Submission to:

Inquiry into the 2019-20 Victorian Fire Season

This submission seeks to provide scientific insight into the following specific items listed in the Terms of Reference:

- Consider all challenges and implications for bushfire preparedness arising from increasingly longer and more severe bushfire seasons as a result of climate change.
- Review of all opportunities and approaches to bushfire preparedness, including different methods of fuel and land management (for example 'cool burning', mechanical slashing, integrated forest management, traditional fire approaches) to protect life and property as well as ecological and cultural values.

Prepared by

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The Research Centre for Future Landscapes is a multi-disciplinary environmental research centre based in the School of Life Sciences, College of Science, Health and Engineering at La Trobe University, Australia. The Centre is primarily concerned with the nature of landscape change, its drivers and management interventions that are necessary to sustain species, communities, ecosystems and society.

23th April 2020

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Summary

Evaluation of the scientific evidence indicates:

1. Hazard reduction burning can reduce the intensity and spread of bushfires, and can aid suppression activities under moderate fire weather conditions.
2. It is most effective for protecting life and property when carried out within 500m of the asset you are trying to protect.
3. Its effectiveness in altering fire behaviour is greatest in the first ~ 1-6 years after burning in many forest types but is likely to diminish significantly after that.
4. Hazard reduction burning is most effective when strategically targeted to protect assets (human or ecological), rather than applied haphazardly across broad landscapes.
5. It can assist suppression efforts on more benign days, but it is largely ineffective on days of extreme fire weather (when most loss of life and property occurs).
6. Its predicted impact in reducing losses to life and property is modest (e.g. ~3-5% reduction in Victoria, even if all hazard reduction burning hectare targets are reached).
7. Many in the Australian community probably hold an unfounded, overly optimistic and potentially dangerous view of how much safer hazard reduction burning can make them. If this creates a false sense of security, tempting home-owners occupying vulnerable homes to stay and defend, rather than flee to a safe haven on extreme fire days, then inaccurate claims about the benefits of hazard reduction burning could result in loss of life.
8. It can do both ecological good and harm, depending on how, where, when and how often it is applied.
9. It is a myth that 'environmentalists' have constrained government agencies from achieving the hazard reduction targets on public land.
10. A primary cause of failure to achieve burning targets has been the brief and shrinking fire-weather window in which agencies can safely conduct hazard reduction burning (~10 days per year), without causing collateral damage to human health and the very assets they are attempting to protect.
11. Given the diminishing window in which it will be safe to conduct hazard reduction burning, increased resourcing will be needed to ensure we capitalise on opportunities when they arise.
12. Relationships between time since fire and fuel hazard are complex. Long unburnt areas can have lower fuel hazard than young and intermediate age classes.
13. Hazard reduction burning is just one method of reducing risk to life and property. Other strategies may offer a better return on investment in some situations, when it comes to reducing risk.
14. Current conflation of the goals of protecting both life *and* property may be diminishing consideration of alternative strategies for saving lives.
15. Too frequent prescribed burning adversely affects fauna species that require dense undergrowth, coarse woody debris and/or leaf litter.
16. Where frequent burning is necessary and unavoidable, the needs of vulnerable species should be addressed through proactive conservation approaches and monitoring.
17. We need to harness the most relevant aspects of both traditional indigenous *site-specific* knowledge and western science to identify the best ways forward. However, indigenous cultural burning should not be equated with hazard reduction burning, as the former was primarily done to achieve other objectives, in a very different climatic, ecological, sociological and demographic context.

Justification of key points based on research published in the peer-reviewed scientific literature

1. **Hazard reduction burning can reduce the intensity and spread of bushfires, and can aid suppression activities under moderate fire weather conditions**

   Most practitioners argue the primary value of hazard reduction burning is in assisting in control and containment when fire weather conditions are below 'severe' or 'extreme' (e.g. Boer et al. 2009, McCaw et al. 2013). It is of value in reducing the rate of lateral spread of a fire and the establishment of control lines under more moderate conditions. Both strategies enhance firefighters' capacity to lessen the impact of the fire if more extreme conditions return.

2. **Hazard reduction burning is most effective when carried out close (<500 m) to the asset you are trying to protect.**

   Analyses of the factors affecting house losses in past bushfires by Gibbons et al. (2012) showed that mechanical fuel reduction close to assets (within 40 m) was more effective at reducing house losses than the more typical broad-scale hazard reduction burning distant from the assets. They concluded that "a shift in emphasis away from broad-scale fuel-reduction to intensive fuel treatments close to property will more effectively mitigate impacts from wildfires on peri-urban communities." Similarly, Penman et al. (2014) found that planned burning at the interface between assets and the forest (<500 from the asset) was the most cost effective means of reducing risk to those assets.

3. **Its effectiveness in altering fire behaviour is greatest in the first ~ 1-6 years after burning in many forest types, but is likely to diminish significantly after that.**

   Numerous studies have documented that the capacity for hazard reduction burning to reduce fuels sufficiently to have a measurable impact on fire behaviour is limited to a short period of time (1-6 years) following treatment (e.g. Fernandes and Botelho 2003, Cary et al. 2009; Bradstock et al. 2010; AFAC 2015; Penman and Cirulis 2019).

4. **Hazard reduction burning is most effective when strategically targeted to protect assets (human or ecological), rather than haphazardly across broad landscapes.**

   Price et al. (2015) showed varying levels of effectiveness of hazard reduction burning across 25 years of fires examined in south-eastern Australia. They reported that the "contention by Burrows and McCaw (2013) and Sneeuwjagt et al. (2013) that prescribed fire is universally effective is not supported by historical fire records in south-east Australia, even when restricted to forests.". Price et al. (2015) also concluded that "The most efficient use of prescribed fire is applying it to the immediate proximity of assets, where a resultant reduction in fire intensity can be of immediate benefit in terms of impacts on structures and ease of suppression (Price & Bradstock, 2010, 2012).". Furlaud et. al. (2017) has shown that realistic, implementable prescribed-burning plans to reduce fine fuel loads in fire prone Tasmanian grasslands, sedgelands and dry eucalypt forests have little potential to substantially reduce the extent and intensity of wildfires at a state-wide scale. The study highlights that prescribed burning can theoretically mitigate wildfire, but that an unrealistically large area would need to be treated to affect fire behaviour at the state-wide scale across Tasmania. It advocates for local-scale design solutions based on improved modelling of fire behaviour, empirical measurement of fuels and analysis of actual wildfires.

Florec et. al. (2019) also found that planned burning close to assets in the urban interface in WA was more effective at reducing damages (i.e. loss of built assets) than burning in the more distant landscape but on balance, less cost effective because burning remotely was much cheaper than burning close to assets. They did, however, acknowledge that their study did not consider any ecological costs associated with prescribed burning and that this was a limitation of their cost/benefit analysis.

5. **Hazard Reduction Burning can assist suppression efforts on more benign days, but it is largely ineffective on days of extreme fire weather (when most loss of life and property occurs).**

The value of hazard reduction burning is primarily to assist with the safe suppression of fire under moderate to benign fire weather conditions. It increases the likelihood that indirect suppression (e.g. backburning) and containment methods (e.g. establishment of control lines) will be successful in reducing fire spread.

Wildfires on severe or extreme weather days account for the vast majority of area burnt, property losses and fatalities. A range of researchers (e.g. Morrison et al. 1996, Fernandes and Botelho 2003, Moritz et al. 2004, Carey et al. 2009, Penman et al. 2011, Gibbons et al. 2012, Penman et al. *in press*) and highly respected fire managers (e.g. Shane Fitzsimmons, NSW RFS Commissioner https://www.abc.net.au/news/2020-01-08/nsw-fires-rfs-commissioner-weights-in-on-hazard-reduction-debate/11850862), have noted that the ability of hazard reduction burning to aid in fire suppression efforts during extreme fire conditions is negligible.

Bradstock (2008, p.811) discussed the correlation between extreme fire weather and high intensity fires and commented that 'maximum severity [of wildfire] in each case is associated with severe fire weather – particularly high wind speeds in association with high temperatures plus low fuel moisture and relative humidity. Effects of weather on severity predominate over effects of terrain and vegetation type and condition [where vegetation type and condition is a reference to fuel load], as found elsewhere in temperate vegetation (e.g. Moritz et al. 2004)'. This statement is supported by numerous studies that have examined the effects of fire weather, fuels and terrain on the occurrence of high severity canopy fires across south eastern Australia (Bradstock et al. 2010; Price and Bradstock, 2012; Collins et al. 2014; Storey et al. 2016).

In their work in Californian shrublands, Moritz et al. (2004, p.70) argued that during extreme fire weather, in particular, "Santa Ana" wind conditions 'fire may spread through all age classes of fuels, because the importance of age and spatial patterns of vegetation diminishes in the face of hot, dry winds (Bessie and Johnson 1995, Moritz 2003)'. Moritz et al (2004 p. 71) noted that 'Rotational prescription burning to maintain a landscape mosaic of different age classes is thought to inhibit large fire development; however, the present study suggests that this strategy will be ineffective.'.

6. **The predicted impact of hazard reduction burning in reducing losses to life and property is modest (e.g. in Victoria, ~3-5% reduction over 3 years from planned burns in 2020), even if all area-based targets for hazard reduction burning are reached.**

Some of the most sophisticated scenario modelling conducted anywhere in the world (using Phoenix Rapid Fire, Tolhurst and Chong 2011) has been used in Victoria by DELWP to predict the extent to which hazard reduction burning on public land can reduce the risk of property losses. This spatially explicit modelling has enabled the agency to estimate the magnitude of the potential reduction in property losses under extreme fire weather conditions compared to a scenario in which no hazard reduction burning on public land had taken place. Across all of Victoria, the estimated total reduction in risk to property losses if DEWLP achieves its annual hazard reduction target for 2020 of 242,400 ha is predicted to be just 5% by June 2022 (i.e. a reduction from 73% to 68% risk) (Statewide 2019/20-2021/22 Joint Fuel Management Program https://www.ffm.vic.gov.au/__data/assets/pdf_file/0028/448165/State-Summary-for-2019-2020-Year1.pdf). Notably, in the Greater Melbourne Region the estimated reduction in risk to property losses that can be achieved under extreme fire weather conditions, even if all hazard reduction burning planned in 2020 on both public and private land takes place, is just 3% by June 2022 (Greater Melbourne 2019/20-2021/22 Joint Fuel Management Program https://www.ffm.vic.gov.au/__data/assets/pdf_file/0032/448169/Greater-Melbourne-Summary-for-2019-2020-Year1.pdf).

7. **Many in the Australian community probably hold an unfounded, overly optimistic and potentially dangerous view of how much safer they will be with hazard reduction burning.**

The call for additional hazard reduction burning by some media commentators and politicians creates an impression in the public mind that hazard reduction burning will substantially reduce the risk to their property on an extreme fire day, well beyond what the agencies' best estimates tell us is likely (see DELWP reports mentioned above). If this creates a false sense of security, tempting home-owners occupying vulnerable homes to stay and defend, rather than flee to a safe haven on extreme fire days, then these exaggerated claims about the benefits of hazard reduction burning could result in loss of life. Further, this belief may perpetuate the misunderstanding that hazard reduction burning is the only, or predominate, action required to prepare for bushfires; diverting attention, resources and responsibility away from other important preparatory actions the home owners could undertake.

8. **Hazard reduction burning can do both ecological good and harm, depending on how, where and when it is applied.**

Plant and animal communities in Australia have evolved to cope with fire regimes exhibiting different fire severity, frequency, extent, season, and configuration (patchiness) (Clarke *in press*). Fire can be a necessary component for the maintenance of some vegetation communities (e.g. heathlands, grasslands), but also cause the destruction of others (e.g. rainforests, alpine peat bogs). It is ecologically simplistic and inaccurate to generalise and claim that the Australian bush "craves" fire or has uniformly evolved to cope with fire, or that it universally "needs" fire to regenerate. Indeed, many native fauna and flora species depend on long-unburnt vegetation for the provision of specific food resources, development of complex vegetation and ground-level structure for foraging and shelter, and tree hollows for nesting and roosting (e.g., Watson et al. 2012; Kelly et al. 2015; Doherty et al. 2015; Davis et al. 2016; Dixon et al. 2018). Too frequent, too intense or too extensive fires are recognised as posing a major threat of local extinction of native species (e.g. Bradstock et al. 1998; Connell et al. 2019) and this is why inappropriate fire regimes are formally listed as a major threatening process for flora and fauna in Victoria and NSW. Gross generalisations, like those of Gammage (2011) that "Most of Australia was burnt about every 1-5 years depending on local conditions and purposes", are neither accurate nor helpful when it comes to working out where and when to apply fire for ecological benefit, or for bushfire mitigation. Our own research has shown the likely ecological impact of both wildfire (e.g. Haslem et al. 2011, Robinson et al. 2016, Chia et al. 2016, Connell et al. 2017, 2019) and hazard-reduction burning on a range of flora, fauna or habitat components can be positive (Morgan et al. 2018) or negative (e.g. Holland et al. 2017, Flanagan-Moodie et al. 2018), depending on the attributes of the fire and the ecosystem. One size does not fit all.

Prescribed burning has been proposed as a means of creating a patch-mosaic of different fire age-classes, on the basis that a 'fire mosaic' is ecologically beneficial for flora and fauna. While it is clear that fire can be used to create ecologically suitable conditions for plants and animals, the application of fire for this purpose varies greatly depending on the species concerned and the type of ecosystem. Similarly, fire mosaics can enhance biodiversity in some ecosystems (e.g. Russell-Smith et al. 2009; Sitters et al. 2014) but the same prescriptions do not necessarily hold in all ecosystems. A growing number of studies have questioned the assumptions underpinning the purported ecological value of patch mosaic burning in a number of different vegetation types (Parr and Andersen 2006; Giljohann et al. 2015; Taylor et al. 2012, 2013; Farnsworth et al. 2014).

9. **It is a myth that 'environmentalists' have constrained government agencies from achieving the hazard reduction burn targets on public land.**

   NSW RFS Commissioner, Shane Fitzsimmons has categorically rejected assertions that the capacity of the RFS to achieve their hazard reduction targets has been constrained by 'environmentalists or greenies' (https://www.abc.net.au/news/2020-01-10/hazard-reduction-burns-bushfire-prevention-explainer/11853366). Furthermore, no environmental-based political party holds the balance of power in any State or federal jurisdiction. Consequently, 'environmentalists' have no legislative power to impose constraints on hazard reduction targets by government agencies. Accusations that that 'environmentalists' have 'locked up' national and state parks and forests have also been refuted by NSW RFS Commissioner and his Victorian counterpart – the RFS/CFA still have access to fire tracks that may be locked for public access, and in Victoria DELWP/PV have upgraded 1000s of km of fire access tracks in recent years.

10. **A primary cause of failure to achieve targets has been the brief (~10 days per year) and shrinking fire-weather window in which agencies can safely conduct hazard reduction burning without causing collateral damage to the very assets they are attempting to protect.**

    Several studies (e.g. Jolly et al. 2015; Quinn-Davidson and Varner 2012) have demonstrated, and senior fire managers from multiple states have reiterated, that failure to achieve hazard reduction hectare targets with current resourcing and capacity is due to being constrained by ever decreasing windows of opportunity in which they can safely conduct prescribed burning due to climate change (https://www.abc.net.au/news/2020-01-10/hazard-reduction-burns-bushfire-prevention-explainer/11853366).

    Whether a fuel will burn, and how well it will burn, depends in part upon its moisture content, i.e. on fuel dryness. Live plant material (green leaves etc) contains high moisture contents (e.g. 70% of dry weight). Mostly such fuels will not burn. They will burn if they are first dried out by heat from other fuels that are burning nearby or underneath. Long-term drought dramatically increases the flammability of fine and even heavy (diameter > 6mm) fuels.

    a. At fuel moisture contents of 18% or higher, fires won't burn.
    b. At fuel moisture contents of 12%, planned burns behave in mild ways.

c. As moisture content falls 5%, 4%, 3%, the effect on fire behaviour is exponential. Fires then become erratic and very difficult to control.

So, the range of moisture content in which fuels are safe to burn is very narrow: 5-17% (Dr Andrew Wilson (retired fire scientist), *pers. comm*.) and the number of days on which fuels fall within this range is small and getting smaller due to climate change.

In addition, the public also often places very high expectations on agencies that our health (e.g. asthma sufferers), property (e.g. damage to Lancefield properties from escaped DELWP hazard reduction burn in 2015) and businesses (e.g. smoke taint to grape crops) will not be impacted by prescribed burning in their vicinity. This can further constrain the number of days and locations in which burning can be conducted safely.

11. Given the diminishing window in which it will be safe to conduct hazard reduction burning, increased resourcing will be needed to ensure we capitalise on opportunities when they arise.

Agencies across all states plan many more hazard reduction burns than they are typically able to complete in any one year (e.g. Victorian Joint Fuel Management Program https://www.ffm.vic.gov.au/__data/assets/pdf_file/0028/448165/State-Summary-for-2019-2020-Year1.pdf). Their failure to conduct all those planned burns is due to a combination of factors including:

a) Very brief windows in which weather conditions are suitable to conduct the burn safely, without threatening human life, health or property.
b) Limited agility of agencies (with their necessary but sometimes burdensome approval lines) to give the go-ahead for a burn when conditions are suitable.
c) Sufficient experienced staff and resources necessary to safely conduct many burns simultaneously, on those increasingly rare occasions when conditions are suitable.

Addressing these last two factors will require additional investment in the conduct of hazard reduction burning and in training to build a larger workforce skilled in this challenging task. It will also require increased public education regarding shared responsibilities for hazard reduction on private land, as well as public land. For example, in the East Central Region of Victoria which includes the Dandenong Ranges, only 35% of the area is public land, whereas 65% is private land.

12. Relationships between time since fire and fuel hazard are complex. Long unburnt areas can have lower fuel hazard than young and intermediate age classes

There is a wide held belief that fuel hazard and fire risk increase with time since burning, until a steady state or asymptote is reached. This is predicated on the assumption that litter fuels on the forest floor are a primary driver of fire behaviour (Penman et al. *in press*). However, recent advances in fire research have demonstrated the importance of connectivity (i.e. size of gaps) between surface, elevated and canopy fuels for fire behaviour (Cheney et al. 2012; Zylstra et al. 2016). Many eucalypt-dominated forests and woodlands exhibit hump shaped relationships between time since fire and fuel hazard and flammability, whereby the greatest likelihood of fire, in particular high severity fire, is observed in early - mid stages (e.g. 5 – 15 years) of regeneration (Taylor et al. 2014; Storey et al. 2016; Zylstra 2018; McColl-Gausden and Penman 2019). This is because the post-fire regeneration of shrubs and saplings in forests can increase connectivity between surface, shrub and canopy fuels, elevating the likelihood of high severity fire. As time since fire increases, the fuel connectivity often *decreases* as a result of growth and senescence of shrubs and saplings (Taylor et al. 2014; Storey et al. 2016; Zylstra 2018; McColl-Gausden and Penman 2019). This is particularly true for regenerating tall, wet forests dominated by Ash-type eucalypts, which were eight times more likely to burn than mature forests, and post-disturbance regenerating open forests were 1.5 times more likely to burn than mature forests (Zylstra 2018). Alpine shrublands exhibit a similar positive feedback, with fire increasing the establishment of shrub seedlings by as much as 33-fold (Camac et al. 2017). In their review of ecological fire in dry box-ironbark forests of central Victoria, Tolsma et al. (2007) reported that many shrubs increase in the first 10 years post-fire. Frequent hazard reduction burning in these forests would lead to increased flammability compared to a mature forest of relatively low flammability box and ironbark trees and a grassy/herby understory with sparse shrubs.

Changes to fuel hazard with time since fire are complex, depending on the fire response traits of plants and the severity of the last fire (Zylstra 2018; Collins 2020). Therefore, a nuanced approach to landscape management of fuel age is required. Preserving areas of long unburnt forests may provide a cheaper means to achieving low fuel hazard than repeated prescribed burning which keeps forest understorey in an early post-fire stage (< 5 years) with a thicker layer of shrubs that is potentially more flammable. to either support or question the efficacy of a particular fire management strategy.

13. Hazard reduction burning is just one method of reducing risk to life and property. Other strategies may offer a better return on investment in some situations, when it comes to reducing risk.

Over-reliance on just one method of reducing risk to life and property from bushfires is poor stewardship of tax-payer dollars. Investment in early warning phone apps and educating the public to 'leave early' has contributed to a remarkable drop in fatalities associated with this season's fires (34 deaths in 2020), compared to 173 deaths on Black Saturday, despite over 13 million hectares burnt this season compared to 450,000 ha in 2009.

Other complementary strategies that need to be considered include:

a. Improved early detection of ignitions
b. Reducing potential sources of ignitions (e.g. putting power lines underground)
c. Enhanced and earlier rapid attack/suppression, especially on fires in remote locations, before they reach built assets (e.g. aerial suppression)
d. Other methods of fuel removal (e.g. slashing, mulching, rolling)
e. Tightening building and maintenance codes for types of dwellings approved in fire prone areas
f. Planning regulation of building placements in fire-prone locations
g. Community shelters in defendable spaces, as is done for cyclones in northern Australia and tornados in vulnerable sections of the USA (e.g. caravan parks in the Tornado belt, Sosnowski 2012 https://www.scientificamerican.com/article/can-you-really-hide-from/)
h. Encouraging construction to an approved standard of private bushfire shelters/bunkers (could be compulsory at least for new buildings in fire prone areas). Lessons could be learnt from personal and communal tornado shelters built below homes or in caravan parks in vulnerable regions of the USA (Merrell et al. 2005).
i. Education and communication programs to encourage people to leave early
j. Legislating for compulsory evacuation powers, including the development of strategies in advance for implementing them (learning from experiences in Canada and USA).
k. Improved acceptance and policing of the responsibility for fuel management on *private* land (e.g. in the East Central Region of Victoria where there is 35% public land, 65% private land), since research by Gibbons et al. (2012) shows fuel removal close to assets is one of the most effectives measures that can be taken to reduce risk to life and property.

14. **Current conflation of the goals of protecting both life <u>and</u> property may be diminishing consideration of alternative strategies for saving lives**

If, as climatologists predict, more frequent, extensive and prolonged drought conditions, coupled with an increase in the frequency of days of extreme fire weather, are likely to occur and become the norm, then the **nature of the fire threat has undergone a step change**. Approaches of the past for reducing risk need to be rethought. For example, we never talk about earthquake or cyclone "management". Perhaps many of our fires are now entering a similarly 'unmanageable' status and we should be more sanguine about how limited an impact our preparations can have in reducing the ferocity of a fire under these new conditions.

We need to re-evaluate the most effective ways to reduce the threat, or risk, to the three key things we value:

a) People's lives
b) Human assets (e.g. homes, farms, crops, infrastructure, water catchments, timber resources)
c) Ecological assets (e.g. threatened species, communities, refugia, corridors)

Current zoning systems for bushfire risk management (e.g. Department of Sustainability and Environment 2012) blur the distinctions between these three different values unhelpfully. For example, in the current Victorian *Code of Practice for Bushfire Management on Public Land*, of its four Fire Management Zones, its most intensive fire management zone (Asset Protection Zone) aims to provide "the highest level of localised protection to human life and property and community assets" – thereby conflating the goals of protecting two different values (human life and assets), as if mitigation strategies will always be synonymous. When the values we are trying to protect become conflated, some mitigation strategies are given greater emphasis (e.g. hazard reduction burning), under the assumption that applying *that* mitigation strategy is the best option for simultaneously reducing the risk to all three values. However, it can lead to the importance of other complementary strategies being undervalued (e.g. early ignition detection, better warning communication systems, rapid attack while the fire is small). Over-reliance on just one mitigation option (e.g. hazard reduction burning or aerial water bombing), that we know has limited effectiveness under severe or extreme fire weather conditions, is imprudent. Instead we should choose mitigation strategies for each of the three different kinds of values we are trying to protect. Efficiencies can be achieved where different values are protected by the same mitigation option, but it is important to be clear about the objective we are aiming to achieve before deciding which tool is the best to apply to protect that value in each different spatial context.

If we only have a hammer in the tool-box, everything begins to look like a nail.

If we consider the future threat of fire more like the threat of cyclones or tornados, we might prioritise mitigation strategies to reduce the threat of fires differently. We might instead prioritise getting people out of harm's way before the cyclone/fire hits. This could involve strategies like:

a. More rapid detection of ignitions and real-time mapping of fire spread
b. Better communication infrastructure for remote communities (e.g. satellite phones), early warnings, clearer communications

c. Better evacuation planning (as we do for remote communities in the paths of cyclones) and better responsiveness
d. Better construction of public fire shelters and safe places (as we do for cyclones)
e. Enforcing building codes and requirements for construction of buildings and private fire bunkers in fire prone regions, as is done for cyclone, tornado or earthquake-rated buildings.
f. Enforce planning regulations where buildings or assets can or cannot be located based on vulnerability and ease of egress during bushfires.

15. Too frequent prescribed burning adversely affects fauna species that require dense undergrowth, coarse woody debris and/or leaf litter.

The primary way in which native fauna are affected by prescribed burning is by its effects on their habitat. Too frequent prescribed burning has the potential to incinerate and deplete critical resources (e.g. hollow logs, hollow-bearing old trees, large clumps of spinifex) (e.g. Stares et al. 2018; Bluff 2016) essential for the survival and persistence of species. Post-fire changes to habitat can extend over many decades in some ecosystems (e.g. Haslem et al. 2011). Currently, 'Tolerable Fire Intervals' used in fire planning are based primarily on the requirements of plant species. We strongly recommend to also take into account the responses of fauna species to fire and the habitat components they use (e.g. shrub cover, large logs, tree hollows) (Clarke 2008).

Frequent prescribed burning causes declines in certain native fauna and flora species that rely on long unburnt vegetation. Frequent prescribed burns have resulted in declines of species that favour shrubby undergrowth (e.g. Golden Whistler) or dense leaf litter (e.g. Red-winged Fairy-wren, Pilotbird) (Woinarski and Recher 1997). Research in eastern Australia's protected area estate shows that bird species richness was reduced by 9.1% for every extra fire that occurred (Lindenmayer et al. 2008). The species most adversely affected by fire were those dependent on closed habitats such as forests and woodlands. Frequent historical prescribed burns also reduced the chance of endangered birds being able to recolonise after fire due to habitat simplification (Lindenmayer et al. 2009) – the critical resources they require for shelter from predators and competitors were no longer present in frequently burnt locations.

Too-frequent fire in the South-west Biodiversity Hotspot of Western Australia has led to 60% of the Banksia woodland having been burnt in the last 7 years, and the decline of some native Banksia species and the Honey Possums that depend on them for food and shelter. This is because obligate-seeding Banksias in this area typically require at least 10-20 years between fires to reach maximum maturity and flower production (Tulloch et al. 2016, Wilson et al. 2014), and Honey Possums in turn require more than 20 years between fires to recover to pre-fire catch rates and densities (Bradshaw and Bradshaw 2017).

16. Where frequent burning is necessary and unavoidable, the needs of vulnerable species should be addressed through proactive conservation approaches and monitoring

Regional-scale planning should identify the most suitable mix of post-fire age-classes necessary to maintain ecological values and to ensure the resilience of the system to fire. Prescribed burning can then be undertaken within this context, with much greater confidence that it can reduce risk to human life and property without compromising other values that society prizes.

In locations where frequent hazard reduction burning is applied on a broad scale, there are several ways to maintain and track the responses of biodiversity, although it is unlikely that all species will persist under frequent burning due to the requirements of many species for longer-unburnt periods (Tulloch et al. 2016):

i) Maintain unburned areas within the fire footprint, as patchy fires are critical for the recovery of several EPBC-listed species e.g. southern populations of the Eastern Bristlebird (Lindenmayer et al. 2009);

ii) preserve a range of microhabitats, including those associated with retained logs, to maintain shelter and food for invertebrate biodiversity (Andrew et al. 2000);

iii) protect keystone habitat (e.g. old hollow trees) though mechanical removal of fine and coarse fuels immediately before prescribed burns are conducted (Bluff 2016);

iv) ensure that insurance populations exist for threatened fauna and flora likely to be impacted by such burning, including the use of National Seed and Gene Banks and captive populations, and;

v) develop and maintain monitoring protocols at sites undergoing hazard reduction burning and nearby non-burnt sites to evaluate impacts on EPBC-listed species, as well as broader flora and fauna. This will require the development of National Standards for assessing the impacts of fire on Australia's biodiversity.

17. Hazard reduction burning should not be equated with indigenous cultural burning, as the latter was primarily done to achieve other objectives, in a very different demographic, sociological, ecological and climatic context.

Indigenous communities have different reasons for burning the bush compared with present-day fire managers; not primarily for hazard reduction. They burn the bush:

a. to promote the production of critical resources (e.g. plants and animals for food, fibre, medicine, shelter, tools and weapons)
b. to enable ease of travel through dense vegetation
c. for ceremonial reasons.

Indigenous communities did not burn everywhere, and large tracts of land were intentionally not burnt by indigenous people in many ecosystems, such as rainforests, tall wet forests and mallee (e.g. Prober et al. 2016). This is contrary to Gammage's (2011) claim that "Most of Australia was burnt about every 1-5 years depending on local conditions and purposes." Indigenous burning usually was carefully targeted and small scale and "characterised by its selectivity rather than it's ubiquity." (Prober et al. 2016). There is limited (and strongly contested) evidence of indigenous burning in tall eucalypt forests of eastern Australia (Hateley 2010) and in dry sclerophyll box-ironbark forests of central Victoria (Tolsma et al, 2007).

Given the huge challenges in managing fire under climate change**, we need to harness the most relevant aspects of both traditional indigenous *site-specific* knowledge and western science to identify the best ways forward.** There is an opportunity for indigenous practitioners and scientists to work together to better learn what works and why; ever mindful that current use of fire is in a novel and more challenging context, due to climate change.

The demographic, sociological, ecological and climatic context in which to conduct burning has become much more complex than prior to European settlement. These additional complexities and challenges for conducting cultural burning include:

a. 25 million humans scattered across the landscape, (compared with around half a million inhabitants at the time of the invasion of Australia by Europeans, Madden and Pulver (2009)).
b. complex networks of vulnerable infrastructure (powerlines, roads, pipelines, bridges, catchment reservoirs) crisscrossing the landscape.
c. fragmentation and depletion of remnant native vegetation, such that much of it exists only in isolated fragments, and extensive tracts of vegetation that can serve as sources for re-populating burnt areas are scarce.
d. fuel layers have changed with the introduction of flammable weed species, like Buffel Grass, Lantana.
e. 150-200 years of European management practices ranging from grazing with hooved livestock to mining and dredging has removed up to 1-2 metres of topsoil from some areas and deposited it in other areas. This means that in many woodlands/dry forests, the soils are re-building through accumulation of sediments and organic matter and do not have the capacity to carry fire or the resilience to withstand fire.
f. landscapes and fuel layers are drying out and becoming more flammable due to increased frequency, extent and duration of droughts caused by climate change.

A distinction must be made between the cultural and social benefits of reviving or using traditional practices, and the hazard reduction and environmental benefits that may be derived from burning. It should not be assumed that in today's landscape context that these will be one and the same. Furthermore, differences between burning techniques utilised by indigenous communities (i.e. ignition using firesticks) and western practices (e.g. broadscale aerial ignition) need to be acknowledged and preserved. For example, implementing an indigenous burning regime of a specific fire-interval and season through broadscale aerial ignition would not be appropriate.

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