Ecological Burning in Box-Ironbark Forests: Phase 2 - Management Strategy

Report to North Central Catchment Management Authority

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Arthur Rylah Institute for Environmental Research

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Phase 2 – Management Strategy

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Front cover: Box-Ironbark forest near Rushworth, central Victoria (photo: Arn Tolsma)

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Phase 2, Management Strategy - Andrew Bennett (Deakin University) made valuable recommendations on research directions and the integration of fauna data into the decision framework.

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EXECUTIVE SUMMARY

The North Central CMA, as part of its Regional Catchment Strategy and Native Vegetation Plan, identified the need to "*Develop and implement appropriate fire management regimes to sustain ecological processes in key private land vegetation remnants*…." Given the lack of knowledge on such fire regimes, a review of current fire knowledge and practices was required (refer to Phase 1, Literature Review), ultimately facilitating the creation of broad criteria for the establishment of an appropriate ecological burning regime. This report comprises Phase 2 of the Ecological Burn Project, the Management Strategy.

A lack of fire-age data currently hinders the planning of broad-scale (mosaic) ecological burning on private land across the CMA. Nonetheless, using the principles for managing fuel-reduction and ecological burning on public land, we have established a decision framework that will enable the requirement for ecological burning to be determined on a site-by-site basis, with a high degree of flexibility. The relationships between fauna diversity and various fire regimes are largely unknown, and the initial planning phase is necessarily plant-focussed. Vegetation composition and fire history have been used to either rationalise or preclude a possible burn, with key fauna species playing an additional 'veto' role if necessary.

Some broader-scale fire planning may become possible in the coming decades as fire-age records accumulate in a regional GIS database. However, the relatively infrequent need for fire (at around 50 year intervals) and discontinuity in private land ownership are likely to impose practical limits on what can be achieved. Therefore, a future fire-age mosaic might simply reflect the current mosaic, modulated by the accumulation of individual site burns.

This research has highlighted that we know little about the responses to fire of specific Box-Ironbark flora and fauna species and communities, and even less about the temporal and spatial patterns of burning that might maximise total biodiversity. Accordingly, this report concludes with a list of research recommendations, most of which could be undertaken in conjunction with other stakeholders. Appropriate use of fire in Box-Ironbark remnants, based on robust scientific data, should ensure that plant structural and floristic diversity can be maintained without disadvantaging fauna species in the long-term.

INTRODUCTION

Box-Ironbark ecosystems comprise approximately 250 000 hectares of predominantly dry sclerophyll eucalypt forest on hills and slopes inland of the Great Dividing Range in northern Victoria (Calder *et al.* 1994; Kellas 1991; Woodgate and Black 1988). A large proportion of this lies within land under the care of the North Central Catchment Management Authority (Figure 1).

Figure 1. Map of North Central CMA, showing Box-Ironbark study area. Note that forest cover is substantially less than that indicated on the map.

These forests are considered not prone to recurrent fires, making them possibly atypical of dry, sclerophyllous vegetation in Australia (Calder *et al.* 1994). The extent of previous indigenous burning is largely unknown (ECC 1997; Meredith 1987), and the effects of fire on flora and fauna communities or on individual plant or animal species are also largely unknown. Indeed, the influence of fire on site productivity and biotic composition is often poorly understood in native vegetation, and the use of fire as a management tool is sometimes controversial (Williams *et al.* 1994). Nonetheless, based on evidence from similar vegetation types, it has been commonly assumed that ecological burning (as opposed to fuel-reduction burning) might be a useful tool for improving the condition of degraded native vegetation remnants and enhancing species biodiversity.

Accordingly, the North Central CMA, as part of its Regional Catchment Strategy and Native Vegetation Plan, identified the need to "*Develop and implement appropriate fire management regimes to sustain ecological processes in key private land vegetation remnants*…." Given the lack of knowledge on such fire regimes, a review of current fire knowledge and practices was required, ultimately facilitating the creation of broad criteria for the establishment (or otherwise) of an appropriate ecological burning regime.

The aims of the investigation were therefore to:

- Review available scientific literature
- Liaise as necessary with universities, government departments or other groups involved in relevant research or with historical information, including anecdotal or "gut feel"
- Source information from similar ecosystems in south-east Australia
- Use plant Vital Attributes to determine burn frequencies and gauge possible plant community responses
- Establish justification (or otherwise) for burning remnants, including possible responses and risks
- Gather any available information on the likely direct and indirect impacts of ecological burning on vegetation structure and fauna habitat
- Identify gaps in knowledge
- Propose next steps to enable the North Central CMA to increase its knowledge of ecological burning

Phase 1 of the project involved a substantial literature review to gather all available knowledge of fire effects on flora and fauna in Box-Ironbark or similar ecosystems (Tolsma *et al.* 2007). While relevant literature specifically pertaining to the effects of fire on Box-Ironbark forests was scarce, there was sufficient evidence to make the following general assumptions:

1. The review was not able to shed light on historical aboriginal burning regimes. Some have suggested that seasonal burning was probably undertaken, but little direct evidence existed, and what evidence there was related to landscape-wide observations that were not site- or vegetation-specific. Fire has probably played a minor part in influencing the vegetation structure and faunal assemblages in Box-Ironbark ecosystems. Management should now be geared towards the needs of the forests as they exist today, not as they existed in some idealised pre-European state.
2. The response of the understorey to applied burning will depend heavily on the nature of individual remnants, season, landscape position, soil type, seed bank, disturbance history and susceptibility to edge effects. Some species, particularly leguminous shrubs and short-lived obligate seeders, will be promoted by fire in the short-term. Resprouting species that make up a large proportion of the flora will be little affected unless burning is frequent. Few species rely on fire for germination, and most species that are stimulated by fire will still recruit at a low level in the absence of fire. No species should be lost through burning provided the inter-fire period allows all species to reach reproductive maturity (a minimum of 10-20 years) but absent species are highly unlikely to reappear. Most species will persist even when the interval between fires exceeds 50 years.
3. The response of the canopy will depend on the intensity of the fire. In most instances, fire in small remnants is unlikely to be of sufficient intensity to lead to canopy replacement. In any event, most Box-Ironbark canopy species show continual recruitment in the absence of fire, and thus do not rely on it. In any one patch, the minimum inter-fire period for a fire that kills or severely reduces the overstorey and that allows full recovery of structure is likely to be around 60 years.
4. Litter plays an important role in nutrient cycling, and provides important habitat for invertebrates and small vertebrates. Frequent burning (for example, 3-5 year intervals) will disrupt natural processes in the short-term and may eventually lead to a depletion of soil nutrients and loss of habitat.
5. Research into the effects of fire on invertebrates is confounded by high natural variability, and it is often difficult to determine the baseline or climax community. Short-term effects are intimately linked in many cases to burning of the litter layer, and burning at frequencies as high as every three years should be avoided.
6. The effects of fire on birds are strongly dependent on the severity of the fire and the structural components of the forest that are burnt, and recovery of

populations is linked to the recovery of the vegetation. Some seed-eaters may be advantaged in the long-term if fire promotes new vegetation growth. Other species may be advantaged in the short-term by the availability of post-fire carrion or the reduction in protective cover for prey. However, species that rely on the ground layers for nesting or foraging may be disadvantaged in the short-term by low-intensity fire, particularly if it interferes with breeding. The minimum inter-fire period is likely to be similar to that which will allow full recovery of understorey structure (i.e. at least 25 years).

7. The effects of fire on mammals are also linked to the effects and recovery of the vegetation and the intensity of the burn. Some common herbivores take advantage of the flush of new plant growth, but small animals dependent on the ground layer will be disadvantaged in the short-term. Arboreal mammals are likely to be disadvantaged only if the fire is of high intensity. In general, it is believed that small mammal populations will not be disadvantaged, provided the minimum inter-fire period is at least 15-20 years. However, in isolated private remnants, recolonisation by small mammals after fire may be difficult.
8. Many reptiles and frogs are likely to be disadvantaged in the short-term by any burning due to their dependence on the litter and ground layers. Spring burning will affect the breeding of many reptile species, while autumn burning may affect the breeding of some frog species. In remnants, isolation is likely to be a barrier to recolonisation after fire.

The effects of fire on flora and fauna in Box-Ironbark forests were considered to vary depending on factors such as fire intensity, size of fire, season of burn, site factors, landscape position, soil type, seed bank, disturbance history, edge effects and the life characteristics of individual flora and fauna species.

The review concluded that occasional fire might be useful for ensuring that the soil seed bank for individual species is not eventually depleted, although fire is unlikely to restore 'lost' species. No single burning regime will advantage or disadvantage every species group, and an appropriate burning regime specific to individual remnants should ensure a mosaic of different age classes.

The abundance and species composition in small or disturbed remnants may be substantially different to those in larger or relatively undisturbed blocks, making the effects of fire on remnants difficult to predict, and isolation of remnants may prove to be a barrier to recolonisation. There is insufficient evidence to justify or formulate an ecological burning regime for the maintenance or enhancement of faunal diversity in small Box-Ironbark remnants. However, in the long-term, it is considered that a regime appropriate to the vegetation, which provides for a mosaic of age classes, is unlikely to adversely affect fauna groups in larger blocks.

This report comprises Phase 2 of the Ecological Burn Project, the Management Strategy. The challenge was to determine appropriate fire regimes that might maintain or enhance plant structural and floristic diversity, and which would not disadvantage fauna richness and diversity in the long-term.

DEVELOPMENT OF BURNING REGIME

Application of Key Ecological Burning Principles

For many years, prescribed burning has been undertaken with the primary aim of protecting areas and assets from the adverse impacts of fire (DSE 2004; NRE 1999). There is now recognition that fire has an important role to play in maintaining or promoting biodiversity, and various guidelines have been developed in Victoria and other states to assist land managers with striking a balance between ecological and protection purposes (DSE 2004, 2007b; Lindorff 2001, 2002; NRE 1999; Tolhurst 2000; Tolhurst and Friend 2003; Tran and Peacock 2002; Wouters 2006).

However, a limitation of such guidelines is that they are generally geared towards the management of larger tracts of public land, rather than towards the management of smaller patches of private land. Therefore, in some instances, the recommended principles (DSE 2004) that underpin those guidelines may not be fully applicable, while in other instances the data required may simply not be available (Table 1).

Table 1. Differential application of Key Ecological Burning Principles (DSE 2004) to public or private land.

Key Principles (DSE 2004) as applied to public land		Differential application to private remnants
Scientific principles		
1	Fire should not be regarded as unnatural or catastrophic, but rather as a recurring event which influences the nature of the Australian landscape and the adaptations of its unique flora and fauna and which therefore offers enormous potential as a land management tool.	Applies more or less equally to private and public management, although the potential as a management tool is more limited in small remnants.
2	Species and community types vary greatly in their adaptations to and reliance on fire and a consideration of the temporal and spatial scales of fires in relation to the life histories of the organisms or communities involved must underlie its wise use in natural resource management.	Applies more or less equally to private and public management.
3	Following fire, the effects of season, locality and year-to-year variability in climate and random events like droughts, floods and locust plagues may outweigh any changes attributable to fire.	Management history and remnant size will also affect responses, and perhaps in a less predictable way.
4	An understanding of the ecological impacts of fire comes only through recognition of the interdependence of plant and animal species, their life histories and the state of the external environment.	Applies more or less equally to private and public management, although plant-animal interactions may be substantially modified.

Operational and planning principles		
5	Management of fire is required for two main reasons: (i) to reduce the likelihood of uncontrollable wildfire and (ii) to provide conditions necessary for the persistence of the biota.	Issues of protection (i) are outside the scope of this report (although we recognise that ecological burning can also provide some asset protection), and our recommendations are concerned only with biota (ii).
6	Effective management of fire requires the integration of both ecological and protection objectives in order to optimise outcomes.	See Key Principle 5 above.
7	A range of intensities, frequencies, seasons and scales of burning need to be incorporated into ecologically-based fire regimes if they are to optimise the conservation of biodiversity.	A range of fire intensities and scales may be achievable across a region, but scope is limited within an individual remnant.
8	Ecological burns must aim to achieve one or more explicit ecological management objectives.	Applies more or less equally to private and public management.
9	Ecologically-based fire regimes for an area should be developed from a knowledge of the life histories or vital attributes of the constituent flora and fauna species.	Applies more or less equally to private and public management.
10	Vital attributes should be used to define the Key Fire Response Species for a community or vegetation type, which in turn provide a guide to the upper and lower Tolerable Fire Intervals for the area.	Applies more or less equally to private and public management.
11	Knowledge of the ecological thresholds for Tolerable Fire Intervals enables a Fire Cycle to be defined. From this, a 'theoretical' model of the distribution of age classes within each plant community may be developed.	Applies more or less equally to private and public management, but note that theoretical models do not presently have the capacity to account for faunal needs.
12	Fire history data together with vegetation class mapping (e.g. Ecological Vegetation Classes (EVC) or groups of similar EVCs) should be used to develop known fire-age distribution curves for particular vegetation types.	In many instances the fire history will not be known, and will need to be deduced from the composition and structure of extant vegetation. Thus, a fire-age distribution curve for remnants is likely to be based on a limited number of sites. Data can be built up in future as remnants are assessed, with or without burning.

13	Areas to be included in the three-year Operations Plan should be determined by comparing the known fire-age distributions with those from the 'theoretical' model.	Fire-age distribution is largely unknown at present (see Key Principle 12 above). For ecological purposes, the need for burning should be based purely on the estimated fire-age of the individual remnant.
14	Various areas and age classes may be scaled up into Logical Burning Units.	Little scope to increase size of burn unless neighbouring vegetation is of a similar age class. Larger fires may also involve a higher degree of risk.

The four scientific principles that apply to public land (Table 1) (DSE 2004) apply more or less equally to private remnants, as they relate to our attitudes toward, and knowledge of, fire. However, the application of the operational and planning principles will in some instances be different, particularly because the fire and management histories of private land remnants will often be unknown. It will be impractical to establish *a priori* a fire-age distribution curve for numerous private remnants scattered across a broad region, especially given that in many instances the fire-age will be a coarse approximation only. Thus, while the fire-age distribution curve is a *current input* into ecological burning regimes on public land, derivation of such will be an incremental *future outcome* of ecological burning in private remnants. Over time, as fire records for private remnants accumulate, operational and planning principles will begin to apply more equally to both tenure types, although patch size may remain a limiting factor in terms of developing within-site heterogeneity.

Despite the focus on public land by the key operational and planning principles (DSE 2004), and the aforementioned limitations, these established principles nonetheless provide a basis for the development of ecological burning protocols for private land remnants, with some modifications. In the absence of a known fire-age distribution curve, broad criteria based on the Key Principles may be used with extreme caution on a site-by-site basis only, to generate one of three potential recommendations:

1. Fire should be excluded at present because it would have, on balance, an unacceptable negative impact on flora or fauna species.
2. A site is due to be burnt (either now or at a pre-determined time), because there is a risk that the overall vegetation composition and structure will senesce.
3. There are no known biological imperatives either way.

A conceptual diagram showing key actions and decisions to be made is presented in Figure 2.

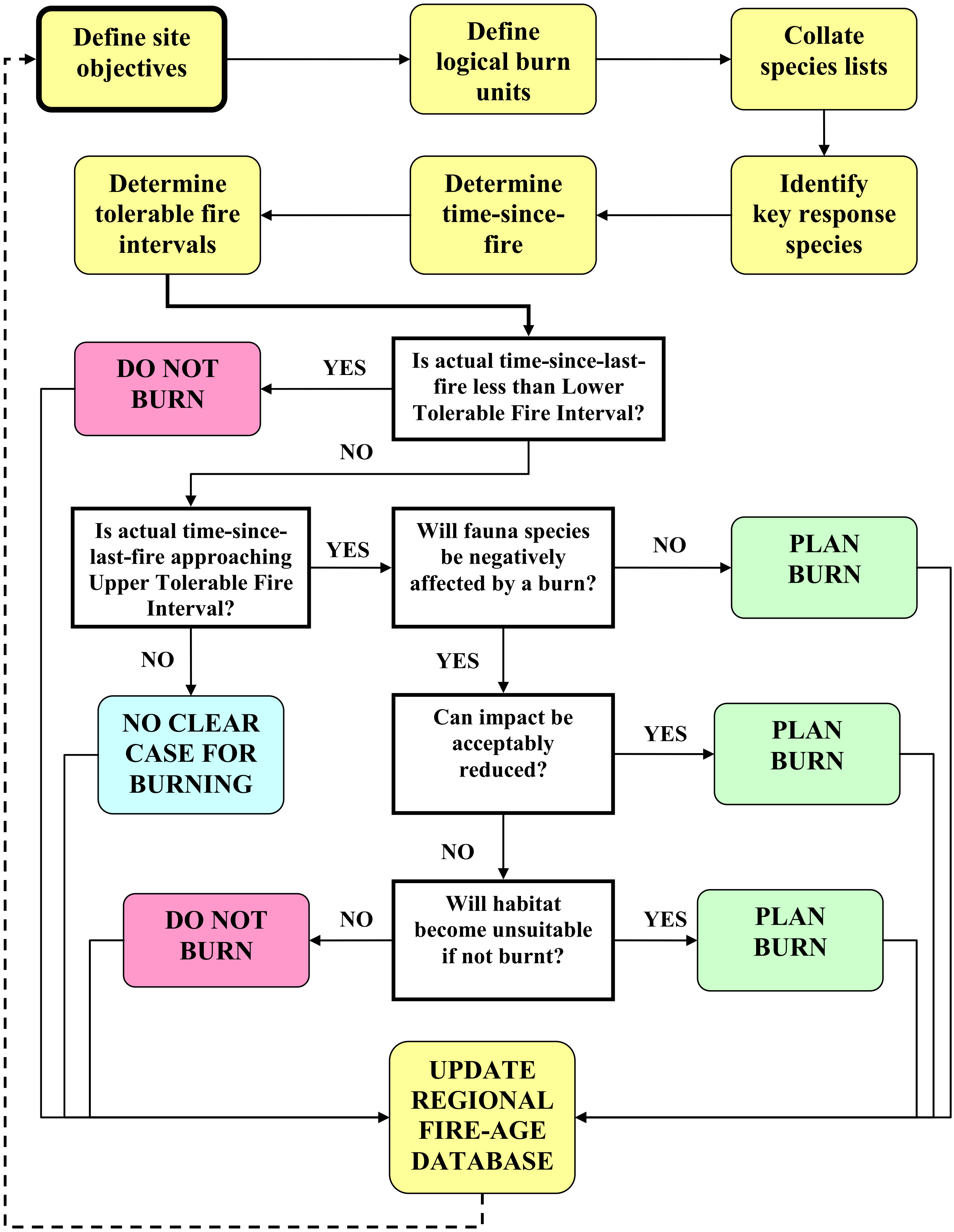

Figure 2. Decision framework for ecological burning of Box-Ironbark remnants.

Define ecological objectives for site

For the purposes of this report, the imperative for burning of private remnants (see Key Principle 5) (DSE 2004) is being directed by the ecological requirements of individual sites, although we recognise that for some years after an applied burn in most forest types there will be an additional benefit relating to increased protection from wildfire. Private remnants may thus be considered equivalent to public Zone 4 Fuel Management Zones, designed for "*specific flora and fauna management, where the aim is to use prescribed fire for the active management of particular flora and fauna species and/or communities which have critical fire regime requirements. Such burns may provide additional protection to complement (other) zones*..." (DSE 2004).

Box-Ironbark forests have not been shaped by regular fire to the extent that many other vegetation types have been, and many extant plant species do not need fire to persist (Tolsma *et al.* 2007). Since European settlement, fragmentation has been an additional process, potentially modifying the response of flora and fauna to fire, particularly in smaller remnants where isolation may create a barrier to recolonisation after such fire.

Nonetheless, fire remains a normal habitat process that in some instances may be necessary for the maintenance of species, and it should not be seen as necessarily bad, or something that should be avoided at all costs. The challenge for the land manager is to determine whether the positive effects of a proposed burn will outweigh the negative effects, that is, whether more species will be advantaged by a burn than disadvantaged. If there are no biological imperatives either way, and management is being driven simply by the desire to reinstate or consolidate a small number of discrete species, then a simple planting program might suffice. Similarly, the cover of palatable understorey species might be enhanced by fencing the area off to exclude grazing by rabbits, macropods or domestic stock.

In most remnants, if burning can be justified, a reasonable objective will be to maintain or enhance overall plant structural and floristic diversity (because the overall vegetation composition and structure is at risk of senescing), in a manner that will not disadvantage extant fauna species in the medium to long-term. Thus, the loss of habitat such as deep litter or the shrub layer in the short to medium term needs to be justified in terms of the eventual gains in total diversity. Note, however, that we do not know enough about the effects of burning in Box-Ironbark forests to attempt to use ecological burning for the benefit of individual flora or fauna species.

Define the management (logical burn) unit/s

Landscape Management Units are used in public land management to define the broad area across which management prescriptions will be applied (Tolhurst 2000). For private remnants, a Landscape Management Unit will be the entire remnant block, and of greater importance is the identification of sub-units that may have a different vegetation type or a different management or disturbance history. For example, a remnant may have been partially burnt in recent times, or contain a section with different grazing history. As another example, a larger remnant may include both a ridge dominated by Ironbark eucalypts and a gully or flat area dominated by Yellow Gum. Each of those sub-units should be assessed separately, as flora and fauna composition and responses to burning, hence recommendations, are expected to vary.

Collate flora and fauna species lists

A list of plant species within each sub-unit should be compiled after a thorough search, and some indication of cover or abundance made. To allow comparisons or contrasts with other remnants or public land, and to facilitate post-fire monitoring, standardised protocols should be used for the plant survey, such as those developed for the monitoring of flora on public land (*Draft Fire and Biodiversity Monitoring Protocols for Flora: User's Guide*) (DSE 2007b). Information on the life-stage of shrubs and trees should also be recorded, as this can assist in determining the likely time-since-fire. Pay particular attention to single-aged cohorts, as these will have established after the same disturbance event, and will provide the best guide to time-since-last-fire.

The vegetation list should also include species that are known to have previously existed at a site, as this can provide valuable information on potential soil seed banks and possible responses to burning. The presence of rare or threatened plant species (Appendix 1) should be noted, as in many instances these may be the subject of published recovery plans, and have specific management requirements documented.

Animal species that are known (or that can be reasonably assumed) to be on-site should also be recorded, with special attention given to the presence of rare or threatened species, or those that might be particularly disadvantaged by fire through the loss of vegetation or habitat components, or that cannot readily recolonise a site (see Appendix 3 and Tolsma *et al*. 2007, and "Consider risks to extant fauna or fauna habitat" on page 21). The established Fauna database may be of some value in estimating the presence of key species, although most records are derived from larger tracts of public land where fauna assemblages may be more intact.

Identify Key Fire Response Species in each sub-unit

Key Fire Response Species (KFRS) are plants that possess vital attributes making them vulnerable to either frequent fire or to long periods of fire exclusion (DSE 2004), making them ideal for both *a priori* determination of Tolerable Fire Intervals (see page 19 for definition) and *a posteriori* estimation of actual time-since-fire. Plant vital attributes have now been used to estimate ecological burning regimes for a wide range of vegetation types (Burrows *et al.* 1999; Cheal 2004; DSE 2006b; Lindorff 2001, 2002; Tolhurst 2000; Tolhurst and Friend 2003).

In Phase 1 of this research, the Literature Review (Tolsma *et al.* 2007), a list of Box-Ironbark vascular plant species was compiled and analysed, using available data (DSE and Parks Victoria) and expert knowledge, to determine those species that would be most informative for fire research. Criteria for appropriate species included their distribution, fidelity to Box-Ironbark, ease of identification, a known response to fire frequency, and reasonable certainty with regard to longevity of life stages, sensitivity to successive fires and conditions for establishment. In all cases there is a known relationship between density (or cover) and time since fire. Details of 159 common or widespread Box-Ironbark species are provided in Appendix 1, while a short list of 46 Key Fire Response species is presented in Table 2 (page 29) and with additional descriptive information in Appendix 2.

Two species were considered most suitable as key response species specifically in Box-Ironbark (KFR = 1), and particularly for estimating time-since-fire. *Xanthorrhoea glauca* subsp. *angustifolia* (Grey Grass-tree) is a long-lived perennial with a distinct growth form that resprouts after fire (Table 2). The depth of the skirt indicates time since last fire, and it has its highest density in infrequently burnt vegetation and its lowest seedling density in frequently burnt vegetation. Unfortunately, its presence in private Box-Ironbark remnants is likely to be limited. *Brachyloma daphnoides* (Daphne Heath) is also a long-lived perennial, but with a seed-bank that germinates completely after fire. It requires five to ten years to reach reproductive maturity, then reaches its highest density at intermediate to low fire frequencies. It is a common Box-Ironbark species, and should be suitable as an indicator species in most remnants. Other widespread and common species are also included in the list, even if they do not show fidelity to Box-Ironbark vegetation, to ensure that assessment can be readily undertaken in most modified remnants.

All suitable species (including KFR = 2 or 3) had various characteristics (see page 28 for key to symbols used):

- Complete germination of seeds after fire (SD = C or G). All seed is used after a single fire, and is not replenished until after the new plants' juvenile period (JUV). A subsequent fire within this period will eliminate the species at the site, if it cannot survive by vegetative means. Note that species with a very short juvenile period (e.g. annuals) are unlikely to be affected, as the chances of fire recurring within a year or so are remote (Tolhurst 2000).
- Death of juvenile resprouters (VG = W). These are potentially sensitive to sequential fires, because the amount of reproductive material will be reduced immediately after fire.
- Inability to establish in older vegetation (TIR = I). These species generally establish as a single-aged cohort after fire, and are vulnerable to long periods of fire exclusion.
- Lengthy juvenile phase. Depending on their method/s of persistence, these species require the longest intervals between fires.
- Shorter time to local extinction. Depending on their establishment tolerance (TIR), these species require the shortest time between fires.

More detailed instructions on the determination and utility of Key Fire Response Species can be found in *Management of Fire for the Conservation of Biodiversity* (Friend *et al.* 1999), Tolhurst and Friend (2003) or various management plans such as Tolhurst (2000) or Lindorff (2001, 2002).

Determine time-since-fire for management sub-units

In some instances the landholder may know when a sub-unit was last burnt, or the frequency at which it has been burnt in the past. It is also possible that the remnant may have been burnt in a larger wildfire, in which case the relevant authority may be able to provide fire-age information from fire records. However, in most instances, the record of time-since-fire or past fire regime may be uncertain. Nevertheless, hints about the most recent fire at that site will be contained within the vegetation itself.

Actual floristic and structural characteristics on-site can be used to provide some estimates of the approximate time-since-fire and possible fire regime at a site, using the 46 Key Fire Response Species in Table 2 (page 29) and Appendix 2. These key species generally reach their highest density or cover at a particular time since fire, or under a particular fire frequency. For example, *Chrysocephalum apiculatum* s.l. (Common Everlasting) is an annual or short-lived perennial, which tends to be at its highest density in young vegetation. *Hypoxis glabella* (Tiny Star) and *Tricoryne elatior* (Yellow Rush-lily) are usually at their highest density in frequently-burnt vegetation, although, because they may also increase somewhat in long-unburnt vegetation (50-70 years), they need to be assessed in conjunction with other plant species. In contrast, *Bursaria spinosa* subsp. *lasiophylla* (Hairy Bursaria), *Joycea pallida* (Silvertop Wallaby-grass), *Persoonia rigida* (Hairy Geebung) and *Themeda triandra* (Kangaroo Grass) tend to be at their highest density or cover only when the vegetation is long-unburnt (around 50+ years).

To simplify the estimation of time-since-fire at a site, we have created a Gantt chart that shows the approximate range of times-since-fire when each of the 46 species is likely to be present at its highest density or cover (without considering other factors such as drought or animal browsing). The species are presented in alphabetical order in Table 3a (page 30) and in chronological order (age at highest relative density or cover) in Table 3b (page 31). Up to four stages are shown:

- the species is either absent or its abundance is trivial
- the species is present at low cover values (but there may be many individuals)
- the species is common but not dominant in any stratum of the vegetation
- the species is at its most common, and may be dominant in a stratum

As an example, germination of *Acacia pycnantha* (Golden Wattle) is stimulated by fire. The Gantt chart (Table 3) shows that in the first years after fire the cover is low, although in this case there will be many individuals, all small seedlings. The species is common and at high cover from around 10 to 30 years post-fire, after which senescence reduces its dominance. After around 50 years it is present at low cover values, sustained by a low level of background recruitment.

Note that these ranges are best estimates from expert opinion, and they should be refined as further research data become available. Note also that the data are relatively coarse, to the nearest decade or so, but these should be sufficiently accurate for planning purposes given the lengthy inter-fire periods in Box-Ironbark forests.

If any of the 46 species have been detected at a site, their average position on the chart (based on their relative densities) should provide some estimate of the time since a last fire. The life stage of each species present, particularly shrub species, must be taken into consideration when referring to the chart. For example, the senescence of legumes (such as *Acacia paradoxa* or *A. pycnantha*) that have a recruitment flush after fire, indicates that their period of highest density has passed, even though seed stored in the soil will last longer on-site. Care must also be taken to consider the confounding influence on foliage cover of drought, dieback or animal browsing, to ensure that age-based senescence is not confused with other condition states.

Determine upper and lower limits for Tolerable Fire Frequency

With flora and fauna management in mind, the key principle that will be most important in developing an ecological burning regime for an individual remnant is Key Principle 10 (Table 1): *Vital attributes should be used to define the Key Fire Response Species for a community or vegetation type, which in turn provide a guide to the upper and lower Tolerable Fire Intervals for the area* (DSE 2004).

The *lower* Tolerable Fire Interval is determined by the species that take the longest time to reach reproductive maturity, and the time is generally set at double the age of first seed set (DSE 2004; Tolhurst 1999). This ensures that there is sufficient reproductive material to maintain viable populations of those species in the community. The *upper* Tolerable Fire Interval is determined by the species with the shortest time to local extinction (DSE 2004), that is, the time taken for both the plants and their seed bank to disappear from the community. These fire intervals relate to the vegetation community at any single site, and in practice heterogeneity across the broader landscape is enhanced by having a wide range of age classes.

Based on those species that take the longest time to reach reproductive maturity, (set as double the juvenile life), regular burning of Box-Ironbark forests with an inter-fire period of less than 10-20 years may lead to the local extinction of species such as *Grevillea alpina* (Cat's Claw Grevillea), *Eucalyptus viridis* (Green Mallee), *Eucalyptus behriana* (Bull Mallee), *Brachyloma daphnoides* (Daphne Heath), *Exocarpos cupressiformis* (Cherry Ballart), and *Leptomeria aphylla* (Leafless Currant-bush) (Table 2, page 29 and Appendix 1), and no doubt other species (particularly shrubs) for which longevity data are still being compiled. Inter-fire periods as low as 6-10 years would affect a far larger suite of shrub species, and lead to major changes in vegetation structure and composition. The minimum inter-fire period estimated for Box-Ironbark Forest EVC in the Northern Bendigo Landscape Management Unit was 5 years (DSE 2006b). However, the authors do not appear to have doubled the juvenile period. Further, such a short inter-fire period does not allow for the recovery of fauna habitat or communities. Therefore, as a general rule, the minimum inter-fire period for typical Box-Ironbark vegetation is expected to be around 20 years, depending on the floristic composition of the individual site.

The data suggest that the shortest time to reach local extinction in the absence of fire in 'typical' Box-Ironbark forests is by *Daviesia leptophylla* (Narrow-leaf Bitter-pea), after 20 years. However, this is likely to be an underestimate, because numerous individuals are still present in forest at Paddys Ranges near Maryborough 22 years after wildfire (Arthur Rylah Institute, unpublished data), and their seeds might be expected to be viable for many years yet. Of the other 105 species for which a species life has been determined (Appendix 2), 25 are expected to persist for at least 20-50 years, and 80 should persist for at least 50-100+ years. Only around one quarter of these species is considered to be intolerant of germination in older vegetation. Therefore, as a general rule, the maximum inter-fire period that should preserve all species in 'typical' Box-Ironbark vegetation is around 50 years. This agrees with the estimated maximum inter-fire period for the Box-Ironbark Forest EVC in the Northern Bendigo Landscape Management Unit (DSE 2006b). In practice, to achieve heterogeneity across the broader landscape, there should be a range of inter-fire periods applied, including longer than 50 years.

The theoretical estimates of the upper and lower Tolerable Fire Intervals discussed above apply to large tracts of Box-Ironbark forests, and are essentially generic in nature. Private remnants may have been subject to a long history of disturbance, and the extant structure and composition will reflect that disturbance. Thus, while some remnants may be large and resemble 'typical' forest, others may have changed to such an extent that it may be difficult to estimate which EVC type was originally present. Just as importantly, post-fire composition of dry sclerophyll forest generally reflects the pre-fire composition within a few years of burning (Christensen *et al.* 1981), and no amount of careful burning will restore 'lost' species in a disturbed remnant (Orscheg 2006). Therefore, in most instances, upper and lower fire intervals should be determined on an individual site basis rather than a generic EVC basis, using the suite of species that still exist on-site (recorded during the floristic survey), or that are known to have once existed there, in conjunction with Table 2 and Appendix 1.

More detailed instructions on the use of Key Fire Response Species to estimate Tolerable Fire Intervals can be found in *Management of Fire for the Conservation of Biodiversity* (Friend *et al.* 1999) or various management plans such as Tolhurst (2000) or Lindorff (2001, 2002).

Identify areas where time-since-fire is approaching upper fire interval

A remnant (or sub-unit) in which the estimated time-since-fire is approaching, or has exceeded, the upper Tolerable Fire Interval <u>for the vegetation on-site</u> (usually around 50 years) is considered a possible candidate for an ecological burn. In the absence of such a burn, and depending on the species composition present, the plant diversity on site might decline in future (if it is not already declining) as mature plants senesce and the soil seed bank decays.

If possible, other remnants or public land blocks in the area should be considered in this planning phase, to allow various areas and age classes to be scaled up into the equivalent of public land Logical Burning Units (see Table 1, Key Principle 14) (DSE 2004). This may not always be practical, particularly at present, but may be viable in future years as regional fire-age records accumulate.

In many situations, depending on the nature of a remnant and its disturbance history, there may be little biological imperative for ecological burning even if the theoretical upper Tolerable Fire Interval has been exceeded. This can occur when:

- there are no extant species that require fire for germination, nor knowledge of them having previously occurred there.
- there is on-going recruitment of all extant shrub and tree species in the absence of fire.

- vegetation is not senescent, and the retention of a small number of discrete species could be readily facilitated by a simple planting program.
- site characteristics of a heavily-disturbed remnant suggest that an undesirable shrub or weed invasion is likely to outweigh any small benefit derived from burning.

Conversely, in other situations, a burn might be planned substantially before the theoretical upper Tolerable Fire Interval has been reached. This can occur when:

- the time-since-last-fire has exceeded the lower Tolerable Fire Interval,
- and on-site fauna are not at risk from another burn,
- and plant species in the remnant (e.g. orchids) might be stimulated by an earlier burn in a particular season,
- or the burn forms part of a longer-term strategic plan to create a burn mosaic in a large area of homogeneous, even-aged vegetation.

However, always bear in mind that plant species in most forests are more likely to be disadvantaged by fire that is too frequent, rather than too infrequent (Meredith 1987). Further, few Box-Ironbark species rely on fire for germination, and the majority will persist in the community as plants or seeds for 50-100 years (Tolsma *et al.* 2007), and the imperatives for regular burning are not as strong as in other, more fire-prone vegetation. Burning need not be undertaken "just in case", and the onus is on the land manager to prove a clear case for burning. **If in doubt, don't burn.**

Consider risks to extant fauna or fauna habitat

The co-occurrence of Bassian (coastal or mountain) and Eyrean (inland) species has led to a particularly diverse fauna, including 'stronghold' species where Box-Ironbark forests provide the most important part of their range (ECC 2001). Many of the animals that have been recorded in Box-Ironbark forests are considered rare or threatened (DSE 2007a), not all of them listed yet under Victoria's *Flora and Fauna Guarantee Act 1988*.

For most fauna species, an occasional low-intensity fire is not expected to have any long-lasting negative impact, provided understorey composition and structure has sufficient time to fully recover - around 25 years (Tolsma *et al.* 2007). Indeed, a long absence of fire may disadvantage species such as Fairy-wrens, which may decline in abundance as shrubby vegetation senesces in some environments, while showing the opposite effect (decreasing when shrub regrowth gets too dense) in other environments (Loyn 1997). However, some species, including rare or threatened species, may be adversely affected in either the long- or short-term by fire, depending on the season, and these impacts must be considered when deciding whether or not a remnant should be burnt. Similarly, the ability of animal species to recolonise a site must be taken into consideration, as small mammals such as *Antechinus* may have their movements restricted by even a partly overgrown track (Barnett 1978). Reptiles and frogs are also expected to have restricted movement in and out of remnants (Tolsma *et al.* 2007), although relevant research data are not available.

A checklist of fauna species that are expected to be in Box-Ironbark forests is presented in Appendix 3, including their conservation status and any strong expected response to fire. For lesser (either positive or negative) responses, refer to Appendices 4-5 in the Phase 1 report (Tolsma *et al.* 2007). Refer also to the Phase 1 report to determine the foraging and nesting requirements of Box-Ironbark animal species, as this will provide additional hints on their likely response to fire.

Burning of remnants in which sensitive or rare or threatened species are known (or reasonably assumed) to exist, or where fauna species are dependent on habitat that would be lost through fire (for example, deep litter or coarse woody debris), should not be undertaken unless it can be clearly demonstrated that the medium to long-term benefits will outweigh the negative impacts. This will apply when:

- vegetation composition and structure are in a state of senescence, such that the remnant is in danger of becoming unsuitable for the fauna in question unless a burn is applied. In this situation there is a trade-off between the abrupt impact of fire and the insidious longer-term impact of habitat decline. The decision on whether or not a burn is justified must be made in consultation with experts on an individual site basis.
- vegetation structure and composition are expected to benefit from burning, and burns can be applied in a season or manner in which the impacts on the fauna species are acceptably reduced.

The size and isolation of remnants are critical considerations when determining the likely effects of burning. However, there is no available research that has determined a minimum, useful remnant size, or optimum burn size, or desired burn mosaic. In the absence of this knowledge, we propose that not more than half of an isolated remnant or sub-unit should be burnt in any single fire, regardless of how small that burn unit might be, with burning of the remaining portion delayed for at least 10 years. This will allow some recovery of vegetation structure, the re-accumulation of deep litter (important for invertebrates and ground-foraging/dwelling animals), and recolonisation of small animals from the unburnt section. This requirement might be less critical when the remnant adjoins neighbouring bushland and small fauna groups are not isolated. Where the impacts of a fire on key fauna species are not season-specific, consideration should be given to conducting the second burn in a different season to the first burn, as this will maximise whole-of-site plant diversity.

Many fauna species rely on coarse woody debris, including branches and hollow logs, or hollows in older trees (Bennett 1999; Irvin *et al.* 2003; Recher *et al.* 1974), and if destroyed these resources may take many decades to replace. Burning of coarse woody debris and old hollow trees should be avoided by careful planning and implementation of the burn, and may include the raking of flammable material away from logs and large trees. Should any fire be smouldering in the wood it must be extinguished immediately after the fire front has passed.

Conduct burn if required

Remnants will qualify for an ecological burn if the assessment has demonstrated that:

- sufficient time has elapsed since the site was last burnt,
- and that such a burn is necessary to maintain or enhance the overall vegetation composition and structure on-site,
- and that the burn will not involve an unacceptable degree of risk to extant fauna species.

Provided the lower Tolerable Fire Interval has been exceeded at a site, there is substantial flexibility in how and when a burn may be conducted (or if indeed it is burnt at all). Again, we state that burning need not be undertaken "just in case", and the onus is on the land manager to make a compelling case that such burning is a useful management option for the site.

On public land, a range of intensities, frequencies, seasons and scales of burning are recommended for ecological fire regimes if they are to optimise the conservation of biodiversity (Table 1, Key Principle 7) (DSE 2004). This has sometimes been described as "pyrodiversity begets biodiversity", although in many ecosystems the desired fire mosaics remain unspecified and the ecological significance of different burning patterns remains unknown (Parr and Andersen 2006). This is especially pertinent in private remnants, where management history and possible vegetation response to fire are often unclear. Nonetheless, some degree of heterogeneity should be possible through variations in the season and frequency of burn, although the ability to substantially vary scales and intensities of burning will be limited in many remnants. In tiny isolated remnants (say 0.5 ha or less) that are unlikely to make any substantial contribution to regional flora and fauna diversity, burning may simply be impractical, and landholders should perhaps explore other avenues for promoting diversity, such as a planting program.

No remnant sub-unit, regardless of how small it is, should be burnt in entirety (see 'Consider risks to extant fauna or fauna habitat', page 21). An exception may be made for small remnants that directly abut other native bushland. Partial burning will maximise the chance that small animal communities can survive and recover, particularly important when recolonisation from outside the remnant is prevented by isolation, and it will also ensure a limited amount of on-site floristic heterogeneity. Further, given the largely experimental nature of burning in private remnants, it allows at least half of the sub-unit to retain the original floristic structure and composition should the burn produce unexpected and undesirable results, such as an invasion of weeds or an increase in macropod grazing. We shall call this the 'Oops' Principle.

Larger remnant blocks can be divided into a greater number of burn units. However, as stated previously, no biological criteria exist for estimating a minimum burn size or optimum mosaic. Suffice to say that while a burn of 0.5 hectares within a larger block might contribute little to heterogeneity on a regional scale it might contribute at the scale of a local orchid population or small animal's home-range.

Therefore, an irregular mosaic should be planned on a site-by site basis, but with landscape context in mind, giving due regard to:

- total remnant size and degree of isolation
- sub-units with different vegetation or management history
- age-class (time since last disturbance) of sub-units (and of neighbouring vegetation where applicable)
- season in which previously burnt (if known)
- requirements of extant fauna species (e.g. breeding season, key habitat components, fragmentation, species mobility)
- requirements of rare or threatened plant species (e.g. orchids)
- natural burn boundaries such as ridges, tracks or creeklines
- fire safety issues, including neighbouring property

A range of fire intensities and scales may be able to be achieved collectively across the broader landscape provided data for a large number of remnant sites can be accumulated and combined with those from public land burns. This may be impractical in advance, but over time as regional fire-age distribution data accumulate, particularly for larger remnants, ecological burning regimes for private land may be able to be integrated with burning regimes for public land (as per DSE 2004). However, the relatively infrequent need for fire (at around 50 year intervals) and discontinuity in private land ownership are likely to impose practical limits on what can be achieved. Therefore, a future fire-age mosaic across private land may simply reflect the current (largely unknown) mosaic, modulated by the accumulation of individual site burns.

Pre- and post-fire monitoring

An essential feature of any prescribed burning program is the ability to measure whether or not the desired ecological outcomes have been, or are likely to be, achieved (DSE 2004; NRE 1999; Tran and Peacock 2002). In private Box-Ironbark remnants, a likely lack of knowledge of on-site fire and management history makes the response of individual patches difficult to predict (Tolsma *et al.* 2007), hence makes estimation of the desired outcomes equally difficult. In this regard the proposed burning regime may be seen as part of an adaptive experimental management program, whereby the results of previously applied burns will inform and guide future burns in remnants with similar floristic, structural and site characteristics.

Long-term detailed monitoring of a large number of burnt remnants, particularly for fauna, is unlikely to be practical, and possible changes in ownership may affect monitoring continuity. Nonetheless, some initial pre-fire assessments followed by post-fire monitoring of burnt sites is strongly recommended, even if it is restricted to general site-by-site assessments of whether or not burning has been beneficial to vegetation composition and structure and has not negatively affected fauna species.

Three broad scenarios are possible:

- The effects of burning are positive, with stimulation of a wide range of plant species and a likely improvement (in the medium to long term) in vegetation structure, and no unacceptable loss of fauna species.
- The effects of burning appear largely neutral, with little change from the pre-fire floristic composition and structure in the short to medium term (excluding seasonal effects), and no obvious differences in fauna assemblages.
- The effects of burning are largely negative, with an unacceptable loss of native plant or animal species or an increase in weeds.

While the first (positive) scenario may appear to be the most desired one, in practice the second (neutral) one may also be useful ecologically, in that vegetation that might be in a senescing phase is 'reset' to a younger seral phase. These changes may not always be obvious or substantial, because the high number of resprouting species in Box-Ironbark forests confers an inherent compositional stability (Orscheg 2006), such that regeneration after a burn tends to follow the pre-fire state in terms of species and their proportions. Therefore, the most important aim of the monitoring program will be to determine the site characteristics and circumstances under which the third (negative) scenario might eventuate. Similar sites can then be treated as 'no-burn' sites, or the burning regime modified.

For meaningful results, and to facilitate adaptive management, several site assessments will be needed in the decades after a burn, as some of the initial fire-induced changes may be short-lived. For example, fire may promote short-lived obligate seeders in the first year post-burning, but within two years the floristic composition in burnt sites may again approach that in unburnt sites (Orscheg 2006). Conversely, a flush in shrubs such as *Acacia paradoxa* or *Acacia pycnantha* may persist for 20 years or more (Tolsma *et al.* 2007). Therefore, estimation of the likely trajectory of a remnant is just as important as determination of current state.

Where practical, and especially for larger remnants, floristic assessments should be undertaken using the standard protocols developed for public land management (*Draft Fire and Biodiversity Monitoring Protocols for Flora: User's Guide*) (DSE 2007b). Use of these protocols will allow direct comparisons or contrasts with the effects of burning on other sites, whether private or public land, that will not be confounded by the use of different techniques or units of measure. The protocols suggest floristic assessment of sites at two and ten years post-burn, with an optional assessment at five years post-burn, and this appears to be a reasonable time-scale for private remnants. The use of these standardised assessment techniques and time-scales will allow some integration of the data from private land with those from public land, which could ultimately lead to a more holistic cross-tenure approach to burning across the CMA.

If comprehensive monitoring is not practical, then periodic monitoring of Key Fire Response Species should be undertaken as a minimum requirement, to ensure that these species have not been lost from the site and that the inter-fire period was appropriate to the vegetation. This is especially important when a sub-unit has been partially burnt, and species such as shrubs that take a long time to reach reproductive maturity should be checked to ensure that their recruitment and growth are progressing satisfactorily. If not, then any burning of the remainder of the sub-unit should be deferred. Detection and treatment of any weed invasions is also important. Species with the longest juvenile period could be assessed after the relevant period has elapsed, to determine if viable seed has been set (Tolhurst 2000). Species with the shortest time to local extinction could also be assessed before that particular period has elapsed, to determine if the population is dying out and allow the appropriate action (Tolhurst 2000). However, the lower Tolerable Fire Interval is around 20 years in 'typical' Box-Ironbark vegetation, and such a recommendation may not always be practical for privately-owned land.

Comprehensive fauna surveys are also unlikely to be practical in private land remnants. Total numbers of non-avian species may be low in Box-Ironbark forest, and even lower in remnants (Tolsma *et al.* 2007), and an expensive, high survey effort may result in limited data only with minimal statistical power. Therefore, fauna surveys may need to be opportunistic only (casual observations of readily-observable species), or restricted to species of concern, with the simple aim of determining whether or not they remain on-site after the burn.

A database should be established in GIS containing fire-age data for all remnant sub-units assessed in the CMA, regardless of whether or not they are ultimately burnt. As records accumulate, spatial analysis can be used to assess 'pyrodiversity' on a regional scale and identify possible candidate areas for pre-burn assessment. If wildfire records are available (historic and future), their inclusion in GIS will supplement the fire-age data, particularly in areas where site assessment data are limited.

Precautionary notes

The aim of this report has been to develop the rationale and protocols for implementing ecological burning in remnant Box-Ironbark forests. The recommendations are relatively generic in nature, and provide for a substantial degree of flexibility in how and when burning is conducted, if at all. However, remnants will vary substantially in their management and disturbance histories, and it is simply not possible to predict with any degree of certainty what the response to fire will be in every case. Fire may be considered a blunt instrument, and the effects of fire may be variously insignificant to substantial, short to long-term, and negative to positive. There is no guarantee that the burning of some remnants will not lead to unexpected and undesirable results. As such, the proposed assessment protocols should be looked at in the light of an experimental management program, and fine-tuning (informed by pre- and post-fire monitoring) will be needed in future as our knowledge grows. If in doubt, don't burn.

Ecological burning should be avoided in drought years, when plants and animals may already be stressed. Further, with forage being limited in dry periods, there is an increased risk of drawing in kangaroos and wallabies that are attracted to the new growth (Christensen and Kimber 1975; Robertson 1985; Tolhurst and Oswin 1992). This may be exacerbated in isolated remnants where supplementary feeding in surrounding paddocks allows macropod numbers to remain high. Post-fire grazing may then lead to increased plant mortality and modification of habitat. The occurrence of dry years that are unsuitable for burning may increase in future if our climate continues to warm and dry. However, the role of climate change in shaping vegetation structure and diversity in these forests, and the possible changes to the 'natural' fire regime that this might entail, are outside the scope of this report.

Large, old trees flower more intensely and more frequently than smaller trees, and represent a valuable resource for many species, particularly honeyeaters (Andrew Bennett, Deakin University, pers. comm.). These trees should be protected from burning, either by clearing flammable material away from the bases before burning, or by preventing fire from reaching them. As mentioned previously, the burning of coarse woody debris and hollows should also be avoided.

Finally, there are risks involved with every fire, and relevant expertise must be drawn upon when planning and undertaking a burn. Proposed burns must comply with all the necessary planning and risk management principles that apply to public land. It is not our intention to attempt to reproduce all the relevant operational principles here, and the reader is directed instead to the *Code of Practice for Fire Management on Public Land* (DSE 2006a) and *Guidelines and Procedures for Ecological Burning on Public Land in Victoria* (DSE 2004).

Key to Table 2 (opposite) and Appendix 1 (page 39)

BIB Ind. (fidelity to Box-Ironbark); C- Common in BIB & found in other vegetation, but not common; R- Largely restricted to part of BIB; R Largely restricted to & widespread within BIB, rare elsewhere; U Uncommon in BIB & rare elsewhere; W Widespread in BIB & other vegetation.

KFR (Suitability for estimation of EVC type, fire history and monitoring); 1 = Highly Suitable, 2 = Suitable, 3 = Somewhat Suitable, NS = Not Suitable, - = not assessed.

SD (Mode of seed regeneration post-fire); C = Short-lived seed bank, exhausted after single disturbance; D = Widely dispersed, seed available at all times after fire; G = Long-lived seed bank, complete germination after fire; S = Long-lived seed bank, seed stored, partial germination after fire; Z = does not re-establish from seed immediately (or soon after) fire.

VG (Mode of vegetative regeneration post-fire); U = Sprouters, mature remain mature, juvenile remain juvenile; V = Sprouters, all ages survive, all become juvenile; W = Sprouters, mature remain mature, juveniles die; X = does not resprout post-fire; Y = Sprouters, mature become juvenile, juveniles die or there are no juveniles before the fire.

TIR (establishment conditions); I = can establish straight after fire, but not in older vegetation; K = can establish immediately after fire and in over-mature vegetation, cannot establish in intermediate-aged vegetation; M = can only establish in intermediate-aged vegetation, cannot establish straight after fire nor in over-mature vegetation; R = cannot establish straight after fire but able to establish in older vegetation; T = can establish immediately after fire and throughout later years as well, thru to over-mature vegetation.

JUV (time to onset of reproductive maturity, in years).

SPP LIFE (time to local extinction, including demise of seed store, in years); 3 = < 3 years, 10 = 3-10 years, 20 = 10-20 years, 50 = 20-50 years, 100 = > 50 years.

IND LIFE (lifespan/form of photosynthetic plants, excluding longer life of stored seed); A = Annual; ASP = Annual or short-lived perennial; SP = Short-lived perennial, < 10 years; MP = Medium-lived perennial, 10-50 years; LP = Long-lived perennial, > 50 years.

MAX DEN (fire frequency at which the density of a species is expected to be highest); L = low, I = intermediate, H = high.

(Additional symbols used in Appendix)

FFG (Flora & Fauna Guarantee Act 1988); f = listed.

EPBC (The Environment Protection and Biodiversity Conservation Act 1999); v = vulnerable, E = endangered.

VROTS (Victorian Rare or Threatened Status); r = rare, v = vulnerable, e = endangered.

Table 2. Key Fire Response vascular plant species in Box-Ironbark forest, sorted by suitability (KFR) then by longevity if known (SPP LIFE). See key opposite.

Scientific Name	Common Name	BIB Ind.	KFR	SD	VG	TIR	JUV	SPP LIFE	IND LIFE	MAX DEN
Xanthorrhoea glauca subsp. *angustifolia*	Grey Grass-tree	R	1		U	T		100	LP	L
Brachyloma daphnoides	Daphne Heath	W	1	G	W	T	10	100	LP	I-L
Daviesia leptophylla	Narrow-leaf Bitter-pea	W	2			I	5	20	MP	I
Phebalium festivum	Dainty Phebalium	R-	2	G	X	I	5	50	MP	I
Acacia genistifolia	Spreading Wattle	W	2	S		I	5	50	MP	I
Acrotriche serrulata	Honey-pots	W	2		Y	T	5	50	LP	I-L
Dillwynia cinerascens s.l.	Grey Parrot-pea	W	2	S		I	5	50	MP	I
Dillwynia sericea	Showy Parrot-pea	W	2			I	5	50	MP	I
Gompholobium huegelii	Common Wedge-pea	W	2		X	I	5	50		H-I
Hakea decurrens subsp. *physocarpa*	Bushy Needlewood	W	2	G	X	I	5	50	LP	I
Persoonia rigida	Hairy Geebung	C-	2	G		T	5	100		L
Eucalyptus polybractea	Blue Mallee	R-	2	G	Y	I		100	LP	H-I
Amyema miquelii	Box Mistletoe	W	2	D		R	5	100	MP	L
Calytrix tetragona	Common Fringe-myrtle	W	2	G	V	T	5	100	MP	I-L
Cassinia arcuata	Drooping Cassinia	W	2	S		T	5	100	MP	I
Goodenia geniculata	Bent Goodenia	W	2	G	V	I	2	100	MP	I
Joycea pallida	Silvertop Wallaby-grass	W	2	Z	V	T	2	100	LP	L
Themeda triandra	Kangaroo Grass	W	2	C	Y	T	2	100	LP	L
Swainsona behriana	Southern Swainson-pea	U	2	Z	W	I	1		MP	I-L
Daviesia ulicifolia	Gorse Bitter-pea	W	2		Y					I
Acacia difformis	Drooping Wattle	C-	3	S		I	5	50	MP	I
Prostanthera denticulata	Rough Mint-bush	R	3			I	5	50		I
Pultenaea largiflorens	Twiggy Bush-pea	R	3			I	5	50		I
Astroloma humifusum	Cranberry Heath	W	3	G	W	T	5	50	MP	I-L
Chrysocephalum apiculatum s.l.	Common Everlasting	W	3		V	T	2	50	ASP	H
Eutaxia microphylla var. *diffusa*	Spreading Eutaxia	W	3			K	5	50		I
Exocarpos cupressiformis	Cherry Ballart	W	3	G	Y	T	10	50	LP	I-L
Hibbertia riparia	Erect Guinea-flower	W	3	G	V	I	5	50	MP	I
Hibbertia sericea s.l.	Silky Guinea-flower	W	3	G	Y	I	5	50	MP	I
Hypoxis glabella var. *glabella*	Tiny Star	W	3	S	U	I	2	50	MP	H
Pultenaea laxiflora	Loose-flower Bush-pea	W	3	S		I	5	50		I
Eucalyptus viridis	Green Mallee	R-	3	G	Y	I	10	100	LP	I
Eucalyptus behriana	Bull Mallee	W	3	G	Y	I/T	10	100	LP	H-I
Leptospermum myrsinoides	Heath Tea-tree	W	3		Y	I	5	100	MP	I
Pultenaea prostrata	Silky Bush-pea	W	3	S		I	5	100		I-L
Tricoryne elatior	Yellow Rush-lily	W	3		V	I	2	100		H
Bursaria spinosa subsp. *lasiophylla*	Hairy Bursaria	C-	3		V	T				L
Pultenaea graveolens	Scented Bush-pea	U	3			I			MP	I
Burchardia umbellata	Milkmaids	W	3		U					I-L
Correa reflexa	Common Correa	W	3	G	Y	T	5		MP	I
Acacia paradoxa	Hedge Wattle	W	3	S		T	5	50	MP	I
Thysanotus patersonii	Twining Fringe-lily	W	3	S	U	I	1	100	SP	H
Acacia acinacea s.l.	Gold-dust Wattle	W	-							I
Hibbertia exutiaces	Spiky Guinea-flower	R	-							I
Platylobium formosum	Handsome Flat-pea	W	-							I
Acacia pycnantha	Golden Wattle	W	NS	S	X	I	5	100	MP	I

Table 3a. Key Fire Response vascular plant species in Box-Ironbark forest, in alphabetical order, showing the range of times-since-fire at which the species is generally at its highest relative cover or abundance.

Years	0-10	10-20	20-30	30-40	40-50	50-60	70+
Acacia acinacea	L	D	D	D	C	C	L
Acacia difformis	C	D	D	C	C	L	
Acacia genistifolia	C	D	D	C	C	L	L
Acacia paradoxa	L	D	D	C	L	L	
Acacia pycnantha	L	D	D	C	C	L	L
Acrotriche serrulata	L	L	D	D	C	C	C
Amyema miquelii			L	C	D	D	D
Astroloma humifusum	C	D	D	D	C	C	C
Brachyloma daphnoides	L	L	C	D	D	D	D
Burchardia umbellata	D	C	L	L	L	C	C
Bursaria spinosa subsp. lasiophylla	L	C	D	D	C	C	C
Calytrix tetragona	C	D	D	D	C	L	L
Cassinia arcuata	L	C	D	D	D	L	L
Chrysocephalum apiculatum s.l.	D	C	L	L	L	C	C
Correa reflexa	C	D	D	C	C	L	L
Daviesia leptophylla	C	D	C	C	L		
Daviesia ulicifolia	C	D	C	C	L	L	
Dillwynia cinerascens s.l.	L	D	D	D	C	L	L
Dillwynia sericea	L	D	D	D	C	L	
Eucalyptus behriana	L	D	D	D	D	D	D
Eucalyptus polybractea	L	D	D	D	D	D	D
Eucalyptus viridis	L	D	D	D	D	D	D
Eutaxia microphylla var. diffusa	C	D	D	D	C	C	L
Exocarpos cupressiformis		L	C	D	D	D	C
Gompholobium huegelii	C	C	C	C	L	L	
Goodenia geniculata	D	C	L	L	L	L	L
Hakea decurrens	L	D	D	D	C	L	
Hibbertia exutiaces	C	D	D	C	L	L	L
Hibbertia riparia	C	D	D	D	L	L	L
Hibbertia sericea s.l.	C	D	D	D	L	L	
Hypoxis glabella	D	C	L	L	L	C	C
Joycea pallida		L	L	C	D	D	D
Leptospermum myrsinoides	C	D	D	D	C	C	L
Persoonia rigida		L	C	D	D	D	D
Phebalium festivum	C	D	D	D	C	L	
Platylobium formosum	L	D	D	D	C	L	
Prostanthera denticulata	L	D	D	D	C	L	
Pultenaea graveolens	C	D	D	D	C	L	
Pultenaea largiflorens	L	D	D	D	C	L	
Pultenaea laxiflora	L	D	D	D	C	L	
Pultenaea prostrata	L	C	D	D	C	L	
Swainsona behriana	C	L	L	L	C	C	C
Themeda triandra		L	L	L	C	D	D
Thysanotus patersonii	D	L	L	L	C	C	C
Tricoryne elatior	D	C	L	L	L	C	C
Xanthorrhoea glauca	L	L	C	C	D	D	D

	species either absent or trivial presence
L	species present at low cover values, but may be many individuals
C	species common but not dominant in any stratum of the vegetation
D	species at most common, and may be dominant in a stratum

Table 3b. Key Fire Response vascular plant species in Box-Ironbark forest, in chronological order, showing the range of times-since-fire at which the species is generally at its highest relative cover or abundance.

Years	0-10	10-20	20-30	30-40	40-50	50-60	70+
Burchardia umbellata							
Chrysocephalum apiculatum s.l.							
Goodenia geniculata							
Hypoxis glabella							
Thysanotus patersonii							
Tricoryne elatior							
Daviesia leptophylla							
Daviesia ulicifolia							
Acacia difformis							
Acacia genistifolia							
Acacia paradoxa							
Acacia pycnantha							
Correa reflexa							
Gompholobium huegelii							
Hibbertia exutiaces							
Acacia acinacea							
Astroloma humifusum							
Calytrix tetragona							
Dillwynia cinerascens s.l.							
Dillwynia sericea							
Eutaxia microphylla var. diffusa							
Hakea decurrens							
Hibbertia riparia							
Hibbertia sericea s.l.							
Leptospermum myrsinoides							
Phebalium festivum							
Platylobium formosum							
Prostanthera denticulata							
Pultenaea graveolens							
Pultenaea largiflorens							
Pultenaea laxiflora							
Acrotriche serrulata							
Bursaria spinosa subsp. lasiophylla							
Pultenaea prostrata							
Cassinia arcuata							
Eucalyptus behriana							
Eucalyptus polybractea							
Eucalyptus viridis							
Exocarpos cupressiformis							
Brachyloma daphnoides							
Persoonia rigida							
Amyema miquelii							
Joycea pallida							
Swainsona behriana							
Xanthorrhoea glauca							
Themeda triandra							

	species either absent or trivial presence
	species present at low cover values, but may be many individuals
	species common but not dominant in any stratum of the vegetation
	species at most common, and may be dominant in a stratum

FUTURE RESEARCH

There are limited research data available on the effects of fire on Box-Ironbark vegetation, fauna and habitat, and the Literature Review (Phase 1) and this Management Strategy (Phase 2) have drawn heavily on research from other ecosystems that share similar characteristics and species. The Literature Review identified various knowledge gaps as candidates for future research in Box-Ironbark forests, many of which are ideally suited to student projects. Few of these knowledge gaps are specific to a CMA and the research necessary in most cases would be better conducted in larger tracts of forest than in private remnants. Accordingly, the following recommendations should be considered as candidates for research, ideally in collaboration with public land managers undertaking fuel reduction or ecological burning. The first three research suggestions should be considered the highest priority, as the resultant data underpin the present protocols for recommending (or otherwise) the use of fire on public land across Victoria.

- The Vital Attributes for many plant species in Box-Ironbark forests (and indeed most EVCs) have not been confirmed. Data from the monitoring being established for burns on public land (DSE 2007b) should be used to supplement existing information, thereby providing improved knowledge on the effects of sequential fires on plant species.
- The time-to-local-extinction of many plant species is a 'best estimate'. Data from public land burns, particularly where the forest has been long-unburnt, should be used to provide better estimates of how long seeds remain viable in the soil. This will enable burns to be conducted within a more appropriate range of times. Sites with *Xanthorrhoea glauca* subsp. *angustifolia* (Grey Grass-tree) would be ideal as 'old' sites, as the size and density of this species are good indicators of fire-age.
- There are few data on the responses to fire of Box-Ironbark plant species and structure. The response of the 'typical' Box-Ironbark vegetation types to fire should be determined using fuel-reduction and ecological burns conducted by Parks Victoria and the Department of Sustainability and Environment, using standard monitoring protocols recently established (DSE 2007b). This should include the differential effect of season of burn. We acknowledge that it may not be practical to monitor burns on private land as comprehensively as official burns on public land, and public land burns should probably remain the key focus for research. However, a range of key sites (around six) with specific ecological (flora and fauna) goals should be established with the aim of determining whether or not those goals are achieved. In other remnants, as a minimum, the response of vegetation such as weeds should be opportunistically assessed to determine the extent to which different disturbance histories might affect responses.
- Little is known about the germination requirements for Box-Ironbark understorey species. Data from public land monitoring projects should be used to determine which species are poorly represented in terms of

recruitment, and trials set up to determine the factors that trigger germination in those species. These data can help determine the desirability of burning at a particular time. Research data from Parks Victoria's ecological thinning program may indicate if germination of particular species might be enhanced by disturbance other than fire.

- Anecdotal evidence suggests that recruitment of Ironbark eucalypts (presumably both *Eucalyptus tricarpa* and *E. sideroxylon*) is low and sporadic compared to recruitment of other canopy dominants. Research should determine the germination requirements of these species and the role that fire plays in their persistence in the landscape.

- Anecdotal evidence also suggests that recruitment by Red Stringybark is disproportionately high compared to its contribution to the canopy. Research should investigate whether this species acts as a "fire weed" in burnt areas, thereby eventually leading to a more fire-prone forest [with Stringybarks providing more flammable bark than other eucalypt species (ECC 1997)].

- Macropods are attracted to new growth, particularly if other forage is limited, and this has implications for understorey recovery. The interaction between fire and grazing should be explored. Suitable sites may already exist on private or public land, or fenced and unfenced monitoring plots could be established in a Before-After-Control-Impact study.

- Termites are considered to be key drivers of secondary productivity in many dry forests. However, little is known about the effects of fire on this invertebrate group. Consideration should be given to monitoring of termite communities before and after official burns on public land.

- Research in Box-Ironbark has suggested that bird richness declines as forest blocks become smaller than around 80 hectares (Bennett 1999). In blocks of around 10 hectares or smaller, aggressive bird species such as Noisy Miner may drive adverse changes in species abundance (Grey *et al.* 1997, 1998; Loyn 1987). More information is required on the relationship between fauna diversity and the spatial arrangement of different habitat elements (i.e., what should a mosaic look like?).

- There is anecdotal evidence that overstorey eucalypts and a species-poor shrub layer (for example, *Cassinia* dominated) re-establish when farmland is abandoned or converted to 'lifestyle' blocks. Research should determine the value of these species-poor areas for fauna, and whether active revegetation might improve their utility and contribution to catchment quality.

- Suitable fire mosaics (including the minimum useful size of a burn or the desired spatial distribution of age classes) have not been established. This limits our ability to justify or plan ecological burning, particularly in smaller remnants. Research should establish upper and lower burn sizes, and the contribution by different burn mosaics to faunal diversity.

- The isolation of many remnants may be a barrier to recolonisation of small or arboreal animals after fire. Research should determine the limits of recolonisation for fauna species, including small mammals, arboreal mammals, ground-dwelling birds, frogs and reptiles.

- Fire may affect fauna by removing their habitat (for example, hollows in trees or coarse woody debris) or by removing the vegetation in which they forage, nest or shelter. The relative contribution by these two factors on post-fire fauna changes has been little explored, but the various debris retention' treatments in Parks Victoria's ecological thinning trial may provide some useful data.
- Highly disturbed remnants may contain less suitable habitat for fauna, such as logs or tree hollows, and the effects of adding hollow logs or artificial nest boxes on fauna types and abundance should be examined.
- Fires of a higher intensity may impact on fauna species that live in the canopy or in hollows. Using public land fuel reduction or ecological burns, research should determine the impact of burning on bats and arboreal mammals, and the ways in which adverse effects might be minimised.
- Invertebrates, reptiles and ground-foraging birds rely on the deep litter layer that is partially consumed by fire, yet little is known about the recovery of this litter in Box-Ironbark forest. Limited studies have suggested that it might take longer than eight years in some circumstances (Hartskeerl 1997), but as that research was hampered by a lack of replicates a more likely time-frame is the (approximate) four years measured in mixed eucalypt forest (Tolhurst and Kelly 2003). While both estimates are well inside the minimum tolerable fire interval of around 20 years for this forest type, confirmation of the recovery time will nonetheless be useful for informing the effects of unplanned sequential fires or overlapping burns.

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APPENDIX 1. PLANT VITAL ATTRIBUTES FOR SOME BOX-IRONBARK SPECIES

Species have been sorted in order of their fidelity as Box-Ironbark species, then alphabetically. Refer to Page 28 for key to symbols used.

FFG	EPBC	VROTS	Scientific Name	Common Name	BIB Ind	KFR	SEED	VEG	TIR	JUV	SPP LIFE	INDIV LIFE
			Acacia difformis	Drooping Wattle	C-	3	S		I	5	50	MP
		r	*Acacia flexifolia*	Bent-leaf Wattle	C-	-						
		r	*Austrostipa breviglumis*	Cane Spear-grass	C-	-						
			Bursaria spinosa subsp. lasiophylla	Hairy Bursaria	C-	3		V	T			
			Cheiranthera cyanea var. cyanea	Blue Finger-flower	C-	NS				5	50	MP
			Cyanicula caerulea	Blue Fairy	C-	NS		U	T	5	100	MP
			Dampiera dysantha	Shrubby Dampiera	C-	-						
			Daviesia benthamii subsp. humilis	Spiny Bitter-pea	C-	-						
			Dichelachne hirtella	Hairy Plume-grass	C-	-						
			Dillwynia ramosissima	Bushy Parrot-pea	C-	-						
			Eucalyptus tricarpa subsp. tricarpa	Red Ironbark	C-	-						
			Goodenia hederacea subsp. hederacea	Ivy Goodenia	C-	NS			T	2	100	MP
			Hyalosperma praecox	Mayweed Sunray	C-	-						
			Juncus remotiflorus	Diffuse Rush	C-	NS		V	T	2	100	
			Melichrus urceolatus	Urn Heath	C-	NS			I	5	100	LP
			Persoonia rigida	Hairy Geebung	C-	2	G		T	5	100	
			Pterostylis cycnocephala	Swan Greenhood	C-	NS		U	T	5	100	LP
			Pultenaea pedunculata	Matted Bush-pea	C-	-						
			Rhodanthe laevis	Smooth Sunray	C-	-						
			Stuartina muelleri	Spoon Cudweed	C-	NS	C	X	T	1	100	A
		v	*Thelymitra X macmillanii*	Crimson Sun-orchid	C-	NS		U	T	5	100	LP
		v	*Acacia ausfeldii*	Ausfeld's Wattle	R	-						
		r	*Boronia anemonifolia subsp. aurifodina*	Goldfield Boronia	R	-						
			Hibbertia exutiacies	Spiky Guinea-flower	R	-						
			Olearia teretifolia	Cypress Daisy-bush	R	-						
			Philotheca verrucosa	Fairy Wax-flower	R	-						
			Prostanthera denticulata	Rough Mint-bush	R	3			I	5	50	
			Pultenaea largiflorens	Twiggy Bush-pea	R	3			I	5	50	
			Xanthorrhoea glauca subsp. angustifolia	Grey Grass-tree	R	1		U	T		100	LP

			Xerochrysum viscosum	Shiny Everlasting	R	NS	G		T	2	100	SP
			Acacia aspera	Rough Wattle	R-	-						
		r	*Acacia williamsonii*	Whirrakee Wattle	R-	-						
		r	*Cassinia diminuta*	Dwarf Cassinia	R-	-						
f		r	*Eucalyptus froggattii*	Kamarooka Mallee	R-	-						
		r	*Eucalyptus polybractea*	Blue Mallee	R-	2	G	Y	I		100	LP
			Eucalyptus viridis	Green Mallee	R-	3	G	Y	I	10	100	LP
		r	*Grevillea dryophylla*	Goldfields Grevillea	R-	-						
		r	*Grevillea obtecta*	Fryerstown Grevillea	R-	-						
f	V	e	*Lepidium pseudopapillosum*	Erect Peppercress	R-	-						
		r	*Olearia tubuliflora*	Rayless Daisy-bush	R-	-						
f		v	*Phebalium festivum*	Dainty Phebalium	R-	2	G	X	I	5	50	MP
			Philotheca angustifolia	Narrow-leaf Wax-flower	R-	NS						
f	E	e	*Pterostylis despectans*	Lowly Greenhood	R-	-						
		r	*Pterostylis setifera*	Bristly Greenhood	R-	NS						
f		v	*Pultenaea graveolens*	Scented Bush-pea	U	3			I			MP
		r	*Swainsona behriana*	Southern Swainson-pea	U	2	Z	W	I	1		MP
f	E	e	*Westringia crassifolia*	Whipstick Westringia	U	-						
			Acacia acinacea s.l.	Gold-dust Wattle	W	-						
			Acacia acinacea s.s.	Gold-dust Wattle	W	-						
			Acacia genistifolia	Spreading Wattle	W	2	S		I	5	50	MP
			Acacia paradoxa	Hedge Wattle	W	3	S		T	5	50	MP
			Acacia pycnantha	Golden Wattle	W	NS	S	X	I	5	100	MP
			Acrotriche serrulata	Honey-pots	W	2		Y	T	5	50	LP
			Amyema miquelii	Box Mistletoe	W	2	D		R	5	100	MP
			Arthropodium fimbriatum	Nodding Chocolate-lily	W	NS			T	1	100	MP
			Arthropodium strictum s.l.	Chocolate Lily	W	NS			T	2	100	MP
			Astroloma humifusum	Cranberry Heath	W	3	G	W	T	5	50	MP
			Austrodanthonia caespitosa	Common Wallaby-grass	W	-						
			Austrodanthonia eriantha	Hill Wallaby-grass	W	NS		Y	T	1	100	MP
			Austrodanthonia fulva	Copper-awned Wallaby-grass	W	NS					100	
			Austrodanthonia geniculata	Kneed Wallaby-grass	W	NS		Y	T	1	100	MP
			Austrodanthonia pilosa	Velvet Wallaby-grass	W	NS	S	Y	T	1	100	MP
			Austrodanthonia setacea	Bristly Wallaby-grass	W	NS		Y	T	1	100	MP
			Austrostipa mollis	Supple Spear-grass	W	NS		U	T	1	100	SP
			Brachyloma daphnoides	Daphne Heath	W	1	G	W	T	10	100	LP

			Brachyscome multifida	Cut-leaf Daisy	W			W				SP
			Brachyscome perpusilla	Rayless Daisy	W	NS	C	X	T	1	100	A
			Brunonia australis	Blue Pincushion	W	NS		U	T	2	50	SP
			Burchardia umbellata	Milkmaids	W	3		U				
			Caladenia cucullata	Hood Orchid	W	NS		U	T	5	100	LP
			Caladenia gracilis	Musk Hood-orchid	W	NS		U	T	5	100	LP
			Calochilus robertsonii	Purple Beard-orchid	W	NS		U	T	5	100	LP
			Calytrix tetragona	Common Fringe-myrtle	W	2	G	V	T	5	100	MP
			Cassinia arcuata	Drooping Cassinia	W	2	S		T	5	100	MP
			Chamaescilla corymbosa var. corymbosa	Blue Stars	W	NS		U		1	50	MP
			Cheilanthes austrotenuifolia	Green Rock-fern	W	NS	Z	V	T	2	100	LP
			Chrysocephalum apiculatum s.l.	Common Everlasting	W	3		V	T	2	50	ASP
			Chrysocephalum semipapposum	Clustered Everlasting	W	NS	S		T	2	50	
			Correa reflexa	Common Correa	W	3	G	Y	T	5		MP
			Corunastylis sp. aff. rufa (Goldfields)	Dark Midge-orchid	W	NS		U	T	5	100	LP
			Crassula decumbens var. decumbens	Spreading Crassula	W	NS	C		T	1	100	A
			Cymbonotus preissianus	Austral Bear's-ear	W	NS		U	T	2	50	SP
			Daviesia leptophylla	Narrow-leaf Bitter-pea	W	2			I	5	20	MP
			Daviesia ulicifolia	Gorse Bitter-pea	W	2		Y				
			Dianella revoluta s.l.	Black-anther Flax-lily	W	NS	Z	V	T	5	100	MP
			Dillwynia cinerascens s.l.	Grey Parrot-pea	W	2	S		I	5	50	MP
			Dillwynia sericea	Showy Parrot-pea	W	2			I	5	50	MP
			Diuris pardina	Leopard Orchid	W	NS		U	T	5	100	LP
			Einadia hastata	Saloop	W	NS	C/D		T	2	100	SP
			Einadia nutans subsp. nutans	Nodding Saltbush	W	NS	C		T	2	100	SP
			Elymus scaber var. scaber	Common Wheat-grass	W	NS		Y	T	1	100	MP
			Eucalyptus behriana	Bull Mallee	W	3	G	Y	I/T	10	100	LP
			Eutaxia microphylla var. diffusa	Spreading Eutaxia	W	3			K	5	50	
			Eutaxia microphylla var. microphylla	Common Eutaxia	W	-						
			Exocarpos cupressiformis	Cherry Ballart	W	3	G	Y	T	10	50	LP
			Gnaphalium indutum	Tiny Cudweed	W	-						
			Gompholobium huegelii	Common Wedge-pea	W	2		X	I	5	50	
			Gonocarpus elatus	Tall Raspwort	W	NS		V	R	2	100	SP
			Gonocarpus tetragynus	Common Raspwort	W	NS	G	W	T	2	100	SP
			Goodenia blackiana	Black's Goodenia	W	-						
			Goodenia geniculata	Bent Goodenia	W	2	G	V	I	2	100	MP
			Goodenia pinnatifida	Cut-leaf Goodenia	W	NS			T	2	100	MP

			Grevillea alpina	Cat's Claw Grevillea	W	NS	G		T	10	100	MP
			Hakea decurrens subsp. physocarpa	Bushy Needlewood	W	2	G	X	I	5	50	LP
			Hibbertia obtusifolia	Grey Guinea-flower	W	NS	G	V	T			MP
			Hibbertia riparia	Erect Guinea-flower	W	3	G	V	I	5	50	MP
			Hibbertia sericea s.l.	Silky Guinea-flower	W	3	G	Y	I	5	50	MP
			Hydrocotyle callicarpa	Small Pennywort	W	NS	S		T	1	100	A
			Hydrocotyle foveolata	Yellow Pennywort	W	-						
			Hydrocotyle laxiflora	Stinking Pennywort	W	NS	Z	Y	T	2	100	
			Hypoxis glabella var. glabella	Tiny Star	W	3	S	U	I	2	50	MP
			Isolepis marginata	Little Club-sedge	W	NS	G	X	T	1	100	A
			Joycea pallida	Silvertop Wallaby-grass	W	2	Z	V	T	2	100	LP
			Juncus amabilis	Hollow Rush	W	-						
			Juncus bufonius	Toad Rush	W	NS	S	X	T	1	100	A
			Juncus subsecundus	Finger Rush	W	NS		V	T	2	100	
			Lachnagrostis filiformis	Common Blown-grass	W	NS			T	1	100	ASP
			Lagenophora huegelii	Coarse Bottle-daisy	W	NS		U	T	1	100	
			Lepidosperma curtisiae	Little Sword-sedge	W	NS		Y	I	5	100	
			Leptomeria aphylla	Leafless Currant-bush	W	NS	S			10	100	LP
			Leptorhynchos tenuifolius	Wiry Buttons	W	-						
			Leptospermum myrsinoides	Heath Tea-tree	W	3		Y	I	5	100	MP
			Leucopogon fletcheri subsp. brevisepalus	Twin-flower Beard-heath	W	-						
			Leucopogon rufus	Ruddy Beard-heath	W	NS	C	W	T	5	100	MP
			Leucopogon virgatus	Common Beard-heath	W	-						MP
			Levenhookia dubia	Hairy Stylewort	W	NS	S		T	1	100	A
			Lomandra filiformis	Wattle Mat-rush	W	NS	Z	V	T	5	100	MP
			Lomandra multiflora subsp. multiflora	Many-flowered Mat-rush	W	NS		Y	I	5	100	MP
			Lomandra nana	Dwarf Mat-rush	W	NS		Y	I	5	100	MP
			Maireana enchylaenoides	Wingless Bluebush	W	-						
			Melaleuca uncinata	Broombush	W	NS	G	W	I	5	100	LP
			Microlaena stipoides var. stipoides	Weeping Grass	W	NS	Z	W	T	1	100	SP
			Microseris sp. 3	Yam Daisy	W	NS	G	W	T	2	100	SP
			Millotia tenuifolia var. tenuifolia	Soft Millotia	W	NS		X	T	1	100	A
			Myosotis australis	Austral Forget-me-not	W	NS	C		T	1	100	ASP
			Ozothamnus obcordatus	Grey Everlasting	W	-						
			Ozothamnus retusus	Rough Everlasting	W	-						
			Pelargonium rodneyanum	Magenta Stork's-bill	W	-						
			Pentapogon quadrifidus var. quadrifidus	Five-awned Spear-grass	W	NS	S	V	T	2	100	

			Pimelea humilis	Common Rice-flower	W	NS	G	Y		5	50	MP
			Pimelea linifolia	Slender Rice-flower	W	-						
			Platylobium formosum	Handsome Flat-pea	W	-						
			Poa sieberiana	Grey Tussock-grass	W	NS		V	T	2	100	LP
			Poranthera microphylla s.l.	Small Poranthera	W	NS	C		T	1	100	ASP
		r	*Pterostylis smaragdyna*	Emerald-lip Greenhood	W	NS			T			
			Pultenaea laxiflora	Loose-flower Bush-pea	W	3	S		I	5	50	
			Pultenaea prostrata	Silky Bush-pea	W	3	S		I	5	100	
			Ranunculus sessiliflorus	Annual Buttercup	W	NS	S		T	1	100	
			Rumex brownii	Slender Dock	W	NS	Z	V	T	1	100	SP
			Sebaea ovata	Yellow Sebaea	W	NS	S	X	T	1	100	A
			Solenogyne dominii	Smooth Solenogyne	W	NS		W	T	1	100	MP
			Stylidium graminifolium s.l.	Grass Triggerplant	W	NS		Y	T	2	100	SP
			Stylidium inundatum	Hundreds and Thousands	W	NS	S	X	T	1	100	A
			Tetratheca ciliata	Pink-bells	W	NS	G/S	Y	I	5	100	MP
			Themeda triandra	Kangaroo Grass	W	2	C	Y	T	2	100	LP
			Thysanotus patersonii	Twining Fringe-lily	W	3	S	U	I	1	100	SP
			Tricoryne elatior	Yellow Rush-lily	W	3		V	I	2	100	
			Veronica plebeia	Trailing Speedwell	W	NS		W	T	1	100	SP
			Wahlenbergia stricta subsp. stricta	Tall Bluebell	W	NS	G	W	T	2	100	SP

APPENDIX 2. RELATIONSHIP BETWEEN FIRE FREQUENCY AND HIGHEST DENSITY FOR 46 KEY BOX-IRONBARK SPECIES

Species have been sorted according to the fire frequency at which they generally show the highest density or cover (MAX DEN). SPP LIFE (time to local extinction, including demise of seed store, in years); 3 = < 3 years, 10 = 3-10 years, 20 = 10-20 years, 50 = 20-50 years, 100 = > 50 years. IND LIFE (lifespan/form of photosynthetic plants, excluding longer life of stored seed); A = Annual; ASP = Annual or short-lived perennial; SP = Short-lived perennial, < 10 years; MP = Medium-lived perennial, 10-50 years; LP = Long-lived perennial, > 50 years. MAX DEN (fire frequency at which the density of a species is expected to be highest); L = low, I = intermediate, H = high.

Scientific Name	Common Name	SPP LIFE	INDIV LIFE	MAX DEN	Monitoring focus
Chrysocephalum apiculatum s.l.	Common Everlasting	50	ASP	H	density (highest in young vegetation)
Hypoxis glabella var. glabella	Tiny Star	50	MP	H	density (highest in frequently burnt vegetation, may increase in density in long-unburnt vegetation)
Thysanotus patersonii	Twining Fringe-lily	100	SP	H	density (highest in young vegetation)
Tricoryne elatior	Yellow Rush-lily	100		H	density (highest in frequently burnt vegetation, may increase in density in long-unburnt vegetation)
Eucalyptus behriana	Bull Mallee	100	LP	H-I	growth form (more tree-like in long-unburnt vegetation) & density (lower in long-unburnt vegetation)
Eucalyptus polybractea	Blue Mallee	100	LP	H-I	growth form (rough-barked tree form only in long-unburnt vegetation) & age structure (multi-aged stands in long-unburnt vegetation) & density (low in long-unburnt vegetation)
Gompholobium huegelii	Common Wedge-pea	50		H-I	density (highest at high to intermediate fire frequencies)
Acacia acinacea s.l.	Gold-dust Wattle			I	density (high at intermediate fire frequencies)
Acacia difformis	Drooping Wattle	50	MP	I	density (high at intermediate fire frequencies)
Acacia genistifolia	Spreading Wattle	50	MP	I	density (high at intermediate fire frequencies)
Acacia paradoxa	Hedge Wattle	50	MP	I	density (high at intermediate fire frequencies)
Acacia pycnantha	Golden Wattle	100	MP	I	density (high at intermediate fire frequencies)
Cassinia arcuata	Drooping Cassinia	100	MP	I	density (highest in intermediate-aged vegetation, persists at low density in over-mature forests)
Correa reflexa	Common Correa		MP	I	density (high at intermediate fire frequencies)
Daviesia leptophylla	Narrow-leaf Bitter-pea	20	MP	I	density (high at intermediate fire frequencies)
Daviesia ulicifolia	Gorse Bitter-pea			I	density (high at intermediate fire frequencies)
Dillwynia cinerascens s.l.	Grey Parrot-pea	50	MP	I	density (high at intermediate fire frequencies)
Dillwynia sericea	Showy Parrot-pea	50	MP	I	density (high at intermediate fire frequencies)
Eucalyptus viridis	Green Mallee	100	LP	I	seedling density (high in intermediate fire frequencies)

Eutaxia microphylla var. diffusa	Spreading Eutaxia	50		I	density (high at intermediate fire frequencies)
Goodenia geniculata	Bent Goodenia	100	MP	I	density (highest at intermediate to low fire frequencies)
Hakea decurrens subsp. physocarpa	Bushy Needlewood	50	LP	I	density (high at intermediate fire frequencies)
Hibbertia exutiacies	Spiky Guinea-flower			I	density (high at intermediate fire frequencies)
Hibbertia riparia	Erect Guinea-flower	50	MP	I	density (low in high fire frequencies, may also decrease in long-unburnt vegetation)
Hibbertia sericea s.l.	Silky Guinea-flower	50	MP	I	density (low in high fire frequencies, may also decrease in long-unburnt vegetation)
Leptospermum myrsinoides	Heath Tea-tree	100	MP	I	growth form (leggy, with low foliage cover /shrub in long-unburnt vegetation)
Phebalium festivum	Dainty Phebalium	50	MP	I	density (high at intermediate fire frequencies)
Platylobium formosum	Handsome Flat-pea			I	density (high at intermediate fire frequencies)
Prostanthera denticulata	Rough Mint-bush	50		I	density (high at intermediate fire frequencies)
Pultenaea graveolens	Scented Bush-pea		MP	I	density (high at intermediate fire frequencies)
Pultenaea largiflorens	Twiggy Bush-pea	50		I	density (high at intermediate fire frequencies)
Pultenaea laxiflora	Loose-flower Bush-pea	50		I	density (highest in intermediate aged vegetation)
Acrotriche serrulata	Honey-pots	50	LP	I-L	density (high at intermediate fire frequencies thru to long-unburnt vegetation)
Astroloma humifusum	Cranberry Heath	50	MP	I-L	density (high at intermediate fire frequencies thru to long-unburnt vegetation)
Brachyloma daphnoides	Daphne Heath	100	LP	I-L	density (high at intermediate fire frequencies thru to long-unburnt vegetation)
Burchardia umbellata	Milkmaids			I-L	density (high at intermediate fire frequencies thru to long-unburnt vegetation)
Calytrix tetragona	Common Fringe-myrtle	100	MP	I-L	density (high at intermediate fire frequencies thru to long-unburnt vegetation) & growth form (develops tree form in long-unburnt vegetation following regeneration from a hot fire)
Exocarpos cupressiformis	Cherry Ballart	50	LP	I-L	density (high at intermediate fire frequencies thru to long-unburnt vegetation)
Pultenaea prostrata	Silky Bush-pea	100		I-L	density (highest in intermediate aged vegetation) & cover (highest lin long-unburnt vegetation)
Swainsona behriana	Southern Swainson-pea		MP	I-L	density (lowest in vegetation burnt too frequently)
Amyema miquelii	Box Mistletoe	100	MP	L	density (highest in long-unburnt vegetation)
Bursaria spinosa subsp. lasiophylla	Hairy Bursaria			L	density (highest in long-unburnt vegetation)
Joycea pallida	Silvertop Wallaby-grass	100	LP	L	cover (highest in long-unburnt vegetation)
Persoonia rigida	Hairy Geebung	100		L	density (highest in long-unburnt vegetation) & growth form (may be able to age back to most recent fire, only large in long-unburnt vegetation)
Themeda triandra	Kangaroo Grass	100	LP	L	cover (highest in long-unburnt vegetation)
Xanthorrhoea glauca subsp. angustifolia	Grey Grass-tree	100	LP	L	growth form (depth of skirt indicates age since last fire) & density (highest in infrequently burnt vegetation) & seedling density (low in frequently burnt vegetation)

APPENDIX 3. BOX-IRONBARK FAUNA SPECIES AND CONSERVATION STATUS

List sorted by animal type (bird, mammal, reptile, frog), then as per the Australian Biological Resources Study: Census of Australian Vertebrate Species (CAVS) (Department of the Environment and Water Resources). * = introduced.
FFG (Flora & Fauna Guarantee Act 1988); f = listed.

EPBC (The Environment Protection and Biodiversity Conservation Act 1999); V = vulnerable, E = endangered.

VROTS (Victorian Rare or Threatened Status); c = critically endangered, e = endangered, v = vulnerable, n = near threatened, d = data deficient.

FIRE (major long- or short-term effects expected); S = Spring burn, A = Autumn burn, + = positive (green), - = negative (pink). For lesser estimated effects, refer to Phase 1, Literature Review, Appendices 3-5 (Tolsma *et al*. 2007).

Type	Common Name	Scientific Name	FFG	EPBC	VROTS	FIRE
Bird	Emu	*Dromaius novaehollandiae*				+S,+A
Bird	Brown Quail	*Coturnix ypsilophora*			n	+S,+A
Bird	Black-shouldered Kite	*Elanus axillaris*				
Bird	Square-tailed Kite	*Lophoictinia isura*	f		v	
Bird	Black Kite	*Milvus migrans*				
Bird	Whistling Kite	*Haliastur sphenurus*				
Bird	Brown Goshawk	*Accipiter fasciatus*				
Bird	Grey Goshawk	*Accipiter novaehollandiae*			v	
Bird	Collared Sparrowhawk	*Accipiter cirrhocephalus*				
Bird	Wedge-tailed Eagle	*Aquila audax*				
Bird	Little Eagle	*Hieraaetus morphnoides*				
Bird	Brown Falcon	*Falco berigora*				
Bird	Australian Hobby	*Falco longipennis*				
Bird	Grey Falcon	*Falco hypoleucos*	f		e	
Bird	Black Falcon	*Falco subniger*			v	
Bird	Peregrine Falcon	*Falco peregrinus*				
Bird	Nankeen Kestrel	*Falco cenchroides*				
Bird	Little Button-quail	*Turnix velox*			n	+S,+A
Bird	Painted Button-quail	*Turnix varia*				+S,+A
Bird	Bush Stone-curlew	*Burhinus grallarius*	f		e	-S
Bird	Common Bronzewing	*Phaps chalcoptera*				
Bird	Crested Pigeon	*Ocyphaps lophotes*				
Bird	Diamond Dove	*Geopelia cuneata*	f		n	
Bird	Peaceful Dove	*Geopelia striata*				
Bird	Yellow-tailed Black-Cockatoo	*Calyptorhynchus funereus*				
Bird	Gang-gang Cockatoo	*Callocephalon fimbriatum*				
Bird	Galah	*Cacatua roseicapilla*				
Bird	Long-billed Corella	*Cacatua tenuirostris*				
Bird	Little Corella	*Cacatua sanguinea*				
Bird	Sulphur-crested Cockatoo	*Cacatua galerita*				

Bird	Cockatiel	*Nymphicus hollandicus*				
Bird	Musk Lorikeet	*Glossopsitta concinna*				
Bird	Little Lorikeet	*Glossopsitta pusilla*				
Bird	Purple-crowned Lorikeet	*Glossopsitta porphyrocephala*				
Bird	Superb Parrot	*Polytelis swainsonii*	f	V	e	
Bird	Crimson Rosella	*Platycercus elegans*				
Bird	Yellow Rosella	*Platycercus e. flaveolus*				
Bird	Eastern Rosella	*Platycercus eximius*				
Bird	Swift Parrot	*Lathamus discolor*	f	E	e	
Bird	Red-rumped Parrot	*Psephotus haematonotus*				
Bird	Blue-winged Parrot	*Neophema chrysostoma*				
Bird	Turquoise Parrot	*Neophema pulchella*	f		n	
Bird	Pallid Cuckoo	*Cuculus pallidus*				
Bird	Brush Cuckoo	*Cacomantis variolosus*				
Bird	Fan-tailed Cuckoo	*Cacomantis flabelliformis*				
Bird	Black-eared Cuckoo	*Chrysococcyx osculans*			n	
Bird	Horsfield's Bronze-Cuckoo	*Chrysococcyx basalis*				
Bird	Shining Bronze-Cuckoo	*Chrysococcyx lucidus*				
Bird	Powerful Owl	*Ninox strenua*	f		v	
Bird	Barking Owl	*Ninox connivens*	f		e	
Bird	Southern Boobook	*Ninox novaeseelandiae*				
Bird	Masked Owl	*Tyto novaehollandiae*	f		e	
Bird	Barn Owl	*Tyto alba*				
Bird	Tawny Frogmouth	*Podargus strigoides*				
Bird	White-throated Nightjar	*Eurostopodus mystacalis*				
Bird	Spotted Nightjar	*Eurostopodus argus*				
Bird	Australian Owlet-nightjar	*Aegotheles cristatus*				
Bird	White-throated Needletail	*Hirundapus caudacutus*				
Bird	Fork-tailed Swift	*Apus pacificus*				
Bird	Laughing Kookaburra	*Dacelo novaeguineae*				
Bird	Sacred Kingfisher	*Todiramphus sanctus*				
Bird	Rainbow Bee-eater	*Merops ornatus*				
Bird	White-throated Treecreeper	*Cormobates leucophaeus*				
Bird	Brown Treecreeper	*Climacteris picumnus*			n	-S,-A
Bird	Superb Fairy-wren	*Malurus cyaneus*				
Bird	Spotted Pardalote	*Pardalotus punctatus*				
Bird	Striated Pardalote	*Pardalotus striatus*				
Bird	White-browed Scrubwren	*Sericornis frontalis*				
Bird	Chestnut-rumped Heathwren	*Hylacola pyrrhopygia*	f		v	
Bird	Speckled Warbler	*Chthonicola sagittata*	f		v	
Bird	Weebill	*Smicrornis brevirostris*				
Bird	Western Gerygone	*Gerygone fusca*				
Bird	Brown Thornbill	*Acanthiza pusilla*				
Bird	Chestnut-rumped	*Acanthiza uropygialis*				

	Thornbill					
Bird	Buff-rumped Thornbill	*Acanthiza reguloides*				
Bird	Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*				
Bird	Yellow Thornbill	*Acanthiza nana*				
Bird	Striated Thornbill	*Acanthiza lineata*				
Bird	Southern Whiteface	*Aphelocephala leucopsis*				
Bird	Red Wattlebird	*Anthochaera carunculata*				
Bird	Little Wattlebird	*Anthochaera chrysoptera*				
Bird	Noisy Friarbird	*Philemon corniculatus*				
Bird	Little Friarbird	*Philemon citreogularis*				
Bird	Regent Honeyeater	*Xanthomyza phrygia*	f	E	c	
Bird	Noisy Miner	*Manorina melanocephala*				
Bird	Yellow-faced Honeyeater	*Lichenostomus chrysops*				
Bird	White-eared Honeyeater	*Lichenostomus leucotis*				
Bird	Yellow-tufted Honeyeater	*Lichenostomus melanops*				
Bird	Fuscous Honeyeater	*Lichenostomus fuscus*				
Bird	White-plumed Honeyeater	*Lichenostomus penicillatus*				
Bird	Black-chinned Honeyeater	*Melithreptus gularis*			n	
Bird	Brown-headed Honeyeater	*Melithreptus brevirostris*				
Bird	White-naped Honeyeater	*Melithreptus lunatus*				
Bird	Painted Honeyeater	*Grantiella picta*	f		v	
Bird	Crescent Honeyeater	*Phylidonyris pyrrhoptera*				
Bird	New Holland Honeyeater	*Phylidonyris novaehollandiae*				
Bird	Tawny-crowned Honeyeater	*Phylidonyris melanops*				
Bird	Eastern Spinebill	*Acanthorhynchus tenuirostris*				
Bird	White-fronted Chat	*Epthianura albifrons*				
Bird	Jacky Winter	*Microeca fascinans*				
Bird	Scarlet Robin	*Petroica multicolor*				
Bird	Red-capped Robin	*Petroica goodenovii*				
Bird	Flame Robin	*Petroica phoenicea*				
Bird	Hooded Robin	*Melanodryas cucullata*	f		n	
Bird	Eastern Yellow Robin	*Eopsaltria australis*				
Bird	Grey-crowned Babbler	*Pomatostomus temporalis*	f		e	
Bird	White-browed Babbler	*Pomatostomus superciliosus*				
Bird	Spotted Quail-thrush	*Cinclosoma punctatum*			n	
Bird	Varied Sittella	*Daphoenositta chrysoptera*				
Bird	Crested Shrike-tit	*Falcunculus frontatus*				
Bird	Crested Bellbird	*Oreoica gutturalis*	f		n	
Bird	Gilbert's Whistler	*Pachycephala inornata*				
Bird	Golden Whistler	*Pachycephala pectoralis*				
Bird	Rufous Whistler	*Pachycephala rufiventris*				
Bird	Grey Shrike-thrush	*Colluricincla harmonica*				

Bird	Leaden Flycatcher	*Myiagra rubecula*				
Bird	Satin Flycatcher	*Myiagra cyanoleuca*				
Bird	Restless Flycatcher	*Myiagra inquieta*				
Bird	Magpie-lark	*Grallina cyanoleuca*				
Bird	Rufous Fantail	*Rhipidura rufifrons*				
Bird	Grey Fantail	*Rhipidura fuliginosa*				
Bird	Willie Wagtail	*Rhipidura leucophrys*				
Bird	Black-faced Cuckoo-shrike	*Coracina novaehollandiae*				
Bird	White-bellied Cuckoo-shrike	*Coracina papuensis*				
Bird	White-winged Triller	*Lalage sueurii*				
Bird	Olive-backed Oriole	*Oriolus sagittatus*				
Bird	White-breasted Woodswallow	*Artamus leucorynchus*				
Bird	Masked Woodswallow	*Artamus personatus*				
Bird	White-browed Woodswallow	*Artamus superciliosus*				
Bird	Black-faced Woodswallow	*Artamus cinereus*				
Bird	Dusky Woodswallow	*Artamus cyanopterus*				
Bird	Grey Butcherbird	*Cracticus torquatus*				
Bird	Pied Butcherbird	*Cracticus nigrogularis*				
Bird	Australian Magpie	*Gymnorhina tibicen*				
Bird	Pied Currawong	*Strepera graculina*				
Bird	Grey Currawong	*Strepera versicolor*				
Bird	Australian Raven	*Corvus coronoides*				
Bird	Little Raven	*Corvus mellori*				
Bird	White-winged Chough	*Corcorax melanorhamphos*				-S,-A
Bird	Singing Bushlark	*Mirafra javanica*				
Bird	House Sparrow*	*Passer domesticus*				
Bird	Zebra Finch	*Taeniopygia guttata*				
Bird	Double-barred Finch	*Taeniopygia bichenovii*				
Bird	Red-browed Finch	*Neochmia temporalis*				
Bird	Diamond Firetail	*Stagonopleura guttata*	f		v	
Bird	Mistletoebird	*Dicaeum hirundinaceum*				
Bird	Welcome Swallow	*Hirundo neoxena*				
Bird	Tree Martin	*Hirundo nigricans*				
Bird	Fairy Martin	*Hirundo ariel*				
Bird	Rufous Songlark	*Cincloramphus mathewsi*				
Bird	Silvereye	*Zosterops lateralis*				
Bird	Common Blackbird*	*Turdus merula*				
Bird	Common Starling*	*Sturnus vulgaris*				
Bird	Common Myna*	*Acridotheres tristis*				

Type	Common Name	Scientific Name	FFG	EPBC	VROTS	FIRE
Mammal	Short-beaked Echidna	*Tachyglossus aculeatus*				
Mammal	Yellow-footed Antechinus	*Antechinus flavipes*				
Mammal	Brush-tailed Phascogale	*Phascogale tapoatafa*	f		v	
Mammal	Fat-tailed Dunnart	*Sminthopsis crassicaudata*			n	
Mammal	Common Dunnart	*Sminthopsis murina*			v	
Mammal	Long-nosed Bandicoot	*Perameles nasuta*				
Mammal	Common Wombat	*Vombatus ursinus*				
Mammal	Koala	*Phascolarctos cinereus*				
Mammal	Common Brushtail Possum	*Trichosurus vulpecula*				
Mammal	Eastern Pygmy-possum	*Cercartetus nanus*				
Mammal	Sugar Glider	*Petaurus breviceps*				
Mammal	Squirrel Glider	*Petaurus norfolcensis*	f		e	
Mammal	Common Ringtail Possum	*Pseudocheirus peregrinus*				
Mammal	Feathertail Glider	*Acrobates pygmaeus*				
Mammal	Western Grey Kangaroo	*Macropus fuliginosus*				+S
Mammal	Eastern Grey Kangaroo	*Macropus giganteus*				+S
Mammal	Black Wallaby	*Wallabia bicolor*				+S
Mammal	Southern Freetail Bat (lp)	*Mormopterus planiceps*				
Mammal	White-striped Freetail Bat	*Tadarida australis*				
Mammal	Gould's Wattled Bat	*Chalinolobus gouldii*				
Mammal	Chocolate Wattled Bat	*Chalinolobus morio*				
Mammal	Lesser Long-eared Bat	*Nyctophilus geoffroyi*				
Mammal	Gould's Long-eared Bat	*Nyctophilus gouldi*				
Mammal	Inland Broad-nosed Bat	*Scotorepens balstoni*				
Mammal	Large Forest Bat	*Vespadelus darlingtoni*				
Mammal	Little Forest Bat	*Vespadelus vulturnus*				
Mammal	House Mouse*	*Mus musculus*				
Mammal	Black Rat*	*Rattus rattus*				
Mammal	Feral Dog*	*Canis familiaris*				
Mammal	Red Fox*	*Canis vulpes*				
Mammal	Cat*	*Felis catus*				
Mammal	Brown Hare*	*Lepus capensis*				+S
Mammal	European Rabbit*	*Oryctolagus cuniculus*				+S

Type	Common Name	Scientific Name	FFG	EPBC	VROTS	FIRE
Reptile	Common Long-necked Tortoise	*Chelodina longicollis*				
Reptile	Tree Dragon	*Amphibolurus muricatus*				
Reptile	Eastern Bearded Dragon	*Pogona barbata*			d	
Reptile	Wood Gecko	*Diplodactylus vittatus*				
Reptile	Marbled Gecko	*Christinus marmoratus*				
Reptile	Southern Spiny-tailed Gecko	*Diplodactylus intermedius*				
Reptile	Thick-tailed Gecko	*Nephrurus milii*				
Reptile	Pink-tailed Worm-Lizard	*Aprasia parapulchella*	f	V	e	
Reptile	Striped Legless Lizard	*Delma impar*	f	V	e	-S
Reptile	Olive Legless Lizard	*Delma inornata*				-S
Reptile	Burton's Snake-Lizard	*Lialis burtonis*				-S
Reptile	Common Scaly-foot	*Pygopus lepidopodus*				-S
Reptile	Hooded Scaly-foot	*Pygopus schraderi*	f		c	-S
Reptile	Southern Rainbow Skink	*Carlia tetradactyla*				
Reptile	Carnaby's Wall Skink	*Cryptoblepharus carnabyi*				
Reptile	Large Striped Skink	*Ctenotus robustus*				
Reptile	Copper-tailed Skink	*Ctenotus taeniolatus*				
Reptile	Eastern Striped Skink	*Ctenotus orientalis*				
Reptile	Cunningham's Skink	*Egernia cunninghami*				
Reptile	Black Rock Skink	*Egernia saxatilis intermedia*				
Reptile	Tree Skink	*Egernia striolata*				
Reptile	White's Skink	*Egernia whitii*				
Reptile	Three-toed Skink	*Hemiergis decresiensis*				
Reptile	Garden Skink	*Lampropholis guichenoti*				
Reptile	Bougainville's Skink	*Lerista bougainvillii*				
Reptile	Grey's Skink	*Menetia greyii*				
Reptile	Boulenger's Skink	*Morethia boulengeri*				
Reptile	Blotched Blue-tongued Lizard	*Tiliqua nigrolutea*				
Reptile	Common Blue-tongued Lizard	*Tiliqua scincoides*				
Reptile	Stumpy-tailed Lizard	*Tiliqua rugosa*				
Reptile	Sand Goanna	*Varanus gouldii*				
Reptile	Tree Goanna	*Varanus varius*			v	
Reptile	Carpet Python	*Morelia spilota metcalfei*	f		e	
Reptile	Peter's Blind Snake	*Ramphotyphlops bituberculatus*				
Reptile	Gray's Blind Snake	*Ramphotyphlops nigrescens*				
Reptile	Woodland Blind Snake	*Ramphotyphlops proximus*			n	
Reptile	Eastern Tiger Snake	*Notechis scutatus*				
Reptile	Red-bellied Black Snake	*Pseudechis porphyriacus*				
Reptile	Eastern Brown Snake	*Pseudonaja textilis*				
Reptile	Dwyer's Snake	*Suta dwyeri*				
Reptile	Little Whip Snake	*Suta flagellum*				
Reptile	Mitchell's Short-tailed Snake	*Suta nigriceps*				
Reptile	Bandy Bandy	*Vermicella annulata*	f		n	

Type	Common Name	Scientific Name	FFG	EPBC	VROTS	FIRE
Frog	Plains Froglet	*Crinia parinsignifera*				
Frog	Common Froglet	*Crinia signifera*				
Frog	Sloane's Froglet	*Crinia sloanei*				
Frog	Southern Bullfrog	*Limnodynastes dumerilii*				
Frog	Spotted Marsh Frog	*Limnodynastes tasmaniensis*				
Frog	Barking Marsh Frog	*Limnodynastes fletcheri*			d	
Frog	Mallee Spadefoot Toad	*Neobatrachus pictus*				
Frog	Common Spadefoot Toad	*Neobatrachus sudelli*				
Frog	Brown (Bibron's) Toadlet	*Pseudophryne bibronii*			e	-A
Frog	Southern Toadlet	*Pseudophryne semimarmorata*			v	-A
Frog	Southern Brown Tree Frog	*Litoria ewingii*				
Frog	Plains Brown Tree Frog	*Litoria paraewingi*				
Frog	Peron's Tree Frog	*Litoria peronii*				
Frog	Growling Grass Frog	*Litoria raniformis*	f	V	e	

APPENDIX 4. Glossary of Terms

Adaptive Management Cycle	The systematic process for continually improving management policies and practices by learning from the outcomes of operational programs. In its most effective form (Adaptive Experimental Management), it employs management programs that are designed to experimentally compare selected policies or practices, by evaluating alternative hypotheses about the system being managed.
Age class distribution	The actual distribution of the proportion/area of the classes (groups of similar age) of a particular vegetation type or community. This is usually represented as a plot of area (y-axis) versus age class (x-axis).
Biodiversity	The variety of life forms: the different plants, animals and microorganisms, the genes they contain and the ecosystems they form.
Burn Objectives	A set of objectives, stipulated in a Burn Plan, that specify particular burn parameters (e.g. fire intensities, area burnt, patchiness etc) which are necessary to achieve the overall protection and/or biodiversity goals. These objectives are distinct from the Ecological Management Objectives (see below).
Burn Plan	The plan which, in the required Departmental format, is approved for the conduct of prescribed burning and contains a map identifying the area to be burned and incorporates the specifications and conditions under which the operation is to be conducted.
Burning unit	A specific land area for which prescribed burning is planned.
Ecological burn	Treatment of vegetation in nominated areas by use of fire, primarily to achieve specified ecological objectives.
Ecological Burn Plan	A burn plan (see above) which specifically addresses the ecological parameters, standards and objectives for a prescribed burn carried out for ecological purposes.
Ecological Fire Strategy	A document that utilises the key steps for Local Area Planning, as presented in these Guidelines, and sets forth a plan and nominates areas for burning based on ecological criteria.
Ecological Management Objective	An objective, stipulated in a Burn Plan, that specifies particular ecological outcomes (e.g. population abundances, species composition, habitat structure) which are desired as a result of the burn. These are distinct from the Objectives of the Burn (see Burn Objectives, above).

Ecological Vegetation Class (EVC)	A level within a hierarchical vegetation classification system identified on the basis of floristics, vegetation structure and environmental and ecological features. An EVC may comprise one or a number of floristic communities that exist within a common set of ecological processes and habitat variables and may occur across a number of biogeographical zones. Areas of the same EVC manifest similar lifeforms, genera, families, vegetation structure, and landscape position.
Ecological Vegetation Class Group (EVC Group)	A collection of EVCs with broadly similar environmental features, used to simplify presentation or consideration of EVC data (e.g. on a 1:250 000 statewide map). In the context of ecological management of fire, EVCs which have similar (or the same) Key Fire Response Species and similar Tolerable Fire Intervals/Fire Cycles, generally have similar structure, occur in the same bioregion and share dominant and character species.
Extant .	Still existing; not destroyed
Fire behaviour	The manner in which a fire reacts to variations in fuel, weather and topography. Common measures of fire behaviour are "rate of spread", "flame height", "fire spotting distance" and "intensity".
Fire cycle	A time period, approximately half the maximum Tolerable Fire Interval, over which an area equivalent to the total area of a community/ vegetation type/area is burnt. It is not the frequency at which each segment of a community/vegetation type/area is to be regularly/ repeatedly burnt.
Fire ecology	The study of the inter-relationships between fire and the biota.
Fire history	The record of fire events over time at a particular site or over a particular area or vegetation type. This is best depicted in spatial form using maps or computer-based Geographic Information Systems.
Fire intensity	The heat (kilowatts) released per metre of fire front; generally classified as low (<500 kWm-1), moderate (500-3000 kWm-1), high (3000-7000 kWm-1) or very high (7000-70,000 kWm-1).
Fire interval	The time period between successive fires at a particular site or over a particular area or vegetation type. (A sub-component of this is the fire period which is the fire interval averaged over a number of fires.)

Fire management	All activities associated with the management of fire-prone public land values, including the use of fire, to meet land management goals and objectives.
Fire Management Unit	A unit of land upon which a specific fire management strategy is planned. Each unit will usually be defined by distinct topography and vegetation characteristics and will therefore allow for accurate and meaningful recording of fire history and other environmental data.
Fire Operations Plan	The plan of all prescribed burns and other fire management works to be conducted over the next 3-year period for a DSE Fire District. It includes ecological burns.
Fire prevention	All activities concerned with minimising the incidence of wildfire.
Fire protection	All activities designed to protect an area (including human life, property, assets and values) from damage by wildfire.
Fire Protection Plan	A plan prepared by the Department for the purpose of planning proper and sufficient works for the prevention and suppression of wildfire on public land. The plan is strategic in its approach, addressing fire protection at a regional (geographic) level.
Fire refuge	Areas in the landscape where fauna and flora can escape the effects of fire. Examples include some rocky areas and wetlands that do not burn and fire shadows (see below). Also used to describe areas that offer protection to humans during wildfires.
Fire regime	The season, intensity, frequency and scale of fire in a given area over a period of time. Some definitions also include the type of fire viz. solely above ground vs also consuming the organic layer of soil.
Fire scale	The areal extent of fire within a particular landscape or vegetation type.
Fire season	The time of year or season in which a fire occurs.
Fire sensitive species	Species of plants and animals whose life history attributes (see below) render them intolerant of fire.
Fire shadow	Areas in the landscape sheltered and protected from fire by natural features. Examples include some leeward aspects of hillsides and deep gullies.

Fire suppression	Activities connected with restricting the spread of wildfire and making it safe (=fire control).
Floristic community	An assemblage within a hierarchical vegetation classification system identified on the basis of the plant species present. This may comprise one or more sub-communities and reflects the vegetation's response to environmental influences (e.g. geology, soils, aspect and disturbances such as fire) at the regional or sub-regional scale.
Fuel Management Zone	DSE determined areas for hazard and/or ecosystem management by prescribed burning.
Fuel reduction burning	The planned use of fire to reduce fuel loads in a specified area (often also described as prescribed burning).
Key fire response Species	Those species whose life histories or vital attributes (see below) indicate that they are vulnerable to either a regime of frequent fires or to long periods of fire exclusion.
Landscape Management Unit	An individual remnant or cluster of remnants, for which assessment is required. This may be further divided into Logical Burning Units.
Life history	The combination of attributes with respect to growth, shelter, food/ nutrients and reproduction which determine a species requirements for existence.
Logical Burning Unit	A fire management unit used to conduct ecological burning. Such a unit is defined on the basis of biophysical parameters and operational and resourcing considerations (including safety) and/or by the distributions of the metapopulations of the key fire response species or other significant species (e.g. those rare or threatened).
Mosaic Landscape	An heterogeneous landscape comprising different patches; varying both in space and time with regard to time-since-fire &/or developmental stage.
Obligate	Necessarily so; no option(s).
Prescribed burning	The controlled application of fire under specified environmental conditions to a predetermined area and at the time, intensity and rate of spread required to attain planned resource management objectives (see also fuel reduction burning).
Protection burning	See fuel reduction burning.
Public land	All State forest, national park and protected public land as defined by section 3 of the Forests Act 1958, except that managed by the Victorian Plantations Corporation or its successors.

Rare or threatened	When used in the context of species or communities of flora or fauna, refers to those indigenous species or communities which are listed under schedule 2 of the Flora and Fauna Guarantee Act 1988 and/or on other lists maintained by the Department, including lists of vulnerable or endangered species.
Senescing/senescent	Growing old, over-mature, degrading concomitant with age or dying.
Species composition	The different types of species which make up a community assemblage in an area.
Species richness	The number of species in an area.
Structural diversity	Variety in a vegetation type that results from layering or tiering of the canopy and understorey and the dieback, death and ultimate decay of trees.
Succession	The directional and continuous series of changes in the composition of the populations and species of plants and animals in an area. Secondary succession, which occurs after disturbances such as fire, describes cases where well-developed soil and seeds/spores remain from which early successional vegetation re-emerges.
Suppression	See 'Fire suppression'.
'Theoretical' age class Distribution	The age class distribution (see above) which mathematically arises through the random application of fire (or other disturbance) to any area of vegetation. This distribution takes the form of a negative exponential (inverse-J) relationship. It is 'theoretical' in the sense that it cannot be achieved in the field, but provides a broad guideline for fire management planning.
Threatened	see Rare or Threatened.
Tolerable Fire Intervals	The maximum and minimum intervals for fire disturbance across an area or vegetation type which are within the limits set by the constituent species' life histories (see above). These guide how frequent fires need to be in the future to allow persistence of all species at the site.

Triage approach	An approach based on the premise that effective conservation planning must avoid the allocation of scarce resources to areas/assets that will fail to persist regardless of actions taken to protect or manage them. Assigns action to one of three categories: 1. Those which can be helped by action, 2. Those which will probably persist without action, 3. Those which are likely to continue to decline regardless of the amount of action.
Vital attributes	Vital attributes are the key life history features which determine how a species lives and reproduces. With respect to fire, these attributes govern how a species responds to fire and/or persists within a particular fire regime.
Wildfire	An unplanned grass, scrub or forest fire.