may be supported. Many plant species have propagation mechanisms that can take advantage of disturbances through seed germination for example, so such disturbances result in dense propagation of small individuals competing to survive the inevitable self-thinning.

The result is a common vegetation dynamic: following disturbance that removes higher foliage (e.g. scorching or consumption by flames, or mechanical removal for timber), vegetation growth is stimulated close to the ground. This grows taller, but also self-thins until eventually a more open understorey returns. The implications of this for flammability dynamics can be illustrated using an example from SW Australia's karri (*E. diversicolor*) forest, contrasting the scientific expectations with the traditional ones.

Following even mild fires, karri understoreys experience dense growth of shrub and midstorey species. Self-thinning causes these shrubs to become increasingly sparse, so that the understorey is essentially open by 30 years post-fire (*Fig. 6*) (*16*). The traditional view that 'fuel' is defined specifically as fine dead material on or close to the ground considers this fact only relevant in that thinning produces dead plants that increase the fuel load.

In contrast, the scientific view considers it axiomatic. At first, the regenerating forest has a dense cover of low foliage close to the ground where it will act as fuel. This grows in height, supporting larger flames. At the same time though, self-thinning occurs and some plants grow large enough that flames cannot reach them, so the increase in gap-size makes these less likely to ignite. Eventually, self-thinning results in a sparse, low-flammability understorey.

While the West Australian "Red Book" (*17*) does consider plants to some degree, these are inexplicably weighted to have much lower importance, and are ignored by many in practice (*16*). CSIRO's "Project Vesta" (*10*) does utilise three plant descriptors (*18*), but these are insufficient to capture many of the important vegetation dynamics such as self-thinning. To date, only the FRaME (Fire Research and Modelling Environment) fire behaviour model is capable of quantifying the effect of these dynamics on fire behaviour (*11*, *19*, *20*).

The predicted trend has three flammability phases: a short *young* period of bare ground and very small seedlings, followed by a period of highly flammable *regrowth* that may last for decades, then an indefinite period of low flammability, *mature* forest. This trend is the direct opposite of that expected from the traditional belief, in that long-unburnt forests will frequently have low flammability. The traditional approach suggests that fuel accumulation renders these forests highly flammable and thereby encourages the introduction of fire. The scientific approach indicates that long-unburnt forests are in-fact fire advantages due to their low flammability.

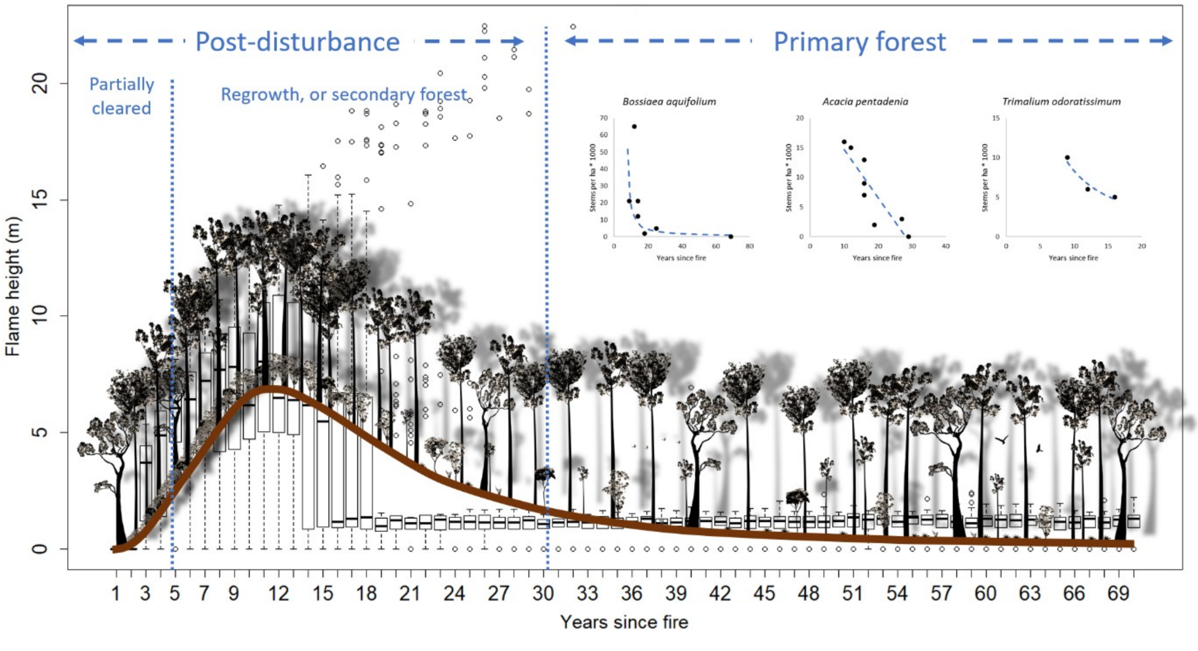

Figure 6 | Growth and self-thinning of the understorey in karri forest. Modelling suggests that this results in the initial increase in flammability, followed by the decrease to low flammability in long-unburnt stands.

Empirical evidence

By definition, a flammable age class will over time burn more often than a less flammable class. Flammability Ratio (*19*) is a recent technique that measures every mapped wildfire in an area to find how much they favoured each age class. It is best understood as a mass analysis of case studies, where these are conducted for every part of every fire, examining every age. As a result, it is a very powerful analysis, and has so far reported clear trends at the highest level of significance. In all cases to date, these are consistent with those predicted from mechanistic modelling, showing the three periods and ending in low flammability *mature* forest (see for example *Figs. 7, 8*, taken from (*21*)). These three periods have been measured in woody communities ranging from low, dry open woodland through to tall wet forests and subalpine communities. The empirical evidence is consistent with the mechanistic expectations: enhanced flammability is a product of forest disturbance. Forests become less flammable if they are allowed to recover beyond the regrowth period.

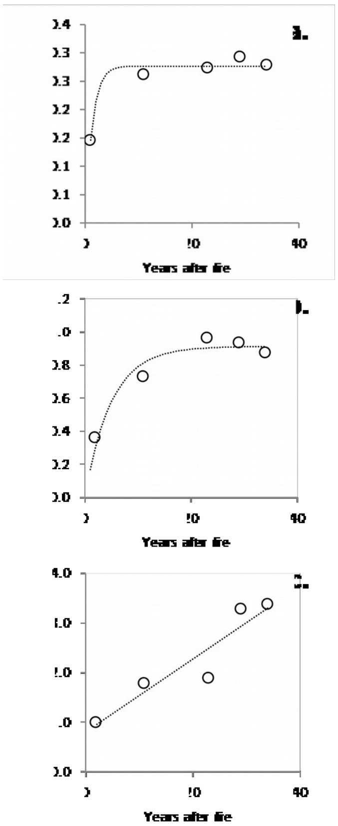

Figure 7 | Measured dynamics for Southern Tablelands Dry Sclerophyll forests. a) height of grasses, b) height of shrubs, and c) separation between shrubs, increasing over time as expected from the self-thinning rule.

Until recent years, h[…] assumed that long-u[…] most flammable state[…] Empirical analysis[…] effectiveness has a[…] quantifying the deg[…] confers, rather than[…] actually conferring a[…] introduced biases to th[…]

- Validation ha[…] perceived suc[…]
- Success is a[…] stopped at the[…] the edge of[…] evidence that[…] the burn in an[…]

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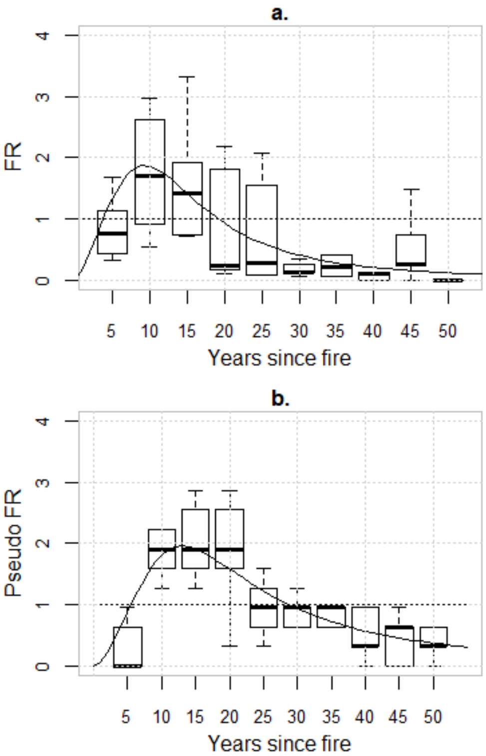

Figure 8 | **a.** Empirically measured FR for Southern Tablelands Dry Sclerophyll forests (from Zylstra 2018). **b.** modelled FR for Southern Tablelands Dry Sclerophyll forests. Box plots show standard interquartile ranges; whiskers extend to 1.5 standard deviations.

a) Assume that long-unburnt forests are more flammable than young forests due to fuel accumulation
b) Treat regrowth forest as if it is long-unburnt because the weight of fuels has reached a quasi-equilibrium state, when the regrowth forest is still actually in recovery from the past fire
c) Compare the flammability of young and regrowth forests, thereby confirming a).

Analysis of three reviews of prescribed burning effectiveness found almost no instances where the long-unburnt category was older than the range of regrowth forests that have been measured, just in the south east (*5*, *22*, *24*), and these periods are comparatively short. Burning the Great Western Woodlands can initiate a regrowth period that lasts centuries (*25*). These case studies therefore provide no insights into the value of burning forests instead of maintaining them in a mature state. Instead, they externalise the cost of treatments, measuring the decades of flammable regrowth as if they are untreated areas, when in fact they were made flammable by the treatments.

A more recent form of analysis is the measurement of 'leverage', which is the area of wildfire reduction per area of young forest (*26*). Leverage is inherently more objective than case studies because it is a landscape measure and not subject to cherry picking. However, it maintains an inherent bias. Leverage divides the area of *young* landscape from the rest, combining *regrowth* and *mature* forest into a single long-unburnt category. This again externalises costs, artificially inflating the flammability of older forests by measuring flammable regrowth along with mature forest instead of accounting for it as a cost of the treatment.

Despite this inbuilt exaggeration of the effectiveness of prescribed burning, leverage studies rarely report a statistically significant effect of prescribed burning. A global analysis found that leverage was statistically significant in only one Australian location: spinifex communities burnt with indigenous cultural burns in the Great Sandy Desert (*27*). A larger study of leverage across SE Australia reported that of the 30 bioregions measured, leverage was positive (recent fire reduced subsequent wildfire) in only four, and that it was more often negative (recent fire made subsequent fire more likely). Importantly though, no test was made to determine whether these relationships were statistically significant or not.

Historical evidence

Prior to the mid-20th century, graziers and some other private landholders burned forested areas widely and regularly. It is popularly claimed in more recent years that this was a continuation of Aboriginal cultural burning practices, but that is highly unlikely. Far from seeking out guidance and learning from the First Nations, graziers were the front line of the widely documented colonisation of Aboriginal lands. Widespread burning of forests conducted by many graziers bears no resemblance to what is known of Aboriginal cultural burning (discussed under TOR G), but in fact represents a continuation of traditional British practices. It is well-documented that English and Scottish graziers burned forests for the purpose of land clearing to create grazing lands, and that this is the origin of the English moors (*28–31*). This history is reflected in the language used, where removal or replacement of native species with European species is termed "improvement", native shrubs are referred to by the names of English species that were burned regularly (*32*), and burning is referred to using the widespread European notion of "cleaning up" the forest.

What is known of the history of fires prior to the 1950s reveals that very large fires were in fact common, but – critically – they were predominantly escaped burns lit by graziers (*33*). Reconstruction of some of these such as the 1939 Black Friday fires (*Fig. 9*) enabled some analysis of this period for the Australian Alps, revealing that very large burnt areas in the range of one million ha or more occurred only as a confluence of many fires, invariably lit by graziers and other landholders, or escaped from timber mills (*34*). When strict controls on fire were introduced to the area during the 1950s, these very large fires immediately ceased to occur. The largest fires after that period were an order of magnitude smaller, until the onset of the 21st century. Very large fires returned in 2003, again in 2006, and now again in 2019/20. As before, such large burnt areas have only occurred through the confluence of multiple fires lit under extreme conditions, but the critical difference has been that the source of ignition has been lightning rather than human, reflecting the increase in dry lightning across the southern hemisphere as the climate changes (*35*).

All available evidence at this point then indicates that the widespread burning by landholders prior to the mid-20th century was responsible for greatly increased fire impact. Regulating those burning practices reduced fire impact by an order of magnitude, but this reduction is now being overwhelmed by the effects of climate change.

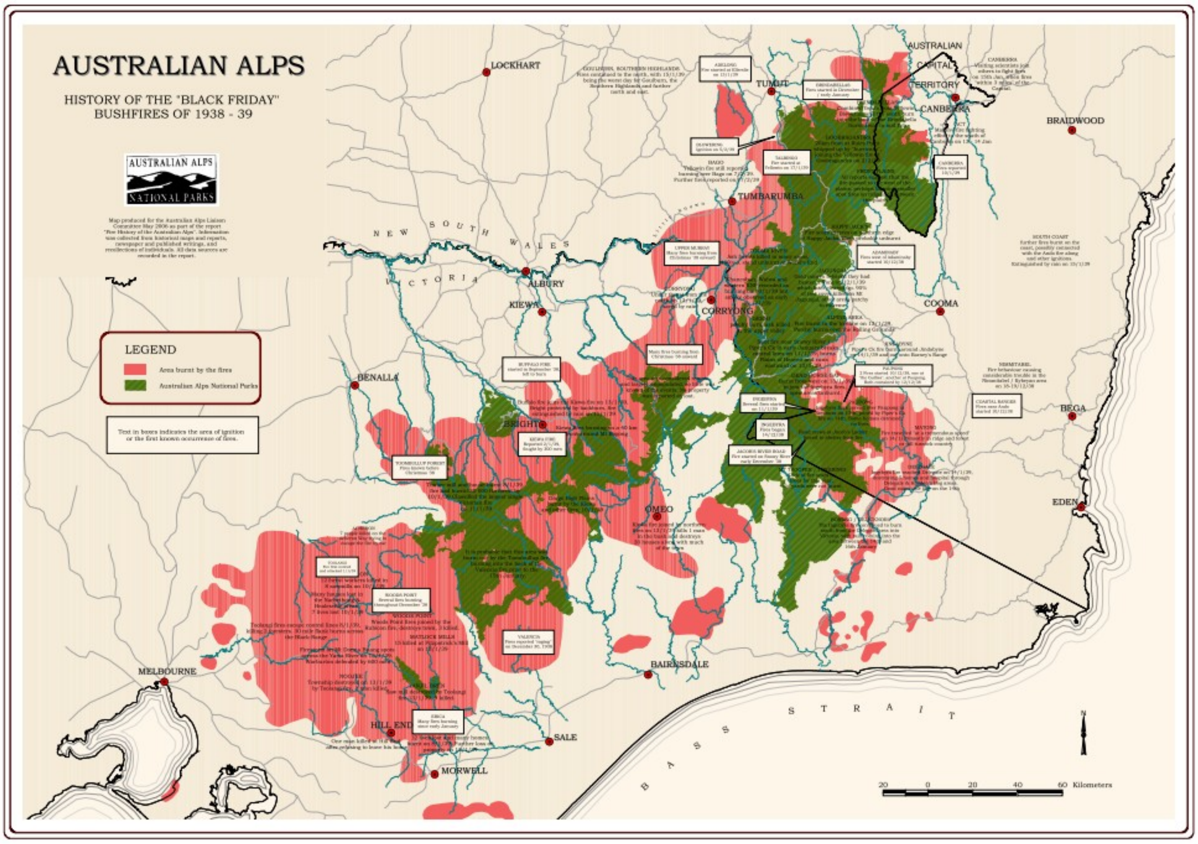

Figure 9 | The 1939 Black Friday fires, overlaid with the 2006 extent of the Australian Alps National Parks. The Victorian component was mapped as part of the Royal Commission, and the NSW component mapped from historical analysis by P. Zylstra. Text boxes detail what is known of ignition sources.

The efficacy of hazard reduction through forestry

Numerous studies have examined the relationship between logging and landscape flammability, whether through selective logging or thinning, or through clearfell approaches. Earlier studies tended to be departmental reports which saw operations to be purely for the purpose of acquiring timber or growing better quality timber. The link to fire was based around concerns that such operations *increased* fire risk (*36–38*). This literature experienced a sharp change in focus in recent years, with forest industry bodies funding research (*39*) that now made the counter-claim: that thinning forests *reduced* fire risk. This work is based on modelled outcomes rather than empirical measurements (*40*, *41*), using models that do not address the issues raised earlier.

Empirical measurements consistently demonstrate that forestry operations cause large increases in fire risk (*42–44*), although these do not differentiate between different forms of forestry. The single apparent exception to this was a 2013 paper led by Peter Attiwill (*45*), which argued that

"…there was an apparent increase in the severity of crown fire with time since logging or bushfire up to about age 30 years (Figure 4), rather than a decrease as shown by Price and Bradstock".

While this statement is correct, it ignores the majority of the data presented in Figure 4 of their paper, which does not support their central finding that "timber harvesting does not increase fire risk". This figure is presented and annotated here (*Fig. 10*) to contrast the claim with the data on which it is purportedly based. The data clearly show that the likelihood of crown fire increases up to about 30 years, but critically, it then shows a consistent *decrease* in likelihood as forests age beyond this point. This non-linear trend of low flammability immediately after disturbance followed by decades of increased flammability declining to indefinite low flammability is exactly consistent with the trends reported for logging effects in mountain ash (*42*, *44*), post-fire effects in ash forests (*46*, *47*), and, indeed consistent with the three-stage dynamics described earlier.

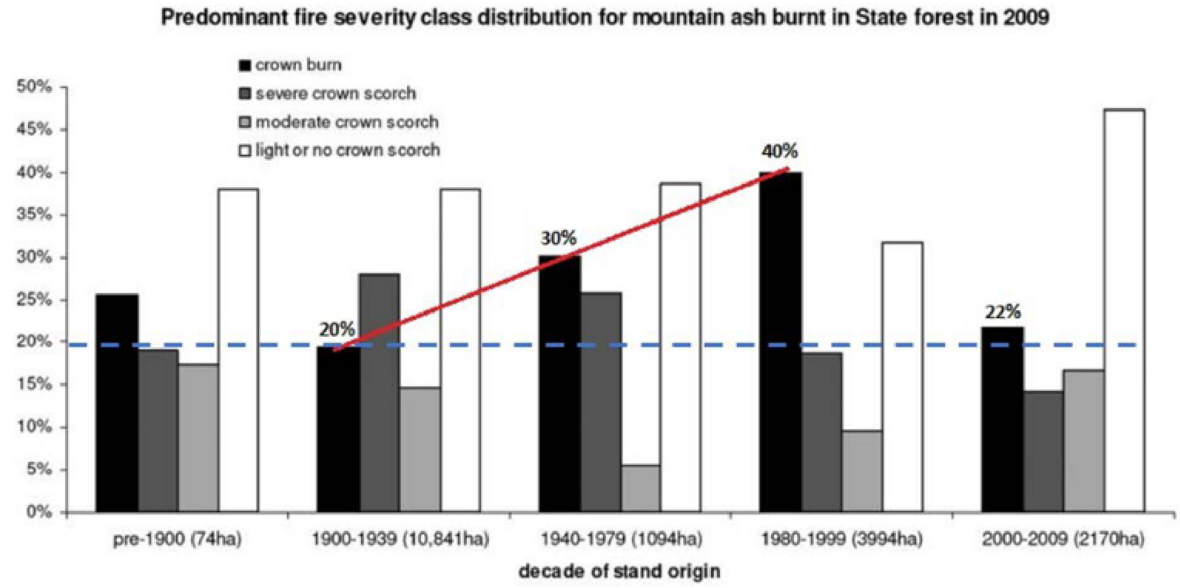

Figure 4 Fire severity classes over the predominant age-class range of burnt mountain ash (*Eucalyptus regnans*) in State forest; the Kilmore East and Murrindindi fires, 7 February 2009. (Data from Department of Sustainability and Environment, 2009.)

Figure 10 | Reproduction of Figure 4 from Attiwill et al (2013), annotated to show the likelihood of crown fire (black columns) measured from the graph, the comparative likelihood of crown fire in 1939 regrowth (dotted blue line), and the declining likelihood of crown fire in older forests (solid red line).

The modelling basis of the argument

An overview paper in Australian Forestry examining the effects of thinning on flammability identified that these may include changes to fuels in all plant strata, but also alterations of the microclimate by allowing greater wind and light access (*39*). Proposed research involved measurement of fuels using subjective visual scores (*48*) along with modelling.

Two studies stand out in this field, both funded by VicForests. In the 2017 study (*41*), the authors showed that eight years after a thinning operation, a *E. delegatensis* forest had marginally lower surface fuel loads, but increased density of understorey plants. To model the effect of this on fire behaviour, the authors used Project Vesta (*10*) to model rates of fire spread under defined conditions, but instead of using the flame height model that forms part of Project Vesta, they estimated the Byram fire intensity (*49*). This measure estimates intensity based on the assumption that all fine dead materials on or near the ground surface all burn with perfect efficiency within the active flame front, and that structure and arrangement have no effect. These assumptions are all incorrect (*50*). In contrast, the flame height model of Project Vesta includes the height of the understorey. By changing models midway through the process, the study was able to exclude the influence of the increased understorey growth on fire behaviour, and capitalise on the small decrease in surface litter.

The 2019 study (*40*) examined a *E. sieberi* forest immediately after thinning, comparing the effects of prescribed burning, thinning, and a combination of the two treatments. Rather than modelling the outcomes this time, the study utilised the overall fuel hazard score(*48*). The findings were that prescribed burning reduced the score from extreme to low immediately afterward, but that thinning made no change to the score. The effect of thinning and prescribed burning was the same as prescribed burning without thinning. The authors, however, argued that the inclusion of thinning was an improvement because it resulted in less trees and reduced carbon storage which, they asserted, were good things and should be added to the scoring system.

These studies demonstrate the weakness of findings based on modelling that do not address the relevant mechanisms driving flammability. As a form of disturbance increasing light access to the forest floor and disturbance of the soil, mechanical thinning of trees results in woody thickening at the understorey level. This was demonstrated in the 2017 study, but its effects on flammability were excluded by changing models. Less tree cover also results in faster drying of surface litter, so that fires can spread on more days. It also results in increased wind access, so that fires burning beneath the canopy are exposed to stronger winds, although the models chosen were unable to assess this impact. All of these factors result in an overall increase in flammability, consistent with the broadscale empirical measurements and long-held understanding.

The costs of prescribed burning

Prescribed burning has significant impacts on health, environmental and economic values. The principal health impact is through smoke effects, and these impose a higher mortality on people than the direct impact of bushfire flames. To compare, in NSW, seventy-seven deaths were directly attributable to bushfires in the years 1901 – 2011, but 14 deaths were attributable to smoke from a single week of prescribed burns in Sydney alone (*51*). Smoke from wild fires is also harmful and can be far more extensive in seasons such as 2019-20 (*52*), but any suggestion that there is a trade-off between the two is not supported. As the previous discussion shows, smoke from prescribed burns is at best additional to bushfire smoke.

Prescribed burning affects the environment through changes to fire regimes. Demographic studies of plant populations have been used to establish suitable fire intervals that will not threaten fire-prone species (*53*). Gill and McMahon (1986) (*54*) showed that seeding patterns in a *Banksia ornata* population were favoured by a period of 16 years between fires, and, following a similar approach, Lamont et al. (1991) (*55*) estimated a period of 20-30 years between fires for the maintenance of the endangered *Banksia cuneata* in Western Australia.

Burrows et al. (2019) (*56*) argue that an adequate answer to the long-term impact of frequent fire regimes requires longitudinal analyses and noted the paucity of such studies. One such study found that populations of the nectarivorous marsupial Honey possum (*Tarsipes rostratus*) recover significantly within six years of a single fire, but take over 25 years to recover, if this fire is followed six years later by a second fire (*57*). Similarly, the occurrence of two fires within 13 years caused the almost complete regeneration failure of *Hakea petiolaris* ssp. *trichophylla* in a granite outcrop community of the southwest Australian floristic region (SWAFR) (*58*). The vulnerability of *banksias*, the primary food source of Honey possums (*59*), is highlighted by a study of flowering and fruiting of *Banksia baueri*, *B. nutans* and *B. baxteri* in kwonkgan heathland on the southwest coast of Western Australia in which all three were extinguished from an area burnt twice on an interval of nine years (*60*). The Critically Endangered *Banksia brownii* has a long juvenile period of five to six years in populations north of Albany and more than eight years in upland Stirling Range populations, making it particularly vulnerable to short fire intervals (*61*). In the Fitzgerald River National Park on the south coast of Western Australia, capture rates of Honey possums increased to a peak 30 years after fire, with a slight decline in vegetation unburnt for 50–60 years (*62*, *63*).

Burning at three-four-year intervals was found to result in a significant reduction in the abundance of key obligate seeder species (those that cannot reproduce vegetatively but depend on propagation by seed) in the southwest of Western Australia, such as *Acacia browniana* and *Crowea angustifolia* (*64*). Some species, such as *Banksia* (formerly *Dryandra*) *sessilis*, may flower within three to four years after fire, but do not set seed until eight years and reach maximum nectar production only after 12 to 15 years (*65*), with important forage implications for threatened seed-eating parrots (*66*).

Young karri trees (*Eucalyptus diversicolor*) are fire sensitive for up to 25 years (*67*) and in jarrah (*Eucalyptus marginata*) and other forests, research suggests prescribed burning on a 5-7 year rotation permanently simplifies the flora and invertebrate fauna, with far-reaching effects on forest hygiene (*68–70*), but see Abbott et al. (2003) (*71*). Major changes in soil structure and permeability have been attributed to the loss of many marsupial ‘bioturbators’, such as bandicoots and bettongs, which, collectively aerate and turnover thousands of tonnes of soil each year (*72–74*), bury leaf litter (*75*), and perform a vital role in the redistribution of mycorrhizal fungi following fire (*76*). Short fire intervals also minimize the availability of large woody debris pieces required by both invertebrate and vertebrate fauna species in *Eucalyptus salubris* and *E. marginata* woodlands in southwest Western Australia (*77*, *78*).

Other late-climax indigenous species that depend on long-unburnt habitats and are negatively impacted by frequent fire regimes include the quokka, *Setonix brachyurus*, and tammar wallaby *Notamacropus eugenii* (*79*, *80*), the mardo, *Antechinus flavipes* (*81*), Noisy scrub-bird, *Atrichornis clamosus* (*82*) and Mallee fowl *Leipoa ocellata* (*83*, *84*). Long-term field studies of the Splendid fairy wren, *Malurus splendens*, have also shown that optimum densities require fire intervals of at least 12 years between fires, which must not occur during the winter/spring breeding season (*85*). Recent research has also highlighted the importance of long-unburnt areas for the survival of both mammals and reptiles in sub-alpine forests and woodlands in eastern Australia (*86*, *87*). The long-term impact of prescribed burning on biodiversity in Mediterranean ecosystems worldwide has recently been reviewed and concludes that fires at too frequent intervals (e.g., six years) and in seasons different from the natural fire period have the most damaging impact on wildlife (*88*).

Despite its much lower human population, the rate of mammal extinctions in Australia is more than 50 times greater than that in the USA. In just the last two decades in Western Australia, the number of plant species listed as Critically Endangered has increased from 25 to 41 and that of fauna species from two to 12.

A significant proportion of the cause for this has been attributed to altered fire regimes (*89–91*). In addition to fire, the loss of many small digging marsupials by feral cat and fox predation has also seriously perturbed ecosystems, altering rates of litter accumulation and soil mycorrhizal populations and potentially rendering them more fire prone. The absence of a whole suite of pre-existing marsupial bioturbators is very evident today in changes in soil structure, permeability and fertility, and major efforts are needed to control predation and to reintroduce fossorial animals into the landscape (*74*).

Recent reviews of the effectiveness and the impact of prescribed burning on biodiversity in Mediterranean and other ecosystems worldwide (*24*, *88*, *92*, *93*) have highlighted the paucity of well-designed scientific studies to address the issue (*94*). Nonetheless, there is sufficient evidence to show that too-frequent burning has a detrimental effect on fire-sensitive plant species and on animals that require long-unburnt vegetation for their survival.

Discussion

Hazard reduction efforts in Australia have focused on disturbance-based methods intended to lower flammability by removing biomass, either through fire or by using mechanical means. These methods ignore biotic responses, but inadvertently set in course what are reasonably well-understood pathways of regeneration. Although the initial removal of biomass may have the desired effect (a short period of low flammability), this is followed by a long period of high flammability while the vegetation regenerates, before returning to an indefinite period of low flammability in the mature forest.

Modelling studies have underpinned these approaches through the use of disproved assumptions, and the failure to consider mechanistic drivers.

Empirical analyses historically failed to identify these trends due to study designs which incorrectly treat post-fire regrowth as if it is mature forest. Recent advances have now quantified the mechanistic drivers and removed the bias from empirical study techniques, confirming that this three-stage flammability trend (low flammability *young* forest, high flammability *regrowth*, low flammability *mature* forest) is the likely trend for most Australian forests.

Prescribed burning is the most widely-used tool for hazard reduction, yet it imposes high rates of mortality on human populations relative to direct bushfire impacts, while threatening the survival of many flora and fauna.

For these reasons, we caution against the imposition of any national standard for hazard reduction. Australian knowledge of effective bushfire hazard management is in its infancy, and no national standards can be implemented until we develop effective methods that are grounded in sound science.

Despite this, it is possible to improve the efficacy of the way we manage bushfire hazards in Australia. We suggest that the central reason for ineffectual management has been a lack of sound science and transparency in the field, enabling discredited notions to continue influencing management.

The purpose of science is to question and challenge ideas via processes such as falsification. Science gives ideas authority by grounding them in evidence and reason, but this process is inherently divisive as it challenges existing authority. This is particularly problematic in fire management, as fire has a deep culture of hegemonic masculinity (*95*), entailing a fundamental affinity with power-based authority (*96*).

This culture is evidenced by the reality that theories have been falsified by science, but retained and promoted by recognised authorities. In 2019, for example, the opening keynote address to a Sydney international fire conference held by the Bushfire and Natural Hazards CRC and the International Association of Wildland Fire criticised the scientific community as insufficiently right-wing, and openly denounced the peer-review process for its failure to block papers that conflicted with long-held beliefs in the fire management community (*97*). This occurred despite strident protest from fire researchers who objected to such an anti-science position, having seen the same speaker provide a similar keynote address at an earlier conference held by the Australasian Fire Authorities Council (*98*).

Recommendations toward improving the national standard of hazard reduction

The standard of bushfire hazard management in Australia can be improved by dismantling the structures that empower popular belief over science. To this end we make the following recommendations.

Recommendation 1: Increase transparency in decision-making

Government programs for bushfire hazard management should detail the science underpinning their programs to a sufficient level that decisions can be replicated. This should be available for public scrutiny so that it can be challenged through established legal processes in cases where decisions are inconsistent with sound science.

Recommendation 2: Move toward independent research funding

Ensure that research funding is provided from sources that do not have a vested interest in particular proceedings. For example, agencies that are tasked with implementing existing policies have a vested interest in attaining their KPIs. Researchers who receive funding from these agencies may be viewed more favourably if they assist the agency in reaching those KPIs, and less favourably if they call them into question or produce findings that could slow progress toward them.

Recommendation 3: Diversify research structures

The formation of 'official' research centres and hubs beyond the level of learning institutions such as universities creates ingroup – outgroup divisions where ideas are more likely to be accepted or rejected for social rather than scientific reasons. Such groups risk excluding scientists that legitimately challenge their ideas, instead providing false orthodoxy and authority to in-group ideas that may be less worthy. We recommend that funding previously directed to such groups instead be directed toward diversified models such as programs through the Australian Research Council, where it can be widely accessed by researchers with more diverse views.

Recommendation 4: Fund independent knowledge brokerage.

Scientific collaboration happens organically as ideas are discussed and gaps in knowledge identified. Knowledge brokers play a key role in collating and interpreting science to facilitate its adoption and identify needs. Where these are answerable to vested interests, they risk becoming gatekeepers with a focus on ideas that are consistent with the existing beliefs. When they are independent, there is greater likelihood that they will challenge existing structures and introduce new thinking.

TOR.G: Re-introducing traditional indigenous fire management practices

We thoroughly support the reintroduction of traditional indigenous burning practices where possible. We caution, however, that these practices were not developed to protect built structures from fire, and efforts to use them in this way are by definition not traditional but a form of cultural appropriation. There is a particularly high risk of this, given that much of this knowledge has been actively destroyed throughout Australian history, and popular narratives about Aboriginal fire do not necessarily correlate with true tradition.

One of the central myths in this regard is the simplification of Aboriginal fire into a regime of extremely frequent fire. In this scenario, practitioners burned forest with such a frequency that they maintained the landscape in a *young* state. This would require a far greater area burned annually than we are currently able to achieve, and all done on foot with firesticks instead of helicopters and vehicle-mounted incendiary launchers. All evidence of Aboriginal fire management in fact suggests the opposite.

Complexities in knowledge transfer

Aboriginal knowledge transfer arises from a primary orality, and this can be a fundamental barrier to western thinking.

A core characteristic of primary orality is its use of story, song and tradition as mnemonics to convey information (*99*). Rather than teaching students the details of fire, weather and survival explicitly, these central tenets were captured in numerous novel approaches. Non-Aboriginal listeners often refer to such information as "Dreamtime" stories. However, many traditional storytellers reject the name as a poor substitute for traditional names such as *burbung* (*100*), *tjurkupa* or *darama* on the basis that people automatically think of the Dreamtime as another time long ago (Pers. Comms. R Mason, Bemerangal elder, 2009). Inherent within darama is *warru* – the specific lore explaining how a person should live in country. The only way to know the right way to live in those places is by learning the warru through listening to and participating in darama.

In Young's (*101*) record of the Ngarragu story of the brown snake and the turtle for instance, the story does not simply describe the origins of the brown snake's poison. The ritual of the story involves drawing the path of the snake in the dust along with the paths of the other animals. Although listeners may focus on the interesting and sometimes humorous or frightening aspects of the story, through the simple act of listening and watching the map being drawn, they learn from this and other stories the lay of the mountains in the area, the places where various important species may be found and important travel routes and boundaries (Pers. Comms. R. Mason 2008, A. Williams 2010).

Another form of mnemonic integral to darama is the place of *bagal* or kinship. In Ngarragu culture, Bagal affords connection with one of the three central spirits – wind, rain or fire (Pers. Comms. R. Mason 2005 - 2009). Association with one spirit excludes the individual from the warru of the other two, so knowledge is divided and essentials to survival are only possible within a cohesive community structure where there is mutual support by those with skills in different areas. The connection with the species itself provides a further specialisation, as each has its own requirements and serves as an indicator of other things. *Maliyan* or *Meerung* (eagle) people for instance will have a closer association with areas that are recognised as Meerung country. Meerung are associated with the Fire Spirit, so there are laws regarding fire in these areas and travellers that see the signs of a place being Meerung country are immediately reminded that their own knowledge may be insufficient in this area. Consequently, they will refer to someone with a more appropriate bagal. The converse is also true – Meerung people could not enter other country and bring their fire; other country had its own warru.

The importance of complexities such as these can easily be lost in translation, as Western thinking is organised categorically, and details deemed irrelevant may be filtered out. To complicate things further, the nature of learning in oral societies places responsibility on the student rather than the teacher, so that knowledge is acquired as the student returns regularly with questions. This requires a level of respect for the teacher that has been rare in Western – Aboriginal interactions. For these reasons, much traditional knowledge has been greatly simplified as it is transferred through Western hands, and may no longer communicate its original intent.

To illustrate, consider a burning tradition conducted at Wadbilliga on the southern Great Dividing Range. Many of the Ngarragu clans including the Bemerangal moved annually between coastal areas and the high mountains of *Tidbillaga* (Kosciuszko area). One of the first campsites once they had gained the Monaro plateau was in the Wadbillaga country at the top of the escarpment. This was an important camp as it was situated near the base of a mountain named for the rainmaker *Djillagamberra*, who presided over the country. As a result, the Bemerangal families stayed at the site for some time.

The camp was also visited on the return journey during the autumn, but in this case, travellers brought with them fruits from several of the Geebung (*Persoonia*) and other food plants of the Tidbillaga area as stores for the crossing of the open *Nullaga* grasslands. This practice over centuries or millennia has meant the movement of large quantities of seed across a natural grassland barrier into a new environment, and the relevant food plants are concentrated around the campsites or 'gardens' (Pers. Comms. R. Mason 2008).

As the time to leave Wadbillaga approached, those with bagal ties to the bipinnate wattles or *Matruk* of the area watched and announced when the flowers had fallen from the plants. From this point, those with a rain kinship watched for clouds resting on the top of Djillagamberra mountain, and when this occurred, the Bemerangal broke camp and walked to the top of the hill looking back down onto their gardens. In Rod Mason's words:

> *"They sing out on top of the hill up there, and they said 'hey, Boodjeree Djillagamu', and they'd chuck a fire-stick into the bush and burn it, then they'd go. And next year when they'd come back, they'd sing out 'hey, Boodjeree Djillagamu', and they'd come back into the area."*

If a Bemerangal teacher had been questioned on the use of fire by an early grazier, they would likely have replied with the most relevant piece of information to that question: every year they burnt the forest by throwing out a fire stick and walking away. Coming from a British culture in which the forest was burnt specifically to clear vegetation and create grazing land, the grazier may have walked away from this exchange satisfied that he had learnt Aboriginal fire management for the area, believing it was an annual burning regime.

When all elements of the tradition are considered together, however, the outcome is fundamentally different. Seasonal movements of the Bemerangal coupled with bagal to the Matruk meant that the burns were conducted in spring at the time when flowers fell from the *Acacia dealbata.* The exact weather pattern was dictated by incoming afternoon sea breezes causing orographic lifting and cloud formation at the top of the escarpment. This set a dew point that was little higher than the campsite. Finally, the recognition of the mountain as an embodiment of a spirit that could be honoured with the gift of a fire stick meant that fire was kindled from a single point ignition on a hilltop overlooking the site. The result was a point fire spreading downhill with rapidly rising litter moisture contents, so that a very small patch was burnt.

This fire regime had three outcomes:

1. Small areas were disturbed regularly, promoting the growth of shrubs and thereby maintaining an ongoing supply of the foodplants.
2. The small area of the fires meant that the main landscape area was in a low-flammability *mature* state.
3. The presence of small patches burnt in the previous spring provided a place to shelter from wildfires if necessary.

Figure 11 | The Wadbilliga ceremony area, and surrounding forest managed under the Bemerangal tradition

Evidence of Aboriginal fire management

Evidence of pre-European fire regimes comes from soil carbon sediments concentrated on the southeast coast, and from fire scars on certain eucalypts over the more recent past. Both sources indicate a widespread and significant increase in fire coincident with the arrival of Europeans (*102*).

In Western Australian jarrah (*Eucalyptus marginata*) forests, fire scars occurred at an average pre-European interval of 81 years (*103*). Following European settlement in 1829, however, the frequency of these fire scars increased, and the average interval between them fell to approximately 17 years in the jarrah forest. Such patterns are similar to those measured in the Australian Alps, where the incidence of fire scars recorded from multiple sources increased seven-fold at the point where European graziers introduced their use of fire (*34*). This observed increase is inconsistent with widespread beliefs about Aboriginal fire use, and has been reinterpreted by some to represent a *decrease* in fire frequency causing a build-up of fuels and consequent increase in injurious fires (*103*, *104*).

The bases of this argument are the claims that:

a) Wildfire frequency is naturally too high to permit such large fire-free intervals, and

b) These trees only scar from higher intensity fires, so low intensity fires would not have been recorded in the scar record

In reference to the first claim, it must be recognised that our current perception of what is the ‘natural’ fire frequency is actually the frequency of fire in the environment after its European modification. Even so, the argument does not stand up. Snowgum scarring in the Brindabella ranges after European occupation increased to an average of every 3.5 years (*34*). For these to represent fires that were injurious due to an excess of fuels would mean that First Nations had burnt these forests at an even greater frequency than this, and that 3.5 years was a dangerously long space between fires. If this were the case, then regular, severe scarring or death of forests should have occurred after legislation in the 1950s prevented the burning of subalpine forests. This did not occur; instead, fire scar frequencies returned very quickly to the same rate that had occurred prior to 1840. Equally telling is the fact that oral accounts of burning by graziers in the Australian Alps record an attempted frequency of approximately every four years, representing the most frequent regime that landowners were able to implement (*105*).

South-west Australia does not have the same change in management to allow comparison, but charcoal evidence also indicates a much less frequent fire regime before European occupation. Of the rare charcoal records from SW Australian cores, sites dated 3,000-4,000 years BP in the Fitzgerald River National Park on the south coast of Western Australia show very low fire frequencies, with fires burning the catchment at a frequency of the order of 30-100+ years (*106*). Charcoal deposits at the Byenup Lagoon in *Eucalyptus marginata/Corymbia calophylla* forest near Manjimup similarly showed infrequent fire with no indication of anthropogenic increases at the estimated time of Aboriginal arrival to the area (*106*). Such lake sediment studies represent the frequency at which fire has occurred within the catchment of the lake, so that unless the entire catchment was burnt on each occasion, the fire frequency at a given point may be significantly lower (*88*, *106*).

Claims that Aboriginal people in Western Australia regularly burnt on a three-year cycle, based on fire scars in balga grasstrees (*Xanthorrhoea preissii*) (*107*) were discredited when careful re-analysis using Landsat imagery failed to substantiate landscape-scale fires they purportedly recorded (*108*, *109*). Noongar Aboriginal people burnt individual grasstrees frequently for various cultural reasons, but apparently confined such fires to the grass trees themselves, not the surrounding landscape (Pers. Comms. Lynette Knapp, Merningar Elder)

Analyses of early European observations have also been used to argue for an average fire return interval of 2-4 years for the Swan Coastal Plain (*110*). However, as noted by Sylvia Hallam, that study inferred the frequency of fire at a point from vague observations across a landscape rather than repeated observations of the same point being burnt. “A record of one fire in 1838 and another in 1840 on the Swan Coastal Plain between Perth and Upper Swan is not sufficient to assure us that a two-year interval would have been the norm” (*111*).

In reference to the second claim, experimental evidence shows that, when burnt as often as possible, Snowgums (*E. pauciflora*) still scarred from eight out of ten fires (*112*). Claims that *E. marginata* required high intensity fire also could not be supported from the literature cited.(*113*). This report in fact showed no consistent relationship between fire intensity and the rate of scarring, but instead, that scarring occurred on smaller-diameter trees, or else on trees close to large coarse woody debris.

The literature on pre-European fire regimes is therefore divided between the evidence provided by charcoal and fire scars on the one hand, and by its reinterpretation to fit European paradigms on the other. This pattern of reinterpretation remains a cause of tension and disempowerment of Aboriginal societies in Australia, where it is at times used to justify the replacement of traditional approaches (*114*). In Kakadu National Park, for example, traditional management involving frequent ground-based ignitions of a scale small enough to selectively burn certain stands and avoid others was reinterpreted by Government authorities into aerial broad-scale burning that was blind to plant communities and seasonal conditions. Early analysis reported that this had resulted in a positive feedback that encouraged flammable grass proliferation (*115*), and there was “near consensus among Aboriginal people that too much of the Park was being burned, and much of that incorrectly” (*93*, *116*). Similarly, a program employing traditional Wik managers as Aboriginal Rangers in the western Cape York Peninsula of Queensland has changed both the scale of burning from fine-scale ground ignitions to broad-scale aerial burning, and the timing and location from historic priorities centred around the movement of people and the seasonality of their resource base, into the protection of infrastructure (*117*).

Oral history accounts of the use of fire by Aboriginal families in southwestern Australia remain poorly investigated. Although much knowledge has been lost through cultural suppression of the ‘stolen generations’ some elders escaped these devastating processes and retain traditional knowledge through a continuous oral tradition across generations. Lynette Knapp of the south coast Merningar Barduk Noongar people is one such elder. Her recent oral history (Knapp, Hopper and Lullfitz, unpubl.) has revealed evidence that fire was used frequently in cool small-scale burns at campsites (*karleep*) and along travel lines (*bidi*). All members of the family, including barefooted children, participated. High frequency burns at campsites were for comfortable walking, safety (easy detection of snakes), and to create spaces for games such as bush hockey. Edging was done first, after which fire was applied inwards in circles of approximately 50m diameter. Trees were protected by removing adjacent flammable material, unless removal was intended in which case litter and dead wood was placed around the tree trunks and ignited. Men would use larger wind-driven strip burning when hunting under strict controls by family elders.

Each family had its own campsites and travel paths. Great shame (*kaanya*) accrued if fires escaped and burnt another family’s areas. Fire exclusion was practised, particularly for highly spiritual places such as granite-topped hill (*kaat*), and for important fire-sensitive resources. Careful burning regimes occurred for peat swamps, for example, dominated by *gidge* or *wattie* (*Taxandria juniperina*), an important source of thin straight light-weight spears called gidge or *burdan*. Regular burning was undertaken to ensure a continuous supply of spears was available, while ensuring that the peat itself was not ignited.

Similarly, oral accounts of cultural burning in the Australian Alps bioregion described highly specific, localised prescriptions. Three of these were recorded from Bemerangal-Ngarragu lore-keeper Rod Mason (*12*), describing two tightly-controlled, fine-scale burns conducted in forested country, and one wind-driven regime to be conducted in grassland. These are consistent with other accounts from south-eastern Australia which indicate a focus of cultural burning in open grasslands (*118*). Importantly, all accounts describe highly-specific practices that contrasted with the European usage of fire, which was frequently viewed with disdain by the First Nations. One Elder spoke angrily of the European use of fire saying that “they lit them and let them run like a child that loved destruction” (*119*).

Ngadju people from Norseman summarised their approach to fire management in the Great Western Woodlands of WA (*120*):

> *‘Fire is significant to Ngadju for its many uses, from warmth and yarns around the campfire to cleaning up the country. As a land management tool, fire has a more select role in Ngadju country than in other regions such as tropical savannahs and spinifex country, where large parts of the landscape are frequently burnt. Historically, only specific, relatively small parts of Ngadju landscapes were actively burnt, to maintain open hunting grounds and camping areas, encourage green pick, facilitate travel, and protect people, important places and resources from fire. Management relevant to fire included not only the application of (usually small) fires, but also management of fuels through plentiful use of timber for campfires and sweeping or scraping up bark, leaves and dead wood around important trees or other assets.’*

Analysis of multi-century-scale vegetation dynamics in the Great Western Woodlands indicates that as the effects of disturbance by fire disappear and the woodlands enter maturity, growth and self-thinning of lower plant strata leads to a less flammable structure (*25*) and an environment that favours greater bird diversity (*121*). Ngadju kala (fire management) therefore favours a low-flammability landscape of long-unburnt woodland that supports high diversity, acting as a matrix supporting fine-patches of recently burnt, intensively managed areas favouring other species. A similar trend is seen in Martu fire management in the Western Desert spinifex country, where burning is typically a tool used on a very localised scale for hunting small fauna such as lizards (*122*).

Thus, a recurrent theme across Australia is that indigenous burning was **not** widespread. Rather, it was sophisticated, generally involving cool burning in small areas, targeted as finely as to protect important trees, places and resources. Misinterpretation of this pattern has been widely adopted by non-indigenous people to justify extensive untargeted prescribed burning.

Recommendations toward integrating aboriginal fire knowledge

Research into aboriginal fire management should be protected from the influence of vested interests as per recommendations 2 – 4. Given the risk that critical details inherent in oral traditions are lost in translation to Western thinking, we recommend that:

Recommendation 5. Collate cultural knowledge

Funding for research into indigenous practices requires a focus on the collation of the underpinning related cultural traditions, subject to permission from the knowledge holders.

Recommendation 6: Build transparency into Government fire management practices that are claimed to be traditional

Indigenous people have felt in some cases that their traditional practices have been replaced by Government programs appropriating their cultures, with very different outcomes. To avoid this and allow this problem to be rectified where necessary, we recommend that Government fire management programs claiming to replicate indigenous management are required to document the underpinning traditions, their sources, and the reasoning used to translate these into fire regimes.

Recommendation 7. Ensure that Indigenous-based Government fire management programs are adaptive

Community consultation should continue after programs have begun. This should involve independent research to gauge the level of satisfaction in the community that the management reflects their intentions.

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