

Pyrodiversity vs Biodiversity

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New research challenges conventional wisdom that the creation of a diverse mosaic of fire histories benefits biodiversity.

Fire is a part of life in Australia. It can be an agent of destruction and loss, and it can promote regeneration and new life.

While most terrestrial ecosystems in Australia are fire-prone, our understanding of the relationships between fire regimes and the Australian flora and fauna remains limited. Such understanding is critical because inappropriate fire regimes – such as burning too little or too often – have been implicated in the decline and extinction of a range of native species.

A large team of scientists and volunteers have set out to rectify this knowledge gap by undertaking a major study across the Mallee region where Victoria, South Australia and New South Wales meet. What we found challenges prevailing wisdom, and suggests that fire management regimes will need to vary between ecosystems to maintain the widest diversity of species.

The Ecological Role of Fire

Picture a site that has recently burned: the canopy scorched and its dead leaves starting to fall; bare ground where the leaf litter has been consumed by fire; and logs blackened to coal on the ground. What looks like a harsh, uninhabitable landscape can in fact be the preferred habitat for species that like open, structurally simple areas and do not rely on thick vegetation for shelter – burrowing species, for instance. These species will be most common in the recently burned landscape.

Now imagine weeks, months and years passing. Grass and shrubs gradually return to cover the ground layer. The race for sunlight is on as trees germinate from seeds, resprout from lignotubers or simply regrow their branches and leaves from individuals that survived the fire. The pace of this change will vary substantially between ecosystems.

These changes to vegetation bring about further changes to the penetration of sunlight through the returning canopy and the availability of habitat resources such as tree hollows, logs and leaf litter. Now, animal species that prefer open habitats are finding it tough. Instead, species that shelter under logs or in leaf litter are becoming more abundant, potentially outcompeting other species for food and other resources.

As even more time passes, trees may senesce and a new raft of changes will favour yet another group of plant and animal species.

Patch-Mosaic Burning

Because ecosystems change over time following fire (although at vastly different rates depending on the ecosystem), an important consideration in fire ecology is how to accommodate all the needs of these different species.

A widely advocated approach is “patch-mosaic burning”. The emphasis of patch-mosaic burning is to maintain a range of different fire histories across a landscape – for instance, some patches that have recently burned, some not burned for a decade, and some patches of much greater age since the last fire. The aim is that by creating a mosaic, the requirements of all species might be met, allowing species to co-exist despite their differing habitat preferences.

A corollary of this logic is that a diverse mosaic of fire ages will accommodate the needs of more species, and therefore the diversity of fire ages within a landscape can be considered a surrogate for the amount of biodiversity. This logic has been captured in the phrase “pyrodiversity begets biodiversity”.

Patch-mosaic burning has become common in fire management around the world, but particularly in South Africa and Australia, where government agencies often work towards



Fire is a key part of ecosystems in the Mallee.

Credit: Peter Teasdale

creating a fine-scale patch-mosaic of fire ages. However, despite its widespread application, until recently very little empirical research had been done to test the assumption that pyrodiversity does indeed promote biodiversity.

Fire in the Mallee

The Mallee Fire and Biodiversity Team sought to fill this knowledge gap by undertaking a large-scale research project in the Murray–Mallee region of south-eastern Australia.

Mallee vegetation extends across vast areas of semi-arid southern Australia, and is characterised by multi-stemmed “mallee” eucalypt trees and red, sandy soils.

As you move through mallee landscapes, the dramatic effects of fire become clear. Recently burned areas can be almost devoid of vegetation, apart from the dead stems of mallee eucalypt trees that remain as legacies of the pre-fire ecosystem. Older areas have a sparse canopy of eucalypts and often an understory of shrubs, chenopod plants and spinifex grass. These landscapes hold a rich fire history as mallee vegetation is highly fire-prone, with frequent, very large wildfires (>100,000 ha) occurring every 10–20 years within the Murray–Mallee region.

At around 5 metres in height, mallee trees are relatively short for eucalypts. As such, the distance between the ground fuel – such as leaf litter, bark and spinifex clumps – and the tree canopy is relatively small. Consequently, fires in mallee vegetation are usually “crown” fires that consume most above-ground vegetation, and are therefore stand-replacing. The

mallee trees regrow after fire from their root system, which is buffered from the fire and remains alive underground. Other plant species regrow by resprouting or from seeds.

Although this area is vast and may seem pristine at first glance, many changes have taken place over the past 200 years that have created novel ecological conditions.

First, large areas have been cleared for grazing and cropping, so formerly continuous tracts of vegetation are now fragmented and dispersed.

Second, many species that once inhabited the Murray–Mallee are no longer there. These include many small- and medium-sized mammals, such as brush-tailed bettongs, pig-footed bandicoots and the lesser stick-nest rat. These species declined quickly as native predators such as quolls and dingoes were replaced by feral cats and red foxes.

Despite these changes, the Murray–Mallee region still supports a large number of rare and fascinating animal species. Native mammals include the mallee ningauai, Mitchell’s hopping mouse, and both the little pygmy possum and western pygmy possum. Western grey kangaroos are the most common large mammal.

The extremely diverse reptile fauna includes approximately 60 species, including a range of dragon lizards, geckoes, skinks, legless lizards and snakes. The bird fauna is also impressive, including iconic and threatened species such as Major Mitchell’s cockatoo, malleefowl and the mallee emu-wren.

Fire in the Murray–Mallee region is actively managed for both protection of human assets and for biodiversity conser-

vation, and sometimes in accordance with the principles of patch-mosaic burning.

All of these factors mean that these landscapes are ideal for researching the ecological role of fire.

The Mallee Fire and Biodiversity Project

The Mallee Fire and Biodiversity Project was undertaken by a team of scientists and PhD students from La Trobe and Deakin universities in collaboration with government agencies, private landowners and several conservation organisations from New South Wales, Victoria and South Australia. In addition, more than 100 volunteers assisted with field work for this project, including installing and checking pitfall traps.

The study area encompassed 104,000 km², an area approximately the size of Tasmania. Because of the large number of researchers involved we were able to study a range of taxonomic groups, including reptiles, mammals, birds, selected invertebrates and plants.

The team established pitfall traps at 280 sites for sampling reptiles, small mammals, scorpions and centipedes. Birds and termites were monitored at 560 sites, and vegetation surveys were conducted at more than 800 sites. Overall, it was one of the largest surveys of its kind.

This survey effort resulted in about 10,000 reptile records, more than 20,000 bird records, about 1500 records of small mammals and nearly 500 centipedes. These large datasets put us in a great position to enhance our understanding of the fire ecology of the mallee.

Fire over the Long Term

Before we could test the hypothesis that pyrodiversity begets biodiversity, it was important to determine whether fire history affects biodiversity in our study region. If fire history does not affect the distribution of plants and animals in the region then fire management, including patch-mosaic burning, will have little effect on the region's biodiversity.

One obstacle we faced was that, as with most regions, systematic knowledge of the fire history of the Murray–Mallee went back only to the 1970s, when satellite imagery became available and was used to document landscapes in a consistent and regular way. The “footprint” of fires is often distinct in satellite images, allowing fire ecologists to map fires through time. However, this reliance on satellite imagery left hidden the age of fires that occurred long before the 1970s.

Our team developed statistical models of the growth rates of eucalypt stems following fire to determine the age of sites up to 110 years after fire. We found that the effects of fire on ecosystems last far longer than we had appreciated. Changes in resources that are critical to fauna, such as the cover of important plant species and the abundance of tree hollows, continued



Fauna of the Murray–Mallee region (clockwise from above): a western pygmy possum, a beaded gecko, a southern legless lizard, yellow-plumed honeyeaters and a mallee ningau with young.

to occur throughout the entire 110-year period.

We found that many of the animal species that are affected by fire are tightly linked to these resources, so they are unlikely to occur where their favoured resources are scarce. Consequently, the effects of fire can continue to influence some species for a century following fire. For instance, the Murray striped skink and the yellow-plumed honeyeater are both most common at sites that have not burned for 60–100 years.

Species that depend on spinifex hummocks, such as the mallee emu-wren, mallee ningau and southern legless lizard, reach their greatest abundance 20–50 years post-fire when large amounts of spinifex cover occur.

Now that we had established that fire is an important and long-term driver of plants and animals in the region, the next question was whether a more diverse patch-mosaic does indeed have more biodiversity.

Comparing Whole Fire Mosaics

When studying ecological processes, it is important that the spatial scale of a study matches the scale of the process to be investigated. In this instance we were interested in whether landscapes that had a diverse fire history (i.e. many fire age-classes present) had more biodiversity than those with more uniform fire histories. Thus we needed to compare biodiversity between entire patch-mosaics that differed in their fire history. This meant sampling both fire history and biodiversity for entire landscapes.



Credit: Lauren Brown



Credit: Lauren Brown



Credit: Mallee Fire and Biodiversity Team



Credit: Lauren Brown



Credit: Simon Watson

Our study design included 28 landscapes, each 4 km in diameter, that represented a gradient in the diversity of their fire history. Some landscapes had a single fire-age, such as being completely burned at a single time recently; other landscapes had two fire age-classes; and yet other landscapes had up to five or six fire ages present, representing a fine-scale fire mosaic.

This sampling approach, known as “whole-of-landscape” sampling, allowed us to directly compare the biodiversity in these 28 landscapes to examine whether those with more fire-ages (i.e. those that are more “pyrodiverse”) did in fact have more species.

Does Pyrodiversity Beget Biodiversity?

We found little evidence that landscapes with more diverse fire histories had greater biodiversity for any of the taxonomic groups studied: that is, landscapes that had a more diverse fire history did not have more species of invertebrates, reptiles, small mammals or birds.

Instead, an important driver for all taxonomic groups was the spatial extent of ecologically important fire age-classes. For example, the species richness of all birds, as well as the richness of threatened bird species such as the malleefowl and mallee emu-wren, was positively associated with the amount of long-unburned vegetation in the landscape (which was classified as mallee vegetation unburned for more than 34 years).

Likewise, the species richness of small mammals and reptiles was not related to the diversity of fire age-classes. Individual

species of mammals and reptiles were often more common in landscapes with a greater area of a preferred fire-age. For instance, the western pygmy possum was more common in landscapes with a greater area of long-unburned vegetation, while the mallee dragon, southern legless lizard and the mallee ningauai – all of which use spinifex hummocks for shelter – were less common in landscapes with a large proportion of recently burned vegetation, where *Spinifex* is less common.

Our findings challenge the dominant paradigm that the creation of diverse fire mosaics will enhance biodiversity, but what do we propose to replace it?

We suggest that the focus for managing fire mosaics should shift from simply creating a diversity of fire ages in landscapes to a strategic focus that seeks to ensure an optimum mix of age-classes at the regional scale. Researchers from the team are currently working on tools that can help determine this optimal mix.

Importantly, the optimal mix of fire-ages will differ substantially between ecosystems due to differences in the amount of time over which the recovery of habitat resources occurs following fire, the different species that occur within ecosystems, and their strategies for dealing with fire. As such, it is critical that targets for the optimal mix of age-classes be set on an ecosystem-by-ecosystem basis, and be informed by knowledge of how fire affects the distribution of resident species.

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