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Monitoring impacts and recovery

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Summary

Context and challenges

- Monitoring provides crucial information to help understand species distribution and abundance, the condition of ecosystems and changes induced by disturbances such as fire, and to evaluate and enhance actions to conserve and recover species and ecological communities.
- However, biodiversity monitoring in Australia is patchy, has poor taxonomic coverage and is generally of low quality.

Main findings

- Lack of baseline monitoring data on species range and abundance, and ecological community condition, limited our understanding of the impacts of the 2019–20 wildfires, making it difficult to efficiently allocate urgent conservation actions, and track recovery.
- For most species impacted by the 2019–20 wildfires, impacts were mostly inferred by estimating the overlap between the fire extent and species' range. Species distribution models and expert knowledge of species vulnerability to fire were used to refine impact estimates for vertebrates, invertebrates, plants and ecological communities.
- For around 300 species and ecological communities, reconnaissance survey programs were established to improve our understanding of impacts and to ascertain whether recovery was occurring. Over 1500 targeted surveys of flora, fauna and ecological communities were undertaken within 18 months of the wildfires.
- For a small subset of species, survey observation data or monitoring programs pre-dating the fires were available, allowing direct estimation of impacts.
- Surveys and post-fire observation data were collected by groups including agencies, non-government organisations (NGOs), citizen scientists and university researchers.

- Wildfire impacts on species and ecological communities inferred from reconnaissance surveys ranged from catastrophic (no individuals of a species found in previously occupied sites) to benign (unchanged occupancy).
- As a condition of the Australian Government's bushfire recovery program, monitoring will measure the effectiveness of post-fire recovery actions for some species and ecological communities.
- There is an urgent need to dramatically increase our understanding of the extent of occurrence, abundance, and condition of species through properly resourced, carefully designed, systematic monitoring programs. Such programs would enhance planning and capacity to respond decisively to future fires, improving conservation outcomes.

Introduction

Monitoring is a key to understanding the state of the environment, to evaluate the success of actions, to learn about how environments work and to trigger actions when unacceptably negative changes have occurred. Monitoring is particularly important in the case of understanding the impacts on species and ecosystems of stressors such as climate change, harvesting, invasive species, drought and fire. Indeed, monitoring is the cornerstone of most impact assessment.

Unfortunately, the investment in monitoring by Australian agencies and organisations is mostly insufficient to report accurately on the state and trends in biodiversity, or the effects of environmental management programs (e.g. Keith *et al*. 2018; Scheele *et al*. 2019). There is also little monitoring of many other components of the natural environment, including of soils (Chapter 5), ecosystem processes, aquatic health, and sites of cultural and biodiversity significance (e.g. Ramsar sites and World Heritage sites). Such shortcomings have proven a significant constraint on accurately assessing the impacts of the 2019–20 wildfires, prioritising management responses and charting subsequent recovery.

Inquiries into previous wildfires in Australia have generally not focused on biodiversity impacts. However, the immense area and diversity of habitats burnt in 2019–20, and widespread media coverage, made biodiversity impacts a stronger focus for the public and policy makers (Chapter 30). This focus on biodiversity during and immediately after the fires generated an instant demand for data and evidence about impacts on biodiversity, shining a spotlight on our biodiversity data infrastructure and, for the first time in decades, injecting some resources into national-scale data synthesis, gap analysis, field reconnaissance and post-fire monitoring. In this chapter, we provide an overview of post-fire field reconnaissance efforts, describe some of the few ongoing monitoring programs that are beginning to paint a picture of post-fire recovery and loss, and discuss opportunities to build on the pulse of survey data that has been generated following the fires.

Findings

Overall

Our ability to understand the true impacts of the 2019–20 wildfires has been hampered by a lack of measured baseline for most species. For most species the lack of (recent) pre-fire occurrence and monitoring data also made prioritisation of where and what actions should be undertaken more difficult. Population strongholds and the status of those strongholds before and after the fires could not be known. This was particularly acute for invertebrates, fungi and many plants that have to date received scant attention and data collection (Chapters 9, 10 and 11).

The use of post-fire reconnaissance surveys helped to refine understanding of impacts, especially where surveys took place at locations previously known to be recently occupied by species, or for which ecological community condition had previously been measured. In rare cases, existing long-term monitoring sites fell across burnt and unburnt locations, making strong inference about declines possible and serving as a basis for ongoing monitoring. On reviewing the post-fire reconnaissance and monitoring data collection and synthesis across the Commonwealth, state agencies (often several within a single state), non-government organisations (NGOs), Traditional Owners, universities and citizen scientists, the weaknesses in current national biodiversity data infrastructure are apparent. Lack of coordination, communication and sharing is muddying the signal from the small amount of data that does exist. A nation-wide initiative to synthesise, organise, streamline and support systematic biodiversity monitoring and analysis is urgently needed.

Post-fire reconnaissance surveys

Reconnaissance surveys are field surveys to rapidly assess the immediate impacts of fires on species or ecological communities. Reconnaissance programs were established in all fire-affected states to help refine the assessment of fire impacts and set post-fire recovery priorities. Surveys were supported by Commonwealth and state funding, public donations and citizen science. The speed of the establishment of reconnaissance surveys, sometimes part of emergency recovery work, was impressive (https://www.ari.vic.gov.au/research/fire/bushfire-response-2020-aquatic-rescues).

At the time of writing (March 2022), based on available national, state and NGO reports, the combined national reconnaissance effort has resulted in the collection of ~1500 new survey datasets across much of the country, using a variety of survey methods and approaches. The actual number is likely to be higher given that some data collections were not directly supported by state or Commonwealth funding; those have generally not been accounted for here. Approximately 850 animal surveys and 271 plant surveys have been undertaken with the support of Australian Government funding. Surveys assessed on-ground impacts and in some instances have provided evidence of early recovery trajectories. Surveys focused on species and ecological communities that were identified as national priorities for management intervention. Additional reconnaissance surveys were supported by the states and some NGOs for national, state or their own priority species and ecological communities.

In Victoria, surveys were conducted for 126 plant and 34 animal species across 1177 individual site surveys (DELWP 2022). A third of these surveys were supported under the Commonwealth bushfire recovery program reported above; the remainder were supported by the Victorian Government. Surveys were prioritised towards species with high apparent levels of loss based on spatial overlap of the fire footprint and previous records, habitat distribution models and high sensitivity to threats exacerbated by fire. Two hundred and eighty-seven sites known previously to contain threatened plants impacted by the fires were searched. Of the 126 surveyed threatened plant species, 108 species were regenerating at impacted sites, while 18 were not. Of the 520 fauna surveys (sites) conducted for 34 species at previously known locations, 175 surveys yielded positive observations.

The impacts of the fires on most fauna appeared stark, even after considering imperfect detection and spatial inaccuracies. For example, 26% of the greater glider's (*Petauroides volans*) Victorian range was burnt based on habitat overlay analysis. Forty-four per cent of the sites at which the glider had previously been observed in the East Gippsland region yielded no detections during post-fire reconnaissance surveys at those sites, even when suitable habitat remained. Results were similar for the yellow-bellied glider (*Petaurus australis*) (Chapter 16). The abundance of endangered galaxid species dropped by around 30%, and some populations of threatened frog species, including four populations of the endangered spotted tree frog (*Litoria spenceri*), could not be detected, suggesting possible local extirpation (DELWP 2022).

Aerial surveys of alpine bog ecological communities indicate that around 12% of Victoria's alpine bog area burnt at varying degrees of severity. On-ground surveys to ascertain the intensity of the damage are pending.

Within 12 months of the fire, on-ground and aerial surveys had been conducted in New South Wales for 200 plant and animal species and ecological communities rated at high risk, based on range overlap with the fires extent and vulnerability assessment (Auld *et al*. 2020). Additional on-ground surveys for 100 high-risk rare or range-restricted plant species are nearing completion. Longer-term monitoring programs for a subset of NSW *Saving Our Species* (SoS) program priority species provides a solid foundation on which impacts for a portion of the state's threatened species and ecological communities will be assessed.

In the Border Ranges region of south-eastern Queensland, post-fire surveys were conducted to detect national priority threatened species in burnt habitats including previously known locations of threatened species such as the brush-tailed rock-wallaby (*Petrogale penicillata*), Hastings River and New Holland mice (*Pseudomys oralis*, *Pseudomys novaehollandiae*), and long-nosed potoroo (*Potorous tridactylus tridactylus*). Surveys generally indicated that species persisted at burnt sites, though population-level impacts were not possible to ascertain given lack of pre-fire population data.

Pre-existing surveys for the broad-toothed rat (*Mastacomys fuscus*) in Namadgi National Park (Milner *et al*. 2016) provided a robust baseline against which post-fire sampling revealed declines in occupancy. Existing survey data informed spatial prioritisation of predator control efforts. Similarly, robust population data for several well-monitored Western Australian species, including the western ground parrot (*Pezoporus wallicus flaviventris*), allowed swift post-fire predator control efforts to help reduce fire impacts on the species (Box 31.1; Chapter 17).

Box 31.1. Coordinated monitoring and recovery planning for the eastern bristle bird and eastern ground parrot

BirdLife Australia has commenced recovery projects, including monitoring, for 12 of the 17 birds identified nationally as priorities for urgent post-fire management (Chapter 15). For example, the eastern bristlebird (*Dasyornis brachypterus*: Fig. 31.1) and eastern ground parrot (*Pezoporus wallicus wallicus*) have populations distributed across three states. Monitoring frequency and methodology vary among states and populations.

In late 2020, BirdLife Australia brought together eastern bristlebird and eastern ground parrot experts from multiple institutions to assess the nation-wide impacts of the 2019–20 wildfires and guide bushfire recovery action and monitoring. The collaboration generated a comprehensive picture of the post-fire distribution of both species, to understand recent range retractions. This information was used to develop eastern bristlebird recovery advice that was ultimately included in a national recovery plan due for publication in 2022.

Fig. 31.1. Eastern bristlebird. (Photo: Duade Paton)

Individual species experts and citizen scientists from across a range of institutions, and large NGO-led post-fire reconnaissance efforts, have been contributing post-fire studies and data into journals and data repositories since the fires. In Victoria, the SWIFFT network (https://www.swifft.net.au/cb_pages/team_bushfire_recovery_-_community_wildlife_reporting.php) was used to harness citizen science in heavily impacted areas for species of concern such as glossy black-cockatoos (*Calyptorhynchus lathami*) and diamond pythons (*Morelia spilota spilota*), which are difficult to detect in systematic survey. Using the national citizen science project, FrogID, Rowley *et al.* (2020) reported widespread persistence, at least in the short term, of many frog species with previous records within the firegrounds (Chapter 13). By mining their citizen science repository, they found that of the 66 frog species detected in the firegrounds before the fire, 45 were detected inside the fire grounds within 125 days after the fires. All 33 frog species with more than five records that were detected in the months of December–March pre-fire were detected post-fire. However, although valuable for reporting on persistence, this dataset is unsuitable for estimating the impacts of fire on the abundance of species.

In a creative analysis of bird species observation changes following the fires, Lee *et al.* (in press) analysed citizen science e-Bird data to test for systematic patterns in species use of the post-fire environment. Analysing observation change data for 76 species, they found that 22 species of smaller birds with smaller ranges and high dietary specialisation were less likely to be found in burnt areas, post-fire. In contrast, 30 larger bird species with larger ranges were more likely to be observed in burnt areas. The remaining 24 bird species showed no statistically significant change.

Carefully designed post-fire reconnaissance studies can reveal significant insights into species-level impacts when enough burnt and unburnt locations can be surveyed, such as in the 'space-for-time' study of fire impacts on the golden-tipped bat (*Phoniscus papuensis*) (Chapter 16). Similar in intent was a study looking at the impacts of the fires on native bees, led by the Arthur Rylah Institute and the Melbourne Museum, in which bee populations within burnt areas were compared with those in adjacent unburnt locations (https://www.ari.vic.gov.au/research/fire/bushfire-response-2020-impacts-on-native-bees). After collecting more than 1100 native bees representing 67 species, they found less than half the number of species in the burnt areas (25) compared to the unburnt areas (54). Bee abundance was also higher at unburnt locations. Very few above-ground nesting bees were found in the burnt areas, possibly because nesting locations were destroyed by the fire or because their preferred food plants were yet to regenerate.

Overall, reconnaissance surveys after the 2019–20 wildfires provided a foundation on which to understand ongoing impact for some species, to prioritise recovery efforts, and in some cases to serve as a baseline for ongoing monitoring efforts. For some species, they represented a much-needed injection of data on their current distribution and conservation status. For other species, such as the greater glider, the surveys revealed an even more urgent conservation status, with declines in observation rates recorded, even at sites with relatively low fire impacts.

Rare and precious gems: learning from pre-existing monitoring

For the species for which regular monitoring had been undertaken before the 2019–20 wildfires, the opportunity existed to gain significant insights into fire impacts and recovery. The examples below highlight the benefits of strong existing monitoring data.

In the Gondwana Rainforests of Australia World Heritage Area, burnt for the first time in recorded history following years of drought, surveys of mountain frogs (*Philoria kundagungan*) and Richmond mountain frogs (*Philoria richmondensis*) had been undertaken by a variety of groups since 2013 (Willacy 2014; Bolitho *et al*. 2021). These studies established sites across the species' ranges, and used a robust methodology that provided a solid basis for estimating changes in occupancy and abundance over time. Following the 2019–20 wildfires, Heard *et al*. (2021) revisited the previously surveyed locations, deploying similarly robust occupancy and abundance surveys. Occupancy rates for these two species at sites burnt in moderate to high severity varied from 14 to 23% compared with occupancies of between 54 and 64% at unburnt sites. The robust sampling design and pre-fire sampling had allowed analyses to estimate abundance change and start to disentangle the role of drought and fire.

The NSW SoS monitoring, evaluation and reporting plans have emerged as a useful tool for helping to target post-fire surveys and to understand impacts on some plant species. Metcalfe's greenhood (*Pterostylis metcalfei*) is a narrow-range endemic orchid that was not initially considered highly sensitive to fire. However, as an SoS program species threatened by grazing, trampling and weed invasion, it was closely managed and monitored. Post-fire monitoring of two populations has indicated the species is yet to recover from the fires, despite strong rains. This may be due to the very high fire intensity it experienced (Chapter 9). Similarly, existing monitoring for Guthrie's grevillea (*Grevillea guthrieana*) on the Carrai Plateau in central New South Wales indicated the sensitivity of the species to fire, and this allowed rapid deployment of post-fire mitigation measures to ensure threats to remaining populations are minimised. A third example is described in Box 31.2.

Box 31.2. The beauty of existing data: SoS priority species

Pygmy cypress pine (*Callitris oblonga*) is patchily distributed through northern New South Wales and is listed as Vulnerable in New South Wales and nationally. Twenty years of monitoring and abundance estimates across most populations provided foundational data on which to base post-fire surveys where it was identified that a large portion of its range had burnt in 2019–20. Immediately following the fire,

Fig. 31.2. A stand of dead adults of *Callitris oblonga parva* at Cathedral Rock National Park (A) living adults at Cathedral Rock National Park pre-2019 (B). (Photos: (A) John T Hunter, (B) Adam Fawcett).

standing dead stems were counted, enabling estimation of the pre-fire population (Fig. 31.2). Following the fire, damage and adult mortality were very high (83–97%) across four of five key populations, amounting to a range-wide 88% loss of adult stems. Immediately following the fire, some germinants were observed, but most have since died, probably due to grazing. This species will require intensive management and fire protection in the remaining population to avoid state-wide extinction.

Across the country, many individual monitoring and research studies will continue to provide crucial data and knowledge to allow us to piece together the evidence about the combined impacts of fire and other stressors, helping to prioritise and support recovery efforts. But despite some rare exceptions, financial and institutional support for such studies is low. With the loss of key long-term resources provided by programs such as the recently terminated LTERN, many monitoring programs rely on good will and opportunism for their ongoing existence (Keith *et al*. 2018). Furthermore, recovery of many species after these wildfires is likely to take many years, even decades, and documenting the pace and extent of recovery, and the effectiveness of supporting conservation actions, is likely to be a similarly long-term proposition. Most post-fire investments in recovery and monitoring, however, are currently constrained to the short-term, with little assurance of longer-term support.

Looking forward: opportunities to improve monitoring and preparedness

The Australian Government's Phase 1 and 2 bushfire recovery programs have prompted the development of short-term monitoring programs to document the outcomes of recovery projects. The MERIT tool (https://www.nrm.gov.au/my-project/monitoring-and-reporting-plan/merit) is being used by proponents of all projects supported by the Australian Government to establish project monitoring. The opportunity to bring monitoring projects together under a nationally coordinated monitoring program could be explored as one means of building a path to improved national biodiversity monitoring systems.

Following the fires several other initiatives that indicate significant opportunities to enhance the amount and quality of ongoing biodiversity monitoring have arisen. For example, a collaborative on-ground monitoring program led by WWF-Australia has provided over 1000 camera traps to researchers and land managers across the country, and is using innovative AI species identification technology to improve ongoing biodiversity monitoring (Box 31.3).

Box 31.3. Eyes On Recovery: a camera trap partnership

Eyes On Recovery is a collaborative venture between WWF, Conservation International, and Google that is using camera traps and AI to track the post-fire recovery of wildlife in Australia. Through partnerships with a range of on-ground land managers and researchers, EOR has deployed over 1000 remote cameras across the country. The initiative is also supporting camera data processing, analysis and sharing through an online photo management platform called 'Wildlife Insights' (WI). WI uses AI to automatically identify species and efficiently process the millions of images generated, providing ready-to-interpret datasets that inform important management decisions. For example, EOR is currently supporting a project led by the Kangaroo Island Landscape Board, to assess the impacts of fire and feral cats on Kangaroo Island dunnart (*Sminthopsis fuliginosus aitkeni*) populations across the island (Fig. 31.3). These data are contributing to an understanding of the recovery of this endangered species and are informing future management of the dunnart, invasive species and fire.

Fig. 31.3. Installation of an Eyes On Recovery camera trap to monitor Kangaroo Island dunnarts and feral cats on Kangaroo Island, South Australia. (Photo: Hannah Byrne-Willey)

To assess the effectiveness of fire management on public land, the Victorian Government is investing in the collection of biodiversity data in key vegetation types across the state. The proposed monitoring design includes ongoing surveys of biodiversity at ~200 locations within each of 11 priority vegetation types (a total of 2200 monitoring sites). Surveys in the sandy heathlands of western Victoria have commenced at 192 sites in fire-prone heathlands, stratified by time since the last fire, fire interval and fire severity. Sampling includes field surveys of birds, ground-dwelling mammals, plants and habitat structure at each site, providing a strong foundation for learning, including about species relationships to fire regimes.

Increasing awareness of invertebrate declines and what these mean for ecological processes and ecosystem services (Braby 2019) is driving a renewed interest in invertebrate monitoring. This is particularly important because of the enormous number of poorly documented, narrow-range endemic species (Box 31.4; Chapter 11).

Box 31.4. Impacts on litter invertebrates in south-eastern rainforests

Australia's invertebrates are incredibly diverse and functionally important, yet only 30% of Australia's insects have been described and there have been limited efforts to document their responses to fire. A set of long-term monitoring sites was established to test the short-term impacts of the 2019–20 wildfires on litter invertebrates of

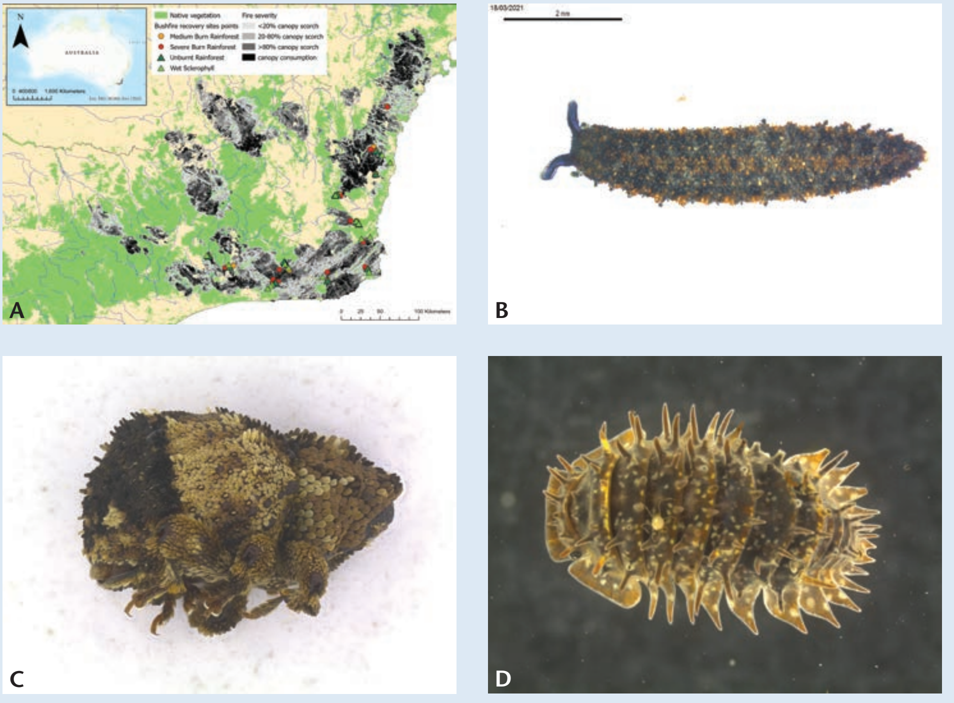

Fig. 31.4. (A) Sites sampled in post-fire survey of litter invertebrates in temperate rainforests; and leaf litter species (mostly undescribed) collected during the fieldwork: (B) velvet worm (Onychophora), (C) cryptorhynchine weevil (Coleoptera: Curculionidae), and (D) pill woodlouse (Isopoda: Armadillidae). (Photos: Joshua Grubb)

Australia's south-eastern rainforests (Fig. 31.4). Isolated and relictual rainforests were targeted because they are likely to support many endemic species. Species were identified using morphology and DNA barcoding. Sixty-eight sites were sampled across a fire severity gradient, 1 year after the fires (Fig. 31.4). Over 50 000 litter invertebrates were collected, 19 000 of which were beetles. Abundances declined with increasing fire severity in rainforest patches. Most species collected were undescribed (e.g. eight out of 11 velvet worm species) and occupied small ranges, suggesting high levels of endemism. The range restriction of most species suggests that large-scale severe fires could have caused the extinction of as-yet-undescribed litter invertebrates in this ecosystem. This systematic and large-scale survey design will make an excellent baseline dataset for future monitoring.

Much of the limited monitoring effort for Australian biodiversity is focused on trends in species' abundance or occupancy. But many other components of our environments are also affected by wildfire and merit consideration in monitoring programs, preferably in integrated programs that can help us understand the links among the elements of biodiversity (Box 31.5). For example, Chapter 5 notes that soils can be severely depleted and changed by wildfire, but that our understanding of that process and its consequences for biodiversity is currently constrained by limited knowledge of impact and recovery; hence more targeted monitoring is required. Chapter 4 reports substantial overlaps of the

2019–20 wildfires with sites of biodiversity significance, including wetlands of international importance and World Heritage areas. In contrast to species abundance and monitoring, such sites commonly have formally accepted definitions of target states, indicators and limits of acceptable change, with ongoing monitoring reporting on the extent to which the condition of these sites is acceptable (BMT WBM 2011). This provides a ready-made framework for monitoring and contextualising the impacts of fires or other disturbance events.

Box 31.5. Integrated ecosystem monitoring: alpine ash forests on the edge

Australia supports few integrated ecosystem monitoring programs that link multiple species and ecological monitoring activities together. Integrated monitoring programs present the opportunity to learn about interactions among species, ecological processes and management in a way that single species monitoring programs cannot. For example, in Victoria's fire-sensitive alpine ash (*Eucalyptus delegatensis*) forests, there is a network of 120 plots across a gradient of fire histories, with variable histories of aerial sowing (to assist recovery from recent fires) (Wagner and Nitschke 2021). The monitoring regime includes a range of structural and compositional components of the ecosystem and soils (Fig. 31.5). Remote camera traps and audio detectors record fauna at sites. The plot network provides a baseline dataset to evaluate changes in biodiversity and ecosystem services as forest structure and composition change over time with disturbance and growth, allowing a clearer understanding of how transitions (e.g. away from dominance by alpine ash) influence fauna and other vegetation dynamics.

Fig. 31.5. Regenerating alpine ash following a single high severity fire in 2007. (Photo: Benjamin Wagner)

The impact of any given fire depends critically on the preceding sequence of fires and environmental conditions, and the environmental conditions after the fire. To maximise our learning from monitoring data, it is important to consider contextual variables such as drought before or after the fire, and fire history (the spatial and temporal dimensions of successive fires). For example, NSW vegetation types have been characterised by their responses to fire, particularly with reference to fire thresholds (mostly defined by successive fires at intervals too short or too long to allow for recruitment and persistence of key plant species). Spatial analysis of fire histories showed that many vegetation types that were largely within the optimal threshold range before the 2019–20 wildfires are now vulnerable because these fires occurred too soon after previous fires, and that the extent of long unburnt vegetation has diminished considerably (Williamson 2020). Such spatial information (e.g. remaining long unburnt patches) can also be critical for management (e.g. as refuges needing protection from future fires and logging).

Conclusions

The efforts to respond to the 2019–20 wildfires highlighted the critical importance of monitoring data. The need to urgently assess the biodiversity impacts of the fires created a spike in biodiversity survey and data synthesis. However, it is suboptimal that data collection and syntheses of monitoring datasets are completed by agencies only after a major disaster. Such an arrangement hinders rapid and accurate understanding of species most in need of rapid recovery actions, and prevents use of biodiversity data in state-wide and national disaster planning and preparation. The acknowledgement by agencies and policy makers of the important role that monitoring data play before, during and immediately following fire provides a unique policy opportunity to substantially and strategically increase investment in more extensive, taxonomically representative, and better coordinated biodiversity monitoring. The opportunity to grow a stronger biodiversity monitoring culture and systems in Australia is enhanced by the number of recent surveys and the compilation of existing monitoring data (Southwell *et al.* 2022). Together these establish a new, post-fire baseline on which a properly resourced ongoing monitoring effort could be founded. However, without effective investment in coordination and infrastructure, the data synthesis efforts of the past 2 years will be largely wasted. Now is the time for a national biodiversity data and monitoring plan and institution that will empower biodiversity management with data and evidence.

Recommendations

- Immediately invest in well-designed and strategic long-term biodiversity data and monitoring programs and infrastructure so that management decisions are routinely based on an accurate understanding of the state of biodiversity and evidence about the effectiveness of management.
- Design new monitoring programs that recognise and redress biases in the existing monitoring effort, to include more representation of the taxonomic groups currently subject to least monitoring (e.g. invertebrates, fungi and many plants).
- Invest in systems of pre-fire preparedness that specify how monitoring data will be used to inform impact avoidance (such as strategic fuel-reduction burning), strategic protection during a fire, and rapid and more accurate post-fire assessment of impacts to inform emergency recovery.

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