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MATURATION PERIODS FOR FIRE-SENSITIVE SHRUB SPECIES IN HAWKESBURY SANDSTONE VEGETATION

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ABSTRACT

Benson, D. H. (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, New South Wales, Australia 2000) 1985. Maturation periods for fire-sensitive shrub species in Hawkesbury Sandstone vegetation. Cunninghamia 1(3), 339–349. The maturation times (period from germination to flowering) for a number of fire-sensitive shrub species in Hawkesbury Sandstone vegetation at sites in Brisbane Water National Park and at Glenorie near Sydney were recorded from marked seedlings established after hot fires. They range from two to seven years for different species. The implications for fire management, particularly for controlled burning, are discussed. A fire-free period of at least nine to ten years is recommended for similar vegetation if successful flowering and seed set, and continued species survival is to occur.

INTRODUCTION

Plant species fall into two main groups with regard to their response to fire: some are characterized by vegetative regrowth, where individuals either resprout from epicormic shoots on the trunk and major surviving limbs or, following the death of all above-ground stems, resprout from underground rootstocks, lignotubers or rhizomes (sprouters); others regenerate from seed either stored in the soil before the fire, carried on the plants in woody fruits and released after the fire, or carried in from adjacent unburnt areas (non-sprouters). Adults in the second group are fire-sensitive and generally killed outright (Gill, 1975, 1981; Bradstock, 1981).

The relative proportions of these groups of species appear to be related to the fire frequency in the habitat (Christensen, Recher & Hoare, 1981). In wet sclerophyll forest the proportion of fire-sensitive species is roughly 50 to 60 per cent (Ashton, 1981). In the more frequently burnt dry sclerophyll forests near Canberra, Purdie & Slatyer (1976) found 65 per cent regenerated vegetatively but only 27 per cent of species were fire-sensitive and only regenerated from seed.

The time necessary for reproduction after fire is an important characteristic, especially in fire-sensitive species. Specht, Rayson & Jackman (1958) noted that fires at intervals of five years in heath vegetation are likely to eliminate or reduce numbers of some species that take several years to reach reproductive maturity. Similarly, for bushland north of Sydney, Siddiqi, Carolin & Myerscough (1976) recorded the localized elimination of the woody fire-sensitive species *Banksia ericifolia, Allocasuarina distyla* and *Hakea teretifolia* by repeated burning. However, to predict the impact of a series of fires, data on the maturation periods for fire-sensitive species are needed. With some exceptions, e.g. *Banksia ericifolia* (Carpenter & Recher, 1979) and *Leptospermum laevigatum* (Burrell, 1968), such data are not available. The potential effect of frequent burning on fire-sensitive species has become particularly relevant with the increased adoption of "controlled" or "prescribed" burning in bushland areas. Such burning generally involves the application of regular fires of low intensity, commonly at intervals of between two and five years.

This paper documents the time required for a group of fire-sensitive species to reach maturity and discusses the implications for regular, frequent burning programs.

METHODS

The main study locality was in Brisbane Water National Park (33° 30′S, 151° 15′E), 40 km north of Sydney. Bushland here is eucalypt-dominated scleromorphic vegetation on low-nutrient Hawkesbury Sandstone. Rainfall is about 1250 mm per annum (Bureau of Meteorology, 1979). The general vegetation is described by Benson & Fallding (1981). A second locality was studied at Glenorie (33° 35′S, 151° 00′E), 15 km north-west of Hornsby, on similar Hawkesbury Sandstone, but with average rainfall of 930 mm per annum, to see whether similar results were obtained in a lower rainfall.

A hot summer (1974–75) fire occurred at the Brisbane Water locality six months before the first observations were made and the size of dead bushes at the time indicated that the area had been unburnt for about 15 years before this. As a result of topographic and drainage features, there was considerable variation in microhabitat; therefore, four sites in generally similar, but slightly different, vegetation were chosen as follows:

- Site A — low-woodland with *Eucalyptus haemastoma* and *E. gummifera* on a gently sloping hillside
- Site B — open-heath on a broad rocky ledge
- Site C — low open-forest of *Banksia serrata* and *Eucalyptus gummifera*
- Site D — woodland of *Eucalyptus piperita* subsp. *piperita* and *E. gummifera* on a sandy ledge below a small cliff-line.

A shrubby understorey characterized all the sites, although site C also had a considerable amount of grassy growth. Sites A and B were poorly drained. All sites were within about 0.5 km of each other.

The Glenorie site was in woodland of *Eucalyptus eximia* and *E. gummifera* on a dry ridgetop and had been burnt in January 1975.

At each site a transect of 10 contiguous 1 m × 1 m plots was established. Each of these plots was subdivided into four 0.5 m × 0.5 m sub-plots and two seedlings within each sub-plot were selected and marked with coloured wires. Seedlings were distinguished from plants regenerating from rootstocks or rhizomes by the presence of cotyledons or by comparison with similar plants that had been dug up and their roots examined. Although restricted to dicotyledonous species, as wide a range of species as possible was chosen, and the most healthy seedlings marked. Table 1 lists the 37 species included in this study, their susceptibility to fire and the total number of seedlings marked ("?" indicates species that are probably fire-sensitive). Initially, 320 seedlings were marked. Many of these died during the first years of recording. Additional plants were marked to replace dead plants during the first two years, after which no additional plants were marked. The occurrence of flowering was recorded four times a year (at Brisbane Water in early March, June, September and December; at Glenorie in early February, May, August and November) for the following eight years.

At the same time all species flowering within about 30 m of the transect were recorded. Because of the range of microhabitats, such as minor cliff-lines, rock platforms and moist soaks, some of which remained unburnt during the fire, flowering recordings may represent as few as one or two individuals of a species.

In July–August 1980 a low-intensity fire burnt part of the Brisbane Water area, including half of the site A transect. There was no canopy scorch and the fire was of such low intensity that in places it was stopped by the trampled single-file track along the edge of the transect resulting from the three-monthly recordings. Although it reduced the amount of data from this site, a number of observations were made on species affected by the fire.

TABLE 1

Susceptibility to fire and number of seedlings recorded for species at Brisbane Water and Glenorie

Botanical name	Susceptibility to fire fs = fire-sensitive r = resprouter	Total number of seedlings marked
APIACEAE		
Actinotus helianthi	fs	44
A. minor	r	6
Platysace linearifolia	r	32
Xanthosia tridentata	?fs	5
DILLENIACEAE		
Hibbertia cistiflora	?fs	5
H. monogyna	?fs	4
EPACRIDACEAE		
Epacris pulchella	fs	2
Leucopogon microphyllus	?fs	5
Woollsia pungens	fs	13
EUPHORBIACEAE		
Poranthera ericifolia	fs	7
FABACEAE		
Acacia hispida	?fs	2
A. suaveolens	fs	4
Bossiaea heterophylla	fs	2
Dillwynia retorta	fs	8
Gompholobium grandiflorum	?fs	6
GOODENIACEAE		
Goodenia bellidifolia	?fs	2
HALORAGACEAE		
Gonocarpus teucrioides	fs	43
LAMIACEAE		
Hemigenia purpurea	?fs	3
LOGANIACEAE		
Mitrasacme polymorpha	fs	6
PROTEACEAE		
Banksia ericifolia	fs	22
B. oblongifolia	r	7
B. serrata	r	3
Conospermum taxifolium	fs	2
Grevillea buxifolia	?fs	2
G. sericea	fs	18
G. speciosa	?fs	2
Hakea teretifolia	fs	15
Petrophile pulchella	fs*	26
RHAMNACEAE		
Cryptandra ericoides	?fs	3
RUTACEAE		
Boronia ledifolia	fs	12
B. serrulata	fs	1
Eriostemon australasius	fs	3
E. buxifolius	fs	38
Philotheca salsolifolia	fs	2
THYMELAEACEAE		
Pimelea linifolia	fs	4
TREMANDRACEAE		
Tetratheca ericifolia	?fs	8
T. shiressii	?fs	4

* Beadle (1940) states that *Petrophile pulchella* has a lignotuber and 92 per cent survival after fire. This is not the case at the study sites here or elsewhere in the Sydney district according to the author's general observations.

RESULTS

The number of years to first flowering of marked seedlings is shown in Table 2. The time taken for different species ranges from one year for *Poranthera microphylla* to seven to eight years for *Banksia ericifolia,* with many species taking four to six years. Although different species are present, the pattern at each site was similar. Table 3 shows the pattern of flowering at site D for the eight-year period. The first flowering for several species took place within two years of the fire, followed by the gradual addition of other species during the succeeding five years. A similar pattern was recorded for the other three sites at Brisbane Water and that at Glenorie.

The onset of flowering rarely included all individuals of a population and commonly only involved a few particularly advanced plants. Figure 1 shows the actual numbers of marked plants for selected species at site D at Brisbane Water and at Glenorie. Here, on the first flowering occasion, between 10 and 40 per cent of individuals of a species were involved, but flowering did not reach a peak for another one to several years. Similar results were obtained for species at the other sites.

TABLE 2

The number of years to first flowering after fire for shrub species at Brisbane Water and Glenorie. Species are arranged in increasing maturation time

Botanical name	Brisbane Water sites				Vicinity	Glenorie site	Vicinity
	A	B	C	D			
Poranthera ericifolia	1				1		
Hemigenia purpurea		2			2		
Actinotus helianthi				*2(3)	1	2(4)	2
A. minor	2			3	1		
Mitrasacme polymorpha	3	2		2	1		
Gonocarpus teucrioides	2		4		2		
Bossiaea heterophylla				3	2		
Cryptandra ericoides		3			3		
Hibbertia cistiflora		3			1		
Tetratheca ericifolia	3			3	1		
T. shiressii	3	4			3		
Platysace linearifolia	3			3(4)	2	3(4)	3
Woollsia pungens				3(5)	2		
Conospermum taxifolium		4			1		
Eriostemon australasius				4	1		
Goodenia bellidifolia				4	1		
Grevillea speciosa		4			1		
Hibbertia monogyna		4			2		
Pimelea linifolia			4		1		
Boronia ledifolia	4			5	1		
Leucopogon microphyllus	4	5			2		
Gompholobium grandiflorum	4			6	4		
Grevillea sericea	4		4(6)		3		
Eriostemon buxifolius			5(5)	5	1	4(6)	4
Acacia suaveolens				5	•2	4	4
Boronia serrulata				5	1		
Dillwynia retorta		5			1		
Philotheca salsolifolia		5			2		
Acacia hispida						5	3
Xanthosia tridentata			6		1		
Epacris pulchella		6			4		
Hakea teretifolia	6	6(6)		7	2		
Petrophile pulchella		6		9	2	8(9)	5
Banksia ericifolia	8	8		7	2		
Grevillea buxifolia						8	6
Banksia oblongifolia	no flowering yet						
B. serrata	no flowering yet						

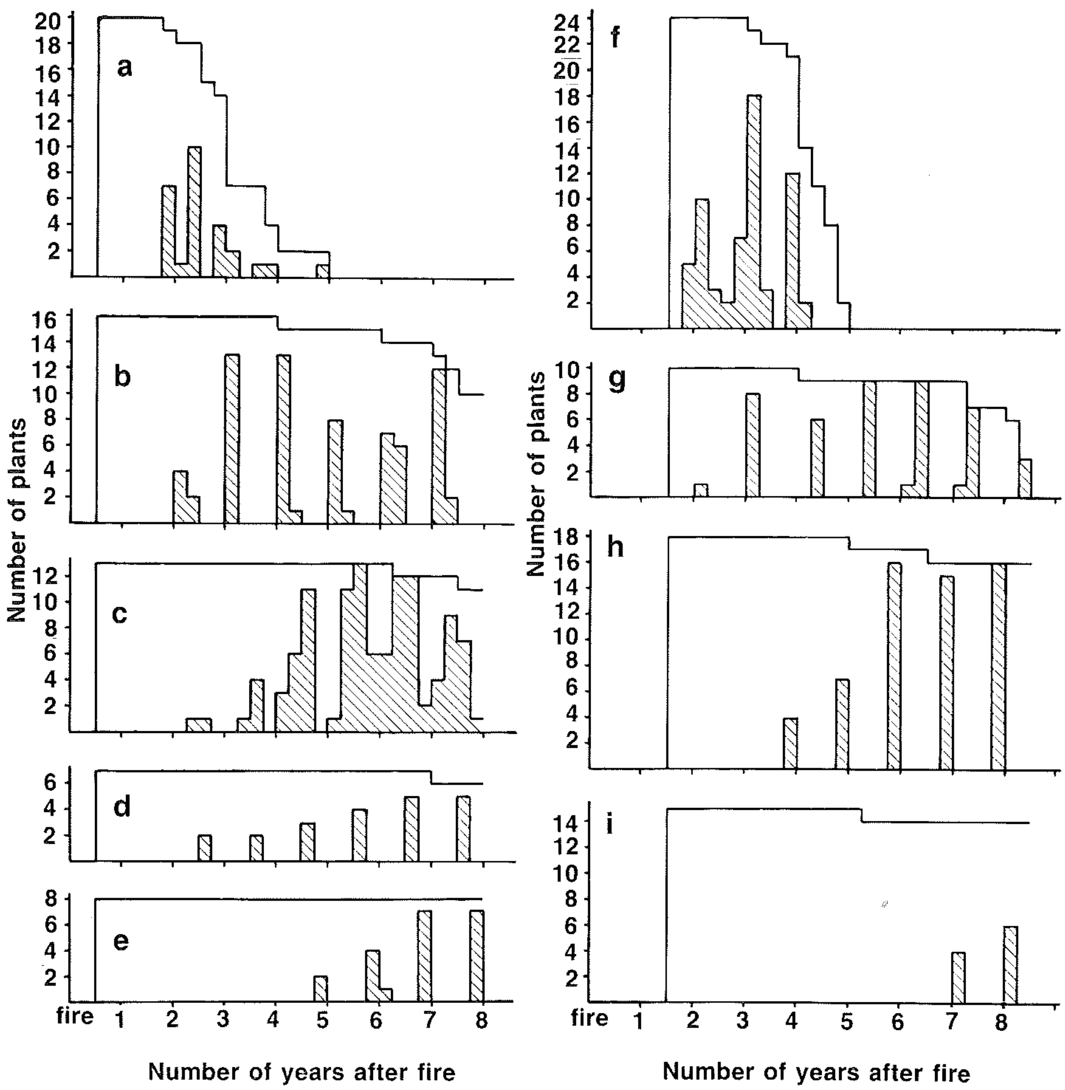
* Where 10 or more individuals of a species were marked at one site, the number of years taken to reach at least 50 per cent of individuals flowering is given in brackets.

TABLE 3

Flowering times for marked plants at Brisbane Water National Park (site D). Months (M J S D) of recording were March, June, September, December

Botanical name	Fire				Time since fire (years)																							
	2				3				4				5				6				7				8			
	M	J	S	D	M	J	S	D	M	J	S	D	M	J	S	D	M	J	S	D	M	J	S	D	M	J	S	D
Mitrasacme polymorpha			x	x	x	x						x																
Actinotus helianthi				x	x	x		x	x		x	x				x												
Platysace linearifolia					x	x			x				x	x			x	x			x	x			x	x		
Woollsia pungens						x	x			x	x		x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
Actinotus minor						x			x			x	x			x				x	x			x	x			x
Boronia ledifolia							x				x				x				x				x				x	
Bossiaea heterophylla							x			x						x						x				x		
Tetratheca ericifolia								x	x			x			x	x			x	x			x	x	x	x	x	x
Eriostemon australasius											x				x	x			x				x				x	
Goodenia bellidifolia												x																
Hibbertia monogyna													x			x	x	x	x	x	x		x	x	x	x	x	x
Acacia suaveolens														x				x				x				x		
Boronia serrulata															x				x				x	x	x			
Eriostemon buxifolius																x				x	x			x				x
Gompholobium grandiflorum																			x					x			x	
Banksia ericifolia																					x					x		
Hakea teretifolia																					x							

Figure 1. Flowering periods after fire for selected species at Brisbane Water (site D) (a–e) and Glenorie (f–i), showing total marked seedlings (upper line) and number flowering (hatched bar) for *Actinotus helianthi* (a & f), *Platysace linearifolia* (b & g), *Woollsia pungens* (c), *Boronia ledifolia* (d), *Eriostemon buxifolius* (e & h) and *Petrophile pulchella* (i). For each graph, the vertical axis represents number of plants, and the horizontal axis represents number of years after fire.



Fruit set occurred in most species. An exception was *Grevillea sericea* in which marked plants failed to set fruit after first flowering, but did so after subsequent flowering. In many species, notably those of the family Rutaceae, seed is released within a few months of flowering, but some species, particularly those of the woody-fruited Proteaceae, take a year after flowering for the characteristic woody follicles to develop. Examples are *Banksia ericifolia, Hakea teretifolia* and *Petrophile pulchella,* the slowest to flower of the species in the study area.

A decline in numbers following flowering was recorded for *Mitrasacme polymorpha, Poranthera ericifolia* and in particular *Actinotus helianthi.* Individuals of these species had completely disappeared within five years; they may be regarded as early successional species. No further species disappeared from the plots during the recording period except for a number of species represented by only a single marked individual.

The recorded times to achieve flowering for plants in the vicinity (Table 2) are almost all much shorter than for the marked plants, but do not really indicate the responses of the population as a whole. This is because many recordings are of individuals that were either unaffected or only slightly affected by the fire, as a result of the protection offered by the minor cliff-line, rock-outcrop and moist-soak microhabitats. The results indicate the potential resilience of a system in which considerable topographic variation provides fire refugia, but cannot be extrapolated to sites with less variable topography.

The effect of the low intensity fire at site A was interesting — *Poranthera ericifolia* and *Gonocarpus teucrioides,* which had died out before the fire, reappeared. However, individuals of *Platysace linearifolia,* which had appeared only as seedlings after the 1974–75 summer fire, were not killed but resprouted at ground level, indicating that fire-sensitivity in that species may be related to the intensity of the fire.

DISCUSSION

Fire-sensitive species may make up a significant component of Australian vegetation. For example, in dry sclerophyll communities near Canberra, of 93 species studied by Purdie & Slatyer (1976), 27 per cent were killed by fire and regenerated only from seed. A similar proportion are present in the scleromorphic flora of Sydney's Hawkesbury Sandstone, particularly on the higher rainfall coastal areas. Of the species recorded in this study 20 are known to be fire-sensitive, and a further 13 are probably so. The only resprouter species to be marked were *Actinotus minor, Platysace linearifolia, Banksia oblongifolia* and *B. serrata* (neither of the marked *Banksia* species flowered during the recording period). Fire-sensitive species are likely to be severely disadvantaged and possibly eliminated by a series of fires at intervals less than the time taken for seedling regeneration to produce further seed. The results here show that fire-sensitive species may not flower for two to eight years after a fire. Major flowering is not attained for one or two years after that. Similar results were found for all sites at Brisbane Water and also at Glenorie, and are likely to apply to other areas on Sydney's Hawkesbury Sandstone.

The results highlight the variability present within most wild populations. For instance, although most individuals may flower simultaneously, there will generally be some individuals flowering out of season.

Flowering is an effective indicator of maturity only if it is associated with the development of mature viable seed and leads to the build-up of an adequate seedbank. Some species, particularly those with woody fruits, take up to a year for the fruits to mature, and are vulnerable to fire during this period. Examples are *Banksia ericifolia, Hakea teretifolia* and *Petrophile pulchella.* Although fruit formation generally appears to accompany flowering, the percentage viability of the first seeds set by an individual may not be known. In *B. ericifolia, B. serrata, P. pulchella* and *Isopogon anemonifolius,* first seed set on juvenile plants is normal in terms of viability, i.e. it is comparable to seed viability produced in older plants. However, the number of seeds per cone is often significantly lower in the first and second crops (R. Bradstock, pers. comm.). The density of seedlings at the beginning of this work and the early seedling mortality encountered suggest that some species recruit from a relatively large seedbank either already stored in the soil or available from woody capsules. Certainly, for the survival of each species a minimum seedbank must be present, though the necessary size for most species is unknown.

Without this seedbank, floristic composition will change to a dominance by resprouter or rhizomatous species, or to annual species, commonly exotics, which seed rapidly. Though rhizomatous species such as *Pteridium esculentum* and monocotyledonous families such as Poaceae and Cyperaceae can spread vegetatively, most dicotyledonous resprouters, with the exception of some which root-sucker, cannot and so rely on seed for the establishment of new individuals. Frequent burning may possibly weaken and eventually kill individual resprouters, so that some seedling establishment is necessary to replace them if the plant community composition is to remain reasonably stable. The critical fire-free period here will be the interval from seedling establishment to the production of an adequate fire-resistant rootstock. However, since seedling recruitment will not be necessary after every fire, the critical fire-free period will not be needed for every fire cycle.

Almost all seedlings appear to establish in the first two years after fire, when there is considerable seedling mortality. Similar results were recorded by Purdie (1977) for dry sclerophyll vegetation near Canberra. After this period, with the exception of a few short-lived species (e.g. *Actinotus helianthi*), few of the marked plants died, despite very dry conditions during the latter part of the recording period. Eight years after fire the shrub component of the plant community appears healthy and actively growing, with no sign of senescence. It is likely that such conditions will continue for 15 to 20 years after fire.

The localized elimination of the tall woody species *Banksia ericifolia, Allocasuarina distyla* and *Hakea teretifolia* by frequent repeated burning has been reported at North Head, Sydney (Siddiqi *et al.*, 1976). Generally, however, the local disappearance of species in bushland has not been recorded. If there has indeed been a loss, the absence of observations could be for two reasons.

Firstly, the physiographic and habitat variation within the Hawkesbury Sandstone environment provides an uneven burn pattern with varying local fire intensities and localized fire refuges such as around rocky outcrops, cliff-lines or moist gullies. Our records of flowering within a year of the 1974–75 fire by the fire-sensitive species *Boronia serrulata, Eriostemon buxifolius* and *E. australasius* were from unburnt individuals growing amongst rock outcrops, which had provided fire protection. Thus, a plant community may be able to recover from potentially disastrous too-frequent burns by re-invasion from unburnt refuges. However, a succession of frequent burns will greatly increase the chances of losing species.

Secondly, the impressive species richness and diversity of plant communities on Hawkesbury Sandstone (426 dicotyledons are recorded for Brisbane Water National Park by Benson & Fallding, 1981) obscures, for most casual observers, changes in the abundance of individual species, particularly the less abundant and less conspicuous species, and particularly where such changes may be taking place gradually over decades. Most of the literature on the effect of fires on fire-sensitive species in the Sydney area concerns *Banksia ericifolia,* one of the most conspicuous and abundant species (e.g. Carpenter & Recher, 1979; Bradstock & Myerscough, 1981). Indeed, it may be the less common species that are more likely to be endangered by too-frequent fires. In their list of rare and restricted species in Brisbane Water National Park, Benson & Fallding (1981) include a number that are probably fire-sensitive. These include *Leucopogon amplexicaulis,* found in areas with low fire frequency, *L. margarodes* in areas not burnt for eight to ten years, *Darwinia procera* on a rocky ridge, and *D. glaucophylla* on rock outcrops that evidently protect it from fire, but it is not known whether these have previously been more abundant and whether frequent burning has endangered them.

FIRE MANAGEMENT IN NATURAL AREAS

The effects of frequent burning in bushland areas have become particularly important with the increasing use of regular burning as a management tool. Such burning may be "controlled" (and intended only for fuel reduction) or "prescribed" (and sometimes involve biological as well as fuel reduction aims). Both involve the application of regular low-intensity fires, generally at intervals of between two and five years, though planned frequencies often vary widely in reality, to reduce flammable fuel. This is most commonly carried out during cool weather in autumn or spring, in order to keep fire intensities low and manageable. High-intensity prescribed burning is theoretically possible and may be biologically desirable, but there are problems with implementation (for details see Good, 1981; Luke & McArthur, 1978; Foster, 1976).

The use of control burning at these frequencies may have the following deleterious effects, which will be particularly undesirable in areas reserved for the protection of native plants.

(1) Fire-sensitive species may be eliminated by repeated burning at time intervals that are less than that required to produce seed. For example, burning an area several times in quick succession is reported by Luke & McArthur (1978) to eliminate species of *Acacia* by exhausting their seedbank without allowing it to be replaced.

(2) Fruiting in both fire-sensitive and fire-resistant species may be reduced by burning when the plants are in flower or have immature fruits. Though there will generally be some species in flower at any time of the year, many species have a concentrated peak in spring (Timms, 1978), followed by seed maturation and release in summer. This is common in the families Fabaceae and Rutaceae, which are particularly conspicuous in the Hawkesbury Sandstone flora. Thus, a season's potential seed supply may be destroyed by burning when it is immature.

(3) Fire-resistant species may be eliminated by continual weakening and death of individuals. For example, Noble (1982) reports that in western New South Wales, mallee eucalypts, generally regarded as having a marked tolerance to periodic fire through their ability to produce epicormic shoots, do die when burnt more than once, especially when one burn closely follows another.

(4) Low-intensity fires may not stimulate adequate seedling germination, though allowing rhizomatous regeneration. Gill (1975) noted that for the Australian flora a high burning frequency often leads to dominance by monocotyledonous and fern species in place of shrubs. For example, Bradley (1972) reports on the occurrence of *Pteridium esculentum* and *Culcita dubia* after cool burns in Sydney bushland, while Luke & McArthur (1978) refer to *Imperata cylindrica* as prominent in coastal forests of northern New South Wales that have been burnt extensively.

A likely result of these factors is that areas of bush may be simplified both floristically and structurally.

For the fire-sensitive species examined, a period of six to seven years is needed to reach regular flowering. In addition, another year is required by some of the slowest-flowering species to develop mature seed. The question of the time needed to establish adequate seedbank reserves, either in the soil or within the plant canopy, has not been determined for many species. It is likely that most species require several seed-bearing seasons for this. Thus, for the communities examined a minimum fire-free period of nine to ten years is needed in a majority of fire cycles. An occasional burn followed quickly by another may be tolerated as seed reserves in the soil may not necessarily be exhausted by one fire. However, this is dependent on an adequate seedbank having been built up prior to the first fire.

The implications for fire management in natural areas are obvious. Before a long-term burning regime is imposed on an area of native bushland, the consequences of that action should be evaluated. As far as the survival of plant species is concerned, where there are often very little reliable data, it is necessary to err on the conservative side. That is, the time intervals between burns, in a majority of fire cycles, should be longer than the minimum suggested by the present findings.

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