VERTEBRATE FAUNA AND FIRE REGIMES: A CONCEPTUAL MODEL TO AID FIRE RESEARCH AND MANAGEMENT

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Vertebrate fauna respond actively to individual fires by movement before and after the event, as well as by mortality and reproduction at the population level. They rely very much on mechanisms for avoiding fire fronts and ex situ recolonisation of burnt and regenerating habitat, as well as in situ survival. This sets them apart from most plant species and the more sedentary examples of invertebrate fauna. Rates of recolonisation after fire events depend on habitat development, and this includes both structure and floristic aspects of the vegetation, and also on accessibility of refuge habitat. Strategies for conserving vertebrate fauna need to take a broad landscape perspective to ensure that fire regimes are designed so that species can survive particular fire events in the broad landscape, and have potential to recolonise habitat as it becomes suitable over time. Long-unburnt vegetation provides important habitat for some species and should be valued accordingly. Long time-frames may be needed for some structural elements to develop after severe fires. Hence it is necessary to think big in managing habitat for vertebrate fauna, at both spatial and temporal scales. A conceptual model is offered for doing this, and a research program is described which aims to provide the detail necessary to make appropriate settings in policy and management frameworks.

Keywords: Bushfire, vertebrate fauna, conservation strategies,conceptual model.

FIRE has been a dominant agent of disturbance in the Australian landscape for many millennia (Gill 1975; Gill et al. 1981). Climate and people have affected the way in which fire operates, and inevitably there have been changes in fire regimes with arrival of Aboriginal people many thousands of years ago, and more recently with intensity of human settlement following colonisation by people from Europe and Asia in recent centuries. Still more changes are happening as modern societies recognise the nature of these changes, and attempt to manage them for the benefit of society and to conserve natural values, including biodiversity. Changes are also likely as a result of changes in climate (Mackey et al. 2002; Hennessy et al. 2006), some of which are predicated by the global increase in human population and influence.

Victoria is a highly fire-prone environment, and mega-fires in recent years (notably 1939, 1983, 2003, 2006/7 and 2009) have caused massive loss of human life and property. The State Government is expected to act to reduce the human risk from future fires, and also to conserve what people value in the natural environment that we have inherited, notably biodiversity. The Department of Sustainability & Environment (DSE) responded to this challenge with a set of new policies and an ambitious program of research and monitoring (DSE 2008), with further impetus and direction provided by the Victorian Bushfire Royal Commission after the 2009 fires (Parliament of Victoria 2010).

Much effort has gone into definition of Tolerable Fire Intervals for particular vegetation communities (DSE 2008; Cheal 2010), based on the capacity of plant species to regenerate at certain minimum and maximum ages after fire (their vital attributes; Noble and Slatyer 1980). These concepts have been applied recently to 'Ecological Vegetation Divisions' in Victoria (Cheal 2010). This approach is based on the idea that areas should not be burnt until the characteristic plant species have reached reproductive maturity, and that they should be burnt before those plant species are too old to reproduce. If burning regimes are planned so that fires fall at appropriate growth stages (older than juvenile, younger than senescent), it can be expected that the full suite of plant species will be able to reproduce and perpetuate themselves within the landscapes subject to this management. The concept provides a useful guide, but needs to be developed further to cater for the needs of fauna and to address issues such as those listed below:

1. Tolerable fire intervals and vital attributes are imperfectly known, even for common "fire response species" of vascular plant;
2. Plant species compete with each other, and

it can be expected that variations in fire regime may favour one species over another, even within a tolerable range of fire intervals: hence subtle variations in fire regime may have cumulative impacts on floristic composition;

3. Recent evidence shows that some plant species do not reach their full reproductive capacity until many years after the minimum tolerable fire interval (Muir 2011), so they may be disadvantaged by burning at high frequency;

4. Vertebrate fauna species may depend on structural features of the vegetation that take many years to develop, beyond the interval necessary for plant species to reproduce (Clarke 2008). Such features can include particular configurations of shrub thickets and open ground, as well as classic features of mature forest such as hollow-bearing trees and abundant epiphytes such as mistletoe;

5. Vertebrate fauna, along with the more mobile species of plant and invertebrate, depend on maintenance of suitable habitat within broad landscapes not on specific sites; and

6. People care about vertebrate fauna at the species level and as components of the ecosystem. Hence there is a public demand (with associated legislation and obligations) that vertebrate fauna species will be conserved.

This paper attempts to propose a useful way forward that will accommodate the needs of vertebrate fauna and also meet the human needs for improved safety from severe bushfires. Some of these ideas were developed and explored in an earlier report (MacHunter et al. 2009). Several authors have stressed the need to consider fauna as well as flora, and to invest seriously in collecting new information through targeted research, monitoring and adaptive management (Friend 1993; Clarke 2008; Haslem et al. 2011). Scale is a particularly important issue when considering the needs of vertebrate fauna (and some invertebrates), because of their mobility in the landscape. Some vertebrate fauna have remarkable abilities to survive fires *in situ*, but many species disappear temporarily from severely burnt forest and depend on mobility in the landscape for survival (escape) and subsequent recolonisation (Woinarski 1990; Friend 1993; Loyn 1997).

Some welcome initiatives have been made in recent years to meet these challenges. These include research and monitoring programs, some of which were described at the Victorian National Parks Association (VNPA) symposium. This paper is informed, in particular, by the program of research at the Arthur Rylah Institute (ARI). This program includes a major retrospective study examining effects of fire regimes on flora and fauna in eastern Victoria, and contributions to the Hawkeye biodiversity monitoring program. Vertebrate fauna considered in these studies include diurnal birds, owls, bats, arboreal mammals and ground-dwelling mammals. However, it would be premature to present results of these studies at this stage, and so the paper aims to set the scene and describe how the results are expected to contribute to policy and management.

POLICY QUESTIONS

The aim of government research is generally to support development and implementation of public policy, as well as land management actions within the jurisdiction of the respective government agency. The Victorian Government has recognised the need for policy reform in fire management, including the need for more information and adaptive management (DSE 2008), and has accepted the recommendations of the Victorian Bushfire Royal Commission (Parliament of Victoria 2010). One of the VBRC recommendations was that fuel reduction burning should be conducted on 5% of public land each year, with concomitant monitoring and research programs to assess effects on biodiversity. Given that this policy decision has been made, what further room is there to adjust policy to balance the needs of biodiversity and asset protection? Do we have to burn 5% of the treatable area systematically each year so that all of it is burned on a uniform 20-year rotation, or can we choose to burn some areas more or less frequently than others?

The VBRC recognised the need for further information on these matters, which would undoubtedly be used to refine policy settings over time (and in less time than the 20 year cycle over which potentially all treatable land may be burned). We already have a zoning system whereby some parts of the public estate are burned frequently for asset protection (Zone 1), others are burned strategically to assist future fire-fighting actions (Zone 2), a large portion is burned for ecological purposes, currently with the prime goal of maintaining vegetation within Tolerable Fire Intervals (TFIs) (Zone 3) and some parts are excluded from planned burns (Zone 4) (DSE 2006). Current concepts of TFIs may be revised when the needs of vertebrate fauna are better understood.

Table 1. Advantages and disadvantages of different strategies for spatial and temporal arrangements of fuel reduction burns

Strategy	Advantages	Disadvantages
1. Systematic burns 5%/year until all treated (100%)	Simple to apply, provides even level of protection	Does not allow some areas to grow old since fire; misses opportunity to build desired landscape patterns.
1a. Spatial arrangement independent of fire history	Simple to plan	Neglects historical or desired future patterns
1b. Starting with sites with longest interval since last fire	May be seen to address fire danger hot spots; maximises fit with TFIs for plant species	Quickly eliminates long-unburnt areas (which may have high habitat value)
1c. Planning to maintain sites in Tolerable Fire Intervals for plant species	Logical for plant conservation	Neglects uncertainty re TFIs, and needs of fauna
1d. Starting with sites that give best protection to valuable assets (human & natural)	Quickly protects valuable assets	Delays providing active protection for large parts of the landscape
2. Concentrating burns in small part of landscape, ~15%	Provides high levels of protection to some areas; allows many other areas to grow old since fire; reduces risks to biodiversity from artificial application of frequent burns	Does not provide active protection for large parts of the landscape; treated areas may be burnt more frequently than TFIs, and untreated areas less often
2a. Spatial arrangement independent of fire history or natural assets	Simple to plan; may allow maximum protection of human assets	Neglects historical or desired future patterns; does not provide an ecological basis for selecting where to burn
2b. Concentrating on sites with longest interval since last fire	May be seen to address fire danger hot spots; maximises fit with TFIs for plant species	No logical basis for concentrating future efforts on such sites
2c. Concentrating on sites that give best protection to valuable assets (human & natural)	Protects valuable assets, quickly and on ongoing basis	Positive effects of fuel reduction may only eventuate in or close to the 15% selected
3. Intermediate level of dispersion, say 50%	Allows balance to be found between advantages and disadvantages listed above; can be achieved using current zoning system	Complexity may require more effort in communicating with stakeholders and the public

Most importantly, the VBRC made no recommendations about where the 5% should be applied, and that raises several questions of strategic importance. Policies about where to burn need to be refined as new evidence becomes available from research and experience, within the current framework established by Government in response to the VBRC.

For example, under the current policy setting (5% target) there is a whole spectrum of possible ways to arrange the burns in space and time (Table 1). One approach is to burn a different 5% each year quite systematically until every parcel of land had been subject to fuel reduction. After 20 years there would then be no large parcels of land (>~1 ha) where fuel reduction had not occurred within that time, though of course there would be many small patches of long-unburnt forest within the mosaic, as fuel reduction burns never burn all the vegetation within their boundaries. Note that this systematic approach effectively excludes substantial patches of long-unburnt vegetation from the landscape being managed, especially if priority is given to burning parcels of land that are most conspicuously beyond their designated TFIs. If long-unburnt vegetation has value for biodiversity (as in the Mallee; Haslem et al. 2011; Nimmo et al. in press), this is a high-risk strategy for biodiversity conservation, and it may not be the best approach for asset protection either.

At the other extreme, it may be possible to burn a parcel of land as early as 3 years after it was last burnt, maintaining a constantly low level of fuel (vegetation) on that parcel. This could be desirable for asset protection (Zone 1). If we were to invest all our fuel reduction burning efforts in that strategy, we could meet our 5% annual target by doing fuel reduction on only 15% of the public land estate, leaving 85% not subject to fuel reduction for as long as we choose to continue the policy (effectively Zone 4). This would provide a high level of protection to selected assets and lower levels of protection to the rest of the forest. 15% of the land would experience potentially negative ecological consequences from being kept below its TFI, and the remaining 85% would develop a changing mosaic of age-classes in response to bushfire and other disturbance. Some parts of the 85% would undoubtedly grow old (exceeding their TFI), while others might burn more frequently or severely than they would have done if there had been a broader fuel reduction program in their vicinity. These strategies are expected to have different sets of consequences both for biodiversity conservation and human risk mitigation, and we need to know more about those consequences.

Neither extreme is a desirable policy option (Table 1), but where in the continuum of intermediate options does the Victorian community want to be? What are the best options for asset protection and for biodiversity conservation? The answers are likely to differ for different vegetation communities (Ecological Vegetation Divisions, EVDs). The current DSE research program is designed to provide some of the answers and help managers and planners avoid some of the risks identified.

Current research will clarify which species depend on long-unburnt vegetation, and they may include many that inhabit EVDs that are too wet, too dry or too rocky to support frequent fires. For species such as these, the most risky strategy is to focus burning efforts on long-unburnt vegetation. The reverse philosophy is preferable, where areas of long-unburnt vegetation are valued and protected (by fuel reduction burning nearby, if appropriate) in much the same way as human assets. It is important to realise that long-unburnt vegetation can be converted quickly to a young age-class (by burning it) but it may take many decades or centuries to reverse the process. Valuing long-unburnt vegetation reduces risks to biodiversity.

CONCEPTUAL MODEL

A conceptual model has been developed to help link these policy issues with the need for new information through appropriate research. Figure 1 shows part of this model, listing the variables that may influence fire regimes, fire events and hence the responses of vertebrate fauna to those fire events and subsequent change. People and fire management feature strongly in these lists, providing the community with the opportunity to influence outcomes in various ways. It is expected that the abundance (density) of vertebrate fauna in a continuous habitat depends primarily on the nature of the habitat (and hence the resources that the habitat offers) (Loyn 2004). These resources vary over time after disturbance events such as fires, depending on development of the vegetation and its associated structures (Kavanagh et al. 2004; MacHunter et al. 2009). When suitable habitats are discontinuous (patchy), some may remain unoccupied for long periods, depending on the mobility of the fauna species, the nature of the intervening habitat and its variability through space and time. These effects of patchiness will be manifest by reduced fauna occupancy rates (and hence reduced levels of mean animal abundance across large numbers of sites) for the respective species. Hence the spatial and temporal arrangement of suitable habitat patches across the landscape needs to be considered in assessing strategies to manage fire across the landscape, especially when considering mobile taxa such as vertebrate fauna.

The model will be used to guide developments in research and its application to policy. Despite the complexity, fauna species show a limited range of responses to fire regimes and management, as discussed below, and policy settings can be adjusted accordingly. The current ARI fire ecology retrospective research aims to describe those responses and generate models relating relative abundance of vertebrate fauna (and flora) to four key explanatory variables: time since fire, fire frequency, fire type (bushfire or planned burn) and fire patchiness. These variables are considered further below.

TIME SINCE FIRE

For continuous habitats, response curves can be generated for vertebrate species or guilds, showing how their relative abundances are expected to change with variables related to fire regimes (Kavanagh et al. 2004; MacHunter et al. 2009; Nimmo et al. in press). Time since fire is arguably the most useful of these variables, because it relates the faunal response to a scale that is easily understood and directly related to management. If species recolonise quickly after fire,

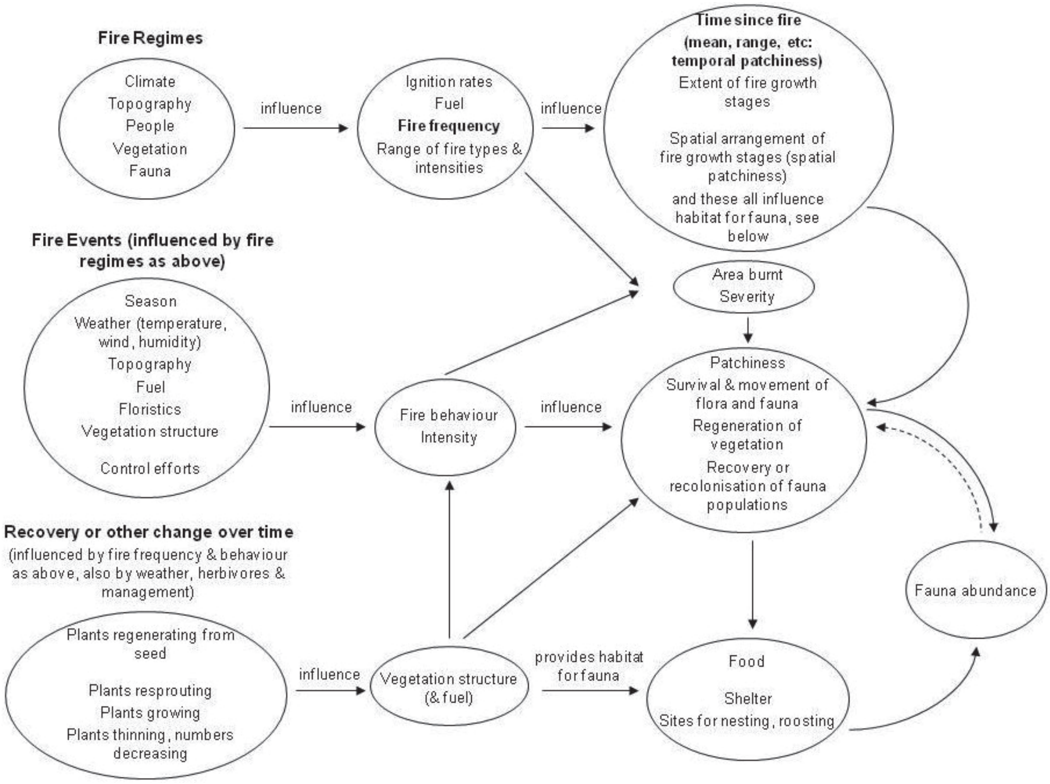

Fig. 1. Simplified conceptual model for some of the factors influencing fire regimes, fire events and fauna habitat. Variables such as fire frequency (and hence time since fire) can be managed directly, with indirect effects on fauna habitat.

they may benefit from frequent fires. If they recolonise more slowly, they will need longer intervals between fires. If they need habitat features that are reduced by fire and take x years to regenerate, they will need fire regimes where parts of the forest remain unburnt for much longer than x years.

Retrospective studies ('space for time') can be used to provide response curves of this sort in realistic time-frames, but require high levels of replication to detect patterns amid the noise from spatial variation and uncertainty about the nature of previous fire regimes and events (Loyn 2004; Nimmo et al. in press). Longitudinal studies over long periods of time are also needed to provide a temporal perspective in real time (Woinarski and Recher 1997; York 1999; Bradstock 2008; Lunt et al. 2011). Both approaches are included in the current DSE research programs.

Of course, the fauna species do not respond directly to time, but to the development of habitat which itself responds to time, albeit in an imprecise way. Some plants grow and increase in size, while other plants wither and die, but in general after a major disturbance it can be expected that the volume of vegetation will increase with time, while the actual number of plants may decrease through competition, which is often intense (Gill et al. 1981). In many forest types, the understorey vegetation is more dense 2–5 years after fire than at any other stage: this has important implications for fuel as well as fauna habitat. These processes are mediated by many variables apart from time, with climatic variables playing a crucial role (including global warming and cycles of wet and dry periods). Hence it is no surprise to find that vegetation structure is a better predictor of faunal response than time since fire (Monamy and Fox 2000; Di Stefano et al. 2010), but this should not deter us from attempting to relate responses to time since fire, and seeking to understand how these responses may vary with other factors that may or may not be within our power to manage.

Hypothetical response curves of this sort have been developed for responses to clearfell logging

Table 2. Comparison between different types of forest disturbance (fire and logging at different intensities)

Types of disturbance	Similarities	Differences
Planned fuel reduction burn vs intense bushfire	Complete or partial loss of green vegetation in understorey	Tree canopy usually remains unburnt with fuel reduction
	Produces a mosaic of age-classes (growth stages) in the landscape	The fire mosaic varies between years and is strongly influenced by climate, whereas the fuel reduction mosaic is potentially less variable, finer-scaled and subject to deliberate planning (cf logging)
		Loss of understorey cover is generally incomplete and patchy
		Regeneration may be less than with intense fire
		Intensity varies over a narrower range than for bushfires (which may be as mild as fuel reduction burns when weather is benign, eg at night or when running downhill)
		Individual fuel reduction burns usually cover smaller areas than bushfires
Intense bushfire vs clearfell logging	Loss of canopy cover; complete or partial loss of green vegetation at all levels	Most tree-trunks remain standing after fire (with hollows, etc), compared with few after clearfell logging
	Extensive foliage scorch or combustion	Many trees survive, especially in mixed-species forests
	Produces a mosaic of age-classes (growth stages) in the landscape	The mosaic is likely to include extensive areas of one age-class after fire.
		The fire mosaic varies between years and is strongly influenced by climate, whereas the logging mosaic is less variable, finer-scaled and subject to deliberate planning.
	Dense regeneration of eucalypts and understorey plants, from seed or vegetative reproduction	Obligate resprouters may prosper more after fire than logging, compared with species that regenerate from seed

(Kavanagh et al. 2004), with four distinct patterns recognised. Despite the obvious and well known differences between logging and fire (Table 2), a similar set of four response patterns proved useful in an initial attempt to describe possible responses of fauna species to two distinct types of fire (severe bushfire and planned fuel reduction burns) (MacHunter et al. 2009). This was based on expert opinion about the habitat requirements of fauna species and the likely responses of vegetation to fire events, and will hopefully be superseded or at least supplemented by empirical data when results of current research become available. The four response curves are summarised in Table 3, with the term 'pre-fire levels' used to signify a hypothetical mean condition for the landscape under consideration:

Pattern A is typically shown by mammal and bird species that need open ground (e.g. Red-necked Wallaby *Macropus rufogriseus* and Superb Fairy-wren *Malurus cyaneus*), and in shrubby types of forest the pre-fire level may be zero: these species only occur in such forests in the immediate aftermath of disturbance from fire or logging (Loyn 1997, unpublished). A spectacular example was found in our pilot studies in Bunyip State Park and Kinglake (McNabb et al. unpublished data), where flocks of White-browed Woodswallows *Artamus superciliosus* invaded the burnt forest in spring 2009 and bred there, becoming locally the commonest bird species. These birds are usually absent from these forests and are found mainly in drier forest types north of the Great Dividing Range.

Pattern B is the most common, in relation to both logging and fire, with varying rates of recovery.

Pattern C is an extreme variant of A: it is shown by species that need open ground, and benefit from initial effects of disturbance but then cannot cope with the dense shrub regeneration that may follow.

Pattern D is an extreme variant of B: it is shown when a fire removes a resource that takes a long time to regenerate, such as large hollows in trees, abundant mistletoe or an understorey structure with scattered mature shrubs and open spaces.

A fifth possible pattern is for species that show no response to time since fire at all.

In terms of policy, species that show a temporary increase after certain types of fire (pattern A) will be served by frequent fires over a spatial scale that allows individuals to move between recently burnt areas within the landscape. Species that decrease after fire and recover quickly (response Br) will be served by any fire regime other than severe fires over large areas. Species that decrease after fire and recover slowly (response Bs or D) will be served by fire regimes that allow long-unburnt habitat in suitable parts of the landscape. The policy challenge is to cater for these different responses in the landscape.

Despite our efforts to categorise likely species responses, few studies have been conducted and few empirical data are available to test these predictions: recent work in the Murray Mallee is a notable exception (Haslem et al. 2011; Nimmo et al. in press). Our current research aims to address this issue in two ways, using existing data from the Victorian Biodiversity Atlas and using purpose-collected data from selected vegetation communities in eastern Victoria (Loyn 2011).

FIRE FREQUENCY

Fire frequency is a fundamental property of fire regimes (Gill et al. 1981), whereas time since fire relates just to one moment in time, in relation to the previous fire. Plant species are expected to respond strongly to fire frequency (Cheal 2010) because they usually regenerate *in situ* and do not respond passively to vegetation structure (they make the vegetation structure!). Hence our current research is explicitly examining fire frequency as well as time since fire. However, we predict that vertebrate fauna will show stronger responses to time since fire than to fire frequency, because of their need for aspects of vegetation structure.

In terms of policy, it may be as useful to know about effects of time since fire as it is to know about effects of fire frequency. As discussed in the previous section, if a particular fauna species does not recolonise a burnt area for a long time, it will become excluded from areas where frequent fires are applied: it will be locally disadvantaged by that fire regime. If such a regime helped to protect other parts of the landscape from severe fire, the species might benefit overall: this highlights the need to consider the needs of fauna over broad landscapes.

TYPE AND INTENSITY OF DISTURBANCE

Describing effects of fire is a much more complex exercise than describing effects of a single artificial practice such as logging, and further comment is needed about the similarities and differences between these forms of disturbance. Logging always involves a degree of loss of canopy cover whereas this is not inevitable with fire, happening to varying degrees.

Table 3. Hypothetical response patterns after disturbance by fire (adapted from Kavanagh et al. 2004 and MacHunter et al. 2009).

Pattern	Description	Consequence
A	Short pulse of abundance followed by decline to pre-fire levels (which may be zero in some habitats)	Frequent fires may be beneficial or necessary
B	Decrease followed by recovery which may be rapid (Br) or slow (Bs), to levels which may exceed pre-fire levels at intermediate stages	Most beneficial fire regimes will be those where fire frequency is long enough to allow recovery, short enough to maintain intermediate stages
C	Pulse of abundance followed by decline to below pre-fire levels for long periods (post-fire levels may be zero)	May apparently benefit from very frequent fires or very infrequent fires but not from intermediate fire frequencies
D	Decrease followed by little sign of recovery for many years	Low fire frequencies are needed in habitats most suitable for these species
X	No apparent response	Fire regimes apparently of no consequence for these species (within limits); can cope with wide range of fire regimes

Fire and logging have many differences and common features, notably their variable intensity and potential temporary loss of mature canopy cover (Table 2). It is obvious that different responses would be expected to severe bushfire (with extensive defoliation or mortality of canopy trees) compared with fuel reduction burning (with most of the combustion in the understorey layers, and minimal canopy scorch). It is also obvious that different responses would be expected in different vegetation communities. The well-known dichotomy between montane ash forests and mixed-species foothill forests is a prominent example (Gill 1981; Adams and Attiwill 2011). Ash forests are usually too wet to burn, but when they do burn, conditions are generally extreme and fires correspondingly fierce. Trees of Mountain Ash *Eucalyptus regnans* and Alpine Ash *E. delegatensis* have limited capacity to survive such fires (Ashton 1976), and usually (though not always) suffer high mortality. Some trees may produce shoots from epicormic foliage, producing mixed-age stands (e.g. at Wallaby Creek after the 2009 fires, pers. obs.), but seedlings generally provide the dominant form of regrowth, often in dense even-aged stands. In contrast, bushfires in mixed-species forests are more variable in intensity (as they may burn under a greater range of climatic conditions), and trees are well adapted for surviving these fires and regenerating largely from epicormic buds embedded in the trunks. Bushfires may cause extensive canopy scorch or defoliation, but tree mortality is rarely as high as in ash forests. Hence the change in forest structure is temporary in mixed-species forests, without the dramatic state-change from a tall to a dense low forest commonly seen in ash forests. Fauna will respond differently in each case (Loyn 1997, 2004; Lindenmayer and Franklin 2002), and response curves (Table 3) must reflect these differences.

Studies of fauna and fire events need to consider effects of fire intensity. Extensive bushfires may burn for many days, and vary markedly in intensity depending on when they are burning (e.g. day or night, weather conditions at the time, especially temperature and wind) and topography (burning much more fiercely when running uphill than on level ground or downhill slopes). Hence a single fire may exhibit extremely different intensities as it traverses a complex landscape over many days or weeks. Unfortunately, it is not a simple task to map fire intensity, and detailed historical records are generally lacking. Modern methods of remote sensing and data recording using GIS are helping to redress this deficiency for recent fires, but are not readily applied to previous fires.

PATCHINESS

Spatial patchiness can be assessed in many different ways, and there is no general agreement about the best approach. This is hardly surprising, as different species respond to patchiness in multiple and diverse ways. What may be a barrier for one species, may be a super-highway for another. Our highways serve as a classic barrier to some animal species (Taylor and Goldingay 2010; van der Ree et al. 2011).

In practical terms, there are limits to the types of patchiness we can seek to develop in the forest landscape. At one extreme, we could aim to have most of our burns so ‘cool’ that they burn patchily at the scale of a few metres, regardless of the area ‘treated’ within the burn perimeter (Tolhurst, this volume). The details of such patchiness might never be mapped except in terms of fire intensity. Or we could aim to have patchworks of small fuel-reduction burns each covering a few hectares, creating a high degree of patchiness regardless of the intensity of each burn. The opposite extreme to both situations is to aim for large burns of high intensity, with little patchiness within or between burns. Or do we want combinations of these conditions? Recent large fires have provided unusual opportunities to examine effects of extremely low patchiness, within large burns far from large areas of unburnt vegetation. There is a common perception that such situations will be adverse for biodiversity, but a remarkable dearth of empirical data and some contrary evidence (Bradstock 2008; Gill and Allan 2008; Williams et al. 2008). The opportunity exists to test that hypothesis.

RETROSPECTIVE AND HAWKEYE PROJECTS IN EASTERN VICTORIA, AND HOW THEY RELATE TO POLICY CHALLENGES

DSE has initiated a range of research and monitoring programs to address these questions, and some of them are described elsewhere in this volume. The ARI fire ecology retrospective project was designed to assess effects of fire regimes in eastern Victoria (Central Highlands, Gippsland and NE Victoria), with special reference to time since fire, fire frequency, fire type (bushfire or fuel reduction burn) and patchiness. The Hawkeye monitoring program has allowed us to extend the work spatially (examining more landscapes) and temporally (selecting some to monitor over time into the future). Some initial results were presented at the symposium and further modelling is under way. The aim is to produce models relating relative abundance of groups of plant and animal species to those variables. Vertebrate fauna considered in these studies include diurnal birds, owls, bats, arboreal mammals and ground-dwelling mammals. By learning how relative abundance changes over time after particular fire events, we should improve our capacity to predict how it will change under different fire regimes, where fires become more or less frequent, with direct consequences for the age-profile in terms of time since fire.

The models have direct relevance to some of the policy issues described above. For example, if some species or groups need long periods of time to regain their pre-fire abundance after a particular type of fire, then their conservation depends on ensuring that suitable samples of long-unburnt vegetation remain in the landscape in perpetuity, configured to allow populations to move between patches of habitat as they gain or lose their desired characteristics. Paradoxically, this may involve intensifying our fuel reduction burning efforts in some parts of the landscape, to achieve the necessary goals for protecting assets while leaving other parts of the forest to grow old and develop habitat characteristics needed by particular fauna species or groups. If most species regain their pre-fire abundance quickly after fire, there may be scope for a wider range of burning strategies, to meet the needs of biodiversity and asset protection in different ways to suit local geographic, ecological and social needs, including the need to reduce risk to human life and property.

CONCLUSION

Much more needs to be learned about the effects of different fire regimes on flora and fauna, and current research is beginning to address some of the key questions. The needs of vertebrate fauna differ substantially from those of plants and invertebrate species, and may require distinct responses in terms of policy and management. Vertebrate fauna include some highly mobile species with large home ranges and complex needs for elements of structural habitat (at various spatial scales). By considering the needs of vertebrate fauna, we get a distinct perspective on some of the difficult policy questions involved in managing fire over large landscapes with dual objectives to conserve biodiversity and protect human assets, life and property.

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