Refuges for Flora and Fauna in Fire-Prone Landscapes

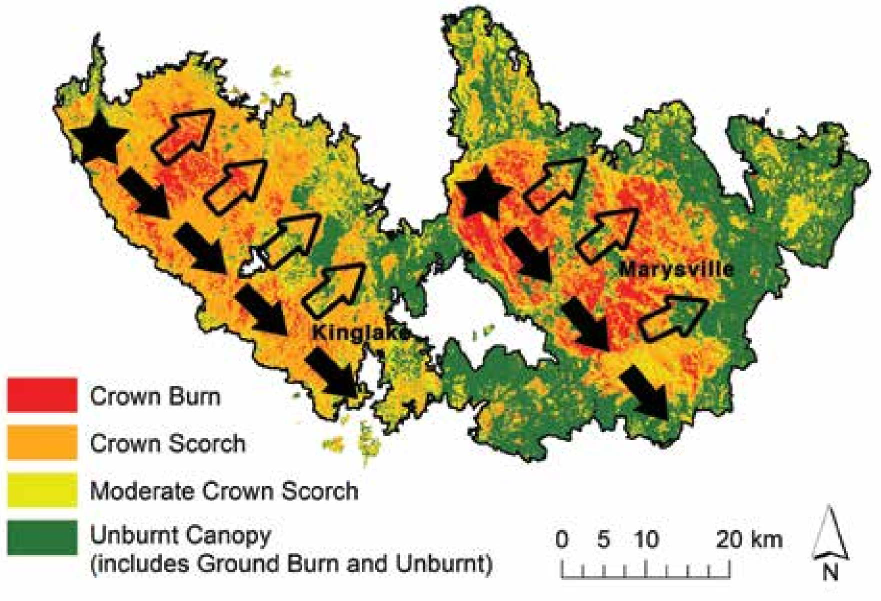
Large bushfires, such as those that occurred on Black Saturday 2009, are a reality in Australian forests. As well as threatening human life and property, they have profound impacts on native animals and plants.

Yet even within these large fires, unburnt or less severely burnt patches remain. Do these function as refuges allowing animals and plants to remain in the post-fire landscape? Can planned burning be used to create more of these refuges?

The Kilmore – Murrindindi bushfire

The Kilmore-Murrindindi fire complex began as two separate ignitions on 7th February 2009 ('Black Saturday'). Weather conditions were extremely hot (> 40oC), dry (RH < 10%) and windy (gusts > 100 km hr-1). The fires initially moved in a south-easterly direction. A wind change late in the day caused the fires to break out to the northeast on wide fronts. The Kilmore-Murrindindi fires ultimately affected 250 000 ha, destroyed over 1700 houses and resulted in the deaths of 159 people.

Variation in fire intensity created a mosaic of patches burnt to varying degrees. In most of the area burnt during extreme conditions on 7th February, the tree canopy was incinerated or scorched. As conditions ameliorated later that day, the fire mainly burnt the forest understorey (ground burn).



Movement and severity of the Kilmore-Murrindindi fire complex. Stars indicate ignition points. Strong north-westerly winds on 7th February caused the fires to move in a south-easterly direction (solid arrows), until a wind change in the evening caused the fires to break out to the north-east on wide fronts (hollow arrows). Fire severity mapping courtesy of Department of Environment and Primary Industries.

Fire severity

Fire severity refers to the degree of damage to vegetation caused by fire. Fire severity had a strong effect on the vegetation structure present 2-3 years post-fire, when this study was undertaken. Crown-burn and crown-scorch sites had a dense layer of eucalypt seedlings and saplings that had germinated post-fire. Ground-burnt sites tended to have fewer shrubs than sites that remained unburnt. The response of the fauna to fire severity reflects a response to vegetation structure, rather than to fire severity *per se*.

Crown burn

Crown scorch

Ground burn

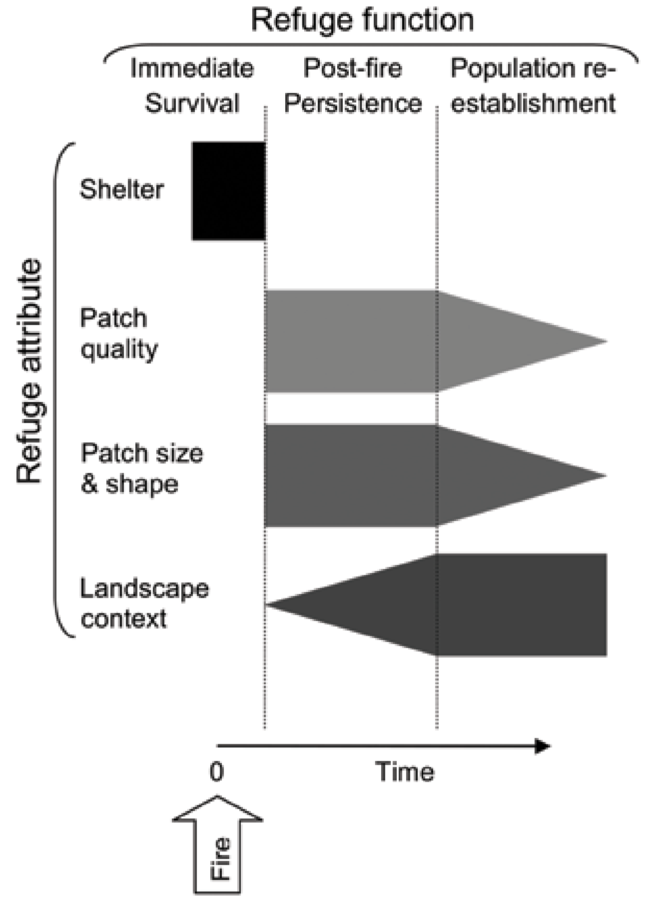
Unburnt

Refuges in fire-prone environments

Refuges can serve three main functions:

a) assist organisms to survive during and immediately after a fire;
b) facilitate the persistence of organisms and populations within the fire boundary;
c) assist the re-establishment of populations within the burnt area as it recovers.

Refuges arise from natural processes, or by human manipulation of the environment. Natural refuges include patches of unburnt vegetation that missed being burnt by chance, or because they are less flammable (e.g. moist gullies). Other features, such as rock outcrops or unburned logs, may also serve as natural refuges for some species of plants and animals. Refuges may also be created by reducing fire fuel loads. Planned burning can reduce fuel such that a particular site is less likely to burn in a subsequent bushfire; or it can be used strategically to prevent a bushfire spreading into adjacent unburnt habitat.

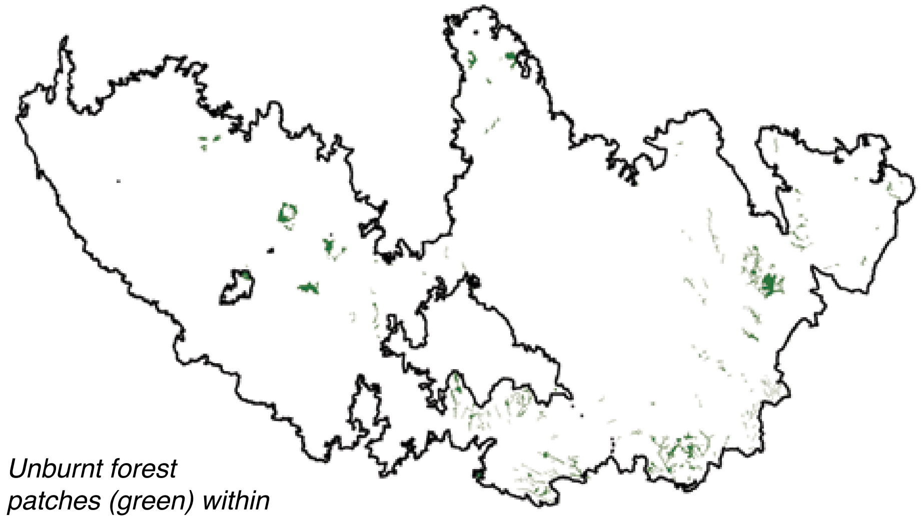


Refuge function: Patches may allow plants and animals to escape incineration. However, longer-term persistence and recolonization depend on patch attributes, i.e. the degree to which a patch provides the resources needed by organisms. The relative importance of attributes (represented here by the thickness of bars) varies over time after fire

Unburnt forest patches within the Kilmore-Murrindindi fire boundary

Unburnt forest patches within the fire boundary were rare (note that much of the area mapped as unburnt canopy in the map on the previous page was ground burnt). Examination of aerial photographs taken after the fire revealed only 85 unburnt patches greater than 1 ha in size (range from 1 – 306 ha), together making up less than 1% of the overall fire area. These mostly consisted of rainforest or wet eucalypt forest along gullies. Unburnt patches were most likely to arise due to moister fuels in sheltered locations.

However, a small number of unburnt patches occurred in dry eucalypt forest. These patches were more common where burning had occurred less than three years prior to the 2009 bushfires.



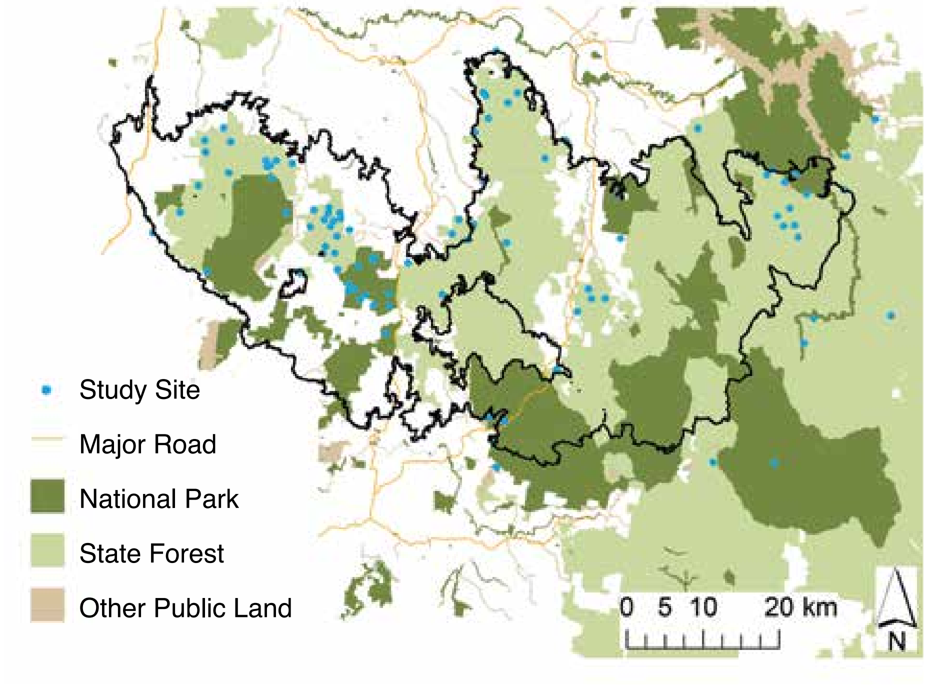
Unburnt forest patches (green) within the fire boundary.

A typical unburnt patch - rainforest vegetation along gully lines.

Our study involved a 'natural experiment'. We selected 96 sites to represent combinations of two main attributes:

a) different fire severities after the 2009 fire (i.e. not burned, ground burn, canopy scorch, canopy burn);
b) different fire histories before the bushfire (i.e. burned ≤ 3 years prior, or not burned for >20 years prior to the bushfire).

Sites were within, or close to, the perimeter of the 2009 fire (plus reference sites > 2 km outside the fire boundary), in foothill eucalypt forests (i.e. not including wet mountain forests). Each site was 5 ha, and encompassed a gully and adjacent slope. The forest vegetation comprised two main Ecological Vegetation Classes, Damp Forest (gullies) and Herb-rich Foothill Forest (slopes).



Study sites across the region. The boundary of the Kilmore-Murrindindi bushfire is shown in black.

Research questions

How common are unburnt patches of forest after a major bushfire and what determines their distribution?

To what extent do recent planned burns moderate the impact of a large bushfire on fauna and flora through the creation of unburnt, or less severely burnt, refuge areas?

How important is the extent of natural and transient (fuel reduced) refuge areas in maintaining the diversity of organisms in the landscape and does their importance differ between different kinds of plants and animals?

We conducted targeted surveys

at 2-3 years post-bushfire for:

- *birds*
- *mammals*
- *invertebrates*
- *vegetation structure*
- *vascular plants*
- *bryophytes*

Bryophytes and fire

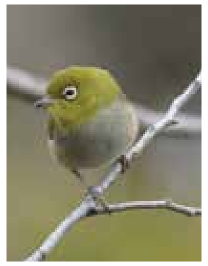
Forty species of bryophytes (32 species of mosses, 8 liverworts) were detected at sites in dry forest, surveyed 1-2 years post-fire. Most species (n = 26) were recorded at one or two sites only. Fire severity had a strong influence on both the species richness and composition of bryophytes. Forest sites that were unburnt, or had only the understorey burnt, had more species than sites with canopy scorch or canopy burn. In particular, unburnt sites had a distinctive bryophyte community that differed markedly from all types of burnt sites.

Effects of fire severity

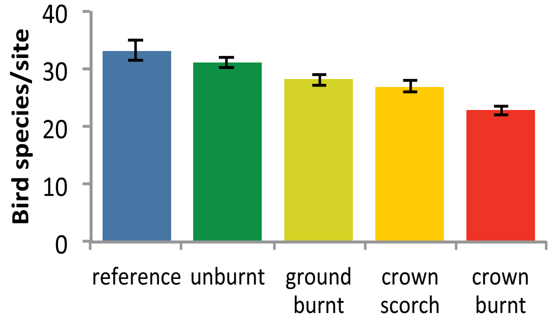
Birds

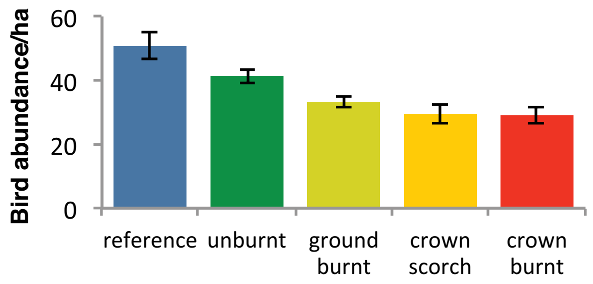
A total of 79 bird species was recorded during surveys. The number of species and the abundance of birds was lower at sites that were burnt more severely. The composition of bird communities also was influenced by fire severity. Some species, such as the Flame Robin that favours open habitat, were more common in severely burnt sites; while other species such as Eastern Spinebill, Eastern Yellow Robin and Silvereye, were more common in unburnt sites.

Flame Robin



Silvereye





Mammals

Six species of **arboreal mammals** were observed during surveys, all in low density. The overall abundance of arboreal mammals, and of the Greater Glider, were lower in severely burnt sites (crown scorch or crown burn), but did not differ between unburnt sites and ground-burnt sites. In severely burned forest, isolation was important. Arboreal mammals were more common with increasing amounts of unburnt or ground-burnt forest nearby (within 1 km radius).

Terrestrial mammals overall did not show strong responses to fire severity at 2-3 years post-fire. However, the Bush Rat was more common in severely burnt sites than in unburnt sites, while the Agile Antechinus was more common in unburnt sites than ground-burnt sites.

Sugar Glider, and other arboreal mammals, were scarce in severely burnt sites.

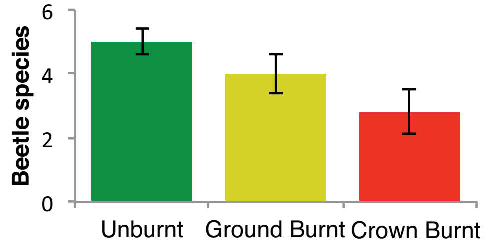
Common Brushtail Possum, detected by a remote camera.

Invertebrates, leaf litter and fire

Invertebrates play a key role in breaking down leaf litter in forests. This is important for nutrient cycling and also reduces fuel build up.

Severe fire results in complete loss of habitat for litter-feeding and dwelling macro-invertebrates. For moisture-dependent wingless species, such as native woodlice, this may result not only in local extinction, but may inhibit their capacity for recolonisation after fire. Litter-dwelling invertebrates, including beetles, were less abundant and less diverse in more severely burnt sites three years after fire. Fire had a negative effect on a number of invertebrate families, including earthworms, millipedes, native woodlice, rove beetles and non-biting midges.

Some invertebrates appear to depend on long unburnt sites to persist in the landscape. One family of native woodlice was found only in deep drifts of leaf litter at long unburnt sites. This suggests that this group is vulnerable to both bushfires and planned burns.



The diversity of beetle species is sensitive to fire severity.

Woodlice depend on leaf litter and are vulnerable to fire.

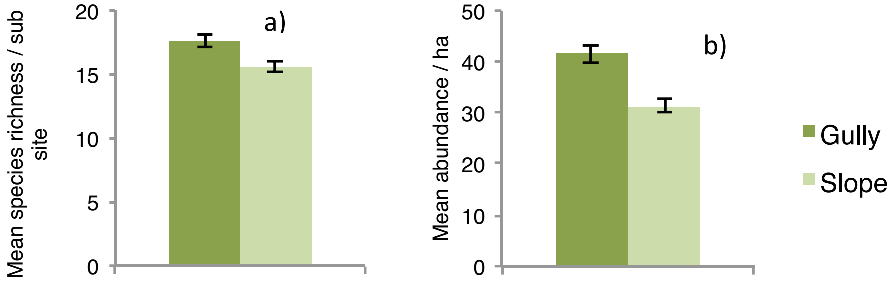
Gullies and slopes

An unburnt gully.

Topography is a major source of variation in the landscape, with slope, aspect and landscape position influencing soils, vegetation and fire behaviour. Gullies are important habitat features: they often are more productive, and contain more complex vegetation and a higher abundance of hollow logs and trees than adjacent slopes. We investigated the effect of the interaction of fire and topography on plants and animals by comparing responses between gullies and slopes.

Birds

Severe fire is sometimes thought to have an homogenising effect on landscapes, reducing all sites to a common baseline. We hypothesised that with increasing fire severity, the differences in habitat attributes, and hence bird communities, between gullies and slopes would be diminished. This was not the case. Across all fire severity classes, gullies had a) more bird species, and b) more birds than slopes.



Logs

Logs are important habitat features in forests. Fire can both create logs (by causing tree collapse) and remove them (by burning). We found that large logs (>30 cm diameter) were more common in gullies than on slopes. There were fewer small logs in gullies subject to severe fire, but otherwise there was no net effect of fire on the abundance of logs in either gullies or slopes.

Mammals

Arboreal mammals tended to be more abundant in gullies than on slopes, probably because gullies often have more large trees than slopes. The relationships of ground-dwelling mammals to topography were mixed. Some, such as the Bush Rat, were detected more commonly in gullies than on slopes, while the reverse was the case for detections of the Black Wallaby and Common Wombat. The Agile Antechinus was generally more likely to be recorded in gullies, except at ground-burnt sites, where it was more commonly present on slopes.

Do lyrebirds create fire breaks?

The Superb Lyrebird is an iconic species, well known for its mimicry and spectacular plumage. By raking through leaf litter when foraging, lyrebirds play an important role in decomposition and nutrient cycling. By using exclusion plots, we found that lyrebirds reduced litter fuel loads by 1.66 t/ha or 25%, on average, over a nine month period. Lyrebird foraging also inhibited shrub and fern establishment, reducing horizontal and vertical fuel continuity. The reduction in litter fuel load by lyrebirds was predicted to result in significantly lower flame heights and fire rate of spread (using the MacArthur Mk5 fire behaviour model).

Lyrebird foraging was concentrated in unburnt gullies. We propose a positive feedback loop, whereby lyrebird foraging decreases the likelihood and/or severity of fire, and maintains their favoured foraging habitat. Dense plant regeneration after severe fire may inhibit lyrebird foraging, leading to build up of litter, and dense shrub and fern growth, promoting further fire.

Above: Lyrebird foraging
Below: Sparse litter layer as a result of lyrebird foraging

How does planned burning influence the effects of a large bushfire?

A major focus of the study was to shed light on the interactions of planned burning and bushfire. With bushfires predicted to become more frequent and severe as climate change takes effect, planned burning increasingly is seen as a means of reducing the negative impacts of bushfire on both human assets and ecological values. However, the ecology of planned burning remains poorly understood.

Planned burning and unburnt patch occurrence

Most of the 85 unburnt forest patches identified within the fire boundary were in gullies vegetated by wet eucalypt forest or rainforest. In general, time since fire (a surrogate for fuel load) had limited influence on whether patches burnt or not. However, in dry eucalypt forest, while gullies were still less likely to burn, recent planned burning decreased the chances of a site burning in the bushfire. This difference appears to be due to variation in fuel accumulation rates amongst forest types. In wet eucalypt forest and rainforest, fuels build up rapidly after fire, such that there is no window during which low fuel loads prevent fire. In dry eucalypt forest, fuel loads are low enough to inhibit fire spread for around four years post-fire. It is important to note that no unburnt patches remained in areas burnt under extreme weather conditions prior to or immediately after the wind change on 7th February 2009, irrespective of whether they had been recently burnt or not.

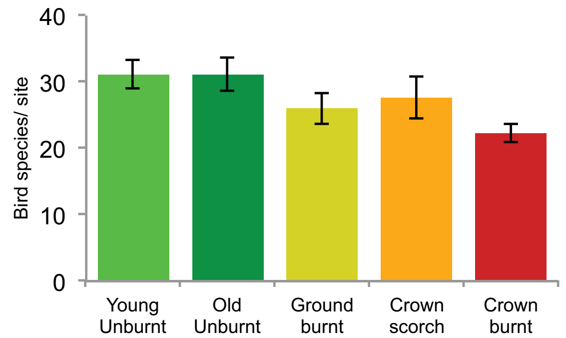
Planned burning is likely to contribute to the retention of unburnt patches during bushfire in dry eucalypt forest only under moderate fire weather conditions. While fuel reduction can reduce the chance of a patch burning during bushfire, it also simplifies vegetation structure. This will diminish the quality of patches as refuges for species that depend on complex habitat structure.

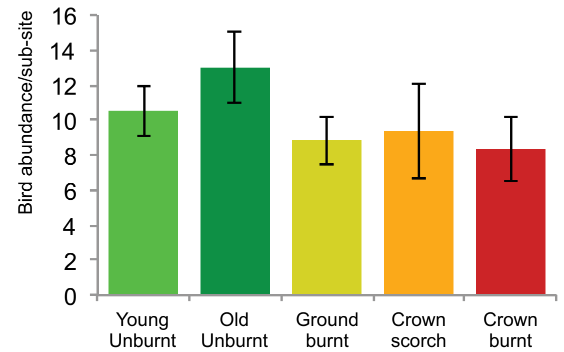
Patches that remain unburnt due to higher fuel moisture have complex vegetation structure.

Patches that remain unburnt due to prior burning have simple vegetation structure.

Birds

Both ‘young’ (burnt ≤ 3 years prior to 2009) and ‘old’ (burnt > 20 years prior to 2009) unburnt sites acted as refuges for birds. Old unburnt sites had the highest numbers of birds within the fire boundary; they had a greater abundance of birds than young unburnt sites, as well as all sites burnt by bushfire. Old unburnt sites also had a distinct assemblage of bird species, that differed from that present at all burnt sites.





Bird species associated with old unburnt patches. Clockwise from top left: Eastern Yellow Robin, Satin Bowerbird, Eastern Spinebill, Eastern Whipbird.

Conclusions

1. Large, severe bushfires can have a profound effect on wildlife and ecosystems, but that effect is not uniform. Variability in fire severity contributes to landscape heterogeneity (patchiness) after fire.
2. Unburnt patches of forest arose mainly due to the effects of topography and vegetation type on fuel moisture and were more common in gullies with rainforest and wet forest, than in drier foothill forests. In dry forests, recent (< 4 yr) prior burning contributed to the formation of unburnt patches under low intensity bushfire, but across the region these were fewer than those arising 'naturally'. In extreme fire conditions, no unburnt patches remained.
3. Surveys of the flora and fauna 2-3 years post-fire revealed rapid recovery, with most species present within the burned landscape, albeit frequently in lower abundance.
4. Fire severity is a key influence on the post-fire status of plants and animals. Greatest impacts generally occurred at sites that were severely burnt (crown scorch, crown burn).
5. Unburnt forest patches have an important role as refuges for fauna. They often supported a greater richness and abundance, and distinct composition, for faunal groups, compared with burnt sites. Old unburnt patches, in particular, may harbour a greater abundance of wildlife following severe bushfire.
6. Increased levels of planned burning could result in more unburnt patches in dry forest exposed to bushfire, under moderate weather conditions. These have a simplified vegetation structure compared with long unburnt patches and so their value to wildlife may be limited. Planned burning potentially could be used strategically to protect long-unburnt stands, enhancing and preserving these valuable components of landscape heterogeneity. Given limited resources for fire management, planned ecological burning could target areas of relative topographic uniformity where 'natural' occurrence of unburnt patches is less likely to occur.

Further Research

Direct effects of fire on fauna

It is often assumed that animals will flee an approaching fire and seek refuge to avoid harm. Little is known of the ability of different species to escape the direct effects of fire, or to survive in the post-fire landscape. Ignorance of how fauna use refuges, both during and immediately following a fire, impairs our ability to identify landscape features that function as refuges.

Succession patterns

A shortage of sites of known age (time since last burnt) across a century or more, constrains our ability to document change in the structure of foothill forests, and their fauna, following severe fire.

Interaction of drought and bushfire

Severe bushfires commonly are preceded by drought. The effect of preceding drought on populations of plants and animals and its impact on their recovery after fire is poorly understood.

Tree hollows

Many species require tree hollows for shelter and breeding (e.g. possums, parrots, bats). Little is known about the time for hollows to develop, or the impacts of fire in the creation and loss of hollows, in foothill forests.

Effects of introduced species

Introduced pest species, like foxes, cats and deer, were widespread throughout the post-fire landscape. The magnitude of their impact upon recovering vegetation and wildlife populations is poorly understood.

Further information

http://www.latrobe.edu.au/zoology/research/specialisations/fire-ecology/projects/habitat-refuges

Publications

Leonard, S. W. J., Bennett, A. F., & Clarke, M. F. (2014). Determinants of the occurrence of unburnt forest patches: Potential biotic refuges within a large, intense wildfire in south-eastern Australia. Forest Ecology and Management, 314, 85-93.

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Robinson, N. M., Leonard, S. W. J., Bennett, A. F., & Clarke, M. F. (2014). Refuges for birds in fire-prone landscapes: The influence of fire severity and fire history on the distribution of forest birds. Forest Ecology & Management, 318, 110-121.

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Photo credits
Rohan Clarke (birds and sugar glider). Woodlouse photo(pg. 5) by Alastair Robertson and Maria Minor, Massey University

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