The Ecological Society of Australia Ltd (ESA, www.ecolsoc.org.au) is the peak group of ecologists in Australia, with over 1200 members from all states and territories. Our members work in universities and other research institutions, government departments, NGOs, private industry and consultancies. We are a national not-for-profit organisation formed in 1959.

Submission to:

Finance and Public Administration References Committee for inquiry and report, "Lessons to be learned in relation to the preparation and planning for, response to and recovery efforts following the 2019-20 Australian bushfire season" 22 May 2020

SUMMARY

The ESA welcomes the opportunity to comment on the lessons to be learned from the 2019/20 bushfire season, to manage the increasing threat of bushfire, as informed by the best science available. Australia is a world leader in the fields of modelling and quantifying bushfire behaviour, bushfire risk management, bushfire impacts on natural ecosystems and the ways in which nature recovers after fire. We draw upon this substantial scientific legacy to provide an overview of the science that is applicable to this Inquiry.

Based on the expertise of our membership, we pay particular attention to current evidence about land management, hazard reduction, biodiversity monitoring, indigenous burning practices and flora and fauna recovery, and stress the following critical messages as they relate to preparation, planning, response and recovery to bushfires:

(i) PREPARATION

There is extensive scientific evidence indicating that Australia is becoming increasingly prone to more natural and human disturbances, including large-scale catastrophic events. It has been well documented that wildfires will become more frequent, widespread, severe and intense as a result of rapid changes in climate (Williams et al. 2009; Cary et al. 2012).

There should be a greater awareness of the need to balance human and socio-economic objectives with those of environmental resilience. **All actions to prepare, plan and recover from extreme wildfire events in Australia should be accompanied by monitoring and research**, ideally in an adaptive management framework that enables learning while doing, and particularly when threatened biodiversity and human lives might be impacted. Such a framework must consider the costs and benefits of actions not only for the economy but also for the environment (Penman and Cirulis 2019, Auerbach et al. 2014).

Preparing for the human, infrastructure, biodiversity and environmental impacts of wildfire requires:

a) **Federal Government policies on climate change mitigation and adaptation** that will avoid the impacts of worsening heat and fire extremes for Australia, including commitment to zero net emissions by 2050.

b) **Increased government capacity and resourcing to prepare for natural disasters**, using the US architecture as an exemplar.
c) Establish through the Environmental Protection and Biodiversity Conservation (EPBC) Act a **requirement for a natural disaster environmental response strategy**, to be prepared in advance and executed during a crisis.
d) **Legislative requirements for resourcing recovery planning and recovery actions** for all threatened species and communities, including mapping of critical habitat (Taylor et al. 2005), to ensure that vulnerable species, ecosystems and locations are identified prior to wildfire events.
e) **Maximise understanding of species, ecological communities and ecosystem response to natural disasters** through long-term monitoring and research, including re-establishing a network of long-term ecological monitoring plots from different ecosystems to boost knowledge and capacity to respond effectively, and funding collaborative research on climate adaptation, biodiversity resilience and recovery, climate extremes and natural disasters.

(ii) PLANNING

There should be no hectare-driven targets for burning in Australia's ecosystems. Although planning to reduce the impact of natural disasters is critical, the focus on hazard reduction burning as the panacea to an increased bushfire risk is misguided. Hazard reduction burning reduces the intensity and spread of bushfires and enhances fire suppression activities only under limited circumstances. Inappropriate fire regimes and hectare-based fuel reduction targets can threaten the existence of plant and animal species and ecosystems, without reducing risks to human populations or built assets. Regional-scale planning that identifies the most suitable mix of post-fire age-classes is necessary to maintain ecological values and to ensure the resilience of ecosystems to fire.

Pre-planning to determine how and when to respond post-disaster is critical. This includes management of ecosystems and native plants and animals. Species and ecosystems can shift from low risk to high risk of extinction very quickly in the advent of large-scale natural disasters. Many decisions made soon after major disasters are done so in a crisis management mode (Lindenmayer et al. 2008a). These are not necessarily optimal, evidence-based decisions, and can undermine previous good management actions. An example is rapid decisions to conduct post-fire (salvage) logging in protected areas. This can have long-lasting negative impacts on ecosystem integrity and on biodiversity, including species listed under the EPBC Act. A better model is for governments to plan their future environmental decision making to natural disasters, well before such events take place.

There are many other strategies that can be employed further to reduce bushfire risk to assets, environment and human life, for example:

1. Incorporating traditional land and fire management practices of Indigenous Australians into future fire management practices, noting that 'one-size-fits-all' is not possible, and approaches will be bespoke for each region of Australia.

2. Addressing widespread human-forced threatening processes that interact with fire, such as invasive species, habitat loss and climate change, through established but underutilised Threat Abatement Plans (Allek et al. 2018).

(iii) RESPONSE

The 2019–2020 fires highlight the need for better information on biodiversity responses to fire, in particular, mega-fires. Many post-fire assessments of the likely impact of these mega-fires on biodiversity were based on 'best guesses' rather than empirical evidence (Legge et al. 2020), as most impacted species had never been monitored in relation to fire impacts. These fires provide an opportunity to closely examine species' responses to landscape-scale fires that are projected to become more frequent. Post-fire monitoring of environmental response to natural disasters is critical to fill knowledge gaps and ensure post-fire recovery actions are efficient and effective at restoring impacted species and ecosystems. The range of species recovery actions required is broad and informed by each species' response to fire and the suite of threatening processes that affect it. Such actions include invasive species control, supplementary feeding, and captive breeding programs. Timely management and monitoring actions implemented in an adaptive framework will have the best chance of 'learning whilst doing', to ensure that subsequent responses to natural disasters are better informed and more effective.

Timely, effective responses to bushfires and other natural disasters requires:

1. **Increased government capacity and resourcing for rapid environmental responses** to natural disasters to monitor and mitigate immediate impacts and subsequent degradation of environmental health. The US architecture for this kind of response could provide a model to follow. Such responses include the capacity to trigger rapid, post-disturbance environmental and biodiversity assessments.
2. **Development of an agency tasked specifically with protecting and managing the environment in the face of disasters, e.g. an Environmental Disaster Risk Agency.** Such an agency would ensure coordinated, well-planned response efforts as well as oversee natural disaster preparedness.

(iv) RECOVERY

Many Australian native species have been historically maintained within a certain fire regime. Altered frequency, severity or timing of extreme events such as wildfire can increase the extinction risk of native species and the intensity and extent of threatening processes such as invasive species. Many species and ecosystems are known to be at risk because of the effects of multiple, interacting disturbances (Didham et al. 2007; Foster et al. 2016). The effects of interactions between disturbances are often not recognised in the listing processes for threatened species, ecological communities or ecosystems. For example, arboreal marsupials in the wet forests of Victoria, including those listed under the EPBC Act are declining rapidly as a function of: (1) repeated fire, (2) logging, (3) an interaction between fire and logging (salvage logging) (see Lindenmayer and Ough 2006) and (4) an interaction between logging and fire (where young logged and regenerated forests are more prone to subsequent high severity fire through an interaction chain) (see Taylor et al. 2014). Effective recovery of Australia's species and ecosystems relies on all the previous points (Preparedness, Planning and Response) having been effectively implemented.

RESPONSES TO TERMS OF REFERENCE A, D, E AND G

TOR A: advice provided to the Federal Government, prior to the bushfires, about the level of bushfire risk this fire season, how and why those risks differed from historical norms, and measures that should be taken to reduce that risk in the future.

Scientist use climate models - simulations that use all available information about what drives our planet's climate - to understand what will happen as Earth warms and predict associated events such as extreme wildfire risk. These climate models are extremely good at modelling certain aspects of the climate, particularly global temperature patterns, but fire is much more complicated. It is affected by many factors, including rainfall, wind, land cover and population density - everything that increases the risk of fire, fuels and spreads it. The issue with the 2019/2020 season was that:

- No existing scientific models predicted the level of bushfire risk that was experienced in Australia during the 2019/2020 fire season, during which fires burnt a globally unprecedented percentage of any continental forest ecosystem (Boer et al. 2020);
- Despite shortcomings of recent fine-scale scientific fire risk models, there had been no shortage of scientific warnings leading up to this scenario. The most compelling can be found in the Garnaut Climate Change Review (Garnaut 2008), a 2008 report to governments which (citing as its key source a publication from 2007 – Lucas et al. 2007) predicted that the effect of longer and more intense fire seasons 'should be directly observable by 2020';
- Fire risk was greater than predicted by models because of extreme drought and record high temperatures in the preceding year (Sanderson and Fisher 2020);
- Human-forced climate change is the most likely cause of the prolonged drought and extreme weather conditions that led to the 2019/2020 wildfire season (Phillips and Nogrady 2020, Sanderson and Fisher 2020); and
- Australia's historical and contemporary logging regimes have made many Australian forests more fire prone and contributed to increased fire severity (Taylor et al. 2014) and flammability (Zylstra et al. 2018).

TOR D: the adequacy of the Federal Government's existing measures and policies to reduce future bushfire risk, including in relation to assessing, mitigating and adapting to expected climate change impacts, land use planning and management, hazard reduction, Indigenous fire practices, support for firefighters and other disaster mitigation measures.

The extreme 2019/2020 fire season was made at least 30% more likely because of climate change (Thompson 2020). Indicators are that prolonged drought, linked to climate change, has increased the flammability of the parts of the landscape we could previously rely on being damp enough to slow down/extinguish past bushfires (Nolan et al. 2020). Existing measures and policies to reduce future bushfire risk will be inadequate until they incorporate effective actions in response to climate change at all levels of Government.
There is an urgent need for governments and the disaster-response systems they have in place to take the rising risks of climate change and associated changes to fire behaviour in Australia into account. Current Australian policy fails to effectively reduce Australia's emissions to a point that might stave off the worst of these changes. Furthermore, Australia's largely local and volunteer bushfire-fighting force will require greatly improved investment and support in order to deal with the extent and ferocity of future fire seasons under the new norm of bigger, hotter fires.

Climate change measures and policies
Current Federal Government policies on climate change mitigation and adaptation are inadequate for avoiding the impacts of worsening heat and fire extremes for Australia. The 2019-20 bushfire season occurred in the context of global average warming of 1 degree Celsius, with current international emission reduction pledges projected to result in over 3 degrees Celsius of climate change. First, greenhouse gas emissions must be reduced significantly and rapidly to reduce the severity of climate change impacts. A goal of zero emissions is necessary. Second, Australia must prepare for longer, more severe fire seasons occurring over larger spatial areas.

Current Federal Government measures and actions to assess and adapt to bushfire risk and associated climate change impacts on biodiversity are also inadequate. While some species and locations are monitored sufficiently, most are not (Scheele et al. 2019). Additional resources are required to support on-ground monitoring that helps quantify fire impacts on species and ecosystems. Such monitoring is also critical for informing biodiversity recovery planning and management decisions such as identifying priority areas for post-fire recovery efforts. However, monitoring is currently not a legislative requirement under the EPBC Act. The best way to quantify environmental responses to repeated natural disasters is through long-term monitoring. The importance of long-term data is particularly important in the context of natural disasters because it is often the sequence of disturbances over time (e.g. as part of the fire regime [sensu (Keeley 2009)]) that have the most profound effects on species. For example, long-term fire history (such as the number of past fires) is a significant driver of overall bird species richness in Booderee National Park in the Jervis Bay Territory (Lindenmayer et al. 2008b). Investing in long-term ecological monitoring is a critical step to boosting knowledge and capacity to respond effectively.

Additionally, increased investment into climate change adaptation research is needed to understand the responses of species, ecological and ecosystems to natural disasters and interacting anthropogenic threats (e.g. invasive species). The range of species recovery actions required is broad and informed by each species' and ecosystem's sensitivity to fire and the suite of threatening processes that affect it (Victoria State Government 2020). Such actions include invasive species control, supplementary feeding, captive breeding programs, species translocations and reintroductions (e.g. Smales et al. 2000, Tulloch and Dickman 2007). Monitoring and research will inform assessments of the areas to be prioritised for long-term conservation action, including protecting unburnt refuges and large intact areas of forests or streams, and where needed, restoration of habitats (Legge et al. 2011).

Hazard reduction and land use management

Significant focus is required on the role of fuels on private land, something critically ignored in the 2009 Victorian Bushfires Royal Commission. Bushfires do not respect tenure boundaries and nor should a risk-based consideration of community and environmental protection. It is important that fuel reduction activities recognise the multiple players in land management, and that the government alone should not be solely responsible for risk treatments.

Bushfires such as the Black Saturday fires (Victoria, February 2009) have been extensively dissected by a previous Royal Commission and its recommendations provide much context for interpreting the recent Black Summer fires, and how one might respond to them. Recommendations from the Black Saturday Royal Commission relevant to the current fire season's events include:

1. Broad hectare targets for hazard reduction burning were recommended following the Black Saturday fires (e.g. 5% of Crown Land in Victoria should be burnt each year). Hectare targets were subsequently found to be "unachievable, affordable or sustainable" and "ineffective in achieving the primary intent of the Bushfires Royal Commission recommendations to ensure the protection of human life and community safety" (Bushfire Royal Commission Independent Monitor 2013).
2. The state-wide hectare target recommended for Victoria created a perverse incentive for land management and fire agencies to treat large areas in remote locations (that represented a low risk to life and property), rather than smaller, more costly and difficult burns in places where they would provide better protection of human assets (Handmer and Keating 2015). Furthermore, "hectares treated objective puts a significant constraint on the capacity for communities and stakeholders to have their views genuinely incorporated into decision-making because the directive to burn a certain number of hectares overrides all other considerations. Hence there is a disincentive to genuinely engage communities and stakeholders" (Handmer and Keating 2015).
3. A primary cause of failure to achieve hazard reduction targets has been the brief and shrinking fire-weather window in which agencies can safely conduct hazard reduction burning, without causing 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 (Kinsella and Jackson 2020), that failure to achieve hazard reduction hectare targets is due to being constrained by an ever-decreasing window of opportunity in which to safely conduct burning.

TOR E: best practice funding models and policy measures to reduce future bushfire risk, both within Australia and internationally.

Policy measures to reduce future bushfire risk require responses not only to climate change but also to historic and current land management. It is important that policy makers acknowledge that climate change affects fire weather and is making fires worse across Australia (Jones et al. 2020, Lindenmayer et al. 2020). Policy makers must additionally recognise that land management such as logging operations also has profound effects on fire severity, fire frequency and other key aspects of fire regimes (Lindenmayer et al. 2020).

Policy measures should focus more on long-term preparedness and mitigation of wildfire impacts than on short-term disaster risk management. Long-term mitigation of bushfire risk can only be achieved with strong policy reform and clear emissions reductions targets that will reduce long term predictions of climate change, drought and associated fire risk.

In addition to policy reform, funding reforms are required for research bodies responsible for filling key knowledge gaps in bushfire risk and management. Centres responsible for building the scientific evidence base (the Australian Research Council's Centre of Excellence for Climate Extremes and the Bushfire and Natural Hazards CRC) are funded through short term funding models, which leaves us vulnerable to critical knowledge gaps. Increasing investment into fire research preparedness and planning research, and specifically investing in continual funding streams for such research, should realise considerable benefits in relation to:

- greater consistency of natural disaster assessment processes and outcomes, because data from other like cases can be more readily drawn upon to inform decisions on future disasters;
- cost savings for businesses engaged in disaster forecasting and management, as well as for the Australian Government, as administering preparation and review of material becomes faster and easier;
- accountability for disaster risk management decisions, and;
- improved outcomes for species and ecosystems impacted by natural disaster through enabling improved collaboration between science and government, adaptive learning and management (Hauser et al. 2019). Such processes would be enhanced through the development of an agency tasked specifically with protecting and managing biodiversity in the face of disasters, e.g. an Environmental Disaster Risk Agency.

To improve Australia's preparation for and management of natural disasters, we recommend the following policy measures:

1. **Development of an agency tasked specifically with protecting and managing the environment in the face of disasters, e.g. an Environmental Disaster Risk Agency.**

   Such an agency would ensure coordinated, well-planned response efforts as well as ensure natural disaster preparedness.

2. **Development of national environmental standards for monitoring and evaluating environmental change and biodiversity recovery actions, and adequate resourcing for such monitoring.**

   Effective monitoring is a critical part of improving resilience, adapting to change and predicting future risk. To inform effective mitigation of natural disasters, Australia must develop national environmental standards for monitoring and evaluation of environmental change and recovery actions, which enable data to be incorporated into national datasets in a timely fashion, and allow data to be made publicly discoverable, accessible and reusable (Tulloch et al. 2018). National standards will increase data interoperability and ensure that different jurisdictions deliver and assess natural disaster risk management, preparedness, resilience and recovery activities efficiently and effectively. Australia does not have reliable, comprehensive and publicly available environmental information systems to map, monitor, forecast and report on environmental conditions and disaster risk (Lindenmayer et al. 2015, 2017, Sparrow et al. 2019). Much of Australia's ecological monitoring data exists in institutional silos, and monitoring is done using disparate methods that are not standardised across space or time (Scheele et al. 2019). This means that there is no comprehensive database of Australian environment responses to fire that could assist governments and practitioners in managing Australia's ecosystems with regards to wildfire and prescribed fire.

   Improved data collection and access not only requires the development of clear, science-based national standards, but also necessitates adequate resourcing to collect and collate monitoring data against these standards using common assessment methods. All prescribed burning should be accompanied by monitoring and research, ideally in an adaptive management framework (e.g. Hauser et al. 2019) that enables learning while doing, and particularly when EPBC-listed species and ecological communities might be impacted.

3. **Long-term investment in research on climate adaptation, environmental resilience and natural hazards**

   There is a critical gap in investment in research about reducing future impacts and risks of extreme events related to climate change, including bushfires and floods. Collaborative research centres including the Australian Research Council's Centre of Excellence for Climate Extremes and the Bushfire and Natural Hazards CRC provide the critical scientific evidence base for preparing for extreme events such as bushfires. Yet such centres are funded through short-term funding models, which leaves us vulnerable to critical knowledge gaps. A sustainable long-term investment model for research on climate adaptation, environmental resilience and natural hazards is required.

4. **Investment into forecasting research and applications that can provide near-term and seasonal predictions of how disaster risk is likely to impact society, economy and biodiversity.**

Improved monitoring data and data-sharing infrastructure are critical for producing near-term and seasonal forecasts of the likely impacts of natural disasters on society, the economy and biodiversity (Tulloch et al. submitted). Near-term (within 6 months of the prediction) forecasts enable efficient operationalisation of limited resources to the places and activities that would most benefit from actions (e.g. hazard reduction burning, biodiversity conservation management) *before* a disaster occurs.

Scientific models predict that rising temperatures into the future, linked to global carbon emissions, will result in more fire-prone conditions (Kirchmeier-Young et al. 2017). Investment into development of more robust Earth and climate system models that explicitly account for this is urgently needed to ensure that, in future seasons, fire risk is not underestimated (Sanderson and Fisher 2020).

5. **Investment into research on alternative environmental management options that complement hazard reduction burning which has limited effectiveness at reducing bushfire risk and protecting biodiversity.**

The three key management actions that can be carried out prior to the outbreak of a fire are:

1. Preventing fire ignition.

Although hazard reduction burning is carried out to achieve this across all jurisdictions, the scientific evidence points to it having limited effectiveness at reducing the risk and spread of wildfire. Other actions to prevent fire ignition include:

- Stronger climate change policy that reduces emissions and associated increased risk of extreme weather events such as drought and heatwaves (see response to TOR D)
- Addressing widespread human-forced threatening processes that interact with fire, such as invasive species, habitat loss and climate change, through established but underutilised Threat Abatement Plans (Allek et al. 2018) and increased investment into threat management actions. Altering fire frequency, severity or timing through prescribed burning can increase the extinction risk of native species and the intensity and extent of threatening processes such as invasive species. Frequent burning can also encourage growth of highly flammable invasive weeds (e.g. Hobbs and Atkins 1990) and may also increase invasion of habitats by introduced predators such as cats and foxes. Restoring habitats by reducing fire frequency and weed invasion is likely to reduce flammability and the risk of future wildfire events (Legge et al. 2020).

2. Reducing the intensity of bushfires by reducing combustible fuel before fires start.
Incorporating traditional land and fire management practices of Indigenous Australians into future fire management practices is key for this approach, noting that 'one-size-fits-all' is not possible, and approaches will be bespoke for each region of Australia.

3. Improving measures taken to protect life and assets in built areas by making communities more resilient to fire.

Management of fuel in close proximity to the asset, as opposed to fuel management on the bushland side of the interface, is often a far more effective strategy to achieve fire protection to a particular asset. Clearing the vegetation within 40m of the asset is more likely to reduce risk of the asset being burnt by wildfire, and reduces the risk of hazard reduction burning escaping from the immediate area and creating a wildfire as has occurred in the past.

Management of biodiversity in high-risk fire areas or areas where regular hazard reduction activities must take place (e.g. near infrastructure) will ensure that ecological communities also maintain resilience. For native species at risk from wildfires, this may require species translocations from high risk to lower risk locations (Victoria State Government 2020, Legge et al. 2020).

TOR G: the role and process of advising Government and the federal Parliament of scientific advice.

Greater scientific oversight of bushfire planning and response is required at all levels of government. The processes of assessing, mitigating and adapting to climate change impacts, land-use planning and management, and disaster mitigation must remain focused on rigorous scientific assessment, with decisions clearly grounded in available scientific evidence. Our scientific understanding about bushfire impacts and planning has evolved considerably over time, and any planning should now consider the wealth of scientific knowledge on the impacts of land-use management actions such as prescribed burning on the health of the environment and society. Australia is a world-leader in ecological research including the impacts of large fire events on the environment. Some of the advances in scientific knowledge are outlined in the response to TOR D, and include research on fire in relation to connectivity, climate change, disaster resilience and threatened biodiversity. It is imperative that Australia implement mechanisms to routinely use Australia's world-leading ecological science to develop evidence-based policies and decisions about Australia's environment.

Biodiversity issues are interconnected with human health and economic impacts of bushfires and should not be seen in isolation. Targeted and interdisciplinary research is required to better understand and predict the impacts of natural disasters, and to offer a scientific basis for the response. Collaborative research funded through long-term models is integral to bringing together expertise in natural disaster and climate change adaptation and resilience and for providing advice to government. Similarly, an agency tasked specifically with protecting and managing biodiversity in the face of disasters, e.g. an Environmental Disaster Risk Agency is needed to support ongoing recovery efforts and to prepare for future events. As well as developing stronger mechanisms for science to inform policy and planning, governments must develop mechanisms for increased representation of Indigenous communities in ecosystem policy and management decisions.

FOR FURTHER INFORMATION

The ESA welcomes the opportunity to provide further information to this Parliamentary Inquiry or to discuss our submission in more detail. We may be contacted using the details below:

Submission prepared on behalf of the ESA by its Policy Working Group and approved by the Vice-President (Public Policy and Outreach) and President, 22 May 2020.

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APPENDICES

The following excerpts are from ESA submissions to previous relevant public inquiries and are provided for your reference.

ESA'S RESPONSE TO THE ROYAL COMMISSION INTO NATIONAL NATURAL DISASTER ARRANGEMENTS 2020

TOR F i) land management, including hazard reduction measures

Current policy measures across States and Territories to reduce bushfire risk focus on hazard reduction burning. The latest science underpinning estimates of the efficacy of hazard reduction burning indicates:

1. *Hazard reduction burning can only reduce the intensity and spread of bushfires, and aid suppression activities, in limited circumstances*
   The primary value of hazard reduction burning is generally accepted as a tool to assist in fire control when fire weather conditions are moderate to benign, but not in catastrophic weather conditions seen in the 2019/20 fire season (e.g. Boer et al. 2009, McGaw 2013). Indeed, the links between fuel loads and rate of spread of bushfires are not always evident. Burrows (1999), for example, meticulously conducted replicated fire experiments in jarrah forest fuels in Western Australia and found no relationship between fuel load and rate of spread. These findings have been supported by later studies (e.g. Cheney et al. 2012; Zylstra et al. 2016).

2. *Its effectiveness in altering fire behaviour is greatest in approximately the first 6 years after burning in many forest types and can diminish significantly after that.*
   The capacity for hazard reduction burning to reduce fuels to have a measurable impact on fire behaviour is limited to the immediate period (i.e. ~6 years) following treatment (e.g. Fernandes and Botelho 2003, Cary et al. 2009; Bradstock et al. 2010; AFAC 2015; Penman and Cirulis 2019). This minimal efficacy of recent hazard reduction burning in mitigating spread has been apparent in the wildfires of the past season. The Gospers Mountain fire in the Wollemi National Park, which appears to be the largest Australian forest fire resulting from a single ignition, was ignited and grew to a very large fire burning in 6-yr-old fuels (Philip Zylstra, *unpublished data*). This is not unusual.

3. *It is most effective when targeted strategically within 500 m of the asset to be protected, and may be ineffective if, after conducted, vegetation is retained within 40 m of the asset.*
   Fuel reduction through mechanical means (e.g. clearing of native and exotic vegetation) close to houses (within 40 m) was more effective at reducing their loss in the Black Saturday fires than undertaking hazard reduction burning distant from the house (Gibbons et al. 2012). This study concluded that the levels of fuel reduction required to reduce house losses are unlikely to be feasible at every house for logistical and environmental reasons. Because of this, infrastructure protection is not guaranteed by hazard reduction burning. Infrastructure is more likely to be saved from wildfire where trees and shrubs have been thinned or removed to a distance of 30-40 m, the grass is mown and the

garden kept green. “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” (Gibbons et al. 2012).
Penman et al. (2014) found that planned burning at the interface between assets and the forest was the most cost effective means of reducing risk to those assets. Florec et al. (2019) found that planned burning close to assets in the urban interface in WA was more effective at reducing damage (i.e. loss of houses) than burning in the more distant landscape. Local-scale solutions are necessary to design effective prescribed burning to protect assets in local communities.
In Tasmania, in relation to using prescribed burning to protect ecological assets, King et al. (2006) found that burning 3% of buttongrass moorland in a strategic configuration was likely to reduce the area of fire-sensitive alpine vegetation burnt annually by the same amount as burning ≥ 10% of moorland in a random pattern.
Thus, a key issue relating to prescribed burning is that it is not necessarily the amount of burning that reduces risk, but where it is applied. We support an approach based on applying planned burning where it is demonstrated that it will have greatest benefit in reducing risk to life, property and ecological assets. We do not support hectare-driven targets for burning in Australia’s ecosystems.

4. *Its effectiveness is lowest on days of extreme fire weather when most loss of life and property occurs, but it can assist suppression efforts on more benign days.*
   The value of hazard reduction burning is primarily to assist with the suppression of fire under moderate to benign fire weather conditions. Wildfires on severe or extreme weather days, however, account for the vast majority of area burnt, property losses and fatalities. Shane Fitzsimmons (NSW RFS Commissioner) noted that the ability of hazard reduction burning to aid in fire suppression efforts during such extreme conditions is negligible (Hayman 2020). This is supported by scientific evidence. Bradstock (2008) concluded 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……” Moritz et al. (2004) suggest that during extreme fire weather “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”.

5. *It is infeasible in landscapes dominated by improved pasture or crops.*
   Bushfires have been shown to burn through farmland dominated by pasture or crops, as occurred in 2015 near Gawler in South Australia where 91 houses were destroyed, and was also seen in Buchan, Victoria on New Year’s Eve 2019 where 1/3 of houses in the rural town were destroyed. The extent of burning required to reduce risk of wildfire makes hazard reduction burning infeasible in landscapes reliant on crops and pasture as their dominant income (Gill 2005). In agricultural lands, grazing or ploughing in paddocks offers an alternative way of reducing overall fuel loads, especially in relation to pasture grasses

(Gill et al. 2013). In agricultural landscapes, native vegetation is rare, often less than 10% of the land area, so is particularly valuable, while also being difficult to manage fire within. In contrast, ploughing and grazing paddocks is routine, and ploughing on farmland can achieve total fuel reduction and is closer to the assets that people want to protect from fire.

6. *Hazard-reduction burning can have both positive and negative effects on natural ecosystems, but negative effects will be substantial if fire return intervals are short enough to have some effect on unplanned fire.*
   Plant and animal communities in Australia have evolved with fire regimes of different fire severity, frequency, extent and season. Fire can be necessary for the maintenance of some native vegetation communities (e.g. coastal heathlands, temperate grasslands), but can also cause the destruction of others (e.g. alpine peatlands). It is dangerously naive to claim that all Australian bush needs fire or has uniformly evolved to cope with fire. There are examples where too frequent, too intense or too extensive fires have contributed to the local extinction of native species (e.g. Bowman et al. 2014). Indeed, generalisations like “Most of Australia was burnt about every 1-5 years depending on local conditions and purposes” (Gammage 2011) are not accurate and are **not** supported by science (Murphy et al. 2013).
   Repeated burning every six years could reduce some unplanned fire in some ecosystems, but this frequency of burning will have substantial ecological costs. For example, out of 20 broad ecosystem types in South Australia, five had minimum recommended fire interval of less than 6 years, and all of these were grassy ecosystems. Most ecosystems have a minimum threshold of 15-20 yrs between fires to prevent species losses. In NSW, minimum fire interval guidelines (Table 3A in Fire Management Guidelines 2004) suggest complete fire exclusion from rainforest and alpine ecosystems, and a minimum interval of 25 yrs for wet sclerophyll forest, with other eucalypt forests having minimum return intervals of 5-7 yrs. **It is not a reasonable trade-off to burn so frequently that there are major biodiversity losses in return for only very marginal, if any, benefit in asset protection during extreme weather conditions.**

7. *Hazard reduction burning is just one method of reducing risk to life and property. Other strategies may offer a better return on investment, when it comes to reducing risk.*
   Investment in early warning mobile phone Apps and educating the public to ‘leave early‘ appears to have contributed to a remarkable drop in fatalities associated with this season’s fires (34 in 2020), compared to 173 deaths on Black Saturday, despite over 13 M ha burnt this season compared to 450,000 ha in 2009. “People are unlikely to activate their plans without warnings or with insufficient time” (Handmer et al. 2019).

TOR F ii) wildlife management and species conservation, including biodiversity, habitat protection and restoration;

1. *Frequent low intensity burns such as hazard reduction burning alters the composition of ecological communities.*

Plant and animal species have been eliminated from local areas due to frequent burning (Tolhurst 1996), whether that be by wildfire or prescribed burning (or both). Frequent low intensity burning alters the composition of the understorey plant species in dry sclerophyll forests and in Banksia woodlands (e.g. Hobbs and Atkins 1990). Such regimes can have significant effects on the survival of some species and may lead to local extinction (Tran and Wild 2000). Studies have predicted high risk of extinction of species - such as shrubs that can only regenerate from seed - under typical hazard reduction burning levels (Bradstock et al. 1998; McCarthy et al. 2001) if burning occurs too frequently to enable plants to mature and set seed. In addition, some plant species can only regenerate following a high intensity fire, not the low intensity burns frequently used in hazard reduction.

In many landscapes, wildfires alone are the optimal management policy for biodiversity where objectives are to maximise species richness and abundance, and to minimise extinction. This is because most species are more likely to occur in vegetation that has not been burnt for a long time than in vegetation that has been burnt more recently (e.g. Connell et al. 2017). Giljohann et al. (2015) showed that a policy to annually burn just 5% of a landscape in semi-arid Australia could increase the average probability of extinction for birds, reptiles and small mammals by 7% over 100 yrs compared to the optimal management scenario of only allowing wildfires to burn.

Altering fire frequency, severity or timing through prescribed burning can increase the extinction risk of native species and the intensity and extent of threatening processes such as invasive species. Frequent burning can also encourage growth of highly flammable invasive weeds (e.g. Hobbs and Atkins 1990) and may also increase invasion of habitats by introduced predators such as cats and foxes.

2. *Frequent prescribed burning adversely affects fauna species that require dense undergrowth, coarse woody debris and/or leaf litter.*

   Frequent prescribed burning has the potential to incinerate critical resources (e.g. hollow logs, hollow-bearing old trees, large clumps of spinifex) 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).

   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, Pilot-bird) (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. 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 yrs, 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 yrs between fires to reach maximum maturity and flower production (Tulloch et al. 2016, Wilson et al. 2014), and honey possums require more than 20 yrs between fires to recover to pre-fire catch rates and densities (Bradshaw and Bradshaw 2017).

3. *Prescribed burning may be required for conservation purposes to maintain populations of some threatened species that are adapted to frequent fire.*
   Where prescribed burning occurs, it will favour species that require a relatively open understorey. In sites with a long-history of such frequent burning (e.g. due to indigenous fire management), some species may be dependent on such habitat being maintained. Such species include the nationally-listed Critically Endangered northern subspecies of the Eastern Bristlebird, of which only 40 remain. Stone et al. (2018) found that "use of appropriate fire to maintain large contiguous patches with a thick, tall grassy ground layer will be critical for the continued persistence and successful reintroduction of the northern Eastern Bristlebird." It should be noted that a true "ecological burn", as needed to maintain specific components of the habitat for the Critically Endangered northern subspecies of the Eastern Bristlebird, should not be equated with a hazard reduction burn which focuses only on total reduction of fuel and undergrowth to reduce fire risk.

4. *Prescribed burning may be required for conservation purposes to protect populations of some threatened species not adapted to frequent fire*
   Targeted prescribed burning may be necessary in strategic locations to protect important ecological assets and populations of threatened species from frequent fire. The planning for such strategic burning requires detailed knowledge of the location of these key assets, their vulnerability to bushfire, and the effectiveness of preventative burning in reducing risk under various wildfire conditions. Other solutions may be easier to implement and should be considered as alternatives in some circumstances. For example, sprinkler systems have successfully protected ancient Wollemi Pines in New South Wales (Morton 2020) and Pencil Pines in Tasmania (Blackwood 2019) from recent wildfires, with only a minimal investment in infrastructure.

5. *Where frequent burning is necessary and unavoidable, the needs of vulnerable species should be addressed through proactive conservation approaches and monitoring.*
   We highlight the need for regional-scale planning that identifies 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 recognises.

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):

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

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

Indigenous communities have different reasons for burning the bush and it should be recognised that fire was not primarily for hazard reduction. Rather, the rationale for burning of the bush included (a) to promote the production of critical resources (e.g. plants and animals for food), (b) to enable ease of travel through dense bush and (c) for ceremonial reasons.

Indigenous communities did not burn everywhere and large tracts of land were intentionally not burnt (e.g. Prober et al. 2016). Indigenous burning was usually small in its scale of application and characterised by its "selectivity rather than it's ubiquity" (Prober et al. 2016). Their nuanced, sensitive and targeted application of fire in the landscape to achieve particular objectives has much to commend it.

"Traditional land and fire management practices of Indigenous Australians" could be incorporated into future fire management practices, but this needs to be nuanced for each region of Australia, especially given the significant cultural, ecological and historical differences that exist between northern Australian Aboriginal Clans and those of south-eastern Australia. Cultural burning practices differ from region to region; they are place-based, steeped in deep local knowledge. Therefore, practices that work well in the savannahs of northern Australia may be totally inappropriate in the tall forests of south-east Australia. One indigenous burning regime does not fit all landscapes of Australia.

It is necessary that a clear separation is needed between the cultural and social benefits of reviving or using traditional practices, and the instrumental and environmental benefits that may be derived from burning. It should not be assumed that in today's landscape context - with 25 million humans settled across much of the landscape, serviced by networks of infrastructure like roads and powerlines, where fuel layers have changed with the introduction of flammable weed species like Buffel Grass, and under a climate regime that is rapidly becoming more fire-prone and unpredictable - that these are one and the same.

The ability to acknowledge Indigenous methods of land management on the Indigenous Land estate (e.g. Indigenous Protected Areas), joint-managed estate, as well as other public and private estate is possible and will encourage greater cross-jurisdictional collaboration and awareness of traditional land and fire management practices. Inclusion of Indigenous Australians and Indigenous Bio-cultural Knowledge (IBCK) should involve Indigenous people in leadership positions as well as knowledge-sharing between Indigenous owners of Country and non-Indigenous participants (Ens et al. 2016). The Akwe Kon Guidelines (2004) provide important guidance in successful implementation of Indigenous land management. One example of incorporation of appropriate use of Indigenous land management practices is the 'Hotspots' fire & biodiversity program developed by the NSW Nature Conservation Council in collaboration with NSW Rural Fire Services, and another is the reintroduction of 'cultural burning' and carbon emission abatement programs in northern Australia.

Recognition of the Indigenous voice will require:

- Greater acknowledgement of Indigenous Bio-cultural Knowledge (IBCK) and the role it currently plays in land management, especially on the Indigenous Land estate.
- Indigenous consultation, acknowledgement and involvement with fire management planning and delivery, ensuring 'free, prior and informed' consent.

Investment in Indigenous land management is smart not only from an environmental perspective but also from an economic perspective. Analyses of the Social Return on Investment of the Indigenous Protected Area (IPA) and Working on Country (WoC) programs show that these are delivering around three-fold investment returns (Social Ventures Australia 2016). A targeted review into how the land and fire management practices can better reflect Indigenous people, knowledge and country is a necessary step towards achieving this goal (Ens et al. 2012, 2015).