Information sheet: Research evidence for actions to improve ecosystem resilience and resistance to wildfires

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Image: Rachel Morgain

Australia faces a growing risk to its ecosystems, landscapes and waterways from repeated, intense wildfires and other natural hazards. The catastrophic 2019-20 wildfires in temperate and subtropical Australia, in many places followed by severe floods, raise critical questions for managers about what strategies could improve the capacity of ecosystems to resist or recover, and how to make landscapes more resilient.

Resistance, recovery and resilience of ecosystems from wildfires

Although we often use the terms loosely, resistance, recovery and resilience imply different approaches to managing ecosystems in the face of wildfire risk.

Resistance of an ecosystem to wildfire is its ability to withstand encroachment; e.g. wetter, cooler landscapes are more resistant to wildfire.

Recovery is the capacity of an ecosystem to "bounce back", often to a pre-existing condition, on its own or aided by us through a range of management interventions.

Ecological **resilience** is the extent to which a biodiverse system can adapt and reorganise itself as a result of the changes that flow from disturbances such as wildfire, without altering its fundamental characteristics or functions.

Each of these approaches can guide strategies for managing wildfire risk to ecosystems, landscapes and socio-ecological systems.

Ecosystem risk from climate change

It is well established that climate change increases the frequency of many natural hazards including wildfire.

Frequent disturbance from extreme events lowers ecosystem resilience, especially when coupled with changes in weather patterns, such as less overall rainfall. Studies show that when changing climate patterns reduce the suitable range of ecosystems (e.g. when the suitable range of a forest system shrinks to higher elevations), the resilience of these ecosystems to wildfire and other disturbance also reduces.

Extreme events in quick succession, which are becoming more frequent under climate change, can substantially compound their impacts.

In 2019, an Australia-wide study showed that as many as nineteen ecosystems across Australia risk 'collapse' from the combined effects of changing climate, natural disasters, and other ongoing pressures. This means they risk transitioning to other states and losing ecosystem services vital for humans, wildlife, plants, waterways and soils.

Strategies to enhance ecosystem resistance and resilience to wildfire are increasingly important.

Understanding resilience

Resilience is the capacity of a system to adapt to changes induced by shocks such as wildfire, while retaining their essential characteristics.

Resilience is often distinguished from resistance, since systems resistant to a disturbance, such as fire-intolerant gondwana remnants, are often very badly affected when that disturbance reaches them.

Building on this insight, Walker suggests seven system strategies that help promote resilience (Table 1). This includes exposure to disturbances (e.g. using fire to promote fire-tolerant vegetation), guiding actions in an open way rather than steering, and being prepared to transform a system where needed.

Resilience can apply to both ecological and social systems. Social values and processes are also an intrinsic part of ecosystem resilience. Fire management requires careful attention to social acceptance and priorities. Values are also essential to determining which outcomes for ecosystems are preferred across different landscapes, e.g. whether dense old-growth woodlands or regularly burned open systems are sought.

Higuera and co-authors distinguish between value-free dimensions of resilience, referring to a system's capacity to withstand disturbance, which can be assessed analytically; and value-explicit dimensions, or whether an existing social or ecological state is desired, which requires bringing together diverse views of stakeholders.

Resilience is not always beneficial. The resilience of fossil-fuel polluting social systems is detrimental to many social and ecological values. Sometimes the most effective management requires active transition from a state which is resilient but undesirable, to a new desired state.

Resilience can also trade off at different scales, e.g. the resilience of fossil fuel polluting social systems globally undermines resilience of ecosystems locally.

Table 1: System strategies to promote general resilience (from Walker 2020)
1. Response diversity (e.g. diverse pea species to fix nitrogen)
2. Exposure to disturbances (e.g. fire to promote fire-tolerance)
3. Being modular, not over-connected or under-connected
4. Being able to respond quickly to shocks
5. Readiness to transform a system if necessary: knowing when this is necessary and being willing to act deliberately (see also Prober et al. 2019).
6. Thinking, planning and managing across scales, recognising that maintaining resilience at one scale may require transforming it at another (e.g. reducing greenhouse gas emissions to support ecosystem resilience)
7. Guiding not steering, keeping options open

Resilience concepts

Writers on resilience see resilience as both ecological and social.

Higuera and co-authors the need to disentangle *value-free* from *value-explicit* dimensions.

- *value-free* dimensions: a system's capacity to withstand disturbance; can be assessed analytically (though note: values inform the choice of which system attributes to focus on).
- *value-explicit* dimensions: whether an existing social or ecological state is desired; requires bringing together diverse stakeholders.

Understanding both together can highlight where different approaches to management are needed:

- **Low-intensity management, oversight or shepherding**: where the existing state is desired and stable or where it is likely to change but that change is desirable;
- **Intensive, potentially costly action needed**: where active transformation of a stubborn existing system is desired, or where change is unacceptable but significant action is required to prevent it.

Chambers and co-authors (2019) distinguish three types of resilience relevant to fire management:

- **ecological resilience**: an ecosystem's capacity to withstand change while maintaining ecological processes, structures and functions;
- **general resilience**: the capacity of systems across a landscape to return to a desired state or recover after disturbance;
- **spatial resilience**: the diverse spatial attributes of resilience across the landscape and how it is configured, accounting for landscape attributes such as refugia and connectivity.

Many approaches distinguish between ecosystem, general and spatial resilience. Managing local interactions, like invasive species, pollution, or over-exploitation, can grow **ecosystem** and **general landscape resilience**. Developing heterogeneity, managing for connectivity, and protecting refugia can foster ***spatial resilience***. Growing landscape resilience can also require trade-offs across a landscape, such as the need to manage for different weed species with different fire preferences. Table 2 highlights spatial and general resilience principles that can be applied to strengthen a landscape's resilience to wildfire.

Table 2: Broad approaches to addressing spatial and general landscape resilience

Action area	Evidence and considerations in the literature	Discussion in the literature
Protecting refugia	Providing additional resources to protect critical fire refugia during emergencies increases spatial resilience by allowing animals to migrate or plants to recolonise neighbouring fire-affected regions.	Meddens et al. 2018; Mackey et al. 2012
Developing an appropriate level of connectivity	Maintaining landscape-level connectivity keeps populations of species connected, and especially supports species mobility in the face of climate change. Connectivity can be critical to post-fire resilience, providing opportunities for recolonisation and leaving potentially greater amounts of biodiverse habitat across the entirety of a species' ranges. However, landscape corridors can also increase the risk of fire spreading further.	Walker 2020
Addressing and managing trade-offs across landscapes	Managing landscapes in an integrated way can ensure long-term landscape-level resilience. This includes addressing trade-offs between managing for specific ecosystem needs or specific threats across landscapes.	Wollstein et al. 2022
Prioritising areas for management action	Recognising pockets of higher or lower resilience can help managers prioritise areas for intervention in order to maximise resilience across the landscape.	Chambers and co-authors 2019
Managing for heterogeneity	Managing for vegetation diversity and creating a successional-stage landscape mosaic can be a significant contributor to landscape-level resilience. This supports maintaining species at different successional stages and enables dispersal of species between patches in the patchwork mosaic. Assessment of benefits and adjustment of approach through adaptive management is needed to design strategies for specific contexts.	Ellsworth et al. 2016; Parr and Andersen 2006
Protecting vulnerable pockets	Some Australian systems, such as remnant Gondwana forests in Tasmania, remain entirely intolerant to fire. Intensive landscape-level management and targeted emergency response are likely to be needed to protect these systems and prevent wildfire incursion if they are to persist.	Rickards 2016; Kooyman, Watson, and Wilf 2020

Novel approaches to reducing wildfire risk and growing resistance to wildfire in biodiverse landscapes

Some specific actions, such as managing fire-prone weed invasion, are used widely to reduce wildfire risk. Others are novel and less widely applied or understood. Table 3 gives examples of actions that may increase fire resistance in specific contexts, and considerations for their application. Each example should be carefully considered in the light of specific expertise and local knowledge about ecosystems and likely responses.

Table 3: Research literature on novel approaches to reducing wildfire risk

This table provides options for consideration and points to research on their benefits in specific circumstances. Note, these novel strategies have not been systematically assessed for effectiveness across diverse fire contexts. These strategies may only work in some circumstances and for some conditions. Specific actions appropriate to particular contexts will be highly variable, and should be assessed by those with expertise in particular regions and ecosystems.

Action area	Evidence and considerations in the literature	Research literature
Direct fuel load management	Fuel loads are the most significant factor for wildfire risk under particular weather conditions. Fuel load management, particularly planned burning, is deeply embedded in local and state-wide approaches to fire management. Increasing attention in Australia is also being given to First Nations fire strategies. Ecological thinning is another approach to direct fuel management. The impacts, costs and benefits of thinning are variable across ecosystems.	**Review of First Nations fire management in southern Australia:** McKemey et al. 2020 **Potential of ecological thinning for reducing fire risk:** Keenan, Weston, and Volkova 2021; Omi and Martinson 2004
Fauna management for indirect fuel management	Fauna can have under-recognised benefits for reducing fire risk. Introduction of grazing animals in grassy habitats can help reduce fuel loads and fine fuel structure in some circumstances, although the timing and consumption patterns of the animals matters, and the potential for grazers to alter the vegetation structure, potentially leading to increased fire risk, must be accounted for. A less widely considered strategy includes re-introducing native digging mammals, which can potentially contribute to litter breakdown, including in forested areas.	**Review of fauna impacts on fire regimes:** Foster et al. 2020 **Impacts of digging mammals on reducing fire risk:** Fleming et al. 2014; Valentine et al. 2017
Reducing human disturbance and incursions; restoring disturbed areas	In some ecosystems, disturbance such as logging can increase the risk of high severity wildfire. Landscape disturbance such as road cuttings or clearing can also increase the risk of weed incursions, which may be more flammable than locally native vegetation. Disturbance and modification of riparian areas and waterways–including grazing, logging and flow regulation–can reduce their capacity to resist fire incursion.	**Logging and fire risk:** Lindenmayer, Taylor, and Blanchard 2021 **Cuttings/clearing and weed incursions:** Chambers et al. 2019; Gelbard and Belnap 2003 **Disturbance of riparian areas:** Dwire and Kauffman 2003
Hydrating the landscape and protecting riparian zones	Protecting waterways and riparian areas from disturbance or restoring them can support fire management as well as generating other ecological benefits. Riparian zones can act as lower-fire risk zones and potentially provide landscape-level fire-breaks and critical refugia, particularly next to larger streams, downstream from headwaters. However, greater productivity in riparian areas can also generate higher fuel loads which, in extended dry periods, can act as corridors conducting fire through landscapes, highlighting a need for ongoing management. Less research has been done directly on the effectiveness of maintaining hydration in the landscape in general for reducing fire risk, but the properties of riparian areas as hydrated, cooler regions often better protected from fire point to the potential benefits of strategies to maintain landscape hydration (such as maintaining soil cover) to reduce fire risk.	**Riparian zones and fire risk:** Hunsaker and Long 2014; Pettit and Naiman 2007; Dwire and Kauffman 2003
Introducing green firebreaks	'Green firebreaks' are plantings that are more fire-resistant than surrounding vegetation, and can in some circumstances reduce landscape-level fire risk. Appropriate low-flammability plants must be tailored to ecological conditions, and for social considerations. This will depend on where they are being used, e.g. as agricultural landscape plantings or at the urban-wildlife interface. The application of green firebreaks is more advanced in other countries, but is being tested in Australia.	**Potential of green firebreaks to reduce landscape-level fire risk:** Curran et al. 2018; Cui et al. 2019; Murray et al. 2018 **Project exploring green firebreaks in Australia:** WWF 2021, 18

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