VEGETATION DYNAMICS IN THE NORTHERN EXTREMITIES OF THE AUSTRALIAN ALPS AFTER THE 2003 FIRES: THE STORY SO FAR

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Abstract
A post-fire monitoring project between CSIRO and NSW DEC is measuring and assessing the impacts on and recovery of floristic composition and vegetation structure after the 2003 fires in Bimberi Nature Reserve, Brindabella National Park and Burrinjuck Nature Reserve in the northern extremities of the Australian Alps. The research aims to measure and detect any long term changes to composition and structure that may have resulted from the fires and to also detail short and medium term impacts and recovery times of species and communities. Of particular focus are species of conservation significance and species which are sensitive to either frequent fires or fires of an inappropriate intensity to allow germination of the soil seed bank. The majority of pre-existing sites in the three reserves were re-sampled after the fires in 2003-2004 and long term monitoring has being undertaken on a sub-sample of sites, selected to cover the range of vegetation types and within each vegetation type, low and high fire intensities. This paper summarises the responses to date of selected fire-killed plant species and the impacts of the fires on plant species that are rare or threatened or at their distributional limits. A discussion of the implications of primary and secondary juvenile periods as they affect compositional and structural change on the sites selected for long-term monitoring is presented and the implications in the medium to long term for fire management are discussed.

Introduction
The wildfires of January 2003 burnt through large areas of the Australian Alps, including National Parks and Nature Reserves to the west and north-west of Canberra. A long term post-fire monitoring project was established (Doherty & Wright 2004) to measure and assess the impacts on, and recovery of, flora and vegetation after the 2003 fires in Bimberi Nature Reserve, Brindabella National Park and Burrinjuck Nature Reserve. These reserves occur at the northern extremities of the Australian Alps and as such contain a spectrum of dry tableland, montane and subalpine vegetation types and many plant species at their northern distributional limits. While the 2004-2005 and 2005-2006 sampling periods continued to collect data which will form the basis of a longer term analysis of fire impacts using multivariate methods, the short term qualitative results of this re-survey provide an opportunity to further gauge the immediate post-fire responses of plant species and to record further details on basic plant fire responses and also data on primary and secondary juvenile periods, although species responses over a number of years will need to be tabulated before there is a complete record of primary and secondary juvenile periods for the majority of species found in the study area. The main focus of this paper is to summarise the responses to date of fire-killed plant species and the impacts of the fires on regionally significant plant species such as those that are rare or threatened or plant species at their distributional limits, which were identified in Doherty (1998a, 1998b).

Materials and Methods
Although all but 7 out of a potential 163 sites in the three reserves were re-sampled after the fires in the 2003-2004 sampling period (Doherty & Wright 2004), the expense and logistics of re-sampling the entire array of sites every season led to long term monitoring being undertaken on a sub-sample of 52 sites. This subset of sites has been selected to cover the range of vegetation types in the study area and within each vegetation type, sites have been selected to cover the range fire intensities from low to high. Site selection was based on re-sampling at least 2 low and 2 high intensity sites within each vegetation type or, if there were 4 or less sites in a vegetation type then 1 low and 1 high intensity fire site were sampled and if only 1 site occurred in vegetation type, then that site was sampled. Low intensity sites were defined as those with <35% scorch of original canopy height; medium as 35-70% scorch of original canopy height and high as >70% scorch of original canopy height. A total of 39 sites in Bimberi and Brindabella and 13 sites in Burrinjuck were re-sampled in Spring-Summer 2004-2005 and 2005-2006 based on the above criteria. As per previous sampling on the sites, full floristic information with an estimation of cover abundance on a 6 point modified Braun-Blanquet scale was collected for all species. Sites were laid out as previously as either 20m x 20m sites or as 40m x 10m sites along creeklines. Structural data and dominant species

were also collected for each layer. For each of the 52 sites, site photographs were re-taken at the rear of each plot and post-fire photos were taken up and down slope from the centre of each plot.

Results and Discussion

As reported in the previous survey for the 2003-2004 sampling season (Doherty & Wright 2004), 80% of the plant species in the study area are re-sprouters and only 20% are obligate seeders. It is this 20% component that in the short to medium term needs to be monitored to establish whether there has been a detrimental impact of the fires on populations of these species and whether adequate recruitment is occurring to replace fire killed adult populations. Of this 20%, there are some common native opportunistic species and many exotic annual species for which there should be no immediate management concern, as the population responses appear to be either adequate for recovery in the former cases (e.g. *Gynatrix pulchella*, *Ranunculus pumilio* subsp. *pumilio* and *Ranunculus sessiliflorus*) or non-invasive and opportunistic in the latter cases (e.g. *Conyza* spp., *Cirsium vulgare*).

Responses of Fire-Killed Native Species

The fire responses of plant species in the study area were tabulated in Appendix 1 of Doherty and Wright (2004). Those native species which are fire-killed (i.e. Gill 1998 categories 1 and 2 - but excluding species with an annual response) and which occur at less than 10 sites or else do not occur in sites at all, have been investigated for their response to date (Table 1). Fire-killed species not occurring at sites were sampled at known pre-fire populations.

Table 1. Fire-Killed Native Species (Gill 1998 Categories 1 and 2) in Bimberi, Brindabella and Burrinjuck

Species	Sampled in Sites	Canopy Seed Bank	Soil Seed Bank	First Seedlings 2003-2004	First Seedlings 2004-2005
Banksia marginata [A]	✓ 1 (Brind 095)	✓		No seedlings	No seedlings
Calytrix tetragona	✓ 1 (Burr 27)	✓		✓	
Dillwynia phylicoides [B]	✓ 5 sites		✓	✓	
Dillwynia sericea [B]	✓ 3 sites		✓	✓	
Casuarina cunninghamiana [C]	✓ 1 (Brind 072)	✓		No seedlings	No seedlings
Eucalyptus delegatensis	✓ 7 sites	✓		✓	
Grevillea oxyantha	✓ 1 (Brind 014)		✓	✓	
Grevillea victoriae	✘		✓	Not re-surveyed	Not re-surveyed
Hovea asperifolia subsp *asperifolia* [B]	✓ 1 (Brind 077)		✓	✓	
Leptospermum grandifolium	✓ 1 (Brind 056)	✓		No seedlings	No seedlings
Leptospermum micromyrtus	✓ 1 (Brind 022)	✓		✓	
Micrantheum hexandrum	✘ Rocky Outcrops		✓		✓
Ozothamnus stirlingii	✓ 1 (Brind 067)		✓	✓	
Phebalium lamprophyllum	✘ Rocky Outcrops		✓		✓
Phebalium squamulosum subsp. *ozothamnoides*	✓ 1 (Brind 022)		✓		✓
Prostanthera lasianthos	✓ 5 sites		✓	✓	
Prostanthera rotundifolia	✘ Rocky Outcrops		✓		✓
Prostanthera ? *cryptandroides*	✘ Rocky Outcrops		✓	Not re-surveyed	Not re-surveyed
Prostanthera sp. aff. *rugosa*	✘ Rocky Outcrops		✓		✓
Westringia eremicola	✓ 1 (Burr 27)		✓	✓	

[A] Some populations of *Banksia marginata* in Namadgi NP are re-sprouting - intermediate age cohorts.

[B] These leguminous species are likely to have a long-lived seed bank.

[C] *C. cunninghamiana* has re-sprouted after being 100% leaf scorched in many instances, but many of the trees have subsequently died, possibly 50%.

These species are deemed either potentially vulnerable due to low population levels and some are also major structural components of vegetation types. Approximately half (55% - 11 out of 20) of the fire-killed native species are found on rocky outcrops and are associated with heath communities and some of these species also form the major structural dominants in these communities e.g. *Leptospermum micromyrtus* on Mt. Coree in Brindabella National Park and *Calytrix tetragona* and *Westringia eremicola* in Burrinjuck Nature Reserve. Along the Baldy Range in Brindabella National Park, re-sprouting species such as *Callistemon pallidus*, *Kunzea ericoides* and *Kunzea parvifolia* also occur in some of these rocky outcrop heath communities but the bulk of the vegetation on most of these outcrops is comprised of fire-killed species such as *Micrantheum hexandrum*, *Phebalium lamprophyllum*, *Phebalium squamulosum* subsp. *ozothamnoides* and *Prostanthera rotundifolia*. The preponderance of fire-killed species on rocky outcrops may reflect the fact that these areas seldom burn and when they do, it is likely to be under conditions of high fire intensity. Clarke (2002) found that rocky outcrops in the Sydney Basin, New England Tablelands, SW Western Australia and Kakadu National Park all shared similar characteristics of being islands of fire-killed species in a sea of re-sprouting species. Clarke stresses that these rocky outcrops are not fire refugia as such, but are areas that experience less frequent fire occurrence. The rocky outcrops found in the Brindabella and Burrinjuck areas show similar characteristics with a high proportion of fire-killed plant species on rocky outcrops as compared to the surrounding forest matrix. On inspection one year post-fire in the 2003-2004 sampling season, there was no obvious germination or establishment of fire-killed species in these rocky outcrop communities other than *Leptospermum micromyrtus* on Mt. Coree. However, by the second sampling season post-fire in 2004-2005, all of these species had germinated and established. By late 2004 on the Baldy Range, *Callistemon pallidus* and *Kunzea parvifolia* had re-sprouted and in the latter case flowered and advanced seedlings of *Phebalium lamprophyllum, Phebalium squamulosum* subsp. *ozothamnoides* and *Prostanthera rotundifolia* were evident. Similarly, the rocky outcrops to the west of Blue Range Road had a good seedling response from fire-killed species. As with the Baldy Range rocky outcrops, by December 2004 re-sprouters such as *Kunzea ericoides* had responded and there were also advanced seedlings of *Calytrix tetragona, Leptospermum brevipes, Leptospermum micromyrtus, Micrantheum hexandrum, and Phebalium lamprophyllum.* There was some adult survival (a few individuals) in *Calytrix tetragona* and *Leptospermum micromyrtus* in these outcrops where the fire was patchy but overall most adult plants had been fire killed. Additionally, there was also recruitment of *Oxylobium ellipticum* which is a re-sprouter but being a legume with a soil stored seed bank, the intensity of the fire has stimulated both re-sprouting and germination of the species. A similar effect can be noted in *Daviesia mimosoides*. Of particular significance at the Blue Range Road location is the re-emergence in the second sampling season of *Prostanthera* sp. aff *rugosa*, which is an undescribed rare species restricted to this locality. Although no response was evident in 2003-2004, by 2004-2005 many advanced seedlings were evident in the rocky outcrops where this species is found and there appears to be very successful recruitment and growth in this species. As with the Mt. Coree heath, the major structural elements in the heath in Burrinjuck Nature Reserve had germinated by the first sampling period post-fire and by the second sampling period, the seedlings of *Westringia eremicola* had grown substantially, up to 25 cm in height. In some instances where this species was growing in a more protected environment above the rocky outcrop under Broad-leaved Peppermint (*Eucalyptus dives*), the species had flowered giving it a primary juvenile period of less than 2 years, but this would appear to be an exceptional case and is not typical or ‘average’ for the species. Although not a rare or particularly restricted species as such, *Eucalyptus delegatensis* is fire-killed under full canopy scorch and is potentially vulnerable to failed recruitment post-fire given that it has canopy seed bank, or else the loss of saplings if a second fire occurs before the tree reaches sexual maturity, which may take 20 or 30 years. Of the stands in the study area, including Namadgi National Park, possibly 30% were killed by the fires. However, in the fire-killed stands investigated, there were signs of germination and recruitment by the end of 2003 and by early 2004 the most advanced saplings were over 1.5 metres high (Doherty & Wright 2004). Although appearing patchy in places, there appears to be good overall recruitment of *Eucalyptus delegatensis* in fire-killed stands and despite continuing drought conditions, growth has been rapid. One species of concern in the study area is *Banksia marginata* which is generally fire-killed and has a canopy seed bank, although there are some re-sprouting populations in the adjacent Namadgi National Park. This species was originally (pre-fire) recorded on only one plot (Brindabella 095) and so far no germination has occurred of this species on that plot, although some scattered individuals in the vicinity outside the plot survived the fire, but no recruitment is evident. Past fire history (last 150 years) may have reduced the populations of this species to very low levels in the region and hence it is a potential a candidate for local extinction, notwithstanding some re-sprouting populations in Namadgi National Park.

The species considered so far have had either a canopy seed bank or else a cryptic and potentially short-lived soil seed bank. In contrast, the native legumes tend to have a long lived soil seed bank and it is recognised that intense fires readily stimulate germination. *Dillwynia phylicoides* was present as mature adults before the fires and readily germinated after the fires in Burrinjuck Nature Reserve with rapid growth into the second season post-fire. Rapid growth has also occurred in the less common *Dillwynia sericea* which occurs in Burrinjuck Nature Reserve. Specimens of both species have attained heights of 15 to 20 cm, two seasons post fire and their local persistence appears likely. One of the most variable and perhaps negative responses has been that of *Casuarina cunninghamiana*. As discussed in Doherty & Wright 2004, this species had originally re-sprouted after the fires where it had been scorched but not charred, which was surprising given that the species is rarely exposed to 100% leaf scorch. However, the subsequent year has seen many of these individuals die. Brindabella 072 on the Goodradigbee River had some large specimens of this species in and adjacent to the plot all of which re-sprouted but most of which have subsequently died. The phenomenon is not uniform and there are still individuals that have successfully re-sprouted and are regaining their canopy. Similarly, particularly along the Goodradigbee, there are many individuals which escaped the effects of the fire. Of concern is the fact that there is little recruitment of this species along most of the regions' rivers due to altered flow regimes, particularly along the Murrumbidgee. The Goodradigbee is the only major unregulated river in the region and it will be interesting to see if there is regeneration along the banks given the sediment pulses occurring from post-fire erosion in places. It is these sand and sediment banks that typically favour the regeneration of River Oak after flood events. Of particular management importance in the immediate years post-fire are those plant species which are uncommon, rare or threatened or at their distributional limits in the study area. Doherty (1998a, 1998b) listed species of conservation significance for the Bimberi, Brindabella and Burrinjuck areas and the post-fire responses to date of these species are summarised in Table 2. Of the 25 species of conservation significance, 15 have responded to the fires adequately so far through re-sprouting or seedling germination, 4 have shown no response to date where surveyed and 6 remain to be surveyed in the next sampling season.

Recruitment Failures and Post-fire Thinning of Seedlings

Although the focus of the previous discussion has been on the recruitment of fire-killed species of conservation significance, there is at least one instance where there has been a failure of recruitment in a major understorey component, at least at the plot level. Although *Daviesia mimosoides* formed a distinct layer pre-fire on Brindabella 068, the fire has killed the adult plants and there is no evidence of re-sprouting and germination of only one or two individuals at the site. Although the fire did not crown at this site, the understorey was completely burnt, so whether the fire was hot enough to kill the plants but not hot enough to stimulate the seed bank is an open question. The time since last fire may be an important factor in this particular case. Overall, the species is adequately re-sprouting and coming back from soil stored seed over the study area generally. In contrast to this example of germination failure, Brindabella 022 on Mt. Coree had significant mass recruitment of *Leptospermum micromyrtus* one year after the fire, but the majority of these individuals have subsequently died and hence recruitment has been significantly diminished at this site, although there were at the 2005-2006 survey some few individuals whose survival and growth should still lead to canopy dominance of this species at the site. In Burrinjuck, some areas of very dense seedling recruitment of *Eucalyptus bicostata* which germinated in existing (pre-fire) sapling stands have been virtually eliminated by insect attack but in other areas, there are still dense thickets of healthy *Eucalyptus bicostata* with post-fire saplings up to 8 m in height and showing no signs of self-thinning in the short term. Not surprisingly, this variability of response over both space and time reinforces the point that any assessment of impact from the 2003 fires can only be gauged over the long term and then only in the context of the timing and intensity of the next fire.

Responses of Species Normally Uncommon or of Low Abundance

In most if not all vegetation types, a small number of species - the structural dominants - provide the bulk of cover or biomass at a given point in time. Hence, while there may be anywhere between 15 to over 100 or more vascular plant species occurring on a given 20 m by 20 m site, the bulk of vegetation cover is provided by only a small number of these species. However, when fires of moderate to high intensity occur in vegetation, these structural dominants may take many years to recover their biomass and this provides an opportunity for other plant species to respond during that time and to grow, flower and reproduce. At the individual plant level, the ability of plant species to recover from fires of even high intensity gives the vegetation types that they constitute a level of resilience to disturbance (Holling 1973; Walker 1995). More broadly though, at the ecosystem level, the aggregated responses of what may have previously been uncommon plant species can provide ecosystem resilience to erosion

Table 2. Post-fire Responses for Species of Conservation Significance

Species	Conservation Significance	Status Post-fire
Acacia pravissima (Fabaceae)	Northern limit	Adequately re-sprouting where sampled (Brindabella 070; 078; 115).
Ammobium craspedioides (Asteraceae).	Nationally listed: 2V	Adequately re-sprouting and flowering where sampled (Burrinjuck 09) and apparent in many other locations, particular in the vicinity of Burrinjuck 32.
Blechnum patersonii (Blechnaceae)	Western edge of range	UNKNOWN. Needs field checking in Coree Creek.
Caladenia sp. aff. *concolor* (Orchidaceae)	Nationally listed: 3VCi	UNKNOWN. Needs field checking by orchid expert at known locations.
Eucalyptus bicostata (Myrtaceae).	Disjunct population	Prolific regeneration by epicormics, coppicing and seedlings.
Eucalyptus camphora subsp. *humeana* (Myrtaceae).	Eastern distributional limit	Adequately re-sprouting and some seedling recruitment where sampled (Brindabella 007).
Eucalyptus delegatensis (Myrtaceae)	Northern limit	Most populations did not suffer crown scorch (Brindabella 029; 038; 046; 048; 068; 069. Where crown scorch did occur (Brindabella 065), tree death ensued. There appears to be adequate seedling recruitment on the site and in the surrounding stands of Alpine Ash.
Eucalyptus fastigata (Myrtaceae)	Approaching western limit	Most populations did not suffer crown scorch. Where crown scorch did occur trees are adequately re-sprouting via epicormics where sampled and as observed in adjacent areas.
Gingidia harveyana (Apiaceae)	Local northern limit	Adequately re-sprouting where sampled (Brindabella 044).
Grevillea oxyantha (Proteaceae)	Northern limit	Adequate germination from seed where sampled (Brindabella 014).
Grevillea victoriae (Proteaceae)	Northern limit	UNKNOWN. Needs field checking at the Waterfall Creek locality.
Hakea lissosperma (Proteaceae)	Northern limit	Adequately re-sprouting from root suckers in northern end of Bimberi Nature Reserve.
Leptospermum micromyrtus (Myrtaceae).	Northern limit	Fire killed in sampled populations (Brindabella 022) with early seedling recruitment but reduced establishment occurring. Also killed in other rocky outcrop areas but recruitment and establishment occurring. Sensitive to a second fire before reaching sexual maturity, which may be 5-10 years and will need monitoring to assess success of re-establishment.
Leucopogon gelidus (Epacridaceae).	Northern limit	NO RESPONSE so far at sites sampled (Brindabella 043; 045; 090). Third year sample needs to target these sites to check for establishment.
Orites lancifolia (Proteaceae)	Northern limit	UNKNOWN. Needs field checking in the highest parts of Bimberi NR.
Ozothamnus stirlingii (Asteraceae)	Northern limit	Adequately regenerating from seed in the vicinity of sampled plot (Brindabella 067).
Podolobium alpestre (Fabaceae)	Northern limit	Adequately re-sprouting where sampled (Brindabella 043; 045).
Persoonia subvelutina (Proteaceae)	Northern limit	NO RESPONSE so far at sites sampled (Brindabella 045). Third year sample needs to target this site to check for establishment.
Pimelea pauciflora (Thymelaeaceae).	Northern limit	NO RESPONSE so far at sites sampled (Brindabella 078; 087). Third year sample needs to target these sites to check for establishment.
Pimelea ligustrina subsp. *ciliata* (Thymelaeaceae).	Northern limit	NO RESPONSE so far at sites sampled (Brindabella 044). Third year sample needs to target this site to check for establishment.
Pomaderris betulina subsp. *actensis* (Rhamnaceae).	Newly described rare species.	UNKNOWN. Needs field checking in the vicinity of creeks leading into Lake Burrinjuck.
Prostanthera ? *cryptandroides* (Lamiaceae).	Undescribed and rare species	UNKNOWN. Needs field checking in known locations.
Prostanthera sp. aff. *rugosa* (Lamiaceae).	Undescribed and rare species	No germination within 1 year of the fire, but significant germination within two years of the fire at the only known locality and the species has regenerated well.
Pultenaea juniperina (var. *mucronata*) (Fabaceae).	Northern limit	Adequately re-sprouting where sampled in 5 out of 8 plots (Brindabella 097, 103, 111, 115, 126); no response to date in 3 out 8 plots (Brindabella 095, 112, 122).
Wahlenbergia gloriosa (Campanulaceae)	Northern limit	Adequately re-sprouting at all sites sampled (Brindabella 044; 065).

and exotic species invasion. This ability of ecosystems to provide suites of species that respond in similar functional ways to disturbance has been termed ‘ecological redundancy’ (Walker 1992) in that the more species and the wider the variety of plant responses present in an ecosystem, the more likely it is that the ecosystem can recover from disturbance and avoid degradation by functional substitution of one species for another, particularly in the short term. An example of this phenomenon in the study area is provided by two species: *Stellaria pungens* in the Brindabella area and *Wurmbea biglandulosa* in the Burrinjuck area. In the case of *Stellaria pungens*, the species responded rapidly after the fires by resprouting and was flowering and fruiting within one year of the fires. This species ultimately provided extensive areas of high cover in the northern Brindabellas and potentially reduced the amount of rain splash and erosion that would have occurred in the absence of a rapid recovery of plant cover. *Wurmbea biglandulosa* also responded in a similar way in the Burrinjuck area and although more patchy in distribution than *Stellaria pungens*, nevertheless provided significant cover rapidly after the fires. Further rapid recovery of a variety of forbs, herbs and grass species has led to a high degree of soil stability in the immediate post fire environment in the study area. Although rains immediately after the fires led to significant erosion in areas of sedimentary and granitic geology to the west and south, the rapid recovery of plants on the volcanic geology of the central and northern Brindabellas has led to a consistent yield of high quality water from the burnt areas.

Conclusions

The basic documentation of plant responses to fire including primary and secondary juvenile periods is critical to managing biodiversity for both planned and unplanned fire events. While rules of thumb such as Gill and Nicholls (1989) doubling of primary juvenile periods can assist in determining burning intervals, such time interval data should be seen as minimal times between fire events rather than optimal times between fire events. In the case of high intensity fire events such as those of 2003, additional time is required for full canopy recovery in those communities most affected by crown fire before any future planned fires are considered. This is particularly the case in some of the intensely burnt drier forest types, which may be the subject of planned fuel reduction burns in the future, but which may require from 10 to 15 years post 2003 to achieve full crown recovery. A similar situation exists in relation to swamp and heath communities which may also take 10 to 15 years to achieve a pre-fire structure and composition (Wahren, Papst & Williams 2001). In areas of fire-killed Alpine Ash (*Eucalyptus delegatensis*) fire exclusion, if possible, will be desirable for upwards of 20 years to allow stands to gain sufficient height to withstand low intensity burns and achieve sexual maturity and a canopy seed bank. Although there are some potential management issues such as the death and failure of re-sprouting in *Casuarina cunninghamiana*, it is still too early to determine the population impacts of such a response, given not all individuals are affected nor are entire stretches of riverine habitat treeless. At this stage post-fire, the overall observed adequate recovery of communities and species is consistent with that of Walsh and McDougall (2004) in their assessment of treeless subalpine vegetation in Kosciuszko National Park. This situation contrasts with more fire sensitive communities such as alpine bogs further to the south in Namadgi NP and Kosciuszko NP which have already received intensive post-fire management (Good 2004). In the short term, the results of monitoring will continue to be evaluated concentrating on both compositional change and structural recovery. The population recovery of obligate seeders in particular should be a focus of continued monitoring and assessment. and.

The flora and vegetation of the study area as surveyed to date is continuing to recover well, with further germination and recruitment of obligate seeder species which had not been recorded in the first year after the fire and continuing growth of seedlings, saplings and re-sprouts. However, notwithstanding these positive observed responses to date, it is premature to make definitive statements as to the long term outcomes for plant species or the compositional trajectories of plant communities, as only three seasons have elapsed since the January 2003 fires. The primary species of concern at present are River Oak (*Casuarina cunninghamiana*) which is exemplifying a failed recovery in places and *Banksia marginata* and *Leptospermum grandifolium* which appear to had very low pre-fire population levels and which no show a continuing lack of recruitment. Some sub-alpine species, e.g. *Pimelea* species in the Bimberi part of the study area, need to be investigated in the 2006-2007 sampling season as there has been no recruitment in these species to date post-fire, but late germination may be a factor in these instances as evidenced by other fire-killed species.

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