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Threatened Species Recovery Hub

National Environmental Science Programme

IMAGE: JAANA DIELENBERG

Editorial...

From the ashes: The 2019–20 wildfires and biodiversity loss and recovery

Fire is a complex, important and pervasive ingredient in the ecology of Australia. It destroys life but brings renewal. It can operate within or beyond our control. Individual fires, and the historic patterning of fires, can have severe impacts on many threatened species and ecological communities. And fire can compound the impacts of many other threats. **Professor John Woinarski** of Charles Darwin University discusses the catastrophic losses of the 2019–20 fires, and how we can move on from mourning to action that can limit such future devastation.

IMAGE: NICOLAS RAKOTOPARE

Although fire is an inextricable component of most Australian ecosystems, the 2019–20 wildfires of eastern and southern Australia were way beyond normal. Catalysed by extensive drought and unusually high temperatures, these fires were exceptionally extensive, long-lasting and severe. More than 12 million hectares were burnt over the period August 2019 to March 2020, across forests, heathlands and farmlands from south-eastern Queensland to eastern Victoria, on Kangaroo Island and in south-western Australia.

Conservation setback

These fires killed residents and firefighters, destroyed infrastructure and had severe impacts on many regional communities. Major conservation values were affected, including many national parks, World Heritage areas, wetlands of international significance, and threatened species and ecological communities. In some cases, the gains made from years of painstaking conservation effort were destroyed or significantly set back. Most likely, no other event in our lifetimes has had such a sudden and drastic effect on wildlife conservation in Australia.

Awareness of the catastrophic scale of the environmental loss was seared in community perception by images of badly burned koalas, the charred corpses of kangaroos and vast blackened landscapes, and by the stories told by those dealing with injured wildlife, or scarred by witnessing such loss of nature. The responses by governments, conservation NGOs, landholders and the Australian and international public were extraordinary, and heartening. Much support was mobilised; many injured animals were rescued; some threatened species (such as the Wollemi pine) were expertly protected from imminent fires; and many agencies undertook emergency post-fire responses.

These were critical and timely actions, but there will be a long and arduous road to recovery for many species and ecosystems. The on-ground actions will need to be complemented by overhauls of management, planning and policy informed by lessons learned from these fires. To help frame such a strategic response, the Threatened Species Recovery Hub (with inputs from other researchers) rapidly developed a blueprint for recovery of biodiversity – see *Further reading*.

Future responses

Unfortunately, government, community and conservation systems were not well prepared for these fires. We need to reduce the likelihood of such future fires; ensure that key biodiversity values are better protected in fire planning and suppression; and be capable of responding even more rapidly and cohesively in the aftermath of any future fires. Building such resilience will be contingent on the manner in which we deal with the fundamental underlying cause of mega-fires – climate change. Unless global emissions are curtailed, it is inexorable that the dystopia we witnessed in the 2019–20 wildfires will recur, with increasing frequency and extent, and with diminishing chances of environmental recovery.

Along with the conservation and research programs of many other groups, many of our projects were affected by these fires. These project impacts have since been compounded by the travel restrictions imposed in response to COVID-19: many of us can't yet access the fire-affected sites critical for our research and management.

ABOVE: Green shoots emerge after an early season burn on the Tiwi Islands.

Inside the Winter 2020 issue of *Science for Saving Species*

Threatened Species Recovery Hub

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The fires also present important research opportunities. There is much that we need to learn about immediate and longer-term impacts and about what recovery actions are most effective. Major knowledge gaps have hindered our remedial management responses this time; and we should aim to have greater preparedness for any next time.

Monitoring is a notable example: notwithstanding many calls to remedy the deficiency, Australia lacks a comprehensive national biodiversity monitoring program. That lack renders it especially difficult to assess the extent of biodiversity loss due to these fires and reduces the capacity to measure the extent and rate of recovery and the effectiveness of recovery actions. Likewise, there is limited distributional information for many species, making it challenging to assess the proportional loss in fires for many species, or to identify key strongholds that may have escaped the fire.

Australian Government responds

The Australian Government rapidly committed $50 million to urgent post-fire conservation actions, with a subsequent $150 million for ongoing strategic responses. Recognising the urgent need to assess the impact of these fires on biodiversity, and that more evidence was needed to help design and prioritise recovery actions, the Minister for the Environment directed $2 million to the hub to undertake a set of priority fire-related research projects. These projects include development of monitoring guidelines; more detailed assessments of wildlife mortality and of the impacts of the 2019–20 fires on invertebrates and frogs; Indigenous involvement in bushfire recovery; development of conservation strategies for fire-affected threatened ecological communities; and many others.

With membership including several hub researchers, an expert advisory panel was established by the Australian Government to assess, at national scale, the national impacts of the 2019–20 wildfires on biodiversity and to help guide allocation of substantial Australian Government funding for urgent and longer-term recovery management actions. Assessments coordinated by that panel have identified 471 plant, 213 invertebrate and 92 vertebrate species that have been most severely affected by these fires.

In most cases, more than 50% of the distributions of these species was burnt; in many cases over 80% of the distribution was burnt; and the entire extent of the known distribution of some species was exposed to high-intensity fire. It may be that the fires have caused the extinction of some of these species, but the evidence is not yet available to demonstrate such an unwanted outcome.

Many of the most affected species were highly restricted (narrow range endemics): there are many such invertebrate and plant examples, especially from the Stirling Range in south-western Australia, and from Kangaroo Island. But even species with vast ranges (such as the yellow-bellied glider) were substantially affected by these fires, leaving large formerly occupied areas now uninhabitable (at least for a time) and severely fragmenting surviving populations.

As a consequence of these wildfires, there will be an urgent need to assess or re-assess the conservation status of hundreds of species, to give those most fire-affected species more legal protection and a profile for conservation management. Many threatened species are now far more imperilled, and many species we formerly considered secure can no longer be presumed safe. The 2019–20 wildfires caused a loss of extraordinary magnitude to Australian biodiversity.

Our challenge is to go beyond mourning that loss, to instead work even harder and more strategically for recovery; to help shape a better future for us and our environments – a future that is more resilient, and less likely to experience another such catastrophe.

Further reading

https://theconversation.com/a-season-in-hell-bushfires-push-at-least-20-threatened-species-closer-to-extinction-129533

https://theconversation.com/after-the-bushfires-we-helped-choose-the-animals-and-plants-in-most-need-heres-how-we-did-it-138736

https://www.nespthreatenedspecies.edu.au/_images/Projects/After%20the%20catastrophe%20report_V5.pdf

Further information

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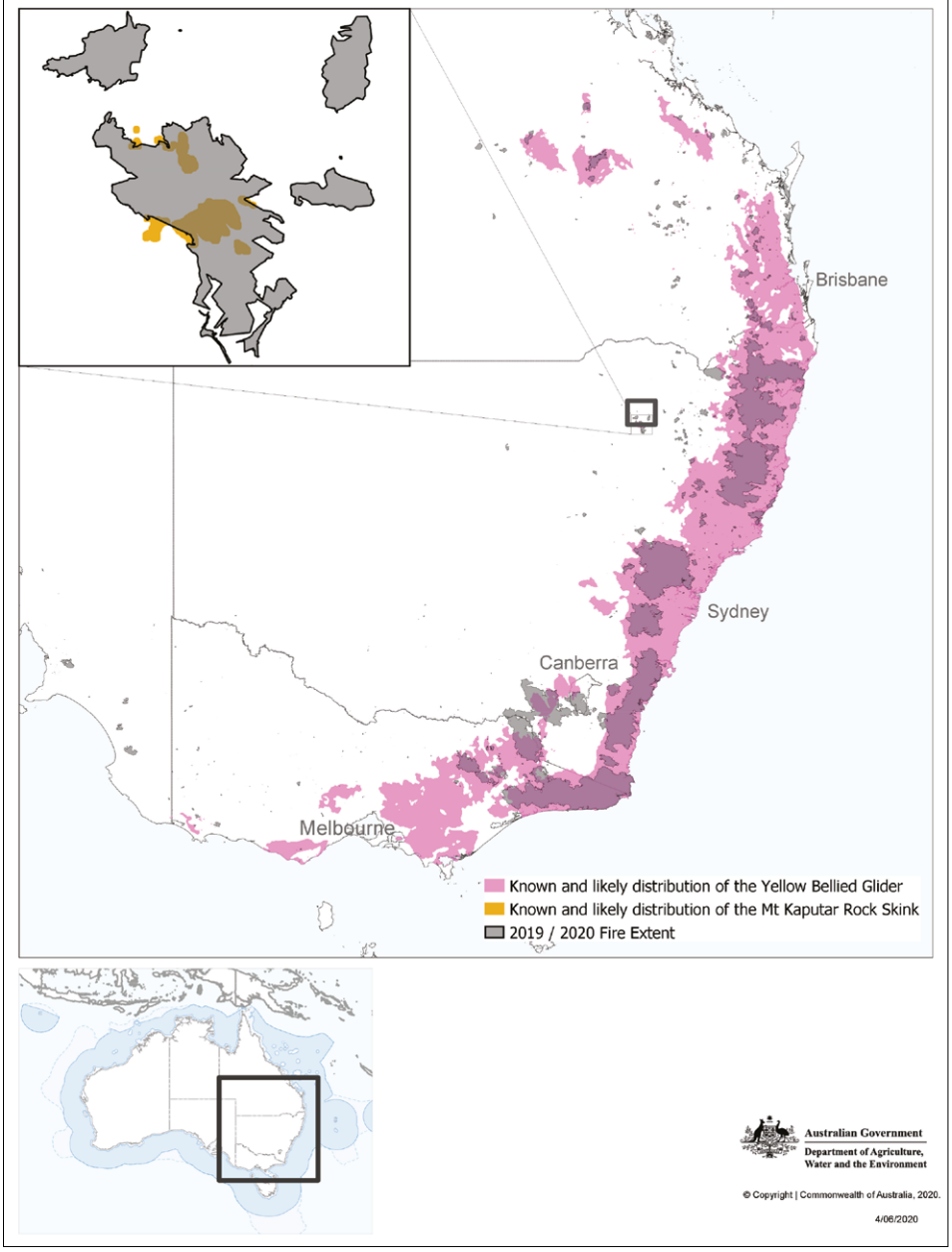
MAP: Geospatial and Information Analytics (ERIN), Department of Agriculture, Water and the Environment, May 2020

Many of the species most affected by the 2019–20 fires had very small ranges, unhappily coinciding with fires (an example is the Mount Kaputar rock skink), but even species with vast ranges (such as the yellow-bellied glider) suffered very significant losses.



Rapid action to save species after the fires

The Australian Government's Threatened Species Commissioner Dr Sally Box talking to Pat Hodgens (left) and Heidi Groffen (right) from Kangaroo Island Land for Wildlife about shelter tunnels for the Kangaroo Island dunnart.

IMAGE: NICOLAS RAKOTOPARE

The Australian Government's Threatened Species Commissioner and Chair of the Wildlife and Threatened Species Bushfire Recovery Expert Panel **Dr Sally Box** talks about the support for long-term recovery of species and ecological communities devastated by the 2019–20 fires.

In January, at the height of the fires, the Australian Government appointed a Wildlife and Threatened Species Bushfire Recovery Expert Panel, which worked rapidly to identify the species and ecological communities most in need of assistance, and the urgent management actions required.

This was a massive, collaborative task involving the Australian, state and territory governments and a wide range of relevant experts, including many from the Threatened Species Recovery Hub, to collate and analyse fire extent mapping, species distribution data and species traits information.

In parallel to this work, wildlife organisations, zoos, local community groups and government agencies took action on the ground – salvaging plant and animal species, providing emergency food drops for native animals, protecting unburnt areas, and controlling feral pests and weeds. The shared goal was and still is to give our precious wildlife, habitats and unique places the best possible chance of recovery.

In January and February, the Minister for the Environment the Hon Sussan Ley MP hosted a series of roundtables with stakeholders to inform the Australian Government's response to the bushfires for the environment. More than 200 experts from the government, NGO, industry and business sectors met to collaborate and develop shared responses to the emergency.

The Australian Government's initial $50 million supported quick emergency intervention early on and, with the additional $150 million investment announced in May, we are now able to focus on longer-term recovery plans and actions. The Expert Panel's scientific advice on priority species and actions has informed the government's investments to date and will continue to guide our response. The panel's close collaboration with the Threatened Species Recovery Hub and its bushfire recovery research program will continue to be vitally important as we move forward.

Stories of hope

There's great work underway across the country, despite COVID-19 presenting some challenges. In the World Heritage-listed Blue Mountains, work continues to support the recovery of the brush-tailed rock-wallaby and Wollemi pines, and to return koalas rescued from the fires back to the wild.

There are signs of hope in even the most severely burnt landscapes. Kangaroo Island dunnarts have been sighted in small areas of unburned habitat. Actions to protect these precious remaining animals include control of feral cats, construction of a new fenced exclosure and installation of shelter tunnels to allow the dunnarts to safely move around.

Greening Australia has identified native seed supply needs and is producing the seedlings needed for landscape restoration and a sustainable, long-term native plant and seed sector.

Taronga Zoo is establishing an insurance colony of the northern corroboree frog from the Fiery Ranges, where 70% of remaining populations were impacted by the bushfires. A new breeding facility for this species is being established and the first 100 eggs have been collected from the wild.

There are many other stories, and time will reveal a clearer picture of the impacts of the fires and what is needed for our species' long-term recovery. But to date, a combined and passionate effort has resulted in rapid assessments and action for species we are most worried about.

Further information

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Wildlife and Threatened Species Bushfire Recovery Expert Panel
http://www.environment.gov.au/biodiversity/bushfire-recovery/expert-panel

Cultural fire: Listening to and caring for Country with fire


IMAGE: VERA HONG

RIGHT: Jacob Morris, an emerging cultural fire practitioner from the Gumea-Dharrawal clan of the Yuin Nation. Jacob was a workshop facilitator at the Bundanon National Indigenous Fire Workshop in 2018.

Cultural fire management is the way that Indigenous people have used fire to care for Country for thousands of years, and it continues today. The devastation wreaked by the 2019–20 bushfires across millions of hectares was a wake-up call for Australia and the world. **Oliver Costello** from the Firesticks Alliance explains how the fires demonstrated the need to listen to and care for Country.

For tens of thousands of years our ancestors of this land, Australia's First Peoples, managed Country with fire effectively to reduce bushfires and improve livelihoods. European colonisation led to a rapid suppression of Indigenous people's rights and access to land and resources. In recent decades, land rights, native title and Indigenous cultural and natural resource management have created strong and growing opportunities for collaboration and changes in how science and land management interact with Indigenous communities.

Cultural values and identity

One of the most significant cultural land management movements is Indigenous cultural fire management, knowledge and practice. Cultural fire management listens to country and draws on Indigenous Traditional Ecological Knowledge and the fundamental cultural responsibilities of Indigenous communities. Cultural fire management is based on people's cultural connections and authority to care for Country. Fire is important in managing the kinship between people, species and places. Fire management practices respond to cultural values and indicators of the Country types (cultural ecosystems).

Cultural values and indicators reflect the cultural and natural features of a community's relationships to a particular Country.

These indicators are specific to landscapes, ecosystems, places, species, vegetation, soils, climate and weather conditions. They relate to people's identity, knowledge, practices, heritage, resources, society, environment, economy and spiritual beliefs.

Burning for resilience

Cultural fire management will protect, maintain, heal and enhance ecosystems and cultural values, as it has done for thousands of years, while also reducing fuel loads that help to lessen negative impacts of bushfire in multiple ways. Cultural burning often involves more patchy, frequent and low-intensity fire regimes, which reduce inappropriate outcomes of fire for species and habitats. Cultural burning may not reduce as much fuel during each fire event compared to some hazard reduction or back-burning; however, over time, the cumulative effect of cultural burning can lead to longer-term fuel reduction and more resilient ecosystems and communities.

High-intensity fires have significant immediate and long-lasting impacts on the presence, distribution and abundance of species. Inappropriate fire regimes can often promote dysfunctional ecosystems, contributing to their longer-term decline and, often, an accumulation of fuel. This vegetation regrowth can lead to more frequent and intense fires, due to its type and structure.

There are also some landscapes that are suffering from a lack of fire. Fire is important to stimulate the germination of many plant species and without it some plant populations can age and die without the recruitment of new plants.

Sharing cultural fire knowledge

Cultural burning can better maintain healthy species dynamics, and reduce opportunities for invasive species to dominate. Cultural fire for ecosystems is a dynamic practice that can be continued or re-established to achieve many benefits. These have been well demonstrated through Indigenous-led programs such as the Firesticks Alliance.

The Firesticks Alliance provides leadership, advocacy and action to protect and enhance cultural and natural values of people and Country through cultural fire and land management practices. Firesticks values and respects Country, local knowledge and the protocols of Elders and ancestors. We are committed to providing a supportive Indigenous-led community of practice to maintain and share cultural fire knowledge and practice on Country.

Further information

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IMAGE: VERA HONG

Bundanon night fire, National Firesticks Workshop, 2018.

New shoots start the long road to recovery.

IMAGE: ANNE KERLE

Plants in the ashes: Prioritising Australian flora after the fires

Australia has one of the highest rates of plant endemism of any country globally. After the catastrophic fire season of 2019–20, **Dr Rachael Gallagher** and **Professor David Keith** are leading two teams to find out which species and ecological communities are most in need of immediate recovery.

During the 2019–20 bushfire season, over 12 million hectares of Australia burned. Many thousands of species were affected, and much focus has been on the rescue and care of Australia's animals. Yet Australia is home to around 25,000 native plant species, most of which are endemic and many that had more than 90% of their range burnt.

While many Australian plants are adapted to fire and thrive through resprouting and fire-induced seed germination, the fires have compounded the effects of other threats such as drought, grazing, disease or flooding, or made many plants more susceptible to those threats. This may significantly increase the risks of local, and even global, extinction. Australia's plant communities face similar issues and there is an urgent need for on-ground actions and legislative protections to ensure their survival.

IMAGE: BRETT SUMMERELL

LEFT: *Boronia imlayensis.*

A national prioritisation exercise is providing an evidence base for decision-making to inform the work of the Wildlife and Threatened Species Bushfire Recovery Expert Panel chaired by the Threatened Species Commissioner. The prioritisation is based on 11 criteria developed by Dr Tony Auld and colleagues within the New South Wales Department of Planning, Infrastructure and Environment to identify species suffering the greatest likely impacts. The criteria first ask how much of the distribution of each species or community fell within the area burnt by the 2019–20 fires. For the 19,004 plants so far assessed, up to 11,887 likely have some part of their range burnt, and 76–136 more than 90% burnt. These estimates are based on three complementary lines of evidence about species' ranges: herbarium occurrence data; modelled distributions based on climates and soils; or – for species listed under the EPBC Act – regulatory maps. Using multiple sources to estimate species' ranges helps to prevent over- or underestimating where plants occur in the landscape. Although knowing how much of the species range may have been burnt is crucial, it is just part of the puzzle for understanding the impacts.

Threats affecting fire recovery in plants

For many species, the bushfires were an additional stressor that worsened the effects of other threats affecting plant recruitment, growth and survival. In recognition of this, several of the 11 criteria concern the interacting effects on species of threats like drought, disease, grazing, weed invasion and changing temperatures. For instance, plants that have lost carbohydrate reserves because of prolonged drought conditions may struggle to resprout after fire, particularly if their storage or regenerative organs have been damaged. Pre-fire drought can also slow down reproduction, reducing the size of the seed bank available for post-fire recruitment. To assess this risk, we coupled plant and ecological community distribution data to estimates of the accumulated severity of drought in the year before the fire season (see Figures A and B). Accumulated drought severity was based on the Standardised Precipitation Index, which measures the variation in precipitation relative to the average.

Of the species we examined so far for the prioritisation, we considered 176 to be at high risk from pre-fire drought interacting with the impact of fire.

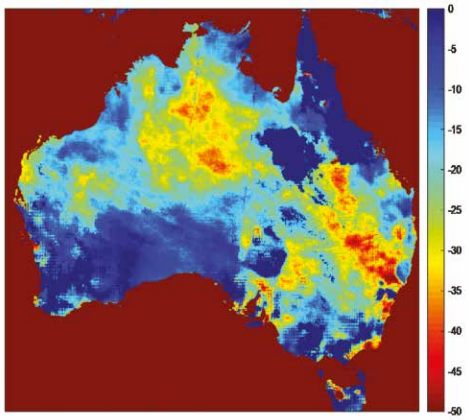

Figure A

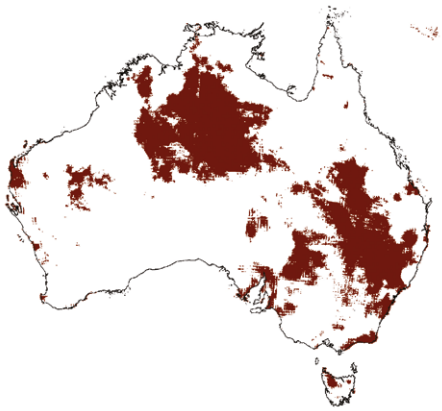

Figure B

Figure C

A) Accumulated severity of drought conditions in December 2019 over the previous 12-month period. More negative values correspond to more severe drought; (B) Classification of areas of significant pre-fire drought conditions used to assess against Criterion A – Interactive effects of fire and drought; (C) *Boronia imlayensis* had more than 95% of its range burned amid existing threats from prolonged drought conditions.

The ability of these species, such as the shrub *Boronia imlayensis*, to resprout after the fires may be seriously compromised by pre-fire drought. The Mount Imlay Boronia (Figure C) – which is currently not listed as threatened – has a highly restricted range, at least 96% of which was burnt. Unless its populations recover adequately, this species is now at risk of extinction.

Other interacting threats may limit the capacity of species to recover, such as high fire frequency (Criteria B and K), browsing and grazing of regenerating shoots (Criterion C) and the impact of diseases, such as myrtle rust and *Phytophthora* root rot, on regenerating plants (Criterion D).

For instance, the Eastern Stirling Range Montane Heath and Thicket Threatened Ecological Community (TEC) is currently listed as Endangered in the EPBC Act and was entirely burnt. Importantly, most of the TEC had also been burnt 18 months earlier, leaving little time for adequate recovery. Further, it is faced with significant risk from root rot disease, which seems to have even greater impacts on plant survival post-fire.

Ongoing analyses are showing that some locations in New South Wales and Western Australia have intervals between fires that are likely too short for recovery of the vegetation. Species in these areas are likely to become locally extinct and replaced by species with short generation times or non-woody underground root stalks, unless there are no further fires in the near future.

Cooperation across borders

The national prioritisation for plants and TECs involves cooperation across jurisdictions, with many agency staff from fire-affected states and territories providing data and knowledge, alongside the Australian Government Department of Agriculture, Water and the Environment. For instance, agencies have shared and integrated data on plant traits and fire extent to provide a more comprehensive picture of impact, while also helping to identify key gaps in our knowledge. The process has highlighted the need for rapid delivery of fire-mapping products and standardised national data about how plants respond to fire.

Assessing extinction risk against IUCN Red List criteria for fire-affected plants and ecosystems will also require collaboration, with experts contributing their knowledge and data. We have already prioritised 471 plant species and 19 TECs for the $12 million Wildlife and Habitat Bushfire Recovery Program. Many of these species need on-ground research to gather evidence about population size, threats and decline for listing under the EPBC Act or state legislation. Although *ex-situ* collection of seed material may be necessary in rare cases, the seed banks of the affected species should be allowed to replenish after the fires. This means avoiding follow-up fires for the next few years and preventing over-harvest of flowers and seed.

Given the richness of the Australian flora and the vast area of the continent, a collaborative approach to ecological research has never been more important.

The resprouting and germination currently underway may be jeopardised by the cascading effects of post-fire drought, grazing, weed invasion or disease.

A combination of boots on the ground, fingers on the laptops and minds on the analysis of data will be crucial to recovering Australian vegetation for the future.

Further information

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Further reading

https://www.environment.gov.au/biodiversity/bushfire-recovery/priority-plants

Regenerating cycads on the south coast of New South Wales.

IMAGE: ANNE KERLE

About three-quarters of the habitat of Kangaroo Island's Endangered glossy black-cockatoo population burned in the January 2020 bushfires.

IMAGE: NICOLAS RAKOTOPARE

Prioritising action for animal species after the fires

The 2019–20 bushfires burnt over 12 million hectares of south-eastern and south-western Australia, causing abrupt losses of biodiversity at a scale never seen before. Over a billion animals were estimated to have died, but the figure is likely much higher. The Australian Government's Wildlife and Threatened Species Bushfire Recovery Expert Panel is guiding the work of prioritising species and ecological communities for emergency interventions and determining what those actions should be. Hub Deputy Director and Expert Panel member **Professor Sarah Legge** takes us though the hows and whys of this prioritisation, and some of its challenges.

Conservation scientists and managers have never experienced anything like these wildfires before, and no precedent existed for designing and implementing a response. The crisis elicited extraordinary and immediate cooperation among governments, NGOs, community groups, universities and carer groups, aiming to reduce post-fire mortality and suffering, and support population recovery.

BELOW: Between 50 and 80% of the range of the Hastings River mouse (*Pseudomys oralis*) was affected by fire.

IMAGE: DOUG BECKERS CC BY-SA 2.0 WIKIMEDIA COMMONS

State, territory and Commonwealth governments rapidly developed strategic responses, to which many non-government and community groups aligned.

In mid-January, the Threatened Species Commissioner convened an Expert Panel to guide the national response to fire-affected species, ecological communities, natural assets and their Indigenous cultural values. The panel produced the first priority list three weeks later, after an assessment of all fire-affected vertebrates, nationally listed terrestrial invertebrates and spiny crayfish (with these two invertebrate groups included because information was readily available). Expert Panel members, who include hub members, collaborated with many other experts, Birdlife Australia and staff from the Australian Government to develop this list.

How to make a priority list of species

In assessing vertebrates and spiny crayfish, we considered all species, not just those already listed as threatened. This was because while the fires have worsened the predicament for some threatened species, others that were previously secure may have been so heavily impacted that they also now face extinction risks. We assessed all listed species with distributions that overlapped with fire by at least 10% and all unlisted species whose distributions overlapped with fire by at least 30%. This resulted in an assessment list of over 220 species.

To assess relative impacts across these species, we considered three questions:

1. How threatened was the species before the bushfires? Species that already faced a high risk of extinction may have been brought to the brink. As a proxy to identify these species, we used threatened species lists from Australia's *Environment Protection and Biodiversity Conservation Act 1999* as well as the IUCN Red List of Threatened Species.

2. How much of the species' distribution was burnt? The more of a species' range that was burnt, the greater the risks. Staff from the Department of Agriculture, Water and the Environment and BirdLife Australia used national fire maps, and combinations of distribution models, distribution maps and observation records to generate figures. The task was especially tricky for fish, which can

be affected by ash and sediment from fires many kilometres upstream. To account for this, we considered the incidence of fire in catchments upstream of each species, as well as the fire overlap with their distribution.

3. Does the species have physical, behavioural or other characteristics that make it more susceptible to impacts during or after fire? Not all species are affected by fire in the same way. For example, highly mobile species like white-throated needletails are more able to flee a fire front than most ground-living animals. Wombats sheltering in deep burrows are more likely to survive a fire event than long-footed potoroos sheltering under vegetation.

Animals that survive the fire itself can still die in the fire aftermath, from starvation, predation and exposure, and some characteristics make species more or less vulnerable to these fates. For example, species with specialised diets like the Kangaroo Island glossy black-cockatoo are more likely to starve post-fire than less fussy eaters. We gathered information on characteristics that affect the risk of fire and post-fire mortality from the literature and experts to rank species within taxonomic groups according to their relative susceptibility to fire.

Our assessment identified 119 species (23 reptiles, 16 frogs, 17 birds, 20 mammals, 5 invertebrates, 22 crayfish and 16 fish) as highest priority for management intervention. Species that were highly threatened before the fire, and have distributions that were substantially burnt, were ranked high priority regardless of their trait assessment. But for other species that were either less threatened before the fire, and/or whose distributions were less impacted by fires, the trait assessments came into play. For example, unlisted species including pilotbirds and red-browed treecreepers were prioritised ahead of the nationally Vulnerable white-throated needletail, partly because the latter has traits that make it much less susceptible to fire impacts.

A roadmap for the future

The assessment of species characteristics also flagged the emergency actions that could help priority species. For example, herbivorous species or species sensitive to post-fire habitat degradation by introduced herbivores (e.g., the northern corroboree frog), often need actions to remove pests like goats, deer and horses. Fish species with small distributions, like stocky galaxias, which could die from sediment slugs coming down their waterways in the days or weeks after fire, were collected and brought into captivity. An insurance population of eastern bristlebirds was flown out of Mallacoota by helicopter as flames approached the town. For very rare species that are prone to post-fire predation (e.g., the western ground parrot), controlling introduced predators becomes critical.

These initial prioritisations can and will be further refined and updated, as we understand more about the variation in fire severity across the burnt areas, and as field data on population survival begins to come in. Hopefully, some species have done better than expected, and we will understand why, which will help shape our responses in the future. Alternatively, and less happily, further information may indicate that some species have been more affected than our initial assessment has indicated.

In the effort to respond rapidly to the bushfires, shortcomings in fundamental data have become apparent. For example, compiling a national map of burnt areas was difficult work and had to draw on several data sources; and both distribution information and monitoring data for many species is scattered across databases, and is of variable and sometimes poor quality. A key task will be identifying the impediments to an effective rapid response so that we can quickly and confidently respond to future natural disasters.

IMAGE: BENJAMINT444 CC BY-SA 3.0 WIKIMEDIA COMMONS

The Endangered Macquarie perch is one of the priority fish species identified as having over 50% of its range affected by fire or post-fire sedimentation events.

Assessments were led by Sarah Legge, John Woinarski, Stephen Garnett, Dale Nimmo, Ben Scheele, Mark Lintermans, Nicki Mitchell, Nick Whiterod and Glen Ehmke, with contributions from many species experts and state/territory agency representatives. Staff from the Department of Agriculture, Water and the Environment (especially the Environmental Resources Information Network (Geospatial and Information Analytics Branch), the Protected Species and Communities Branch and the Office of the Threatened Species Commissioner) and Expert Panel members also made significant contributions.

Further information

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Further reading

https://www.environment.gov.au/biodiversity/bushfire-recovery/priority-animals

https://theconversation.com/after-the-bushfires-we-helped-choose-the-animals-and-plants-in-most-need-heres-how-we-did-it-138736

The Vulnerable three-toed snake-tooth skink (*Coeranoscincus reticulatus*) lost 10–30% of its habitat in the 2019–20 fires.

IMAGE: BERNARD DUPONT CC BY-SA 2.0 FLICKR

A western grey kangaroo (Kangaroo Island subspecies) on Kangaroo Island in February 2020. The 2019–20 wildfires have severely impacted the wildlife in many regions.

IMAGE: NICOLAS RAKOTOPARE

Fire and post-fire impacts on wildlife groups, and priority conservation responses

The 2019–20 wildfires have severely impacted animals of all major species groups. Here, national experts on mammals, birds, reptiles, frogs and freshwater fish and crayfish present some of the key challenges for each group and how these will influence management and research priorities in the aftermath of the fires.

Mammals

Impacts to koalas were very visible in media coverage of the bushfires, but some other mammal species were even harder hit, such as the Kangaroo Island dunnart with an estimated 95% of its known distribution burnt.

Some characteristics mark the mammal species most affected. Those with small distributional ranges (such as the silver-headed antechinus and long-footed potoroo) may readily lose much of their population to single catastrophic events. Even species with large home ranges, such as spotted-tailed quolls, can be very affected when unburnt patches are too small for survivors to be able to repopulate. Many Australian mammals, such as greater gliders, also have very low reproductive rates, so recovery may not happen before the next large fire.

IMAGE: JODY GATES

Kangaroo Island dunnart.

Specialised resource needs are another vulnerability: the golden-tipped bat roosts mainly in the domed nests of a few bird species in the understorey, which are not likely to reappear for several years. Many mammals require tree hollows for breeding and denning. Fire reduces the number of hollows, and post-fire regrowth may not provide suitable hollows for at least 100 years.

Many, like the smoky mouse, are likely to be killed by introduced predators after fire; while others, like broad-toothed rats, need unburnt vegetation, but this may be degraded by introduced herbivores.

Given these susceptibilities, a variety of management responses is needed, depending upon the species and landscape setting. Control of introduced predators (cats and foxes) and herbivores will be critical, as will enhancement of habitat, for example, by establishing nest boxes, safeguarding unburnt patches and carefully nurturing recovery of burnt vegetation.

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Birds

IMAGE: RON KNIGHT CC BY 2.0 FLICKR

Mallee emu-wren.

That birds have wings should mean they can readily escape fires. And some do, even species that are not strong fliers. Following the fires on Kangaroo Island, a survey team found extraordinary densities of emu-wrens and western whipbirds in tiny pockets of habitat spared by the fire, refugees from the scorched woodland. Unfortunately, successful refugees are the minority given the heat and extent of last summer's intense fires. While mobility helps some birds, the characteristics affecting recovery of species will include the number of offspring they raise per year, whether they nest in tree hollows (as there may be a shortage of these), how far young birds disperse (as that affects how quickly they can fill recovering habitat), and the sensitivity of the habitat the birds need to fire (were plants killed or is fire-damaged vegetation resprouting?).

Post-fire research and management will focus on recovery. While in a few places marked birds will allow estimates of individual survival, most research will be about the speed and circumstances under which populations return to their previous densities. How quickly do birds identify recovering habitat as suitable? What features make it so – habitat structure, food availability or nesting opportunities? Where have the recovering populations come from – close by or far away? What is necessary for recovering habitat – nest hollow erection, predator control or active management of vegetation features? Most management is likely to be passive – with the fires an opportunity to assess recovery – but it will provide a basis for the inevitable next time.

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Reptiles

The Kaputar skink occurs across 11,000 hectares of the Nandewar Ranges of New South Wales, and nowhere else. As the ranges burned, destroying more than 60% of its known habitat, fears grew for it. Likewise for Kate's leaf tail gecko, known only from a few sites in northern New South Wales, all of which burned. The Blue Mountains water skink drew attention because populations were already in marked decline before the fires and the fires would further exacerbate this.

The Endangered Blue Mountains water skink, *Eulamprus leuraensis*.

The reptiles considered most likely to be nearing extinction and requiring urgent management intervention due to the fires are often, like these three, narrowly distributed and, in many cases, already imperilled. However, fire does not affect all species equally. Some can survive fires, for instance, smaller lizards sheltering in tiny crevices, while species occurring in vegetation types that burn more often probably have adaptations to fire. In the immediate and more barren post-fire landscape, species that generally use the shelter of leaf litter or vegetation are likely to be at greater risk from predators, while reptiles that dwell under rocks or in burrows might be better able to persist. Interventions to stave off extinction for reptiles post-fire will vary depending on the species, but often include control of invasive predators and herbivores.

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Frogs

Australia has around 240 frog species, with most found along the east coast and ranges. Although rarely seen, frogs are vital to many ecosystems. The 16 frog species found to be most impacted by the fires occupy diverse habitats: rainforest, snow country, woodlands and dry forest.

A northern corroboree frog on recently burnt sphagnum moss.

The most severely impacted frog species share two key characteristics. First, all but one was already listed as threatened (IUCN Red List) – with disease, habitat loss and climate change all drivers of decline. Due to their pre-existing small population size, any reduction in survival is likely to reduce population viability. Second was small ranges. For example, several of the mountain frogs (genus *Philoria*) are restricted to remnant rainforest patches on mountain tops. For these species, the fires are likely to have affected a high proportion of their range.

We now have an opportunity to study frog responses to fire and close gaps in our knowledge. Also integral to management will be resolving taxonomic uncertainty. For example, several of the assessed species are thought to contain populations that may be separate species.

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Freshwater fish

Stocky galaxias, one of the fish species rescued during the fires.

Freshwater fish are largely protected from flames and radiant heat, although in very small, shallow streams they can be impacted. However, fish are severely affected by post-fire rainfall. Fire removes vegetative ground cover so that subsequent rainfall can wash ash and sediment into streams. This clogs fish gills and smothers food, spawning and refuge sites, and can rapidly fill pools. Combined with the loss of overhanging vegetation this leaves fish more vulnerable to predators (other fish and birds) and to increased water temperatures.

After intense rainfall, ash and sediment move rapidly, and have been documented causing fish mortality for up to 80 km downstream. Many fish were already suffering reduced populations and distributions from the prolonged drought. Already threatened species with any of the following features have an increased risk from fire impacts: very restricted distributions; lay eggs on the base of the stream; depend on insects falling into the waterways from overhanging vegetation for food; are short-lived; or breed only annually.

Most threatened fish cannot simply move away from fire-affected areas, so monitoring the impacts of fires and recovery of populations and habitat is critical. No knowledge exists of captive-breeding requirements for most fish "rescued" during fires. Such investigation into breeding requirements will be essential to post-fire recovery.

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Freshwater crayfish

The undescribed but already highly threatened arte spiny crayfish (*Euastacus* sp.1).

Freshwater crayfish are inconspicuous casualties of the bushfires. Their aquatic environments and burrows are deceptively unsafe; post-fire impacts can be severe for days, months and even years. As with freshwater fish, rainfall events soon after fire can be perilous. Additionally, many freshwater crayfish, including those from the *Euastacus* genus of spiny crayfish, are already threatened and possess distinctive traits – small home ranges, limited dispersal, slow growth and low egg production – that make them inherently ill-equipped to recover. Twenty-two *Euastacus* species (almost 40% of all known members of the genus) are considered to need urgent management intervention following the bushfires. This includes gathering knowledge about ranges, identifying remnant populations and assessing the feasibility of conservation translocations. Without such actions, many spiny crayfish species will be pushed closer to extinction, and some may be lost.

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The little things count too: Prioritising recovery efforts for fire-affected invertebrates

Green carpenter bee. IMAGE: ROBERT WHYTE

Professor John Woinarski of Charles Darwin University discusses the importance of averting extinctions of less charismatic animals.

Much media reporting on the impacts of the 2019–20 fires on wildlife focused on searing images of burnt koalas and kangaroos. These images brought home to the community the loss of biodiversity and galvanised the response of concerned governments, but the impacts were far more pervasive than just on those animals most familiar to us.

Attracting far less attention was the impact of these fires on invertebrates. However, if extinctions occurred due to these fires, it was most likely to have happened to invertebrate species. Mostly this is because there are so many invertebrate species (about 320,000 in Australia, about 1000 times the number of Australian mammal species), and many of these have very small ranges, readily encompassed by a single fire.

Difficulties of the poorly known

With contributions from many experts, the Australian Government's expert advisory panel coordinated an assessment to identify priority fire-affected invertebrate species most in need of remedial conservation management. This proved a particularly challenging exercise because limited relevant information is available to inform assessments.

Many Australian invertebrate species have not yet been formally described. Even when a species has been described there are often few publicly accessible distributional records. Little or no monitoring information exists for most invertebrate species, so pre-fire baseline abundance and trends are mostly unknown. Also, for many species little is known about ecological traits and life histories and how these would influence susceptibility to fire.

Furthermore, many invertebrates lead complicated lives, and even a single species can be affected by fire very differently at different life stages. For example, a fire may be inconsequential to a cicada if at the time of the fire most of its population was in underground life stages.

The path to recovery

Notwithstanding these challenges, we developed a list of nearly 200 invertebrate species for which the available information suggests severe fire impacts. Almost all of these species have had more than 50% of their range burnt; many have had more than 80% burnt; and some have had all of their range burnt.

The list of fire-affected invertebrates includes a very wide variety of species, including spiders, land snails, dragonflies, beetles, grasshoppers, moths and butterflies. Most of these species have very small distributions, unhappily coinciding with these fires. One such example is the Banksia montana mealybug, a tiny scale insect that existed only in a few bushes of one plant species in Western Australia's Stirling Range, all of which were consumed by the fires.

Our priority list is likely to be a vast underestimate. Building on this initial assessment, the Threatened Species Recovery Hub is undertaking a more comprehensive analysis of fire-affected invertebrates. This project will also help to identify those species that should now be listed as threatened; and to prioritise management responses to aid recovery of the most-affected species.

Invertebrates do not have a high profile in our community, and some may see little point in worrying about losses of obscure invertebrate species. But losses of any species diminish our nature; and the legal and policy framework in which we live provides clear recognition of the need to try to prevent extinction. Furthermore, invertebrates play critical roles in ecological function and many of these roles, such as pollination, may be necessary for the recovery of ecosystems after fire. We should be concerned about the fate of little things.

Further reading

https://www.environment.gov.au/biodiversity/bushfire-recovery/priority-invertebrates

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IMAGE: JJ HARRISON CC BY-SA 4.0 WIKIMEDIA COMMONS

Fire consumed over half the habitat of the only bird species endemic to New South Wales, the rock warbler.

Protecting persistence: Listing species after the fires

Professor Stephen Garnett of Charles Darwin University walks us through how listing works to afford legal protection to species newly at risk of extinction.

Such was the scale of the 2019–20 fires that many species thought secure suddenly lost a significant amount of their population – burnt in the flames or dying of starvation in the immediate aftermath. Species never thought of as being under threat because Great Dividing Range forests are so extensive suddenly and unexpectedly met criteria for listing as threatened under the globally recognised International Union for the Conservation of Nature (IUCN) Red List. These criteria underpin most threatened species lists, including those of Australia's *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act).

Of the IUCN criteria, only one, the proportion of the population lost, was particularly relevant following the fires. Species can be listed if they are thought to have lost 30% or more of their pre-fire population. For some species, like the gang-gang cockatoo, the fires have exacerbated existing declines, pushing their historical losses over the 30% threshold.

IMAGE: PJ WALLIS

Lyrebirds find shelter around a dam as bushfire approaches.

Other IUCN criteria are for species with small ranges (occupying <2000 km^2), already having small populations (<10,000 mature individuals) or for which there are high-quality population models and ongoing decline. Many species meeting these other criteria had already been listed, or else there were simply inadequate data to create models.

Even when species now meet numerical thresholds, the criteria require evidence of continuing decline. While this requirement will likely lead to future listing for many freshwater fish species, for example, which will suffer for many years from sediment washed from bare catchments by the rains that doused the fires, for many other species population recoveries will begin immediately.

Out of the ashes

We made our initial assessments of population loss simply on the area of the fires, based on distributional records laid over fire scars. Where possible, we augmented fire scar information with vegetation modelling that allowed percentage loss to be estimated from the proportion of a species' habitat that had been incinerated.

However, while the post-fire debris evidenced devastating mortality, estimates of fire intensity are also necessary to estimate the percentage of population loss. In some places this was extreme – a combination of intense drought and fire weather caused unprecedented conflagrations of heavy fuel loads in once damp creek lines. But many species that live in highly flammable eucalypt woodlands have evolved to escape fires and find food among the ashes until their habitat recovers. Remarkable images of lyrebirds, which are usually solitary birds, clustered around a farm dam showed well practised bushfire survival strategies. Also, accidents of fire weather and geography left some patches unburnt or merely singed, so that scorched landscapes were sprinkled with isolated spaces for recovery that went undetected by the coarse satellite maps used to assess initial damage.

Providing for recovery

The last calculations of area and fire intensity are underway. From this we will finalise the numbers of species warranting listing and protection. This listing may not be needed for long for some species as their populations recover to previous levels, but legal protection may well help while they recover, especially for those that respond more slowly.

Listing the species at greatest risk may seem a small step on the road to recovery, but legislative acknowledgement of extinction risk can be key to preventing accidental loss of critical habitat and the lucky survivors.

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IMAGE: DEPARTMENT OF AGRICULTURE, WATER AND THE ENVIRONMENT

Box gum grassy woodland on the private 'Gillinghall' property near Wellington, New South Wales.

Post-fire recovery of Australia's threatened woodlands: Avoiding uncharted trajectories

The 2019–20 bushfires burnt some of Australia's most threatened woodland communities. Researchers from The University of Melbourne have been building a State and Transition Model based on expert knowledge to help inform recovery planning for Australia's threatened woodland communities. Here, **Dr Megan Good** and **Dr Libby Rumpff** demonstrate how their framework could inform post-fire monitoring and management to avoid negative outcomes for threatened woodland ecosystems.

Threatened woodland communities devastated

Australian woodlands occupy 12% of the continent (91.5 million ha) and have declined more than any other major vegetation group since European occupation – currently over 30 woodland communities are listed as threatened under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The catastrophic bushfires of the 2019–20 summer significantly impacted almost half of these woodland communities and affected their component plants and animals over thousands of hectares.

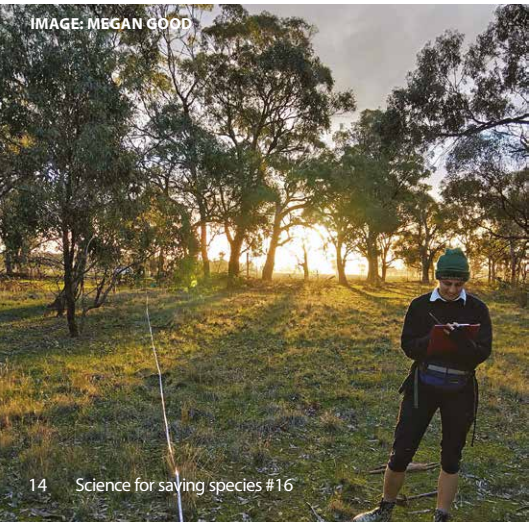

IMAGE: MEGAN GOOD

Post-fire regional analysis has so far highlighted at least eight woodland communities as priorities for recovery action in at least one Natural Resorce Management region.

Recovery planning for woodlands

There are many threatened woodland communities, but few have recovery plans to guide management, although other simpler documentation such as a Conservation Advice is published at the time of listing. Our project began in 2017, with the aim of determining general principles to increase the information available to support fast and effective recovery planning and other management interventions and planning. To this end, we have been working with woodland experts from across southern Australia to synthesise knowledge from a broad range of eucalypt woodlands.

At the heart of this project is a State and Transition Model (STM). STMs help conservation managers better understand how woodlands function and respond to management actions. Managers can use them to decide on the start and end points for restoration, identify the key threats to recovery, and explore which interventions might best target those threats.

Experts identified a series of common "states" of woodland condition found across southern Australia, as well as both positive drivers and threats that can push the condition state of woodlands in different directions. Degraded states are more common, and without intervention negative transitions (towards degraded states) are more likely than positive transitions (towards better condition states). This highlights the importance of preventative threat management in these woodland systems.

Pre-fire condition and post-fire trajectories

We know that many vegetation communities will recover well from fire, and some need fire to maintain ecosystem health and biodiversity. However, listed threatened communities have other pre-existing and ongoing threats that can reduce their resilience to fire, such as severe drought, fragmentation, soil disturbance, grazing and invasive species. Woodland communities facing multiple post-fire threats will almost certainly need assistance to recover through management interventions.

Understanding the pre-fire condition of a burnt woodland can tell us a lot about the probable post-fire trajectory.

LEFT: Research assistant on the "Woodland recovery planning" project Freja Butler in the field north-east of Shepparton, on land of the Taungurung people.

Landscape context and fragmentation are similarly important, as they might indicate the abundance of native or weedy species that are likely to act as a seed source for regenerating woodlands. Small patches of woodland surrounded by cropping or sown pastures will have different requirements for post-fire management than larger patches, or patches surrounded by native species.

For example, the Critically Endangered Lowland Grassy Woodland in the South East Corner Bioregion, which has 30–50% of its distribution in fire-affected areas, is one of Australia's most at-risk ecological communities following the fires. Pre-fire condition would have varied across the burnt area, and this makes a difference. For instance, some of that land may have been in poor condition, like grazed pasture ("Simplified 4" state in our model – see Figure 1). The general advice from our expert model, if the aim were to shift to an improved condition state (e.g. "Simplified 1" – like a high-quality roadside reserve) would be to remove stock, actively control weeds, and replant trees and shrubs or encourage and protect any passive tree recruitment. Indeed, a fire may provide an opportunity to improve the condition of the site by removing weeds, but only if active management is implemented before weeds recolonise.

In contrast, some of the area might have been in a better condition state, like a roadside reserve with a relatively intact understorey ("Simplified 2"). In general, it is much easier to encourage a return to the pre-fire state than to increase the condition of that state, but active management is still required. Protecting a regenerating understorey would be wise. In this case, our general model suggests removing stock and managing grazing pressure (closing water holes), and proactive weed management.

Here, we considered two pre-fire condition states of a single woodland community. A decision tree, like those developed in our project (Figures 1A and 1B), can clarify which outcomes we might expect when our starting points and management interventions differ. Where resources are limited, we can use this framework to prioritise effort and investment.

Decisions! Decisions!

After these unprecedented fires, management decisions should be made quickly with whatever information is available. Ongoing monitoring is also critical to ensure that negative trajectories are identified early, while we can still intervene.

A major aim of this project was to generalise and transfer understanding from one system to another to aid effective conservation management, without losing critical aspects of what defines each distinct woodland type. Experts helped to construct a generalised model to speed up the decision-making process about what works best and where, and for the examples provided above, our recommendations align well with and supplement the official conservation advice (EPBC Act 1999) for listed woodlands. This demonstrates the value of providing structured guidance for managing ongoing threats and large-scale disturbances such as fires as we continue to work towards woodland recovery.

Acknowledgement

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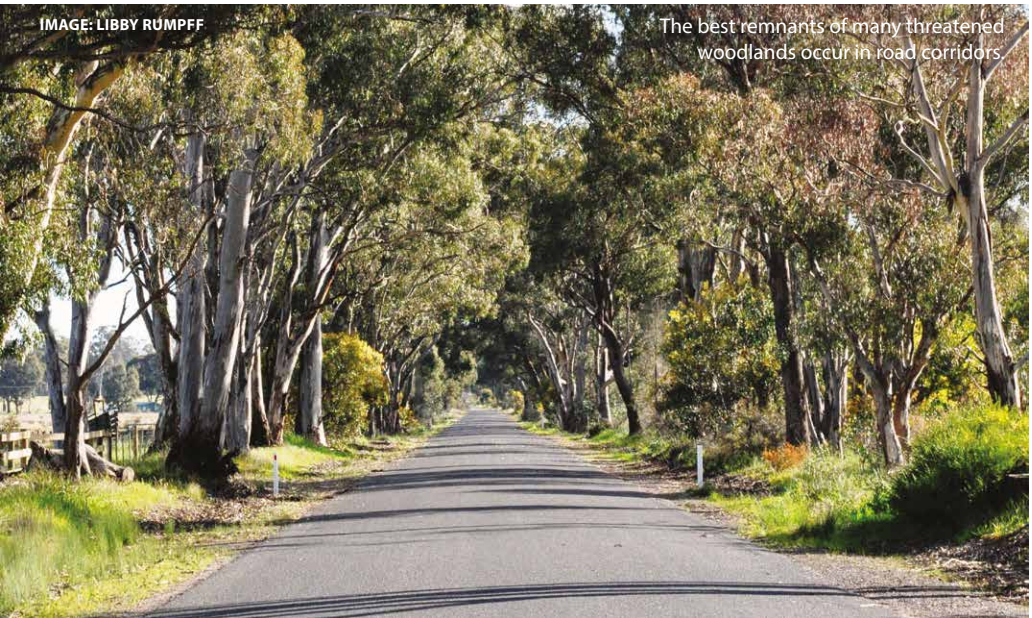

IMAGE: LIBBY RUMPFF

The best remnants of many threatened woodlands occur in road corridors.

Figure 1A

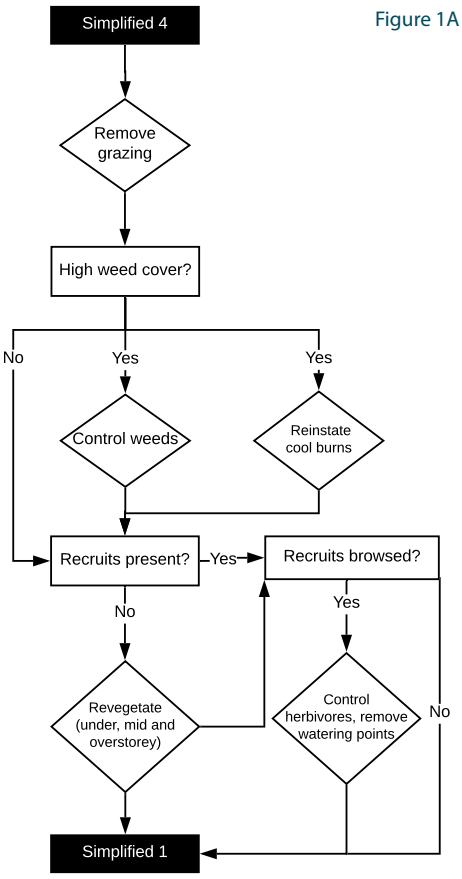

Figure 1B

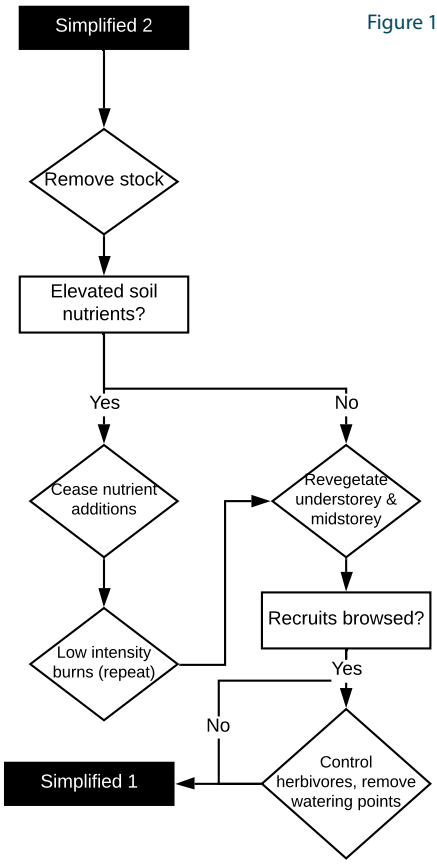

Figure 1. Example decision trees extracted from our general State and Transition Models for southern Australian woodlands. These can be used to guide management decisions for woodlands in different pre-fire condition states. Figure 1A shows the types of decisions that might guide the recovery of a woodland in a grazed pasture state (Simplified 4) towards an improved state (Simplified 1). In contrast, Figure 1B shows how a relatively high-quality site could be managed.

Dr Hugh McGregor radio-tracking a feral cat at Australian Wildlife Conservancy's Mornington Station, Kimberley, Western Australia

IMAGE: HUGH MCGREGOR

Fire, cats, foxes and land management: Lessons learned

Fire is a feature of just about every habitat across Australia, but it operates in myriad ways within landscapes – from frequent low-intensity fires in tropical savannas to once-in-50-years crowning fires in Victorian eucalypt woodlands. There are broad trends and theories that hold in fire ecology in Australia, yet when it comes to understanding fire for conservation management, local management is absolutely essential. **Dr Hugh McGregor** of the University of Tasmania/Arid Recovery explains why.

I learnt the lesson of the importance of local land management some years ago when I was researching feral cats in the Kimberley. After I collected all the GPS movement data from my collared cats and had done all the fire-scar mapping, I plugged in my data for a statistical answer as to how cats interact with fires in the landscape. At first, the results were resoundingly disappointing. Essentially, the stats came back that fires and movements by cats were not significantly related. It meant I would have had a boring study to write about. I know you have to be impartial with science, but of course I was quite annoyed at this. It contradicted many of my observations. I had recorded many examples of cats travelling to fire scars from far away, and had strong evidence that cats were more efficient hunters in fire scars than in unburnt habitats. So why was the first analysis I ran telling me that the cats didn't change their movement behaviour in response to fires?

Managing land for wildlife

It turns out I was missing the most critical variable of all: management. Many of the feral cats I studied were captured and collared around the most intensively managed portions of Australian Wildlife Conservancy's (AWC) Mornington Wildlife Sanctuary. This area was completely destocked of cattle, and native vegetation had recovered. In addition, the occurrence of intense wildfires had decreased as a result of strategic prescribed burning after every wet season and fire suppression in the mid-to-late dry season. The result was an increase in the extent of unburnt, complex vegetation, and native small mammals had consequently greatly increased in numbers. However, this increase in mammal populations also meant that when habitats did burn, a higher density of native animals become exposed by the removal of cover, and cats were motivated to hunt there.

The opposite was true of areas where fire and stock had not been managed so intensely. I also collared feral cats in nearby areas that were not destocked and where fire management had been less intensive or effective. In these areas, native wildlife were scarce even before a fire went through. As a result, fires did not expose so many prey, simply because they were few and far between in the first place. Fire scars in such locations were not lucrative hunting spots, and cats in these areas would actively avoid those places.

BELOW: A feral cat with a native plains mouse. The GPS-collared feral cat was being tracked by Dr McGregor as part of a hub research collaboration between Arid Recovery and the University of Tasmania.

IMAGE: HUGH MCGREGOR

The reason my original analysis did not report any relationship between fires and cat movement was that the two processes cancelled each other out. Half my cats were in the intensively managed areas, half in areas with minimal management, and they averaged out to show no pattern between fires and movement by cats. When I ran a new analysis, this time incorporating management regime, the results emerged: extreme selection by cats of fire scars where management was intensive and native mammal density was high, and avoidance by cats of fire scars in areas with less intensive management and low small mammal density. It was a crystal clear lesson of the benefits of embedding conservation research within well-understood local land management programs.


IMAGE: BRONWYN HRADSKY

A University of Melbourne study in Victoria's Otway Ranges led by Dr Bronwyn Hradsky observed a dramatic increase in feral predators after a prescribed burn.

Same patterns north and south

Several Threatened Species Recovery Hub research projects across Australia have extended this line of research into the interactions between introduced predators and other threats. This work has been conducted in close partnership with managers, further confirming the value of an applied conservation research approach.

In Northern Australia, the Northern Territory Government and Charles Darwin University have found that areas across the Top End with more frequent fire and higher levels of feral herbivores have increased feral cat occurrence (see the story on page 22). Likewise, on the Tiwi Islands, research by Hugh Davies and the Tiwi Land Rangers has shown a similar pattern: more frequent severe fires equal more cats. And the opposite was true, too. Where fire management had been most successful, structural complexity of the vegetation was key to obtaining lower detection rates for cats. Parts of the landscape that retain such complex vegetation are critical to the persistence of Endangered mammals like the brush-tailed rabbit-rat.

In southern Australia, detailed research conducted in the Otway Ranges of south-west Victoria has revealed similar patterns, this time with foxes (see Issue 15, page 12). In this landscape, fires are far less frequent, but individual fires can be of higher severity, removing almost all cover over substantial areas. And fox scats from burnt areas contain more medium-sized native mammals than scats from unburnt areas. As part of a Threatened Species Recovery Hub project, researchers and managers are working together to maximise opportunities to learn from and optimise management. To achieve this, the management is structured as field research and includes nearby areas with no control and patchworks of control burns. And just as for the work in the Kimberley, they are able to investigate the interaction between predators, fire and threatened animals due to the fact it is well-managed landscape that still retains its threatened animals.

These research projects, carried out in very different habitats and with both cats and foxes, all point to the risk of amplified predation after fire. Following the 2019–20 bushfires, increased predation risk could cause as much or more population loss, for some species, than the fire event itself. Reducing post-fire predation by cats, foxes and wild dogs is now one of the priorities for conservation managers across the country. Local knowledge about the locations of susceptible native species, and observations of changes in the density and behaviour of cats and foxes, will be essential for targeting these interventions most effectively.

Working directly with managers makes research more focused, useful and fun, the best combination of attributes you could hope for in field research.

Further information

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An early dry season controlled burn at Glenroy Station in the Kimberley. Patchy low-intensity early burning is a common strategy aimed at avoiding large, intense, late dry season fires.

IMAGE: HUGH MCGREGOR

Eastern bristlebird.

IMAGE: JJ HARRISON CC BY-SA 4.0 WIKIMEDIA COMMONS

Long-term monitoring at Booderee National Park Reveals valuable insights for park management

Professor David Lindenmayer and **Chris MacGregor** from The Australian National University tell us about their long-term monitoring collaboration with Booderee National Park managers, which is revealing detailed insights into how best to manage fires and other threats to biodiversity in the park.

Booderee is an iconic national park, approximately 200 km south of Sydney. It attracts substantially more visitors each year than Uluru or Kakadu. The park is home to an array of threatened animals, plants and vegetation communities. For example, it is a stronghold for the Endangered eastern bristlebird and supports the southernmost population of the eastern chestnut mouse.

Like all natural areas, Booderee National Park faces a range of challenges, including those posed by wildfires, exotic predators such as foxes, and invasive plants like bitou bush. A large amount of management effort and resources is invested in tackling these threats. Park managers want to know if the strategies they are using are effective and the only way to answer this question is through robust, well-designed long-term monitoring.

To facilitate such monitoring, a close collaborative partnership between Parks Australia, the Wreck Bay Aboriginal Community and The Australian National University has been in place since 2002. The work has led to some important insights into how to improve management strategies in the park. For example, monitoring revealed that the bristlebird can recover quite quickly after fire, especially if there are areas of unburnt forest within, or adjacent to, territories that are occupied by the species.

However, long-term datasets also show that care is needed when managing overall bird populations in the face of frequent recurrent fire. This is because the number of bird species present at a site is reduced by more than 9% for every additional fire that occurred in the past 40 years.

These results indicate a need to carefully plan where hazard reduction burns occur, based on how many fires have taken place previously in a given area. They also suggest that if prescribed burns are patchy, with areas of unburned vegetation interspersed within and around places that are burned, it will facilitate animal population recovery.

Insights from long-term monitoring have also enabled park managers to adapt and improve strategies to control bitou bush – one of Australia's worst environmental weeds and a significant problem in Booderee National Park. Control programs typically entail a series of treatments, commencing with spraying, followed by burning, and then respraying to kill seedlings triggered by fire. Our monitoring has shown that spray–burn –spray is the most effective sequence of treatments in controlling bitou bush, but that some variations of this approach can actually make the problem worse (such as only burning without spraying).

Long-term monitoring also found that native vegetation recovery can be stimulated by the removal of bitou bush (rather than weeds simply regrowing where they were previously removed). In addition, the application of the appropriate weed treatment sequence does not have negative effects on recovery of native animals, including key species such as the eastern bristlebird. Indeed, the bristlebird responds positively to the replacement of bitou bush by native vegetation.

The commitment to long-term monitoring is providing a robust scientific body of information to enable park managers to implement best-practice evidence-based management in Booderee National Park, a fact which has led the World Wide Fund for Nature (WWF) to recognise Booderee National Park as among Australia's best-managed national parks.

This Threatened Species Recovery Hub project is a collaboration between Parks Australia, Booderee National Park, the Wreck Bay Aboriginal Community and The Australian National University. It receives funding from the Australian Government's National Environmental Science Program.

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Fire a vital ingredient for the recovery of a Critically Endangered wattle


IMAGE: L. MONKS/DBCA

RIGHT: The golden yellow flowerheads and sickle-shaped leaves of the spiral-fruited wattle.

Many Acacias, including Western Australia's Critically Endangered spiral-fruited wattle, need fire to promote recruitment. **Leonie Monks** and **Dr David Coates** of the Western Australian Department of Biodiversity, Conservation and Attractions explain how prescribed burning has proved critical to the recovery of this threatened wattle.

The spiral-fruited wattle (*Acacia cochlocarpa* subspecies *cochlocarpa*) forms large dense mats of up to 4.5 m in diameter. It has sickle-shaped leaves and produces masses of golden yellow cylinder-shaped flowerheads. In 1997, the species was listed as Critically Endangered in Western Australia, the only place where it is found. Just two populations were persisting in heavily cleared agricultural land on road verge remnants, with a combined total of 51 plants.

Both populations were declining and faced multiple threats, including competition with invasive weeds, spray drift from adjacent farms and accidental destruction during road verge maintenance. Significantly changed fire regimes in the region were also believed to have a role in the decline of the species.


IMAGE: L. MONKS/DBCA

LEFT: Keeping an eye on the prescribed burn of the spiral-fruited wattle.

Recovery program kicks off

The West Australian Department of Biodiversity, Conservation and Attractions (DBCA) commenced a recovery program in 1997, which involved searching for new populations, collecting and storing seed in the department's Threatened Flora Seed Centre, and a translocation program.

The translocation involved propagating seedlings at the Threatened Flora Seed Centre, growing them at the Kings Park Botanic Gardens nursery, and then planting the seedlings in carefully selected threat-free sites. By 2014, three new populations, with a combined total of 830 seedlings, had been established in two nature reserves. In addition, surveys had located another three wild populations with 40 plants, although these were also located on disturbed road and rail verges.

For translocations to be effective in helping to recover a species, a stable, viable population maintained through natural recruitment must be established. While the translocated spiral-fruited wattle plants were successfully producing viable seed, seedling recruitment was not occurring. Based on knowledge of other wattles, we believed that fire was the missing ingredient.

Regeneration burn

Many Acacias need the soil seed bank to be disturbed, often by fire, to break the dormancy of the hard seed coat and promote recruitment. However, fire is now unlikely in the isolated remnants of a heavily cleared landscape where the spiral-fruited wattle occurs. We responded to this challenge by conducting a regeneration burn at one of the translocated populations in June 2015. Before the fire, we measured the size of the existing soil seed bank by collecting soil cores. We used buried temperature loggers during the fire to record soil temperatures in order to understand more about the temperatures required to break seed dormancy. We fenced the translocation site after the fire to prevent grazing by herbivores such as kangaroos and rabbits.

Regular monitoring of the site occurred post-fire and after five months we recorded 952 seedlings and 15 adults that survived the fire. Two years post-fire, the 15 adult plants and 737 of the seedlings were persisting, with around 25% of these producing flower buds.

A population viability analysis model, based on the data collected at both the translocated and wild sites, is now being developed with support from the Threatened Species Recovery Hub. The model will help deliver insight into how effective our current management practices are, and guide future management actions for recovery of the spiral-fruited wattle.

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Managing fire to protect monsoon vine thickets on the Dampier Peninsula

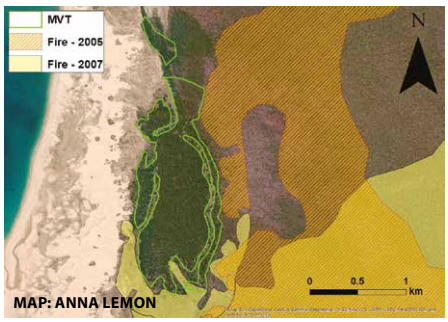
Joongoon, Mamajen *Mimusops elengi*.

IMAGE: LOUISE BEAMES/ENVIRONS KIMBERLEY

Fire is a natural and frequent disturbance in the tropical savannas of northern Australia. But without active fire management, extensive fires that recur every two to three years have come to dominate the savannas. **The Bardi Jawi rangers, Nyul Nyul rangers, Yawuru country managers and Sarah Legge** explain how ranger groups are managing fire to protect and recover monsoon vine thickets in the Kimberley.

The Dampier Peninsula lies north of Broome and covers about 20,000 km^2. The main vegetation community is "pindan", a low eucalypt and wattle woodland. Until recently, the fire regime on the Dampier Peninsula was one of the most extreme in the Kimberley, with very large fires occurring in most years.

From 2016, the peninsula's main land managers (comprising Bardi Jawi rangers, Nyul Nyul rangers, Yawuru country managers, three pastoral stations and the Western Australia Department of Biodiversity, Conservation and Attractions) have managed fire collaboratively, supported by the WA Department of Fire and Emergency Services, two shires and the Kimberley Land Council, through a forum called the Dampier Peninsula Fire Working Group, which is facilitated by Rangelands NRM. This coordinated prescribed burning effort has dramatically changed fire patterns – in the past four years the area affected by fire annually has roughly halved, extensive wildfires have become much less common, the size of burnt and unburnt patches has become smaller, and the area of older vegetation is increasing.



MAP: ANNA LEMON

The change in fire patterns should have positive influences on biodiversity, cultural and pastoral values, many of which are indicators in Traditional Owners' Healthy Country Plans. Biocultural values include savanna trees used to make shields and spears, threatened species such as bilbies and Gouldian finches, and fire-sensitive communities found within the pindan, particularly wetlands and monsoon vine thickets.

Indigenous-led conservation

The peninsula's monsoon vine thickets are a nationally Endangered ecological community, distributed in dozens of separate patches around the coast. They are a short-statured form of closed-canopy rainforest. Many food and medicinal plant species of cultural importance are found there, but these valued species are threatened by intense fire that damages the edges of the monsoon vine thickets and promotes invasion by weeds. As part of demonstrating the outcomes of fire and other management, the Bardi Jawi rangers, Nyul Nyul rangers and Yawuru country managers need to report on the extent and condition of monsoon vine thickets on the country they manage.

A Threatened Species Recovery Hub project is collaborating with these ranger groups and Environs Kimberley to develop aerial imagery, remote sensing and spatial analysis tools that can be used to measure: (1) changes in the area of monsoon vine thickets over many decades; (2) how often intense fires have come into contact with the thickets over the past 30 years; and (3) canopy damage within the monsoon vine thickets, and how this has varied over the past 30 years.

Anna Lemon, an Honours student at Charles Darwin University, is carrying out the spatial analyses, building on work undertaken by Environs Kimberley and the ranger groups to describe fire impacts between 1989 and 2010. Once the methods have been refined, Anna will spend time with the rangers transferring the techniques so they can use the approaches in their regular reporting against their Healthy Country Plans. The data and results gathered will also be used to report on progress by the Dampier Peninsula Fire Working Group, as well as by the Monsoon Vine Thicket Working Group, which is an emerging Aboriginal-led recovery team dedicated to the conservation of this special ecological community.

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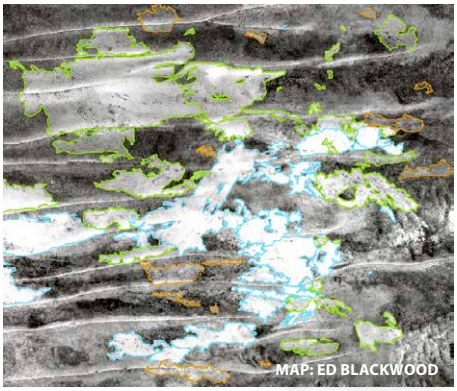
LEFT: The map shows a patch of monsoon vine thicket (green outline), and where intense fires have butted up against the patch over a three-year period. The project will quantify the number of times that intense fire affects the thicket boundaries, and also measure the resultant damage to the patch by examining loss of canopy cover near that boundary.

The recent Karajarri fire walk.
IMAGE: KARAJARRI IPA

Pirra Warlu (desert fire): New ways for traditional burning

The Karajarri Rangers and **Professor Sarah Legge** of The Australian National University talk about the Pirra Warlu (desert fire) project, which is investigating how fire management approaches are influencing the health of Karajarri's desert Country.

Across Australia's deserts, Indigenous people used fire for millennia to manage their Country and its resources, especially around sites they used and visited often. This system was disrupted in the past few decades, as people moved off their traditional lands to missions, pastoral stations and towns. When such exodus happened over large areas, changes in fire regimes may have followed. Desert fires, usually started by lightning strike, can run for weeks and even months, covering hundreds of kilometres. It is not well understood whether traditional burning affected the landscape-scale patterns of fire, or whether those impacts were concentrated at certain sites. It also remains unclear whether changes in fire patterns have contributed to the massive decline in desert biodiversity since European colonisation.



LEFT: Aerial photos from the 1940s are being used to describe the fire regime of the Great Sandy Desert 80 years ago. Once the photographs are stitched together, the outlines of fires up to several years earlier can be made out and drawn on the imagery.

Karajarri reinvigorates cultural burning

Many desert Traditional Owner groups are reinstating fire management over parts of their country, sometimes turning to new technology like aerial incendiary to help them deliver prescribed burning efficiently and effectively over such large, remote areas. An example is Karajarri, the Traditional Owners of almost 30,000 km^2 of the Great Sandy Desert in north-western Australia. Karajarri's "Pirra Warlu" (desert fire) project is developing large-scale prescribed burning, establishing biodiversity monitoring to measure the outcomes of this fire management, and reinvigorating cultural relationships to fire.

As part of this project, historical aerial photographs from the 1940s are being used to reconstruct the fire patterns of 80 years ago. These photos pre-date when Karajarri finished moving off their desert country in the 1960s, allowing a rare glimpse into the outcomes of traditional burning. The historical photographs have been geo-rectified, and the fire scars (which are clearly visible for several years) are being digitised and aged by Ed Blackwood, an Honours student at The University of Queensland. Ed will describe contemporary fire patterns using high-resolution satellite imagery and compare these to the fire patterns of the 1940s.

As well as looking at the broad difference in the sizes and distributions of patches of post-fire vegetation across this 80-year time window, the Pirra Warlu project will lay the historical fire pattern over Karajarri's detailed cultural map, to see if intensive burning occurred at key cultural sites. It is possible this overlay could also identity new areas where people traditionally spent a lot of time burning.

The Karajarri IPA will use the project results to help refine their contemporary fire management objectives, implement their fire management, stimulate new discussions with senior Traditional Owners about cultural burning practices, and underpin Karajarri's ongoing research about conservation and cultural outcomes of their fire management. The fire-mapping project will also shed light on the broader question of whether intensive burning at local sites influenced desert fire patterns at larger, landscape scales.

The Pirra Warlu project is a collaboration between the Karajarri Traditional Lands Association, Environs Kimberley and the Threatened Species Recovery Hub. It receives support from several sources, including the Australian Government's National Environmental Science Program.

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Feral herbivores, like these horses in Kakadu National Park, have a large impact on small mammal populations in the Top End. IMAGE: JAANA DIELENBERG

Small mammal declines in the Top End

Causes and solutions

New research has examined how small native mammals are distributed across the Top End and the factors driving this pattern. It has revealed that while feral cats and dingoes may limit small mammal populations, managing threats to vegetation, principally fire and feral buffaloes, is the best approach to protect and recover small mammals. **Dr Alyson Stobo-Wilson** of Charles Darwin University explains the new findings.

Feral cats and dingoes

Many once-common mammal species have declined markedly across large parts of northern Australia in recent decades. Using a combination of camera-trapping and live-trapping methods over 300 sites, we assessed whether feral cats, dingoes, feral herbivores, human-induced land clearance, fire frequency and size, habitat productivity and ruggedness of the terrain could explain the current distribution of small mammals (that is, those weighing less than about 5 kg).

Camera-trap data indicate that cats and dingoes were more likely to be found in areas that had a simple habitat structure. Feral cats avoided productive habitats (areas that typically have more shrubs and dense vegetation), unless these areas had experienced frequent and large fires. Dingoes avoided rugged habitats, instead using open, lowland woodland.

We found no evidence that feral cats avoided dingoes in the landscape; if a dingo was present in an area it didn't change the likelihood of detecting a feral cat. The best explanation of the presence of cats and dingoes across the Top End was that both predators opt to use more open habitat where they can hunt more efficiently.

In search of small mammals

We also examined where small mammals have persisted or vanished and the factors that influence this. We found that the number of native mammal species declined as the incidence of feral cats, feral herbivores (e.g., buffalo, horses and cattle) and dingoes increased. Additionally, we found that those native mammal species that have declined most – for example, the black-footed tree-rat and the northern brushtail possum – are now restricted to productive habitats (those with denser vegetation).

A revelation of this study was the previously underestimated impact of large feral herbivores on mammal populations in the Top End. Feral herbivores in conjunction with poor fire regimes simplify habitat structure and, in doing so, they remove vital food and shelter for small mammals and create more favourable hunting grounds for predators, including feral cats.

Fire and herbivores are key

Our research points to solutions about how to halt declines and support recovery. The evidence indicates that maintaining and enhancing complex habitat structure in the tropical savannas of northern Australia is likely to be the most effective strategy for conserving small mammals, rather than targeted predator control. Safeguarding habitat for small mammals can best be achieved by removing large feral herbivores and improving fire regimes so that fires are smaller and less severe.

In northern Australia, it is extremely difficult to control cats at a landscape scale through baiting and culling programs. Hence our findings provide hope that habitat management, rather than cat control, might be an effective alternative strategy for conserving small mammals.

We identified that large offshore islands, including the Tiwi Islands and Groote Eylandt, as well as several sites on the mainland, are providing critical refugia for many mammal species that have severely declined throughout much of the Top End. These sites provide important starting points for future conservation efforts as recovery there will be more feasible. As a first step, this should include reducing feral herbivore populations and the frequency and intensity of fires.

This work was led by the Northern Territory Government's Department of Environment and Natural Resources with assistance from Charles Darwin University and funding from the Australian Government's National Environmental Science Program.

Further information

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IMAGE: DAVID BLAIR

Standing dead and damaged trees provide important nest and den sites in regrowth forests. When they are removed through salvage logging, as is occurring in this photo, ecological recovery will be far slower, potentially set back 100 years or more for some species.

Forest condition before a fire influences recovery

Studies of previous major forest wildfires in Victoria in 1983 and 2009 have provided valuable insights into how forest ecosystems will respond to the 2019–20 bushfires. Forest ecologist **Professor David Lindenmayer** of The Australian National University talks about how pre-fire forest condition and age influence recovery.

Old growth forests are more fire-resilient

Recovery is faster from less severe fires as more plants and animals survive. Fire severity is influenced by forest age. Fires in old growth forests tend to be less severe. Young forests such as those regenerating after logging are more likely to burn more severely and for the fire to burn or scorch the tree canopy. This effect was found after the 2009 wildfires in wet ash forests in Victoria, but more recent analyses have shown that there are similar effects in other (drier) forest types, including those burned in the 2019–20 wildfires. The effects of logging on fire severity are long-lasting, persisting for approximately 40 years.

There are several factors that contribute to this increased fire severity: (1) harvesting leaves behind significant amount of debris, which add to fuel loads; (2) wet understorey vegetation such as tree ferns are severely reduced (by up to 96%) by logging operations, thereby drying the forest; and (3) the densely stocked regrowth established after logging rapidly self-thins over time, adding many dead saplings to the forest floor and further increasing fuel loads.

IMAGE: JAANA DIELENBERG

Leaving a legacy

Post-fire recovery is strongly influenced by the legacy of living and dead materials left after the fire that help the forest to recover. This includes things like trees, logs, seeds and surviving animals.

A key insight from 2009 was that many animals survived the fires. For example, every one of the 18 mountain brushtail possums that we radio-collared before the 2009 wildfires survived those fires, even in places that burned at extremely high severity. Genetic studies of populations of surviving small mammals showed that these remaining animals founded most of the recovering populations in regenerating areas.

Population recovery is likely to be fastest when animals persist within a burnt area rather than relying on new animals to move into the area from more distant unburned areas. Of course, for animals to survive and then persist after fires they must have sufficient resources.

In many of Australia's tall, wet forests the most limited resource is tree hollows, which many animal species depend on for breeding and denning sites. It takes at least 120 years for trees to start to form tree hollows, so forests regenerating after logging are generally lacking in tree hollows.

Old growth forests have more tree hollows so are likely to have healthier populations of many wildlife species before fires and more places for wildlife to shelter during a fire.

When old growth forest is burned, many of the large hollow-bearing trees remain, either living or dead. These provide nesting and sheltering sites for many species, and speed the recovery of hollow-dependent wildlife, like the Endangered greater glider and Leadbeater's possum, by as much as 100–200 years.

More mature forests

In summary, the condition and age of a forest at the time of a wildfire matters to the speed of the recovery. It matters because it influences the severity at which a fire burns and what legacies will remain after the fire to aid recovery.

Old growth forests experience less severe fires and recover fastest. However, old growth forests are now uncommon in many parts of the Australian native forest estate. By growing larger areas of native forest through to ecological maturity we will support stronger recovery after fires, both for the forests and the species within them.

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LEFT: The hollows in this fire-killed tree are a precious resource within the surrounding younger forest.

IMAGE: VERA HONG

Oliver Costello

Healing Country with cultural fire

My name is Oliver Costello, and I'm a Bundjalung man. I was born in Byron Bay and grew up around the Northern Rivers region of New South Wales.

As a child, I developed a real appreciation for Country through exploring, camping, hunting and catching fish. My parents were strong about my identity, and made sure I knew I was Aboriginal, and connected me with Elders and communities. As a teenager and young adult, I had many troubled years finding my way in the world. About 15 years ago, my mother married Billy Yalawanga, an Elder from Arnhem Land, and they moved to live with our family in New South Wales. Billy grew up on Country and had a huge amount of cultural knowledge. This is when I really began to learn and get enthused about cultural fire management. We spoke about living on Country, and he became a positive influence on my way of thinking about how to support living on Country and how to care for Country with fire. This was just what I needed at that time in my life.

Sharing knowledge about Country

In 2008, I started a degree in Adult Education and Community Management at the University of Technology Sydney. It put me on a steep learning curve about community education and development. In 2009, I was the first Aboriginal person to complete the Centre for Sustainability Leadership fellowship program in Sydney. Jason De Santolo (Indigenous researcher and lecturer) became a mentor and asked me to come and work on a media project. This is when I met Victor Steffensen (Indigenous fire practitioner) and Jacqueline Gothe (design lecturer). As we were walking together, Victor shared knowledge about burning Country – and all of the things that I had been thinking about for years started to come into focus. We discussed ways in which to do it, and how to address the cultural protocols, fire planning and government regulations to bring cultural fire back to Country. This is when the original "Firesticks" project was started in New South Wales. Since then, it has been an amazing journey of connecting and sharing knowledge with people and Country.

The good fire

Firesticks has now grown into a movement for change, and the Firesticks Alliance Indigenous Corporation was incorporated in 2018. Since then, it has been a journey of fire workshops, training programs, advocating, raising funds and responding to the huge interest created by the 2019–20 bushfires. Firesticks Alliance partners with diverse communities, landholders, agencies and institutions across the continent. Together we are identifying pathways to apply cultural fire to landscapes and to help heal and care for Country, and empowering communities through mentorship and shared understandings that are improving fire management in Australia.

The recognition of cultural fire is growing rapidly, but we still need a lot to change to realise the full benefits of cultural fire. I look forward to seeing more people experience the good fire across the Country, and hope that you and many others will see the healing of people and Country in practice.

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IMAGE: SIAN HROMEK

Oliver conducting cultural burning at Dorrobee Grasslands Reserve, New South Wales.

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Science for saving species

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COVER IMAGE: FIRE IN TOP END TROPICAL SAVANNA (SEE PAGE 22 FOR THE FULL STORY.) IMAGE: JAANA DIELENBERG

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