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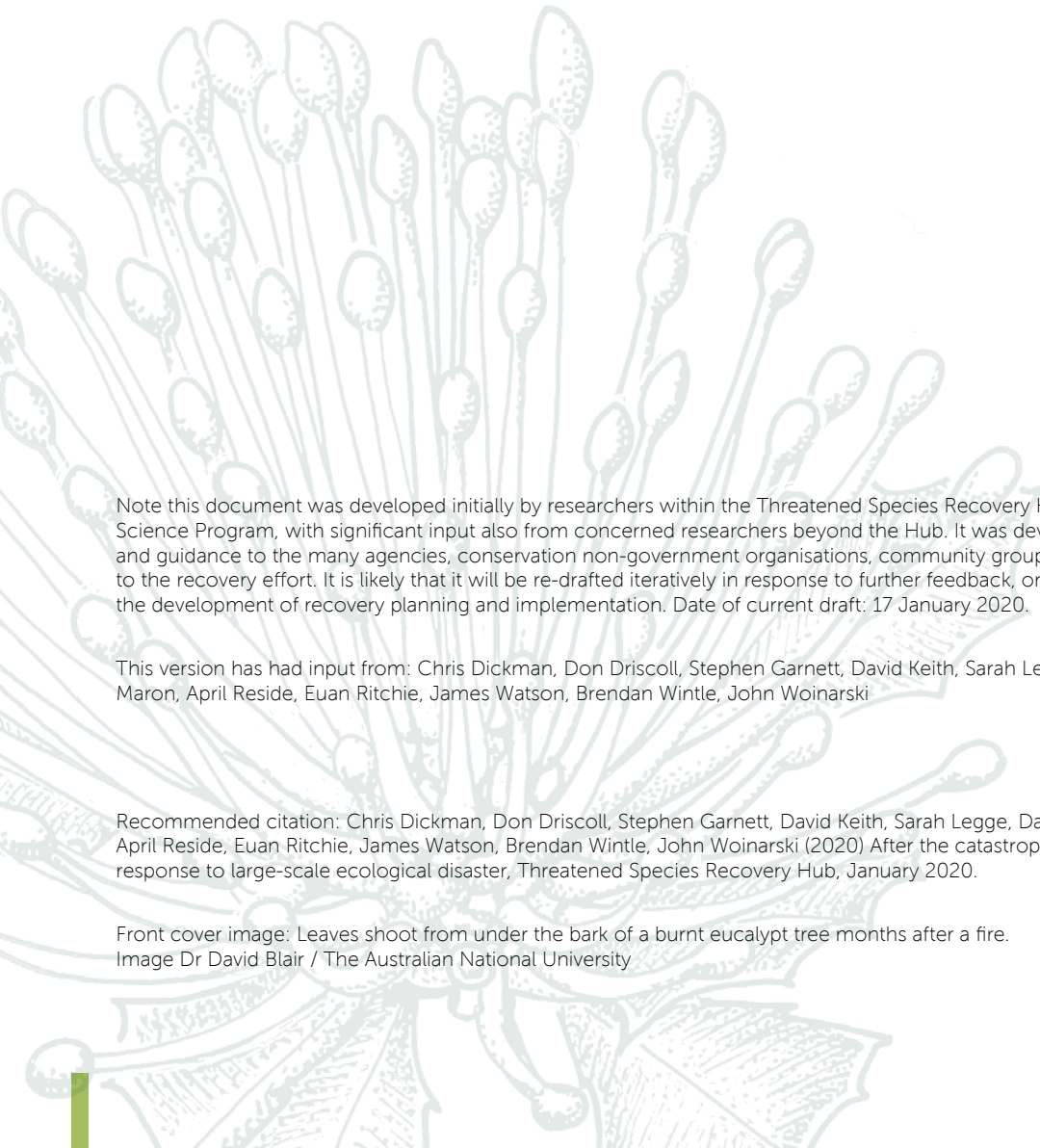
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After the catastrophe: a blueprint for a conservation response to large-scale ecological disaster

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Note this document was developed initially by researchers within the Threatened Species Recovery Hub of the National Environmental Science Program, with significant input also from concerned researchers beyond the Hub. It was developed to provide some context and guidance to the many agencies, conservation non-government organisations, community groups and others wanting to contribute to the recovery effort. It is likely that it will be re-drafted iteratively in response to further feedback, or in response to further impacts or to the development of recovery planning and implementation. Date of current draft: 17 January 2020.

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Front cover image: Leaves shoot from under the bark of a burnt eucalypt tree months after a fire.
Image Dr David Blair / The Australian National University

After the catastrophe: a blueprint for a conservation response to large-scale ecological disaster

Bad things happen. Sometimes they happen suddenly, at enormous scale, and without comparable precedent. The chain of wildfires afflicting Australia in 2019-20, and continuing, is such an example. With escalating global climate change, such large-scale ecological catastrophes are likely to become more widespread and frequent. Here, we describe a blueprint for conservation responses to these wildfires, to document the challenge and attempted solutions to this particular event and as a potential template for dealing with comparable future events.

The purpose of this document is to frame a comprehensive set of linked responses to large-scale impacts for conservation across immediate to longer time frames, in order to best achieve the recovery of affected species, ecosystems and ecological health. It is not an attempt to assess the conservation consequences of this chain of fires, or to investigate the causes of the fires. Such assessments will be conducted by others in due course.

Although consistent with general predictions from climate change models, and presaged (and catalysed) by extensive drought that affected much of Australia for several years, the pace and magnitude of these wildfires shocked Australian communities, fire ecologists and conservation biologists. Between September 2019 and January 2020, the wildfires burnt at least 10 m hectares in largely uncontrollable fires across all six Australian states. These wildfires occurred not only in mainland areas but also on a large island of outstanding conservation significance (Kangaroo Island). At the time of writing (January 2020), the fires are continuing.

The wildfires were beyond anything anticipated in conservation planning and management for Australian biodiversity. Fires of such scale had not been factored into recovery plans for threatened species. Fires burnt through much of the conservation reserve network – the bulwark of conservation in Australia – in eastern and south-western Australia and Kangaroo Island. In many cases, the recent recovery or stabilisation of threatened species hard won from the dedicated and strategic conservation efforts of many government agencies, conservation NGOs and researchers over many decades was subverted in a matter of weeks. Because there was no comparable precedent, and the fire event was beyond any anticipated range, there was no established plan for a systematic conservation response, to identify and act on immediate priorities and to embed longer-term recovery. In part, this lack of clear direction is because coordination of responses is complex in Australia, where responsibilities for nature conservation are shared between Commonwealth and state/territory governments, and many conservation non-government organisations and community groups have significant roles and interests. Moreover, key knowledge and expertise to support recovery is dispersed across agencies, universities and civil society.

Here, we describe what was done, what could have been done, and what still needs to be done. Given this combination of actions that have been conducted, are being conducted and should in the future be conducted, the descriptions of actions in this document are not in consistent tense. The set of responses, and connections among them, is summarised schematically in Figure 1 (page 13) and individual components are described briefly below, in approximate temporal order. For each component we provide a general objective and some specific detail on how that objective is being or could be addressed. A summary of priority actions is given in Table 1 (pages 14-16). Note that the set of actions is based on animal welfare concerns and conservation needs, but the former are important mostly as short-term rescue operations.

The challenge of environmental recovery is substantial and complex, and recovery can be interpreted in many ways. To make the task as tractable and well directed as possible, considered and explicit target setting, at short-, medium- and long-term intervals, and across varying spatial scales, is desirable, with monitoring reporting regularly on progress towards those targets.

We characterise this set of wildfires as a catastrophe, but we note also that impacts depend heavily on context. The impacts (and extent of recovery) will be influenced by how long drought persists at any site into the recovery period. The severity and duration of impact and capability to recover depends also on the antecedent history of fire, which varies from place to place. Where the current fires add to a succession of wildfires or controlled fires at the same sites, negative impacts on nature will be greatly amplified. Furthermore, impact and response also depends on the characteristic of species themselves (Woinarski and Recher 1997) and the way that individual species interact with others. Many plant species have strong evolutionary traits enabling them to persist through, or even exploit intense summer fires, or else recover rapidly from them (Miller *et al.* 2019). Others do not. Moreover, big events such as this produce a rush of resources that some species exploit, sometimes to the detriment of others.

Finally, although much is known about responses of Australian biodiversity to wildfire, there remain major knowledge gaps (Driscoll *et al.* 2010b), and previously described responses may not adequately inform responses to fires of the magnitude experienced in 2019-20.

0. Acting during the catastrophe

Objective: *Attempt to minimise biodiversity losses during the catastrophe, through including key biodiversity sites as assets for respondents to protect, and to use control mechanisms that have least detrimental impacts on biodiversity.*

In many cases, the 2019-20 wildfires were uncontrollable, or control efforts were focused on attempts to save human lives or infrastructure. But knowledge of the location of critical biodiversity features can be used to help guide fire-fighting priorities. In the urgency of responsive action, such features may have been given secondary importance, but there is merit nonetheless in providing to fire authorities locational information about significant biodiversity features such that they can be factored into decision-making as assets to protect where possible – although in the circumstances of the 2019-20 fires, resources were typically too thin to allow such biodiversity values to be protected. In cases where time permits, it may be possible to capture individuals of key threatened species before fire reaches them, but this obviously poses significant occupational health and safety concerns.

Mechanisms used to control fire, such as aerial application of retardants, bulldozing of firebreaks and backburning may themselves have detrimental impacts on biodiversity values (Bell *et al.* 2005), particularly aquatic systems. Fire control operations should take these trade-offs into account when deciding on the most appropriate control actions for a particular place; slight compromise in fire-control efficiency may be more than compensated by reduced long-term environmental damage (Driscoll *et al.* 2010a).

1. Rescue of injured wildlife and short-term provision of food and water

Objective: *Wherever possible, care for individual animals injured in the wildfire, prioritising native species most threatened with extinction by the fire, as these animals may help build populations post-fire; apply best-practice guidelines for care and release.*

Wildlife carers and refuges have been overwhelmed by a huge and rapid influx of injured wildlife over the course of the 2019-20 wildfires. Apart from immediate animal welfare benefits, saving such animals may contribute to longer-term conservation opportunities and outcomes, as rescued animals may well provide the sources needed to re-establish populations in burnt areas when vegetation regrowth allows for habitats to become suitable again. This conservation benefit is particularly so for threatened species, and as such, these species may need to be prioritised in rescue and subsequent care operations. In part because many shelters themselves were burnt in fires, demand has quickly exceeded capacity and urgent additional resourcing has been required. Welfare concerns also extend to the need to euthanise those suffering animals with little hope of recovery.

There has also been a large number of potential volunteers willing to help but who could not be trained and deployed in time and with the resources available for coordination. Indeed, in many places, there was limited coordination among wildlife shelters and governments prior to the fires, and often no well-established best practice guidelines: these characteristics constrained the capability of rapid and effective response of the shelter system to sudden need.

Rapid rescue actions were also hindered by limited resources to open roads after the fires, and by regulations that prohibit public access to recently burned areas. Entering burned areas comes with some risk, so appropriate training and risk management needs to be developed, and risks to rescuers need to be evaluated in the context of the urgency and conservation importance of threatened species rescue.

There are welfare concerns, and conservation implications, also for animals still present in burnt areas, because most food resources have been destroyed. In some cases, the likely doom of these individuals may be averted through provision of food, although such action is obviously impractical at large scales. As an example, in the current wildfire event, food (and sometimes water) has been provided to highly localised populations of the threatened brush-tailed rock-wallaby where the area of these colonies has been severely burnt, but the rock-wallabies survived the immediate impact of fire by sheltering among rocks. The use and practice of supplementary feeding should be designed to avoid risk of introducing invasive species, such as pasture grasses in hay. It should also be informed by animal health considerations, and be consistent with guidelines established by relevant authorities (such as Zoos Victoria). The efficacy, potential risks and conservation benefit of such supplementary feeding are not yet well established, so such actions should be complemented by monitoring that can evaluate the extent of success, extinguish resultant plant invasions where these may be occurring and help hone future applications.

2. Rapid assessment of biodiversity loss.

Objective: To provide an initial assessment of the magnitude of biodiversity loss

It is important to provide a rapid assessment of the magnitude of biodiversity loss, at least in part to inform governments and the community of the need for beyond-normal conservation responses, and to help guide priority responses. In the case of the Australian wildfires, a pivotal quick assessment used a set of previously compiled average density figures for birds, reptiles and mammals (other than bats and macropods), multiplied by the extent of fire, to derive an estimate of 480 million animals 'affected' by fire (in New South Wales alone, up to December 2019) (<https://sydney.edu.au/news-opinion/news/2020/01/03/a-statement-about-the-480-million-animals-killed-in-nsw-bushfire.html>), with this estimate substantially increased as fires spread subsequently. This reasonable and justified estimate attracted enormous global and national interest, and helped galvanise much of the response.

Assessments currently underway are now comparing the spatial overlap between the distributional ranges of threatened species (and threatened ecological communities) with the (still-expanding) fire distribution. Such an assessment will help identify those threatened species for which the fires will have most increased extinction risk, and hence are priorities for rapid conservation responses.

However, in the immediate aftermath of fires, there existed significant uncertainties about which datasets were suitable and available for use, hampering the provision of rapid and accurate assessment of impact and guidance of emergency recovery at the relevant scales – regional to national. Future opportunities to streamline access to key data across the community of analysts able to produce state of the art assessment of impact could be explored.

Comparable analyses should also be undertaken for (i) species and ecological communities not previously listed as threatened, but for which much to most of their range has been fire-affected; and (ii) conservation features, such as important breeding colonies and Ramsar sites. There may be need for the assessment to be two-phased, with an initial coarse assessment for all threatened species followed by a more detailed assessment for those species initially shown to be most affected, with such subsequent assessment using finer detail fire imagery that includes information on fire severity as well as spatial extent, higher resolution species' distributional data and models, and on-ground inspection.

One concern is that distributional data and modelling is often poor for many species not listed as threatened, particularly for invertebrates. However, because many invertebrates are likely to have small ranges, many such species may have been severely affected by these fires. One estimate – made without explicit distributional analysis – indicated that the 2019-20 wildfires are likely to have caused the extinction of about 700 invertebrate species (Lee 2020).

Further value can be added to the GIS-based assessments of proportional loss (or range or population) of species or ecological communities through description of those species' relevant ecological and life history traits, especially those that can provide information on the likely responses of those species to fire, and requirements for recovery (Keith 2012). Ideally, relevant information on the fire responses of animals and plants will have been derived from strategic research, or expert opinion, undertaken prior to the catastrophe. Such assessments are crucial to guiding emergency protection and ongoing recovery actions such as further fire protection, feral predator and herbivore control, and other compounding threats (see below).

In some cases, ecological impacts of these fires extend beyond the burnt area so simple fire-scar mapping will alone be insufficient: for example, water quality in downstream aquatic systems may be compromised by sediment mobilisation arising from ash-filled run-off from burnt areas in only part of the catchment. As another example, widely foraging birds or flying-foxes may have lost critical resources although they reside outside of the burnt areas.

3. Identifying and responding to compounding threats

Objective: *To consider the likely compounding influence and ramifying consequences of other threats, and use these considerations in the development of management responses.*

The immediate impacts of these fires have been profound, but impacts may also be compounded by other threats over multiple time scales. While long-lived drought and episodes of heat wave conditions, both exacerbated by climate change, had critical causal roles in the 2019-20 wildfires and their severity, drought and extreme temperatures also have direct impacts on biodiversity (Welbergen *et al.* 2008; Fensham *et al.* 2009; Seabrook *et al.* 2011; Bennett *et al.* 2014) and will also have a major influence over the post-fire responses of species and ecosystems.

For example, when trees and shrubs regrow after fires, their vascular tissues that transport vital water, nutrients, and sugars are more delicate and prone to collapse under drought stress than regular tissues, a phenomenon known as xylem embolism. If severe drought continues well beyond the fire, many of the trees and shrubs crucial to re-establishing the habitat structure, function and aesthetic appearance of forests will be constrained or compromised. Any such widespread mortality of these long-lived plants would have transformational impacts on forests and their fauna, with legacies that may persist for centuries. The most critical management consideration is the need to avoid repeated events of this type into the future, with a cumulative impact in terms of both spatial footprint and severity of degradation and biodiversity loss. There are no short-term tractable solutions to a problem of this extent and magnitude, except in special cases to increase artificial moisture at very local scales. The only long-term solution is climate change mitigation at a scale that reduces the risk of severe post-fire droughts.

Conversely, when coupled with subsequent episodes of intense rainfall, fires may be associated with transformational erosion events that precipitate habitat degradation of both terrestrial ecosystems and the freshwater streams, lakes and estuaries that may become turbid and choked with sediment.

Post-fire droughts also have direct detrimental impacts on many wildlife species, even in areas unaffected by these fires. Options for management responses to drought and heat are constrained in the short-term, but remedial responses to wildfire should consider the needs of wildlife affected by the other components of this threat package.

Another significant example of compounding threats involves introduced predators, which are likely to hunt more efficiently in recently burnt areas because most of the shelter for any surviving wildlife will have been largely destroyed by fire (McGregor *et al.* 2016). In order to support the persistence of wildlife species after fire, responses should then prioritise management to control introduced predators at key sites. However, such control operations (such as application of poison baits) should also be undertaken prudently and adaptively because, with little other food available, native wildlife may be far more likely than normal to take baits laid to kill pests.

In some cases, populations of threatened species may be reduced, post-fire, to very few individuals, such that even native predators (such as owls, raptors and pythons) may have major impacts on the viability of local subpopulations. However, it is not clear how such a compounding concern should be, or needs to be, managed. One possibility may be to provide artificial refuge structures that allow prey animals to escape from larger predators.

Similarly, feral herbivores (such as rabbits, deer and horses) still present in the post-fire environment can substantially restrict regeneration of palatable native plant species, and this herbivory can profoundly influence development of the plant community, with consequences for the dependent animal community. Native herbivores, particularly macropods, may add to this total grazing pressure in remnant plant populations in unburnt patches, magnifying the fire impacts on recovery of native plant species in burnt areas.

In some ecosystems, fires facilitate the entry and spread of disturbance-favoured invasive plants. The Kosciuszko fires of 2002-03 catalysed rapid and extensive spread of sweet vernal grass through a range of subalpine ecosystems (Verrall and Pickering 2019). Similar interactions between fire and invasive grasses are well known in remnant woodlands and shrublands of the wheatbelts in temperate south-eastern and south-western Australia.

Still another compounding threat involves plant disease. There is emerging evidence that regrowing plants are less resistant to infection by water moulds and fungal pathogens, resulting in higher levels of mortality. This can be especially detrimental to plants in certain families and those with slow rates of growth and reproduction. These include members of the Banksia family, heath family, and native legumes that play critical roles in nutrient cycling and provision of food resources for vertebrate and invertebrate fauna.

Extensive and severe fires may also offer some beneficial opportunity for broad-scale control of some generally intractable invasive plants, animals and pathogens. The populations of many of these species will have been reduced by fire, and in the post-fire landscape survivors may be aggregated in and around unburnt patches, and/or in burnt landscapes they may be far more evident for control responses. The early post-fire years thus offer critical opportunities for control because removal or even eradication is more tractable and economically feasible than at other times, and essential for avoiding runaway invasions, associated impacts and public expense. Coordination and significantly enhanced investments in pest and weed control measures should be a priority for fire disaster responses.

Habitat fragmentation may also compound fire impacts. In a continuous natural landscape, species may be able to extensively recolonise burnt areas from unburnt patches; but where native vegetation is fragmented, species with relatively poor dispersal capability may no longer be able to recolonise extensively from refuges. The local extinction of the greater glider in the isolated Royal National Park after fire there in 1994 is one example (Maloney 2007). The ground parrot is another possible example: in such cases, translocation may be required to introduce individuals to currently unpopulated patches of suitable habitat that are not likely to be reached naturally by parrots from unburnt refuges. Similarly, broad-toothed rats have had their populations reduced and fragmented by feral horse grazing (Schulz *et al.* 2019), so may have reduced capacity for recovery after fire.

4. Locating and protecting key refuge areas

Objective: *To identify and appropriately manage refuge areas (those parts of the landscape that escaped fire).*

Most fires leave some patches unburnt, and such unburnt patches provide critical refuges for particular species of wildlife that may have survived the fire, and source areas for subsequent recolonisation of surrounding burnt areas when vegetation recovers (Lindenmayer *et al.* 2009; Banks *et al.* 2011). The severity and extent of the 2019-20 chain of wildfires meant that there will have been unusually few such areas. These refuges will be of profound importance for species' recovery, and hence should be the immediate and ongoing focus for conservation management. For many years, they will be the only 'mature' habitat patches within extensive landscapes, and hence require protection from subsequent burning.

The identification of unburnt areas may be determinable through fine-scale imagery and on-ground inspection. Patches of varying area and landscape position may be of variable significance for species with different body sizes, home ranges and ecological requirements. On-ground inspection (e.g. including surveys for the occurrence of threatened species) may refine estimates of the value of individual refuge areas beyond valuation based solely on their spatial characteristics. Note that assessments of refuge areas should consider both those unburnt patches within the perimeter of burnt areas but also unburnt areas outside burnt landscapes, because the relative conservation value of these latter areas may have been substantially increased given that in the post-fire landscape they comprise a higher proportion of suitable habitat for many species.

In some places in the 2019-20 wildfires, authorities have let burns continue within otherwise contained fires. This response may mean that some patches that were unburnt as the fire-front passed were burnt in the days or weeks afterwards: in such cases, extinguishment would deliver significant conservation benefits. In some cases, this will require a change in management policy and perspectives: often unburnt vegetation is seen as a risk to be eliminated rather than a necessary refuge.

5. Communications

Objective: *To provide and widely disseminate consistent, reliable and timely information on the type and magnitude of impacts; and of priority responses and their progress.*

Emergency services have been exceptional in providing precise, reliable and timely information about the actual and predicted extent and spread of fires and associated risks, and about losses to human life and infrastructure. Information on the extent of biodiversity losses has been less readily gathered and disseminated.

There is an urgent need for consistent, targeted, specific and best practice responses to relevant frequently asked questions (e.g. when is it appropriate to provide supplementary food for surviving wildlife in burnt areas, and what should feeding protocols be?), and for such responses to be disseminated readily and effectively to all stakeholders. Given the spread of these fires, and the extent of interest and concerns among very diverse stakeholders, provision of such information needs to be carefully targeted to best meet the needs of different groups.

There is also an urgent need for the community to be reliably and periodically informed about impacts (e.g., the numbers of threatened species most affected by wildfire), the types of responses most needed, and how individuals or groups may contribute to those responses. In time, there is also an obligation to report publicly on the extent of recovery.

Communication needs to foster information exchange among responsible agencies, and between them and the broader community. For example, in part to provide a forum for such exchange, the Victorian Government hosted a biodiversity impact and response summit that included representatives of agencies, NGOs and researchers. The New South Wales and Australian governments have held, or propose, similar summits designed as information exchange and to help develop collaborative responses and priorities.

There have been diverse communication responses to the 2019-20 wildfires, including a narrative from some stakeholders that the severity and spread of the fires was due to (or aggravated by) insufficient hazard reduction burning, the existence and management of national parks, wildlife corridors (that are perceived to act as wicks, allowing wildfire spread) and by native vegetation in general. Suggested solutions within that narrative include much more grazing, clearing and timber thinning and harvesting of native vegetation, including in national parks, and far more extensive and intensive programs of hazard reduction burning. Any responsive actions based on these contentions will serve to compound the conservation impacts of these wildfires, and there is an urgent requirement for robust and evidence-based communication responses to such messaging.

6. Coordination, continuity and resourcing

Objective: *To best match, and integrate most effectively and efficiently, the contribution capability of different stakeholder groups to the recovery needs; to clarify responsibilities and accountability for different actions; and to secure the funding and other support to achieve optimal recovery.*

There has been enormous interest and willingness 'to do something' from landholders, community groups, conservation NGOs, animal welfare groups, state agencies, researchers; and many people in Australia and overseas have donated, or sought to donate, money for affected wildlife and their conservation. We suspect such an assemblage of groups and individuals – including some that are normally reluctant partners – wanting to contribute is unprecedented in Australia. However, without clear priorities and national coordination and leadership, some effort has been ad-hoc and possibly sub-optimal.

Hence, there is a need to establish or enhance collaboration among relevant agencies and NGOs on impact assessment, management options, recovery priorities, accountability and responsibilities, and resourcing: essentially to best address the questions of 'who can and should do what, where and when, and with what resources?'

One mechanism to help collaboration is to rapidly develop a prospectus of justified and costed priority actions (e.g., species A needs to be managed through intensive predator baiting at refuge areas X, Y and Z, and needs to be translocated from site P to site Q, with interim captive breeding; species B needs survey and monitoring of recovery at sites V and W). Such a prospectus, widely disseminated, would allow for coordinated buy-in of key actions by different groups. Capacity to rapidly produce a post-fire recovery prospectus depends in part on pre-existing knowledge about how species respond to fire and sophisticated mapping and modelling tools. One such example is the Victorian Government's Fire Analysis Module for Ecological Values (<https://www.ari.vic.gov.au/research/fire/fire-analysis-module-for-ecological-values-fame>).

Many of the actions needed to foster post-fire recovery of biodiversity will need to be maintained over many years, and many will be costly, so there is a need for long-term budgetary planning and accountability. Many individuals, NGOs and governments have contributed funding to animal welfare and recovery efforts in general, but there is still a mismatch between provision of funding (from the community and governments) and the allocation of such funding to priority actions. A prospectus would help make this connection more transparent and better match priorities.

Relevant across all the components described in this blueprint is the need to characterise, direct and contextualise recovery through the careful setting of explicit and measurable targets, and to report through monitoring on the progress towards meeting such targets.

There is also a compelling need to establish and retain environmental disaster planning and response teams on call, such that a coordinated and pre-considered response to extreme environmental impacts can be implemented immediately, as is current practice for infrastructure disasters. In the environmental space, a good example are the oil spill response teams who are appropriately resourced and trained with access to equipment for immediate deployment at short notice even if their skills are required rarely.

7. Monitoring

Objective: To design and appropriately resource and implement an integrated monitoring program that measures and reports publicly on impact and recovery, and the efficacy of individual and collective management actions; and to use monitoring results to enhance management effectiveness.

Monitoring will provide the foundation for more precisely quantifying and publicly reporting on the extent of loss, the effectiveness of management responses, and the pace and extent of recovery. One short-term response would be to identify all sites within the general area exposed to fire that have previously been monitored within a reasonable timeframe (e.g., the past 20 years), and to revisit them to quantify the extent of immediate loss, and eventually the extent of recovery. However, existing monitoring efforts for threatened species in Australia are relatively few and often insubstantial (Legge *et al.* 2018; Scheele *et al.* 2019)

Where there are insufficient existing monitoring programs or sites, additional monitoring effort will be required, including in unburnt areas (controls) to provide insights into rate of the recovery process. Such monitoring can build from initial reconnaissance surveys that may be needed to establish the persistence of priority species at key refuge areas.

Crucially, at least some monitoring needs to begin immediately after the fire, within days, for species that are detectable at that time of year, and continue at regular intervals. Understanding the conditions under which substantial numbers of animals or plants survive the fire, and the time frame over which they subsequently succumb, is essential for setting rescue and fire protection priorities and time-frames. Likewise, monitoring is needed to assess the impacts of compounding threats and the relative benefits of management interventions.

More broadly, well designed monitoring programs are necessary to address key knowledge gaps and management effectiveness. Such programs should be implemented over the full extent of the recovery period, a commitment that would be atypical for monitoring programs in Australia (Lindenmayer and Gibbons 2012).

Monitoring results should be collated across management and monitoring programs at regular intervals, to allow for regular review of management effectiveness and recovery, to help re-prioritise actions, species and sites, to report publicly on progress, to inform broader-scale reviews of post-fire impacts, and to provide accountability for resources spent.

8. Prioritisation of species, sites and actions for response.

Objective: To evaluate the urgency, likelihood of success and cost-effectiveness of potential management options, in order to develop the optimal set of actions, across sites, to achieve greatest possible conservation recovery.

There will be options for many possible management actions at many possible sites, with varying costs, and all such actions may potentially provide some contribution to recovery of at least some species or ecological communities, over varying time scales. Prioritisation may best be achieved through explicit consideration of the relative return on investment across different packages of management actions (e.g., Carwardine *et al.* 2012; Carwardine *et al.* 2014). In general, responses should prioritise actions that are most likely to reduce the likelihood of the extinction of any species, consistent with national legislation and international targets that seek to prevent extinction (Secretariat of the Convention on Biological Diversity 2010). As well as prioritisation according to extinction risk, prioritisation of species, sites and management responses may also be informed by cultural value (particularly in relation to importance for Indigenous culture), taxonomic distinctiveness and ecological significance.

The effectiveness of some potential management actions may be currently poorly resolved, so prioritisation may need regular review and reiteration, informed by results from monitoring of management effectiveness and progress of recovery.

In some cases, a coordinated set of responses should form the basis of regional recovery plans. One such example may be for Kangaroo Island, where many threatened species have been impacted by extensive and severe fire, and management responses may differ somewhat among affected species within the same area.

9. Implementation of priority responses

Objective: To implement the set of priority management responses across species and sites.

The previous section outlined the process for selecting the optimal combination of management responses for species and sites. This section considers what such actions may comprise. The set of required actions will vary between locations, species and environments, and some may be readily applicable at broad scales whereas others are unfeasible beyond priority sites. Where threatened species and ecological communities are much depleted by these fires, these actions may include:

- control of feral predators in and around refuge sites (unburnt patches);
- control of feral herbivores in and around refuge sites (unburnt patches);
- control of weeds in and around refuge sites (unburnt patches);
- provision of nest boxes (or creation of artificial hollows) at key sites;
- provision of artificial shelters at key sites;
- provision of supplementary food (and water);
- establishment of captive-breeding (insurance populations);
- genetic rescue;
- collection of seeds (or other material) of threatened plants;
- salvage of individual animals from sites at which they are unlikely to be viable or which may continue to be threatened;
- translocations;
- enhancing regeneration (including in some cases planting of species that provide critical resources for threatened wildlife);
- aerial seeding for key forest tree species otherwise potentially eliminated from their habitat due to recency of previous fire (e.g., Bassett *et al.* 2015)

Note that implementing remedial actions should be undertaken in an adaptive management framework (Duncan and Wintle 2008), such that actions can be continually refined, and responsive to unanticipated events.

10. Linkages with socioeconomic responses

Objective: *To mainstream and embed conservation responses within a broader societal response or program of responses.*

Major investments commonly follow major disasters to rebuild communities and businesses. The lesson from investment in Indigenous land management shows that conservation investments can also contribute to enhancing social goals (Burgess *et al.* 2009). The program of conservation responses should be coordinated with other community restoration programs. This may also help ensure that community recovery programs do not have unintended consequences for conservation simply from a lack of awareness. Such investments can be employment in the protection of undamaged remnant habitat, wildlife caring, active interventions for threatened species, habitat restoration and reconstruction of the conservation infrastructure.

11. Caring for the carers

Objective: *Appropriate support and counselling are available for those individuals committed to wildlife recovery.*

As with the community generally, many conservation managers and researchers, and animal carers, will be severely traumatised by these fires and their impacts on wildlife. The hard-won fruits (e.g. of recovery of threatened species) arising from dedicated efforts extending over many years have been obliterated almost overnight. Many are now working desperately to try to recover injured animals and species' populations; many have had their own homes destroyed. Environmental catastrophe will exhaust and bring despair to many good people. It is critical that appropriate care be given to not only the affected wildlife but also those caring for that wildlife, such as through the availability of post-trauma counselling.

12. Rapid assessment and re-assessment of the conservation status of affected species and ecological communities; and associated policy response

Objective: *To re-assess (or newly assess) the conservation status of species likely to be most detrimentally affected by these wildfires, such that status properly reflects any changed extinction risk; to revise recovery and other conservation planning and policy.*

Governments proffer particular conservation attention to species (and ecological communities) formally listed as threatened under their legislation. Under normal circumstances this is a considered process that can take place over many months or years. Under emergency circumstances, scientific assessments need to be supported by a more agile and streamlined administrative process to update the statutory schedules, based primarily on the proportion of the population lost, or an appropriate proxy such as habitat. This should include new assessment (i.e., of much-affected species or communities not currently listed as threatened) and re-assessment (i.e., of much-affected species or communities that are already listed as threatened).

Such rapid and agile re-assessment will help guide investments and conservation recovery focus to those whose extinction risk has rapidly become of more concern. Hence, re-assessment needs to be more than simply changed listing status, but also include recalibration of management priorities and policy contexts, to better safeguard populations in burnt and unburnt areas of species substantially affected by these fires. For example, unburnt patches of conservation significance can be more substantially protected through being designated as critical habitat under the *Environment Protection and Biodiversity Conservation Act*, and Regional Forest Agreements may need to be recalibrated to offer more protection of unburnt patches and remnant populations in areas not already in the conservation reserve system. As one example, in Victoria, over 40% of the range of the long-nosed bandicoot and long-footed potoroo have been affected by the 2019-20 fires. But these species are also affected by other factors including timber harvesting operations, and – given the reduced population of these species – the impact of such harvesting may now come with heightened consequences for the conservation of the species. Accordingly, forestry operations that could also affect these species should be re-evaluated in light of the potential change in their conservation status.

Although streamlined assessment processes should still be robustly based on evidence, listings derived from such assessments may turn out to include some species that (on the basis of further information) are subsequently shown to be not affected or to recover more quickly than anticipated. Hence, emergency listings may need to be treated as interim such there is not misallocation of resources to species that do not need help after all.

13. Research into ecological shifts and transitions; and impacts on ecological processes

Objective: To undertake research and monitoring needed to understand and manage major fire-induced ecological transitions.

Beyond impacts on individual species, the scale of the 2019-20 fires is likely to lead to many examples of environmental change, and – especially where the fires have occurred in areas subject to relatively recent previous fires – to ecological shifts and potentially ecosystem collapse. For example, in some areas alpine ash may not have matured sufficiently in the short period between a previous fire and the 2019-20 fires, and hence may not recover naturally as the dominant tree in these forests.

Post-fire research should consider the extent, and potential reversibility (and the desirability of any reversal) of such transitional changes; with outcomes focused on longer-term management recommendations.

14. After-emergency management responses

Objective: To transition appropriately from short-term responses to this crisis to longer-term management priorities; and to ensure that short-term actions do not subvert longer-term options and outcomes.

Short-term management priorities may help prevent extinctions and implement remedial management actions, but the suite of management actions required in the longer-term may be very different to those needed in the immediate aftermath of the catastrophe. Consideration of longer-term management actions (and their implementation) will require inputs from post-fire research and monitoring, and may require major revisions of recovery plans, regional land-use planning, and other comparable advice, to better recognise and prepare responses to the possibility of future major adverse events.

There is potential to learn from this exercise to develop contingency plans not just for the immediate response but for the longer-term recovery objectives to which the immediate response should contribute – care must be taken that immediate responses do not compromise future opportunities for conservation. For example, one obvious conservation response will be to ensure that there are more subpopulations of threatened species so that the risk is spread over larger areas. This may involve putting species in places where they were not formerly present. Existing guidelines on such translocations should not be abandoned under such circumstances and, while they can be applied rapidly, longer-term contingency planning will help avoid the irrevocable consequences of moving species to places where they do more harm than good.

15. Review and inquiry

Objective: Within a broader government process, examine the factors that led to the severity and extent of these wildfires; and the factors that led to shortcomings and constraints in the post-fire response.

Governments will establish major reviews or inquiries about these wildfires, aimed at identifying causal factors and developing and implementing recommendations such that future catastrophes become less likely. It is critical that such reviews appropriately consider natural values and losses (including the economic costs of biodiversity loss) in such review, and that suggested solutions do not compromise recovery efforts, or come at other costs to the natural environment.

16. A changed landscape for conservation

Objective: *To consider need for review of conservation objectives and approaches under a future characterised by more frequent severe events.*

Long-established objectives for biodiversity conservation, and mechanisms to achieve them, may need to be reconsidered in response to the 2019-20 wildfires (and their broader community impact), especially under a future scenario of increasing impacts of escalating climate change. There may be a new normal, and recovery to pre-fire environments and species assemblages may be impossible.

17. Preparation for the next catastrophe

Objective: *To use lessons from the current fire characteristics and impacts, and from monitoring the efficacy of responsive management to develop and institutionalise a more proactive and strategic program capable of effective response should such a severe episode recur.*

Although review and inquest (and results from monitoring programs) would hopefully identify and lead to the implementation of policy and management improvements that would render future catastrophes less likely, these may still happen. Hence, it is critical to develop, institutionalise and support a more integrated and effective program of responses ready to meet future scenarios.

References

- Banks SC, Dujardin M, McBurney L, Blair D, Barker M, Lindenmayer DB (2011) Starting points for small mammal population recovery after wildfire: recolonisation or residual populations? *Oikos* 120, 26-37.
- Bassett OD, Prior LD, Slijkerman CM, Jamieson D, Bowman DMJS (2015) Aerial sowing stopped the loss of alpine ash (*Eucalyptus delegatensis*) forests burnt by three short-interval fires in the Alpine National Park, Victoria, Australia. *Forest Ecology & Management* 342, 39-48.
- Bell T, Tolhurst K, Wouters M (2005) Effects of the fire retardant Phos-Chek on vegetation in eastern Australian heathlands. *International Journal of Wildland Fire* 14, 199-211.
- Bennett JM, Nimmo DG, Clarke RH, Thomson JR, Cheers G, Horrocks GFB, Hall M, Radford JQ, Bennett AF, Mac Nally R (2014) Resistance and resilience: can the abrupt end of extreme drought reverse avifaunal collapse? *Diversity and Distributions* 20, 1321-1332.
- Burgess CP, Johnston FH, Berry HL, McDonnell J, Yibarbuk D, Gunabarra C, Mileran A, Bailie RS (2009) Healthy country, healthy people: the relationship between Indigenous health status and "caring for country". *Medical Journal of Australia* 190, 567-572.
- Carwardine J, Nicol S, Van Leeuwen S, Walters B, Firn J, Reeson A, Martin TG, Chadès I (2014) *Priority threat management for Pilbara species of conservation significance*. Brisbane.
- Carwardine J, O'Connor T, Legge S, Mackey B, Possingham HP, Martin TG (2012) Prioritizing threat management for biodiversity conservation. *Conservation Letters* 5, 196-204.
- Driscoll DA, Lindenmayer DB, Bennett AF, Bode M, Bradstock RA, Cary GJ, Clarke MF, Dexter N, Fensham R, Friend G, Gill M, S. J, Kay G, Keith DA, MacGregor C, Possingham HP, Russell-Smith J, Salt D, Watson JEM, Williams RJ, York A (2010a) Resolving conflicts in fire management using decision theory: asset-protection versus biodiversity conservation. *Conservation Letters* 3, 215-223.
- Driscoll DA, Lindenmayer DB, Bennett AF, Bode M, Bradstock RA, Cary GJ, Clarke MF, Dexter N, Fensham R, Friend G, Gill M, S. J, Kay G, Keith DA, MacGregor C, Russell-Smith J, Salt D, Watson JEM, Williams RJ, York A (2010b) Fire management for biodiversity conservation: key research questions and our capacity to answer them. *Biological Conservation* 143, 1928-1939.
- Duncan DH, Wintle BA (2008) Towards adaptive management of native vegetation in regional landscapes. In *Landscape analysis and visualisation*. (Eds C Pettit, W Cartwright, I Bishop, K Lowell, D Pullar and D Duncan) pp. 159-182. (Springer Verlag: Berlin)
- Fensham RJ, Fairfax RJ, Ward DP (2009) Drought-induced tree death in savanna. *Global Change Biology* 15, 380-387.

- Keith DA (2012) Functional traits: their roles in understanding and predicting biotic responses to fire regimes from individuals to landscapes. In *Flammable Australia: fire regimes, biodiversity ecosystems in a changing world*. (Eds RA Bradstock, MA Gill and RJ Williams) pp. 97-125. (CSIRO Publishing: Melbourne)
- Lee M (2020) Australia's bushfires could drive more than 700 animal species to extinction. Check the numbers for yourself. *The Conversation* January 14 2020.
- Legge S, Scheele BC, Woinarski JCZ, Garnett ST, Keith DA, Lintermans M, Robinson NM, Lindenmayer DB (2018) Summary: monitoring extent and adequacy for threatened species. In *Monitoring threatened species and ecological communities*. (Eds S Legge, DB Lindenmayer, NM Robinson, BC Scheele, DM Southwell and BA Wintle) pp. 127-133. (CSIRO Publishing: Clayton)
- Lindenmayer D, Gibbons P (2012) (Ed.) *Biodiversity monitoring in Australia*. (CSIRO Publishing: Collingwood)
- Lindenmayer DB, MacGregor C, Wood JT, Cunningham RB, Crane M, Michael D, Montague-Drake R, Brown D, Fortescue M, Dexter N (2009) What factors influence rapid post-fire site re-occupancy? A case study of the endangered Eastern Bristlebird in eastern Australia. *International Journal of Wildland Fire* 18, 84-95.
- Maloney KS (2007) *The status of the greater glider Petauroides volans in the Illawarra region*. University of Wollongong.
- McGregor HW, Legge SM, Jones ME, Johnson CN (2016) Extraterritorial hunting expeditions to intense fire scars by feral cats. *Scientific Reports* 6, 22559.
- Miller RG, Tangney R, Enright NJ, Fontaine JB, Merritt DJ, Ooi MKJ, Ruthrof KX, Miller BP (2019) Mechanisms of fire seasonality effects on plant populations. *Trends in Ecology & Evolution* 34, 1104-1117.
- Scheele BC, Legge S, Blanchard W, Garnett ST, Geyle HM, Gillespie GR, Harrison PL, Lindenmayer DB, Lintermans M, Robinson NM, Woinarski JCZ (2019) Continental-scale assessment reveals inadequate monitoring for threatened vertebrates in a megadiverse country. *Biological Conservation* 235, 273-278.
- Schulz M, Schroder M, Green K (2019) The occurrence of the broad-toothed rat *Mastacomys fuscus* in relation to feral horse impacts. *Ecological Management & Restoration* 20, 31-36.
- Seabrook L, McAlpine C, Baxter G, Rhodes J, Bradley A, Lunney D (2011) Drought-driven change in wildlife distribution and numbers: a case study of koalas in south west Queensland. *Wildlife Research* 38, 509-524.
- Secretariat of the Convention on Biological Diversity (2010) *Strategic Plan for Biodiversity 2011-2020 and the Aichi Biodiversity targets: living in harmony with nature*. (Secretariat of the Convention on Biological Diversity: Montréal)
- Verrall B, Pickering CM (2019) Recovery of subalpine grasslands 15 years after landscape level fires. *Australian Journal of Botany* 67, 425-436.
- Welbergen JA, Klose SM, Markus N, Eby P (2008) Climate change and the effects of temperature extremes on Australian flying-foxes. *Proceedings of the Royal Society of London B: Biological Sciences* 275, 419-425.
- Woinarski JCZ, Recher HF (1997) Impact and response: a review of the effects of fire on the Australian avifauna. *Pacific Conservation Biology* 3, 183-205.

Figure 1. Schematic representation of response actions and their linkages. Note that the shaded actions should connect also to most other actions.

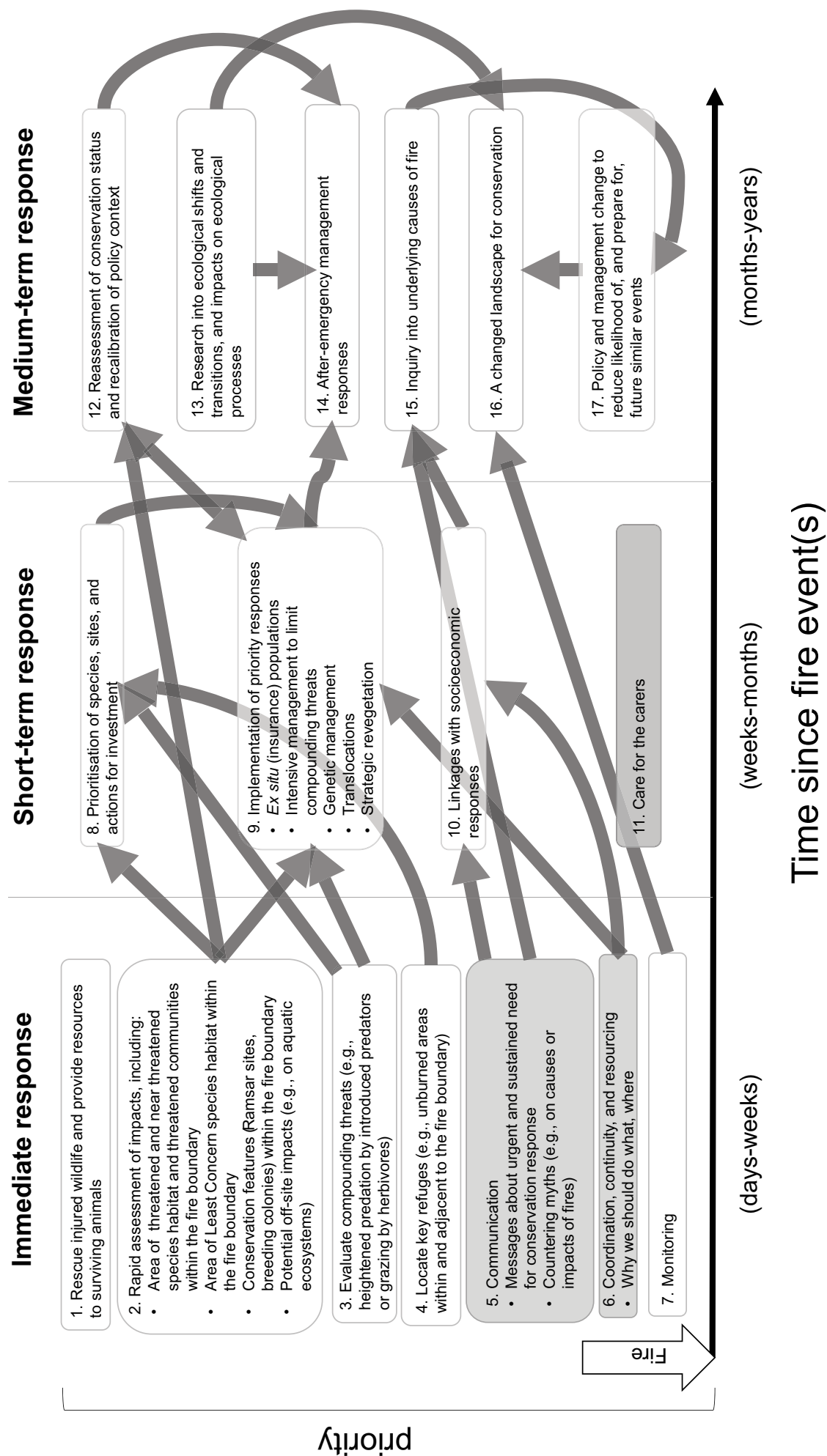


Table 1. Indicative list of priority actions to support post-fire recovery of biodiversity. Shading gives an indication of priority, with highest priorities in darkest shading. Note that although this list is substantial, it is still far from exhaustive. Note also that response areas and actions that are longer term only are not yet included.

Response area	Actions	Short term (days to weeks)	Medium term (weeks to months)	Longer term (months to years)
1. Rescue of injured wildlife	1.1. Rescue and rehabilitate (where possible) injured wildlife			
	1.2. Collate rescue effort and resources			
	1.3. Where there are net conservation and welfare benefits, provide supplementary food and other resources to surviving animals <i>in situ</i>			
	1.4. Monitor outcomes of rescue efforts, to help refine subsequent responses			
2. Rapid assessment of losses	2.1. Overlay distribution maps/models of threatened (and selected not threatened) species and ecological communities with fire scar mapping			
	2.2. For species likely to be most affected, refine assessments with finer detail imagery, on-ground survey and inspections, etc.			
	2.3. Attribute life history and other traits to species, to better predict consequences for species with high proportional overlap with fire			
3. Compounding impacts	3.1. Assess likelihood of compounding impacts for species and sites, and identify potential responses to overcome compounding impacts			
4. Locating key refugial sites	4.1. Map unburnt patches (within and in proximity to burnt areas)			
	4.2. Undertake rapid assessment (survey) of occurrence of priority species in refuge areas			
	4.3. Prioritise refuge areas based on occurrence of priority species, size, landscape context, etc.			
5. Communications	5.1. Develop and disseminate consistent responses to FAQ (e.g. best practice recommendations for supplementary feeding)			
	5.2. Report publicly on impacts, actions and recovery (see also 7.3)			
6. Coordination and resourcing	6.1. Collate recovery effort across government agencies, conservation NGOs, community groups, landholders and the community (e.g. through summits), to address the question of 'what is most needed and who can best do what, where, when?'			
	6.2. Cost management actions required for recovery (see also 8.3), solicit or collate funding, and match funding contributions to priority responses			

Response area	Actions	Short term (days to weeks)	Medium term (weeks to months)	Longer term (months to years)
7. Monitoring	6.3. Set explicit recovery targets across time frames and spatial scales.			
	7.1. Identify existing (pre-fire) monitoring programs that can be continued to detect responses to fire, and continue such monitoring			
	7.2. Design and implement a strategic monitoring program that can measure impact, management effectiveness and progress towards recovery; and embed this program within the broader management program			
	7.3. Report publicly on monitoring results (see also 5.2) and progress towards targets			
8. Prioritise species, sites and actions for management response	8.1. Based on information from extent of spatial overlap of species' range with burnt areas, and life history traits, rank species by impact and urgency of remedial management effort			
	8.2. Use structured decision-making, elicitation or comparable processes based on information about likely management effectiveness, cost efficiency and species' needs to prioritise (and cost) the most appropriate packages of management responses across sites and species			
	8.3. Develop a prospectus (with required budgets) of key recovery actions (including management and monitoring), in a manner that clarifies responsibility and accountability, but allows for buy-in by different groups or individuals			
9. Implement priority responses	9.1. (Where appropriate) implement (and monitor) intensive control for introduced predators at key sites (mostly unburnt refuges)			
	9.2. (Where appropriate) implement (and monitor) intensive control for introduced herbivores at key sites (mostly unburnt refuges)			
	9.3. (Where possible) seek to implement (and monitor) regional-scale control programs for introduced pests to make major dents in their populations			
	9.4. (Where appropriate) implement (and monitor) intensive control for weeds at key sites (mostly unburnt refuges)			
	9.5. (Where appropriate) provide supplementary resources (nest boxes, artificial shelters, food, etc.) at key sites			
	9.6. (Where appropriate) salvage individuals (threatened plants and animals) from sites at which populations are likely to be non-viable and where there is benefit for translocation to other sites			

Response area	Actions	Short term (days to weeks)	Medium term (weeks to months)	Longer term (months to years)
	9.7. (Where appropriate) establish captive breeding (insurance) populations of priority species.			
10. Linkages with socioeconomic responses	10.1. Embed at least some programs for biodiversity recovery within the broader socioeconomic recovery initiatives and programs			
11. Care for the carers				
12. Re-assessment of conservation status and subsequent recalibration of plans and policies	12.1. Amend legislation (or use other mechanisms) to allow for at least interim emergency listing for much-affected species and ecological communities that are currently unlisted; and to allow streamlining to uplist much-affected species and ecological communities that are currently listed as threatened			
	12.2. Following appropriate processes (e.g. CAM), assess or re-assess the conservation status of much-affected species and ecological communities			
	12.3. Draft amended (or new) conservation advices or recovery plans for such newly listed or uplisted species to better reflect impact and pathway to recovery			
	12.4. Recalibrate relevant policy context and instruments to better safeguard remnant populations of fire-affected species			



Further information:

<http://www.nespthreatenedspecies.edu.au>

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