Understorey changes following fire at Myall Lakes, New South Wales

M.D. Fox

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Abstract

Fox, M.D. (National Herbarium of New South Wales, Royal Botanic Gardens, Australia 2000) 1988. Understorey changes following fire at Myall Lakes, New South Wales. Cunninghamia 2(1): 85-95. — Changes in understorey structure and composition of a series of 60 stands ranging in age from 1 month to 16 years since fire were examined at Myall Lakes National Park, New South Wales. Of the 122 vascular species encountered, 47% were obligate seedling regenerators while the remainder were vegetative regenerators. Height increased linearly with time and understorey cover re-established rapidly (due largely to *Pteridium esculentum* in the early years). Species richness was high immediately after fire, peaked at about 36 species after four years, dropped substantially at about ten years to climb to 39 species after 16 years. In contrast, plant species diversity peaked at about ten years and had dropped appreciably by 16 years.

Introduction

Fire is a conspicuous force in many Australian ecosystems and the literature on its effects on the biota is large (Gill, Groves & Noble 1981, and cited literature). However, there have been relatively few studies at the community level of the changes following fire. Classification of plant species by the mode of regeneration after fire has been used for at least 50 years, but few analyses of community composition using such classifications have been published.

This study was designed to analyse the response of a plant community to fire by considering the changes in composition of an open-forest understorey. The changes were assessed from the community attributes of species richness, diversity, and cover, as well as from a consideration of the mode of regeneration of the species. The study area was selected because it combined a relatively uniform substrate supporting a forest with different aged patches of regenerating understorey. Samples were taken in patches with different ages since fire. The same sampling technique has been used to monitor regeneration after sand-mining in the same forest (Fox & Fox 1984) and in nearby heathland (Fox & Fox 1978).

The study area

The forest grows on nutrient-poor Holocene sand near Seal Rocks (32°41'S, 152°09'E) in the Myall Lakes National Park, New South Wales. Seal Rocks is the northern limit of a triple embayment system bounded to the south by Hawkes Nest (Thom 1965). The sediment in the embayments is siliceous sand, the older Pleistocene horizon being heavily humate-impregnated and indurated, while the more recent Holocene deposits are in places lightly podzolized. In the Seal Rocks embayment the Holocene sand forms large transgressive sheets that have mantled the older surface. The northern and westward extent of this transgressive sheet is a high, long-walled ridge, Bridge Hill Ridge, which is in places over 100 m high.

The area experiences equable temperatures and some rain can be expected in every month (1352mm, 30 year annual average 1948–77, Sugarloaf Point 32°26'S, 152°32′E) with a peak in late autumn and early winter and moisture deficits through spring and summer.

The sand surface is forested with trees from 20 to 30 m tall having a basal area of about 25m² ha⁻¹ and canopy cover of about 65% (Fox 1981). The main tree species are *Eucalyptus pilularis* Sm (MAIAA — code according to Pryor & Johnson 1971) and *Angophora costata* (Gaertn.) Druce (AAAD). The understorey is of scleromorphic shrubs, grasses, ferns and some herbs.

The forest is frequently burnt. For the 18 years preceding and encompassing this study, parts of the forest had burnt 15 times (Table 1). Some fires were both extensive and intense, burning several thousand hectares and incinerating the canopies of the eucalypts. However, many others were localized and of low intensity, burning only a few hundred hectares and possibly not even scorching the canopy. The latter kind were often the result of human activities in the area. It is likely that the 'natural' (pre-settlement) fire regime was of less frequent but more intense fires (Walker 1981). Myall Lakes falls within Walker's Fire Region 11, which has a fire interval of 5–15 years.

The fire season for this region is from mid-October to the end of January (Walker 1981). The more extensive fires in the past 18 years have been predominantly spring and summer fires (September 1980; October 1971, 1974, 1977, 1979, 1981; November 1968, 1980; January 1976, 1982; February 1975, 1979). There have also been winter fires (August 1974, 1980, 1984). The most severe (in extent and intensity) were the October 1968, January 1976 and August 1980 fires. The season of fires is important to the community regeneration in terms of the phenology of the individual species.

Table 1: The dates of 15 fires reported in the forest for the period November 1968 to August 1984. The numbers of sites and their ages at sampling (in brackets, years) for the four survey periods are shown.

Date of Fire		Date of Survey*			
		Sept.–Dec. 1976	Nov. 1977	Feb. 1982	Mar. 1985
November	1968	1 (8.0)	1 (9.0)	n.s.	3 (16.3)
October	1971	6 (5.0)	n.s.	n.s.	n.s.
August	1974	7 (2.2)	n.s.	n.s.	n.s.
October	1974	2 (1.9)	1 (3.1)	n.s.	2 (10.4)
February	1975	1 (1.5)	n.s.	n.s.	n.s.
January	1976	24 (0.8)	2 (1.8)	n.s.	n.s.
October	1977	—	n.s.	n.s.	1 (7.4)
February	1979	—	—	2 (3.0)	n.s.
October	1979	—	—	n.s.	n.s.
August	1980	—	—	n.s.	n.s.
September	1980	—	—	n.s.	n.s.
November	1980	—	—	3 (1.3)	1 (4.3)
October	1981	—	—	n.s.	n.s.
January	1982	—	—	2 (0.1)	n.s.
August	1984	—	—	—	1 (0.5)

* n.s. = not sampled

The effects of fire in this forest have been studied for litter accumulation (Fox, Fox & McKay 1979), and small mammal and vegetation regeneration (Fox & McKay 1981). The effects of fire frequency on the floristic composition and structure of woodland in the adjacent Eurunderee embayment (Fox & Fox 1986) have also been investigated.

Methods

In order to study the changes occurring as the community responds to the conditions after fire, a range of sites with different fire histories was used. Data were collected on four occasions spanning 8.5 years from a total of 60 sites, covering a range of ages since fire from one month to over 16 years. Table 1 lists the dates of the 15 fires recorded in the forest for a 16 year period and the number and ages of sites sampled. Because of the high frequency of fires in the forest, many samples were less than a year since fire (n = 27), eight were from one year to two years, 14 from two years to five years, six were between five and ten years, and five were more than ten years. The first set of 45 sites was strongly biased to sites less than a year old because of the extensive fire in January 1976. For this reason subsequent sampling concentrated on older sites of known age.

Figure 1 shows the location of the study sites, mostly south of the Seal Rocks road in an area of 2700 ha of open-forest. Initially 45 sites (numbered 1 to 45) were located on a 500 m grid and sampled in 1976 and 1977 (Fox 1981), with an additional seven sites (46 to 52) located on a transect from the high ridge to the sea (1982), while the 1985 sites (53 to 60) were largely selected to sample sites that had not then burnt for over ten years.

At sites 1 to 45 a quadrat of 0.04 ha (4 x 100 m) was used. The other 15 sites used a larger quadrat (20 x 100 m) to be consistent with data collected from a variety of other communities. All vascular plant species in the understorey (including small trees such as *Banksia serrata* and *Xylomelum pyriforme)* within each quadrat were recorded as the species richness for that site. The sixty sites were grouped into 12 age classes, segregating the smaller and larger quadrat sizes.

At each site the cover of understorey species was measured as line intercepts on a 100 m transect. The height of the understorey was measured at ten points along the transect and a mean value for the site calculated. Both height and cover measurements were independent of quadrat size and were grouped into ten age classes. Using cover values as measures of abundance, species diversity was calculated as the inverse of Simpson's (1949) index of concentration:

$$\Delta_3 = (\Sigma p_i^2)^{-1}$$

where p_i is the proportion of species i in the sample (Hurlbert 1971). Because diversity incorporates richness, the same twelve age classes were used as were distinguished for the richness data.

All vascular plant species occurring in the 60 sites were classified into one of the seven regeneration categories recognized by Gill (1975, 1981), based on observation in the field or consultation with colleagues. In some cases it was evident that some individuals of a species, otherwise considered to be an obligate seeder, may survive a low intensity fire and show vegetative growth from existing structures. Conversely examples of vegetative regenerators occasionally being killed by fire were also observed. All of the vegetative regenerators (categories IV, V, VI and VII) are also facultative seedling regenerators. In all such cases the usual (i.e. the population's) mode of regeneration after fire in the Seal Rocks open-forest was recorded for the species (see Appendix I). The seven regeneration categories (from Gill 1975) are:

I Mature plant killed by fire, seed stored on plant.
II Mature plant killed by fire, seed stored in soil.
III Mature plant killed by fire, seed storage absent.
IV Mature plant survives, sprouts from root suckers or horizontal rhizomes.
V Mature plant survives, sprouts from basal stem or vertical rhizome.
VI Mature plant survives, sprouts from aerial epicormic buds.
VII Mature plant survives, sprouts from undamaged buds that were active pre-fire.

Species fitting the first three categories are sometimes referred to as fire-sensitive species or as obligate seedling regenerators, the other four categories contain fire-resistant species, also referred to as vegetative regenerators or resprouters. At each site the percentage contributions to total richness of fire-sensitive species and fire-resistant species were calculated, and the percentage of total cover of each type also calculated.

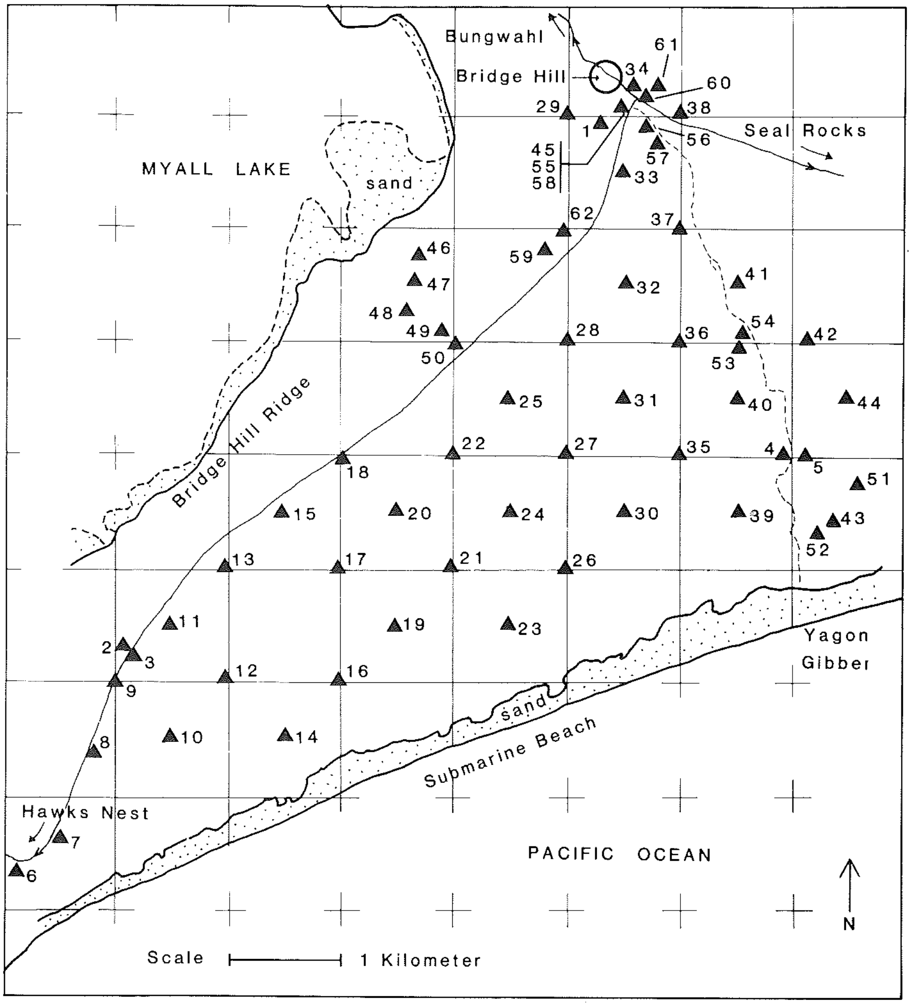

Figure 1. The location of the sixty sites covering approximately 2700ha of open-forest in Myall Lakes National Park.

Results

There is a statistically significant linear increase in the height of the understorey with time since fire (n = 60, r = 0.9764, $p < 0.001$). Figure 2 shows mean values for ten age classes with the regression line calculated from the 60 individual values. Sixteen years after fire the understorey was four metres tall.

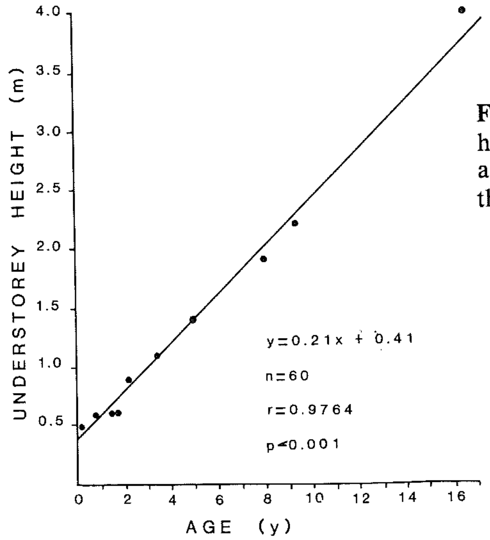

Figure 2. The linear increase in understorey height with time since fire. The points shown are the mean values for ten age classes; the line is the regression for the 60 sites.

One hundred and twenty two vascular plant species were encountered in the 60 sites (Appendix I). The average richness (+/– S.E.) of the sites was 34.8 +/– 0.7 [range 22–50]. There was no significant difference between the richness of the 0.04 ha plots ($\bar{x} = 34.7$ +/– 0.8 species, n = 45) and the larger plots ($\bar{x} = 34.8$ +/– 0.9 species, n = 15).

Figure 3 shows species richness as a function of time since fire. The mean number of species per site for 12 age classes is shown. There is a slight peak at four years, then a decline and then a rise to 39 species after 16 years. The data points can be fitted to a significant third order polynomial equation (r = 0.2665, 56 d.f., $p < 0.05 = 0.255$) which is the curve illustrated. Because of the high variability or 'noise' in the system, indicated by the magnitude of the standard error bars, only 7.1% of the variance is accounted for, but this is significantly better than a linear fit. This confirms that the drop in species richness at ten years and the second peak are real features. There are significantly more species after 16 years than immediately after fire (t = 3.84, d.f. = 4, $p < 0.02$).

Figure 4 shows the mean values for plant species diversity for the same age classes. These begin at values close to 3.0 but rise to peak at about 9.0 after ten years, and then drop substantially by 16 years after fire. The individual points demonstrate a significant fit to a quadratic equation (r = 0.648, $p < 0.005$) which explains 42% of the variance in plant species diversity and models the increase and subsequent decrease.

There is a significant negative correlation between species diversity and the amount of *Pteridium esculentum* cover (r = –0.7041, n = 60, $p < 0.001$).

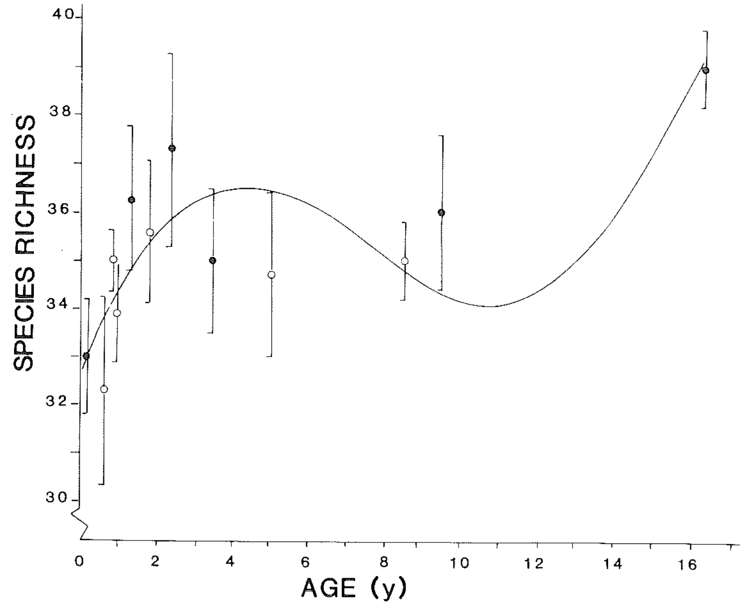

Figure 3. Changes in species richness with time since fire. The means (+/− standard error of the mean) for twelve age classes are shown. Open symbols are 0.04ha and closed symbols 0.2ha quadrats. The curve is a significant cubic function fitted to the 60 data points.

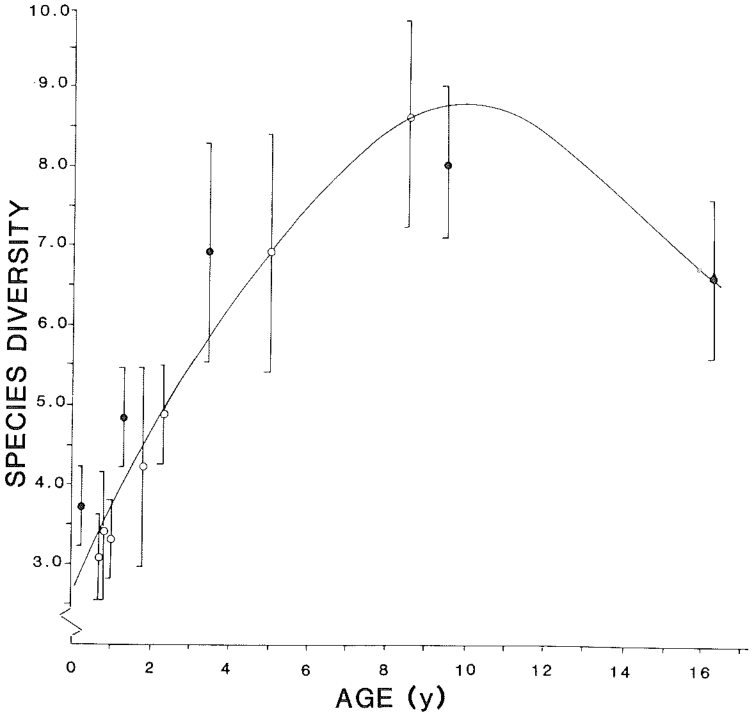

Figure 4. Changes in plant species diversity as a function of time since fire. The means (+/− standard error of the mean) for twelve age classes are shown. Open symbols are 0.04ha and closed symbols 0.2ha quadrats. The curve is a highly significant quadratic function fitted to the 60 data points.

Total understorey cover (Figure 5) returns to quite high values soon after fire, due largely to the rapid response of *Pteridium esculentum*. Cover tends to increase to peak values in the five to ten year period after fire and then to decline slightly. The greater part of the cover is contributed by the resprouting species. There is some fluctuation in the amount of cover from the vegetative regenerators, caused primarily by a second peak in *Pteridium* cover at five years.

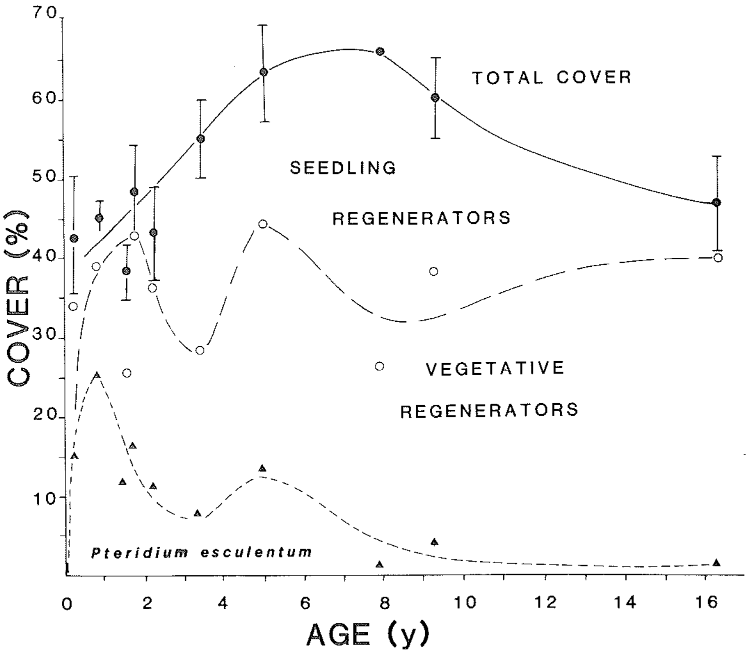

Figure 5. Changes in total cover partitioned into seedling and vegetative regenerators (with *Pteridium esculentum* shown separately) with time since fire. The same age classes are used as in Figures 2 and 3.

When the percentages of obligate seedling and vegetative regenerators are compared, these are remarkably constant with time since fire. The proportion of vegetative regenerators is approximately 61% from 0.3 years to 16.3 years. However, the percentage cover of these regeneration types fluctuates more widely. For the first five age classes (to 2.2 years) over 70% of total cover is provided by the resprouting species, this fluctuates widely between 40 and 80% for the next seven years and by 16 years returns to about 85%.

Only one species was classified as retaining seed on the plant (I, *Banksia integrifolia*), although elsewhere it resprouts from epicormic buds and seed is released when mature; and one as having no seed storage (III, *Senecio lautus*). Of the large number of species in category II (seed stored in soil), many retain some seed on the plant for some time, but ultimately it is shed. Of the vegetative regenerators, most belong to category V (sprouts from basal stem or vertical rhizome), with fewer in categories IV and VI, and only three species in category VII (sprouting from undamaged buds active pre-fire). Of the total of 122 species, 47% are in categories I, II and III (the obligate seedling regenerators) while 53% are in the vegetative categories (IV, V, VI and VII).

Discussion

The Myall Lakes area may have a natural fire interval of 5–15 years (Walker 1981), so the sites that are 16.3 years old are close to the maximum for coastal eucalypt forest. Fuel loads for Fire Region 11 vary from 0.35–2.00 kg m^{-2}; Fox *et al.* (1979) estimated the litter steady-state for the Seal Rocks forest is 1.67 kg m^{-2}. This is at the higher end of the fuel range which in turn would lead to higher fire frequency. This is supported by a recent study indicating that the period between fires in this area probably falls in the 6–12 year range (Fox & Fox 1986) and by the litter steady-state which is reached after about ten years (Fox *et al.* 1979). Anthropogenic fires have increased this natural frequency for much of the forest to about every four years; the much older sites are small relict patches.

For at least the preceding 16 years the oldest sites have experienced only one fire while the younger sites have been burnt several times. This may introduce a factor which differentiates the sites and confounds the previous assumption of homogeneity. In woodland in the adjacent Eurunderee embayment, an area that had burnt twice in 12 years had significantly more species, greater shrub density and greater cover than an adjacent area that had only burnt once (Fox & Fox 1986).

The changes in diversity related primarily to changes in dominance (as expressed by cover) of the understorey species. The early stages of the pyric cycle were dominated by the rapid regrowth of *Pteridium esculentum* but in time its cover was reduced (Figure 5). The greater evenness of other species in the range three to ten years produced high diversity values. By 16 years the understorey was dominated by a few tall shrub species and diversity was reduced. Bell & Koch (1980) found that in jarrah forests both species richness and diversity increased to a maximum at three to five years and then declined. Russell & Parsons (1978) found in heath at Wilsons Promontory that the number of species was reduced from 60 to 49 over 21 years.

Understorey cover was not significantly correlated with either species richness or diversity. After an early increase from 40% it levels out at about 65% between five and ten years, before dropping to about 45% after 16 years. Fox & McKay (1981) have described the changes in the vertical structure of the vegetation profile for this forest for the first eight years after fire.

The relative importance of species capable of vegetative regeneration in this forest is very similar to values reported for other open-forests (Christensen *et al.* 1981). The most striking feature of the data presented here, however, is the consistency of this proportion during the 16 years since fire. This signifies that, regardless of the number of species comprising the understorey or its stage of regeneration after fire, there is the same ratio of sprouters to non-sprouters. With individuals of 47% of the species in the understorey killed by fire, a fire frequency of less than the time needed for those species to flower and set seed, could result in those species being lost from the community.

Two abutting areas of woodland in the Eurunderee embayment (just south of the Seal Rocks forest) with different recent fire histories (Fox & Fox 1986) show an interesting pattern of relative abundance of vegetative regenerators. The area that had burnt only once in the past 12 years had a ratio of 63:37 for seedling regenerators to vegetative regenerators while for the area that had burnt twice in the same period the ratio was 39:61; the area with the higher recent fire frequency had more vegetative regenerators. The Seal Rocks forest (47:53) is about half-way between these two.

Conclusions

The understorey of the open-forest at Seal Rocks rapidly regenerates following fire. Because of the abundance of species capable of regenerating vegetatively, and of obligate seedling regenerators which germinate rapidly, the species richness is quite high one month after fire and shows an interesting pattern of change with time since fire. Contrary to the decline in richness reported in the literature for other communities, the richness after 16 years is higher than that of younger sites. Cover responds quickly as well, mainly due to the rapid vegetative response of *Pteridium esculentum*. Understorey height increases linearly with time since fire.

The proportion of species capable of vegetative regrowth (53%) is similar to values reported for other open-forests. Over all sites 61% of species were resprouters and this is so for over 16 years since fire.

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Appendix I

The vascular plant species encountered in the 60 sites. Nomenclature follows Jacobs & Pickard (1981). The mode of regeneration after fire is given (Gill 1975), and * indicates that the species is introduced.

PTERIDOPHYTES

- DENNSTAEDTIACEAE
  - *Pteridium esculentum* IV
- DICKSONIACEAE
  - *Culcita dubia* IV
- SCHIZACEAE
  - *Schizaea bifida* V
  - *S. dichotoma* V

GYMNOSPERMS

- CUPRESSACEAE
  - *Callitris macleayana* II
- ZAMIACEAE
  - *Macrozamia communis* VII

ANGIOSPERMS — DICOTYLEDONS

- APIACEAE
  - *Actinotus helianthi* II
  - *Platysace ericoides* II
  - *P. lanceolata* II
  - *Trachymene incisa* II
- ARALIACEAE
  - *Astrotricha longifolia* II
  - *Polyscias sambucifolia* V
- ASTERACEAE
  - **Conyza canadensis* var. *canadensis* IV
  - *Senecio lautus* III
- BAUERACEAE
  - *Bauera rubioides* V
- BIGNONIACEAE
  - *Pandorea pandorana* II
- CAMPANULACEAE
  - *Wahlenbergia communis* II
- CASUARINACEAE
  - *Allocasuarina torulosa* V
- CHLOANTHACEAE
  - *Chloanthes stoechadis* II
- CONVOLVULACEAE
  - *Convolvulus erubescens* II
- DILLENIACEAE
  - *Hibbertia acicularis* II
  - *H. fasciculata* II
  - *H. linearis* V
  - *H. scandens* II
- EPACRIDACEAE
  - *Brachyloma daphnoides* V
  - *Leucopogon ericoides* V
  - *L. lanceolatus* V
  - *L. margarodes* VI
  - *L. virgatus* V
  - *Melichris procumbens* V
  - *Monotoca elliptica* V
  - *Styphelia viridis* II
  - *Woollsia pungens* V
- EUPHORBIACEAE
  - *Breynia oblongifolia* II
  - *Poranthera micorphylla* II
  - *Ricinocarpos pinifolius* V
- FABACEAE — Faboideae
  - *Aotus ericoides* V
  - *Bossiaea ensata* V
  - *B. heterophylla* II
  - *Desmodium rhytidophyllum* II
  - *Dillwynia retorta* II
  - *Gompholobium latifolium* II
  - *G. virgatum* II
  - *Hardenbergia violacea* V
  - *Hovea linearis* V
  - *Indigofera australis* V
  - *Kennedia rubicunda* II
  - *Oxylobium ilicifolium* II
  - *Phyllota phylicoides* II
  - *Platylobium formosum* II
  - **Trifolium* sp. II

FABACEAE — Mimosoideae
- *Acacia falcata* II
- *A. longifolia* II
- *A. maidenii* II
- *A. sophoreae* II
- *A. suaveolens* II
- *A. terminalis* II
- *A. ulicifolia* II

GOODENIACEAE
- *Goodenia paniculata* IV

HALORAGACEAE
- *Gonocarpus teucrioides* II

LAURACEAE
- *Cassytha glabella* II
- *Endiandra sieberi* VII

LOGANIACEAE
- *Mitrasacme polymorpha* II

MYRTACEAE
- *Angophora costata* VI
- *Calytrix tetragona* II
- *Eucalyptus gummifera* VI
- *E. microcorys* VI
- *E. pilularis* VI
- *E. robusta* VI
- *Leptospermum attenuatum* VI
- *L. flavescens* V
- *L. liversidgei* V
- *Melaleuca quinquenervia* II
- *M. squarrosa* II

OLACACEAE
- *Olax stricta* IV

PITTOSPORACEAE
- *Billardiera scandens* V

PROTEACEAE
- *Banksia integrifolia* I
- *B. serrata* VI
- *Conospermum taxifolium* II
- *Persoonia lanceolata* II
- *P. levis* VI
- *P. linearis* VI
- *Xylomelum pyriforme* VI

RUBIACEAE
- *Opercularia diphylla* II
- *Pomax umbellata* II

RUTACEAE
- *Boronia pinnata* II
- *Correa reflexa* II
- *Eriostemon australasius* II

SANTALACEAE
- *Choretrum candollei* IV
- *Leptomeria acida* IV

SAPINDACEAE
- *Dodonaea triquetra* II

SMILACACEAE
- *Smilax australis* V
- *S. glyciphylla* V

STERCULIACEAE
- *Lasiopetalum ferrugineum* II

THYMELIACEAE
- *Pimelea linifolia* II

TREMANDRACEAE
- *Tetratheca thymifolia* II

URTICACEAE
- *Pilea microphylla* II

VIOLACEAE
- *Hybanthus filiformis* II
- *Viola hederacea* II

ANGIOSPERMS — MONOCOTYLEDONS

ANTHERICACEAE (p.p. Liliaceae)
- *Tricoryne elatior* II

DIANELLACEAE (p.p. Liliaceae)
- *Dianella caerulea* IV

CYPERACEAE
- *Lepidosperma longitudinale* V
- *Schoenus ericetorum* IV

HAEMODORACEAE
- *Haemodorum planifolium* V

IRIDACEAE
- *Patersonia glabrata* V

LOMANDRACEAE
- *Lomandra longifolia* IV
- *L. filiformis* V

ORCHIDACEAE
- *Acianthus fornicatus* V
- *Caladenia carnea* V
- *Caleana major* V
- *Dipodium punctatum* V
- *Lyperanthus nigricans* V
- *L. suaveolens* V
- *Microtis uniflora* V
- *Pterostylis acuminata* V
- *Thelymitra nuda* V

RESTIONACEAE
- *Restio tetraphyllus* IV

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