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Supplemental Information

Supplemental Information associated with this article can be found online at https://doi.org/10.1016/j.tree.2020.06.005.

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https://doi.org/10.1016/j.tree.2020.06.005

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Science and Society

After the Megafires: What Next for Australian Wildlife?

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The 2019–2020 megafires in Australia brought a tragic loss of human life and the most dramatic loss of habitat for threatened species and devastation of ecological communities in postcolonial history. What must be done now to keep impacted species from extinction? What can be done to avoid a repeat of the impacts of such devastating bushfires? Here, we describe hard-won lessons that may also be of global relevance.

A Season in Hell

Despite the familiarity of Australia with fire, the timing, ferocity, and extent of the 2019–2020 fires was shocking. By area burnt, it was the largest fire season in eastern Australia since European occupation. The total area burnt in eastern Australia from August 2019 to March 2020 was almost 126 000 km^2 or 12.6 million hectares, almost the area of England (13 million ha) (Figure 1). Megafires have occurred intermittently in Australia over the past 150 years, possibly facilitated by the removal of traditional land practices of indigenous people. For example, in 2009, fires in eastern Australia burnt an area <10% of the most recent fires, killing 173 people and destroying >2000 dwellings. However, this most recent fire season was unprecedented in geographical scale, duration, and intensity, and has had major impacts on species and ecosystems that were already under immense stress from prolonged drought. The comprehensiveness of the destruction is striking. Postfire aerial reconnaissance revealed vast landscapes of grey ash extending as far as the eye can see: grey, not a hint of green, bounded only by the blue of sea and sky (Figure 1).

The full impacts on biodiversity will not be fully understood for years to come as extinction debts are realised. Some coarse surrogates paint a stark picture: 327 (272 plants, and 55 animals, including five invertebrates) of the ~1800 listed threatened species in Australia had a significant portion (>10%) of their known distribution within the fire footprint[i], of which 31 were already critically endangered. Among the significantly impacted species, 114 have lost at least half of their habitat and 49 have lost over 80%. Although these numbers are still being refined, this is likely to result in significant population losses. The conservation status of many species [e.g., gang gang cockatoo (*Callocephalon fimbriatum*) and yellow-bellied glider (*Petaurus australis*)] previously considered secure, will now need to be reconsidered. Impacts will be long-lasting, because many of the fire-affected species were dependent upon long-unburnt habitats that take decades to re-establish and many have slow reproductive output and, thus, it will take many years for populations to re-establish. Thousands of less well-known species, including invertebrates and plants, many yet to be described and many with very localised distributions, will have suffered dramatic impacts. Some may even have become extinct before being discovered or named.

Most fires leave a scattering of unburnt patches within the fire footprint, often in small topographical features such as sheltered, wetter gullies, but sometimes also due to the vagaries of sudden windshifts that send the fire in a different direction. Although a comprehensive analysis of the spatial variation in fire intensity across the

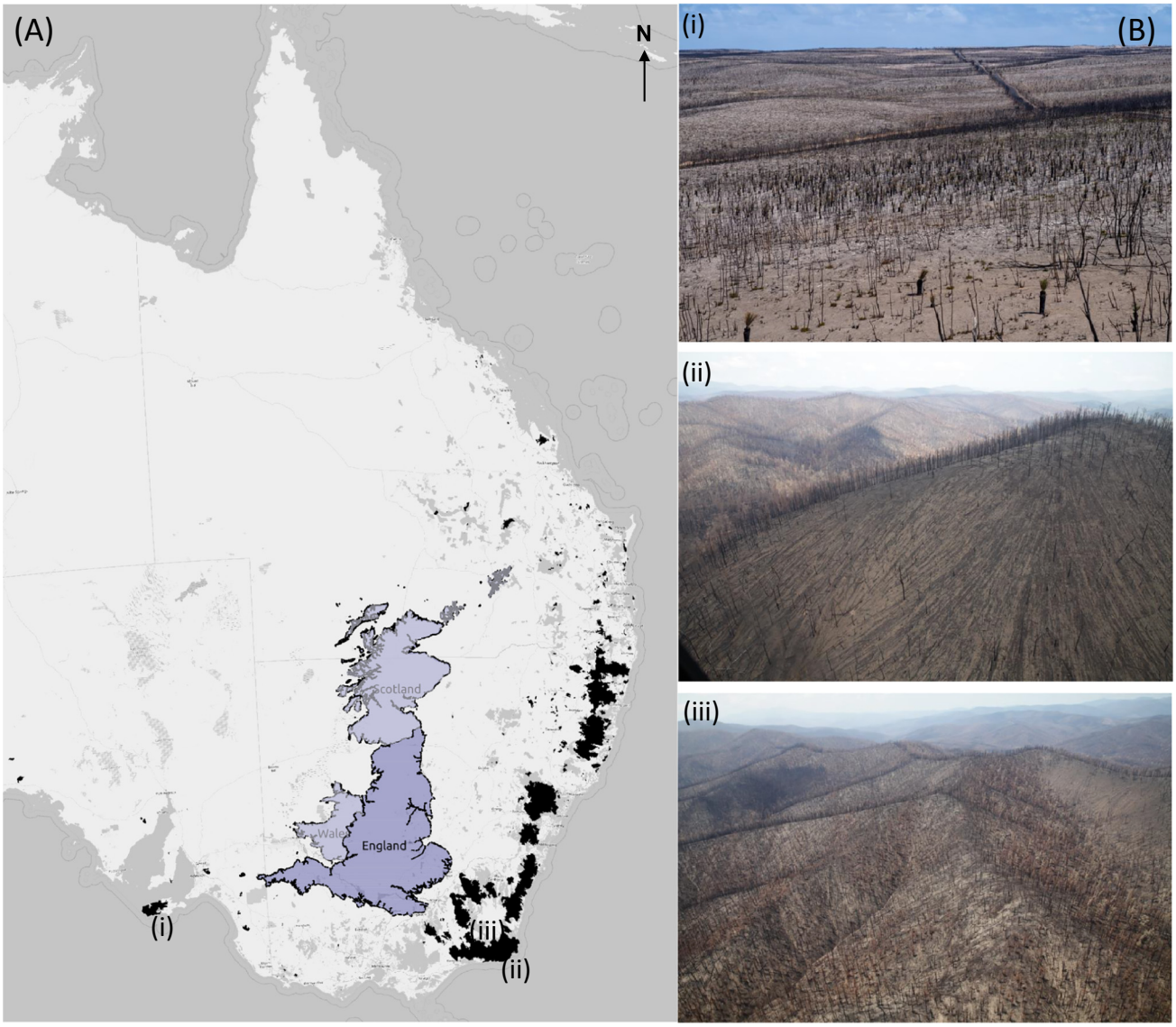

Figure 1. Images of the Extent and Severity of Australia's 2019–2020 Wildfires. (A) The extent of the east-coast mainland Australia and Kangaroo Island fires (2019–2020) is indicated in black. Western Australia also experienced a large number of significant wildfires (not mapped). The ghosted scale map of Great Britain gives a relative indication of the geographical spread of the fires. Locations of the photos in (B) are indicated. (B) (i) A roadside view of a portion of Kangaroo Island firescape looking toward the Cape Du Couedic lighthouse in Flinders Chase National Park (South Australia) with grass trees (*Xanthorrhoea semiplana*) beginning to resprout; (ii) aerial views of East Gippsland firescapes near the town of Mallacoota and (iii) Genoa (Victoria). Photos reproduced, with permission, from Nicolas Rakotopare [B(i); National Environmental Science Program (NESP) Threatened Species Recovery Hub] and Mark Norman [B(ii, iii); Parks Victoria]. Note, in all cases, the absence of unburnt patches that could harbour survivors from fire and provide postfire refuge.

entire fire-affected areas is yet to be done, it appears that, at least in some regions, the 2019–2020 fires burnt extraordinarily thoroughly, even burning through landscape features such as deep gullies, rainforest edges, rocky outcrops, and riparian strips, that have acted as fire refuges in past fire events (Figure 1). This creates a new and more serious challenge for the recovery of species. Immediately following fire, animals that survived the blaze by sheltering underground, in water, or in rocks are faced with the challenge of finding food and avoiding predation in a moonscape environment. Many will perish due to lack of food and shelter. Animals able to find the rare patches of unburnt vegetation will likely find it to be suboptimal habitat or the territory of another animal. Plants regenerating after fire are vulnerable to herbivores and desiccation. Fish die in warm, deoxygenated water

caused by heavy loads of sediment and ash following the first post-fire rains. A particular challenge of megafires is that, as the bushland slowly recovers, the prospects for recolonisation by dispersal-limited species is greatly diminished due to the larger distances over which species need to travel to recolonise suitable habitat. In many cases, those dispersal pathways are now interrupted by cleared land and human settlements or dams and weirs on rivers. Recovery will also be stymied if, as is likely, the interval between successive fires decreases.

In the Heat of the Moment

In the midst of emergency, the response was, understandably, almost solely about human life and property. Unfortunately, there was little strategic priority in fire control operations for the protection of key populations of threatened species, critical habitats, and threatened ecological communities. Thus, aside from a small number of exceptional cases, biodiversity destruction was unabated by human intervention. In the immediate aftermath of fires, the wildlife response focussed primarily on animal welfare. The triage effort by veterinarians was impressively rapid, with significant government support. Images of koalas (*Phascolarctos cinereus*) in bandages being offered water by fire fighters resulted in ~$AU100 million being donated to animal welfare organisations. One of only a few pre-emptive responses aimed at species conservation was for the critically endangered Wollemi pine (*Wollemia nobilis*), a highly restricted species of great antiquity: the species was saved by an air operations crew who deposited fire retardant on the ridge-lines surrounding the few populations, and by conservation managers setting up irrigation systems around trees. This was a wonderful, but sadly exceptional, proactive nature conservation success. The absence of strategic protection targeting the protection of threatened species, ecosystems, and iconic places is disappointing, given that we know how much harder it is to restore or repair nature than it is to avoid its loss or damage.

As the Smoke Cleared

By contrast, the postfire response of agencies has been energetic, focussed, and adept. Before the fires were out, federal and state governments pledged nearly $AU100 million for conservation. Expert panels were formed, impacts on species and ecosystems were analysed with support from science and nongovernment organisations. Experts salvaged birds, plants and their seed, and fish species that faced postfire demise or were in imminent danger from further fire. Actions included targeted control of feral herbivores and predators, erection of artificial nest boxes, and supplementary feeding of endangered macropods. For the most part, it was an impressive start to the long journey of postfire conservation.

At the time of writing, the Australian Government and civil society organisations continue to allocate significant resources to support the recovery of fire-affected species and environments. Such actions include postfire reconnaissance to quantify impacts on species and ecosystems, to manage postfire threats, and to monitor changes in species and ecosystems following fire and in response to recovery actions. Some of the most widely deployed actions have included aerial culling of feral herbivores (mostly deer) that threaten the regeneration of sensitive forest and alpine ecosystems, and intensified baiting of introduced predators (mostly foxes) in fire-affected areas and fire fringes where they hunt native wildlife more intensively and successfully [1].

Compared with the limited consideration of biodiversity protection in preparatory fire management plans and during the fire emergency, the immediate postfire response was generally well organised, science based, and relatively well resourced.

What now?

The increased attention given to the plight of wildlife during the fires in the media has created momentum around postfire biodiversity conservation. Given that recovery efforts may need to be sustained for years, even decades, a key challenge will be to maintain support for those efforts as the collective memory of the fire fades and governments and society now grapple with another disaster, COVID-19. Monitoring the outcomes of recovery efforts and tracking the fate of species after the fires is crucial, not only to inform where ongoing investment of conservation effort is most needed and which recovery actions are working best, but also for public engagement [2].

Numerous challenges remain; systematic prioritisation is required to determine where spending and conservation efforts, such as predator and herbivore control, are most beneficial, and to correctly time and implement the re-introduction of species that were rescued during and immediately following the fire. Translocations will also be needed to 'rescue' or bolster populations, and to re-establish populations in areas from which they were extirpated. Reassessment of conservation status will be required to identify and list species that now face a palpable risk of extinction. Active restoration, including seed harvesting and aerial sowing of some forest ecosystems, will be needed if they are to persist following repeated recent fires [3]. There is a significant opportunity to couple postfire forest restoration efforts with carbon sequestration-funding initiatives to leverage biodiversity conservation. However, most of these actions must be deployed under imperfect knowledge, making rigorous monitoring of the outcomes crucial for improving understanding and maximising ongoing

effectiveness in an adaptive management framework [4].

Avoidance of damaging postfire 'salvage' logging is key to the survival of many species, such as the threatened greater glider (*Petauroides volans*) and sooty owl (*Tyto tenebricosa*) [5]. Protecting residual old-forest habitats is one of the most crucial but politically challenging postfire actions to achieve because conserving habitat for threatened species competes with economic considerations. Unfortunately, each new fire confers greater importance on the diminishing old-forest habitats that remain, making their protection ever more critical to the survival of old-forest-dependent species. Careful analysis of the importance of remaining habitats for the survival of species, based on population viability analysis, provides evidence to support their protection in the face of economic pressures [6,7].

It Will Happen Again: Get Ready

Consistent with an escalating global trend of warming and drying, 2019 was the hottest and driest year on record in Australia[ii]. National annual rainfall was 40% lower than the long-term average and maximum temperatures were, on average 2.1°C above the long-run average maxima. The forest fire index in December 2019 was the highest on record for almost all of eastern Australia [8]. These conditions will increase in frequency with a changing climate, and catastrophic fire events will also become more frequent.

There is little joy to be derived from reflecting on the ever-increasing size of fires and the ever-diminishing interval between them. However, it drives home the importance of learning from each experience and doing better next time, for there will be lots of next times. Clear guidance on how to most effectively organise species and ecosystem conservation activities before, during, and immediately following a major fire event can be helpful (Figure 2). Reflecting on the recent fire season, we failed nature, both in the heat of the moment and beforehand. Precautionary precatastrophe actions should include: the establishment of more insurance populations (which can be used as sources after such extensive fires); translocations to better allow risks to be spread; more effective, sustained, and extensive control of other threats that can compound fire impacts; and collection of baseline monitoring and survey data to help identify places critical to protect, prioritise emergency responses, and provide clarity around what has been lost immediately following a fire event.

Most of the 2019–2020 fires were ignited by lightning strike, and little can be done to stop this. However, many fires are anthropogenic in origin [9]. Reducing anthropogenic ignitions and providing more effective suppression before fires get out of control could both be helpful. As a society, we could make the choice to invest more in early-strike fire suppression capacity. There is also a need for strategy, planning, and a greater recognition in fire control centres of the importance of protecting natural assets during fire. At present, natural assets feature only in some of the plans that form the basis for fire-fighting strategy. In most fire management and control plans, there is little spatial information on the occurrence of critical biodiversity features that must be protected, acknowledging that it is impossible to replace millions of years of evolution. It may be unrealistic to expect critical habitats of our most precarious species to compete for fire-fighting resources with houses and farms. We are far too self-interested. However, could we imagine the last remaining habitat for a brush-tailed rock-wallaby (*Petrogale penicillata*) might feature as an asset for protection in a fire that is burning through a wilderness area? Surely that needs doing. It will require prioritisation, mapping habitats of precious fire-sensitive species, and a signal to the fire controller that these maps should sit alongside critical human infrastructure maps in the fire room. Inclusion of biodiversity assets in fire management plans and fire control operations also needs to be complemented by increased recognition of the risks of wildfire within conservation management and recovery planning: very few of such existing plans for threatened species anticipated such catastrophes or provided useful guidance on how to respond.

We should learn from what went well this past fire season and ensure that successful responses are hardwired for next time, here in Australia and in comparable biomes elsewhere in the world. The rapid production of spatial statistical summaries identifying species that were most impacted facilitated prioritisation of immediate care, and what form that care should take; these actions probably saved species. Fortunately, some of those processes have been documented and made publicly available[i].

There is a role for everyone in reducing risks of fire, minimising losses during fire, and recovery after fire. We have focussed here primarily on the role of land managers, wildlife rescue, policy makers, and ecologists. However, the most crucial role may reside in the media and social sciences. There is a significant risk that mega-fires will be attributed to the occurrence of natural vegetation. We need to better understand these perceptions and design messages that dampen the desire to punish the bush for what happened to rural communities and avoid an outbreak of illegal or state-sanctioned land clearing in the name of fire prevention. It is vital to communicate the awe and wonder of our species and ecosystems, and the message that, while we will always live with the risk of fire in our landscapes, those risks to people and property can be managed and mitigated without the need for further sacrifice of nature.

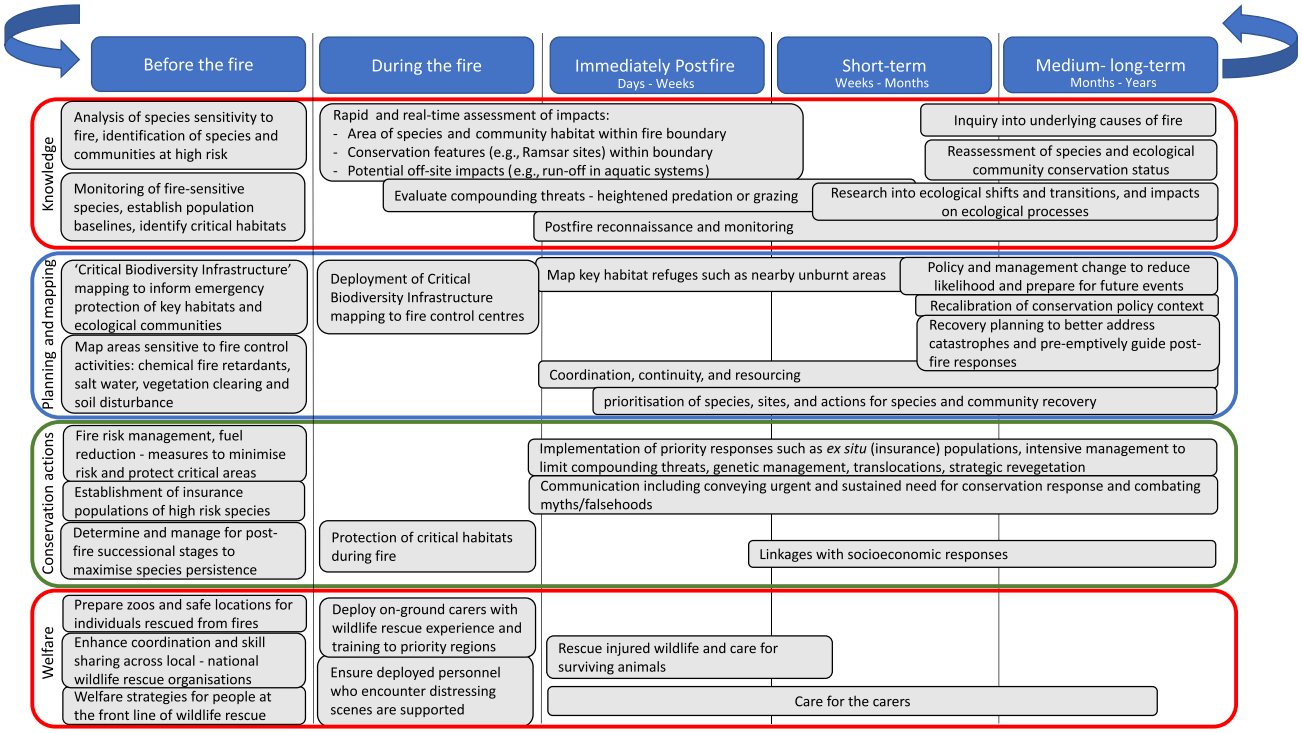

Figure 2. Key Activities in Bushfire Preparation and Response to Minimise the Loss of Biodiversity and to Help Ensure and Expedite its Recovery. Activities are organised according to the relevant timing (columns) and under broad families of activities (rows). Crucial elements in the preparatory phase 'before the fire' that were not adequately addressed before the 2019–2020 Australian megafires include analysis and synthesis of species sensitivity to fire, monitoring, surveying, and mapping to delineate critical habitats for protection and emergency postfire action. Undertaking adequate preparation will help ensure that, during and immediately post fire, actions will be efficiently deployed to protect sensitive and critical biodiversity assets and rapidly drive their recovery. Many of the medium–long-term postfire activities support preparation for the next fire event, such as policy and management changes, to reduce the likelihood and minimise the impacts of future events.

Acknowledgements

Thanks to many people who contributed knowledge, ideas, and data. Thanks to Natasha Cadenhead and Casey Visintin for assistance with editing and figures. Thanks to the community and many agencies for their extraordinary efforts to recover biodiversity.

Resources

[i]www.environment.gov.au/biodiversity/bushfire-recovery/research-and-resources

[ii]www.bom.gov.au/climate/current/annual/aus/#tabs=Overview

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https://doi.org/10.1016/j.tree.2020.06.009

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Science & Society

Valuing Ecosystem Services Can Help to Save Seabirds

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Biodiversity provides crucial but overlooked contributions to human wellbeing. One way to call attention to these contributions is to monetise them. We have estimated that the value of seabird nutrient deposition could be up to US$473.83 million annually. This figure should increase