REGENERATION OF *MELALEUCA LANCEOLATA* OTTO. AND *MELALEUCA SQUARROSA* DONN EX SM. COMMUNITIES OF THE COAST AND RIVER VALLEYS IN THE NORTH-EASTERN OTWAY RANGES 1–10 YEARS AFTER THE WILDFIRE OF FEBRUARY 1983

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Vegetation of the coastal complex (sand dunes and cliff tops) and some river valleys (non-saline swamps) of the Anglesea district includes floristically diverse and species-rich *Melaleuca* communities. Plant species richness ranges from 54–111 for dune communities and 29–98 for swamp communities. Variations in floristics and structure reflect differences in proximity to the sea, topography, soil structure and fertility, fire history and the presence of the pathogen *Phytophthora cinnamomi* in adjacent plant communities.

Following the wildfire of February 1983, 98% sand dune and 78% swamp vascular plant species present before the fire reappeared within the first year. All other species returned by year three. An additional species, the rare lizard orchid (*Burnettia cuneata*), not previously recorded in the district, appeared in the swamps in the first year post-fire.

In all dune and swamp communities maximum post-fire species richness of vascular plants occurred in the early years after fire, then decreased by year 10 as vascular plant cover increased. In contrast, in most communities the number of species of non-vascular plants increased or stayed constant as vascular plant cover increased.

Sixty per cent of all species in sand dune communities were obligate seed regenerators (regenerating from seed only [OSR]), whereas in swamp communities over 60% of all species regenerated vegetatively.

Structural recovery of most *Melaleuca* subcommunities on the dunes and in the swamps occurred by 10 years post-fire. In contrast, a major structural and floristic change occurred in one dune subcommunity where *Acacia longifolia* var. *sophorae* became dominant post-fire, suppressing the regeneration of other species.

Weed invasion of both the sand dunes and the adjacent coastal heathland was stimulated by the wildfire. Five species of OSR shrubs classified as 'environmental weeds', **Chrysanthemoides monilifera* ssp. *monilifera*, **Polygala myrtifolia*, *Acacia longifolia* var. *sophorae*, *Leptospermum laevigatum* and *Paraserianthes lopantha*, appeared immediately after the fire, competing with regenerating indigenous species.

Though no extensive in-ground (peat) fires established in the *Melaleuca squarrosa* closed scrub of the Anglesea River valleys following the 1983 wildfire, some small patches were found where the peaty soil burnt and all above-ground and in-ground vegetation was killed. Almost no recolonisation of these badly burnt areas occurred in the 10 years post-fire, or by 15 years, suggesting that in these seasonally dry swamps recovery from an in-ground fire may take many years.

ON 17 February 1983 (Ash Wednesday) a wildfire burnt almost 40 000 ha of vegetation near Anglesea and Aireys Inlet, in the north-eastern Otway Ranges, Victoria (Rawson et al. 1983). Until then there had been no published study of the fire ecology of the flora of this area. Following the wildfire, a ten-year study of the post-fire recovery of the vegetation was initiated. The aims of the study were to monitor vegetation regeneration following wildfire in six of the major plant communities in the district, coastal heath, heath woodland, open-forest, sand-dune scrub, swamp thicket and gully complexes. Regeneration of the heath, heath woodland, forest and gully communities has already been described (Wark et al. 1987; Wark 1996, 1997).

This paper presents data on vegetation recovery of two different *Melaleuca* communities 1–10 years after the 1983 wildfire, and describes their floristics and structure. Regeneration strategies and post-fire flowering response of species are also described. The communities are *Melaleuca lanceolata* open

Site	Location Height above SL Topography Geological origin	Fire history before Ash Wed.	Fire intensity Ash Wed. (1983)	Subsite	Aspect	Soil type (A horizon) 3 years after fire	Vegetation formation	Dominant species	Approx.* prefire height (m)	Height 3 years after fire (m)	No. of quadrats Ys 1,3,10	Area sampled (ha)
D	Coastal, 0-5 m above SL. Topography undulating Dunes of calcareous aeolian sand, overlie Tertiary rock of the Demons Bluff Formation	Not burnt for at least 50 years	All crown fired	D1	S 12°	>90 cm sand[†]	Open scrub	*Leucopogon parviflorus* *Acacia longifolia* var. *sophorae*	2.5 3.5[δ]	0.6 1.2[δ]	3,5,5	0.25
				D2	N 12°	>90 cm sand[†]	Open scrub	*Melaleuca lanceolata*	4.5	2.0	1,2,2	0.1
				D3	N 0°	>90 cm sand[†]	Open heath	*Melaleuca lanceolata* *Leucopogon parviflorus*	1.9	1.0	2,4,4	0.1
			Not burnt	D4	N 0°	>90 cm sand[†]	Open heath	*Leucopogon parviflorus* *Correa alba*	1.25	N.A	2,2,2	0.25
S	4 km inland at SL, on Anglesea River Topography flat Alluvium & peat overlie soils of the Eastern View Formation	Control burnt 1973	All crown fired	S1	W 1°	>90cm fibrous peat	Closed scrub	*Melaleuca squarrosa*	3.5	1.5	0,9,9	0.5
				S2	W 1°	>90 cm fibrous peat	"	"	3.5 6.6[ψ]	2.3 4.1[ψ]	0,5,5	0.25
	As above but on an easterly tributary of the Anglesea River (Harrison Track)	Control burnt 1973 then crown fired 1980		S3	S 3°	>90 cm fibrous peat	"	"	3.5 6.3[ψ]	2.0 4.6[ψ]	3,10,10	0.25
				S4	S 17°	40 cm[#] loamy coarse sand	Heath woodland/ Closed scrub (ecotone)	*Eucalyptus obliqua* *Melaleuca squarrosa*	2.0 10.4[¥]	1.0 8.7[¥]	3,5,5	0.25

Table 1. Site descriptions of sand dune (D) and swamp (S) sites. *Tallest stratum. [†]With shell lime. [#]Coffee rock present. [δ]*A. sophorae*. [ψ]*E. ovata* emergents. [¥]*E. obliqua*. N.A = not applicable.

scrub and open heath of the sand dunes, and *Melaleuca squarrosa* closed scrub (swamp thicket) of the non-saline swamps in the river valleys north and west of Anglesea. Mammal, bird and insect data have been studied and reported separately (Wilson & Moloney 1985a, 1985b; Reilly 1985, 1991; Andersen 1987).

SITE DESCRIPTIONS

Two sites (D and S) containing *Melaleuca* scrub communities (Fig. 1, Table 1) were selected within 3–4 km of Anglesea. Site D, sand dune, was on narrow Quaternary coastal dunes of calcareous aeolian sand and shell grit (Pitt 1981), situated south of the Great Ocean Road (between Anglesea and Urquhart Bluff, and east of Hutt Gully) and adjacent to coastal heathland. Site S, swamp, was on Quaternary alluvial peats overlying Tertiary sediments known as the Eastern View Formation (Pitt 1981). It was situated 3–4 km inland on the Anglesea River and some of its eastern (Harrison Track) and western (Edwards Creek) tributaries, adjacent to heath woodland. All sites supported natural vegetation.

Each site contained several plant communities (subsites) ranging from open heath to heath woodland and closed scrub. The structural terminology used follows Specht (1970). Except for subsites D1 and S4, which may have been affected by previous road making, all subsites were undisturbed.

The fire history of each site differed (Table 1). The high-intensity 1983 wildfire (Rawson et al. 1983) incinerated the surface vegetation and crown fired the *Melaleuca* overstorey at all subsites (Table 1). This fire occurred following a drought year (1982) in which the total rainfall at Anglesea was 452 mm; 68% of the annual mean of 657 mm. Rains of over 80 mm fell one, three, seven and eight months after the fire. Total rainfalls for Anglesea from 1983 to 1993 were 683, 685, 717, 622, 740, 643, 825, 596, 614 and 758 mm, respectively (Wark et al. 1987; Wark 1996).

Because of the extent of the fires, no comparable unburnt subsites were available for study. No in-ground fires (peat fires) occurred in the dunes following this wildfire, although, in drier parts of the swamps (eg. subsite S3), occasional small peat fires (20–40 m^2) were ignited. Here the humus-rich soil of the *Melaleuca squarrosa* closed scrub was burnt to a depth of about 0.15 m and all in-ground and above-ground vegetation was killed.

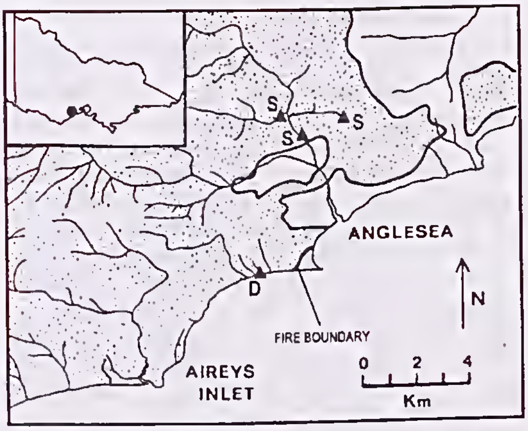


Fig. 1. Locality map showing location of the eastern Otway Ranges, Victoria and sites D (coastal dune) and S (swamp). Reading east to west, the three swamp sites (S) are Harrison Track, Anglesea River and Edwards Creek, respectively. Stippling indicates the area burnt on 16 February 1983. The fire advanced from the south west.

These small in-ground fires did not become extensive, as had previous peat fires in swamps of the district (Wark 1997).

METHODS

Soils

Methods used to sample soils, examine profiles and perform chemical analyses and isolate *Phytophthora cinnamomi* have been described (Wark et al. 1987; Wark 1996). Chemical analyses were carried out by the State Chemistry Laboratory, Victoria; soil profiles were examined by Dr D. J. Robertson (Charles Sturt University), and *P. cinnamomi* isolations carried out by Dr G. C. Marks (Department of Conservation and Natural Resources, Victoria).

In this paper, friable material formed by burning peaty loam will be called 'burnt peat' as in Wark (1997).

Vegetation

Pre-fire data. Detailed species lists of vascular plants (White 1982) were prepared for each site prior to the 1983 fire. However, no quantitative data on pre-fire floristics or vegetation structure were available. Approximate pre-fire heights and densities of shrubs were estimated from charred canopy remains, and pre-fire field observations and photographs.

Data collection and data analysis. Forty-two 1 × 3 m permanent quadrats (surrounded by 11 × 13 m extended plots), placed randomly on 0.25–1 ha subsites (Table 1) 1 month or 2 years after the fire, were used for data collection. In the swamps an additional 15 random quadrats (at 2 locations; one on the Anglesea River and another on a western tributary, Edwards Creek, of the Anglesea River; Fig. 1) were used at year 3 to confirm that the floristic and structural data collected at subsites S1–S4 were a representative sample of the swamp thicket communities in the area. Throughout the study, field observations on the dunes and cliffs at Port Roadknight, Anglesea, and the cliff tops at Aireys Inlet, were used to supplement quadrat data on floristics, structure, flowering and regeneration response of coastal communities.

For methods see Wark et al. (1987) and Wark (1996, 1997). Data were collected in spring 1, 3 and 10 years after fire. Nomenclature of vascular plants follows Ross (1996); for Orchidaceae—Backhouse & Jeanes (1995); mosses—Scott & Stone (1976); liverworts—Scott (1985); and lichens—Filson & Rogers (1976). Name changes of vascular plants which have occurred since Wark (1996) are given in the Appendix.

Total species lists were made for each site and subsite at each survey, and this information used to supplement quadrat data on floristics, flowering and regeneration strategies. As in the previous three papers (Wark et al. 1987; Wark 1996, 1997), the term 'total' number of species at a site, or subsite, refers to the total number of species recorded in the quadrats plus any additional species recorded at that site, or subsite. In the present paper, quadrat data alone is used to analyse the relationship between plant species richness and total vascular plant cover.

Regeneration strategies terminology. Terminology follows Purdie & Slatyer (1976) and Purdie (1977a, 1977b), namely: OSR = obligate seed regenerator (regenerating from seed, spores or propagules only); FRR = facultative regrowth regenerator (regenerating from seed, spores or propagules and by regrowth also); ORR = obligate regrowth regenerator (regenerating by regrowth only).

Environmental weeds terminology. Terminology follows Carr (1993), namely: Environmental weeds are 'naturalised, exotic, or ecologically "out-of-balance" indigenous species outside the agricultural or garden context which, as a result of invasion, adversely affect survival or regeneration of indigenous species in natural or partly-natural vegetation communities'.

RESULTS

Soils

Profiles. All soils had A horizons greater than 0.9 m, and color falling in the Munsell 'black' or 'dark brown' range. Profiles of the A horizon at Site D were comprised of 'black brown'/'black' calcareous sand, whilst at site S unstructured 'black' peat extended to a depth of >0.9 m. The color of 'burnt peat' at site S was in the Munsell 'red' range, and extended to a depth of about 0.15 m.

Chemical analysis. Soils at the subsites ranged in pH from 3.7–8.3 and were low in exchangeable nutrient cations, N and P (Table 2). Swamp soils (site S) were high in organic matter (Table 2). The level of Ca and Mg was higher in coastal soils (site D), probably due to their geological history and to salt spray deposition from on-shore winds (Parsons & Gill 1968; Parsons 1979).

Analyses of topsoil sampled one and two years after fire showed no significant change in nutrient levels between these times (Table 2, $P > 0.05$) and suggests that any 'ash bed' effect had disappeared by the first year. Unfortunately topsoil samples collected two months after the fire were mislaid so no information is available on nutrient levels for that period.

Moisture. Soils at all swamp sites were waterlogged during winter, June–August, and appeared droughted during summer, December–February). Soils in the interdune corridor of the sand dunes, between subsites D1 and D2, were waterlogged during winter. Roadworks and dune fencing along the Great Ocean Road in the first year after the fire resulted in some diversion of surface road water onto site D1.

Phytophthora cinnamomi. Phytophthora cinnamomi was isolated by Dr G. C. Marks three years post-fire from roots of plants of the heath woodland and heath woodland ecotone (subsites B2 and B3; Wark et al. 1987) adjacent to site S. Both these communities were uphill from subsites S3 and S4. Symptoms of possible *Phytophthora* infestation such as dead plants of *Sprengelia incarnata* were seen in the swamp ecotone (subsite S4) and adjacent swamp (subsite S3) at years 2, 3 and 10 post-fire.

Vegetation

Floristics. The floristics of the plant sub-communities one, three and ten years post-fire are presented as presence–absence data in Tables 3, 4, and Fig. 2.

Community (subsite)	Year after fire	pH (H_2O)($CaCl_2$)	Exch. Na C mol(+)/kg	Exch. K C mol(+)/kg	Exch. Ca C mol(+)/kg	Exch. Mg C mol(+)/kg	Avail. P mg/kg	Total Kjeldahl N g/g²	Organic C g/g²	C/N
Leucopogon parviflorus, *Acacia longifolia* var. *sophorae* Open scrub (D1)	1*	6.9, 6.4	0.10	0.10	5.10	2.00	13.4	0.27	4.2	18
	2**	7.2, 6.1	0.50	0.30	5.50	3.00	13.8	0.17	2.9	21
Melaleuca lanceolata, *Leucopogon parviflorus* Open scrub (D3)	1	8.3, 7.7	0.10	0.10	9.50	2.60	4.6	0.20	3.7	19
	2	8.3, 8.0	<0.10	0.10	9.90	2.30	6.6	0.21	4.3	14
Melaleuca squarrosa Closed scrub (S3)	1	4.9, 4.7	9.45	0.70	2.35	1.75	2.7	0.81	19.6	30
	2	4.4, 4.3	10.20	0.95	1.30	1.90	1.4	0.67	17.1	32
Eucalyptus obliqua, *M. squarrosa* Heath woodland/Closed scrub (ecotone) (S4)	1	4.8, 3.8	0.40	0.10	0.60	0.10	1.7	0.18	6.0	33
	2	4.6, 3.7	<0.1	0.10	0.20	0.20	1.2	0.15	4.8	33

Table 2. Soil analysis of the A horizon (0–10 cm) of sand dune (D1, D3) and swamp (S3, S4) communities 1 and 2 years after fire. *Year 1 values are from single samples. **Year 2 values are from composite samples of 40 cores.

(a) Coastal dunes (site D, Table 3)

(i) Number of species. A total of 124 species of vascular plants were recorded prior to the fire. All but 2 species (over 98%) reappeared during the first year; and all were present by 3 years post-fire. In contrast, 11 species of non-vascular plants appeared by year 3 and an additional 17 non-vascular plant species between years 3 and 10.

A total of 28 shrub species, 86 species of herbs, 8 creepers and climbers, 2 ferns and 28 species of non-vascular plants were present, giving a total species list of 152 for the 10 years post-fire at site D (Table 3). In this paper, the term graminoid will not be used, and the term herb used to mean an herbaceous species.

(ii) Introduced species. Twenty-eight introduced species, mainly members of the Asteraceae and Poaceae, were present at moderate to high density in the sand dune communities, especially in the scrub adjacent to the Great Ocean Road (subsite D1, Table 3). These included two exotic shrubs classified as 'environmental weeds', **Chrysanthemoides monilifera* ssp. *monilifera* and **Polygala myrtifolia* (Carr et al. 1992); one exotic creeper, *Rubus ulmifolius*, classified as a noxious weed; and two Australian shrub species, *Leptospermum laevigatum* and *Paraserianthes lopantha*, naturalised outside their geographic range and classified as 'environmental weeds' (Carr et al. 1992; Carr 1993).

Many introduced species of herbs and shrubs appeared in other coastal communities of the district post-fire. Field observations made in coastal scrub on the dunes and cliffs at Point Roadknight (Anglesea), and in coastal scrub and heath on the cliff tops at Aireys Inlet, show that huge numbers of seedling shrubs of exotic, **Chrysanthemoides monilifera* ssp. *monilifera* and **Polygala myrtifolia*, and indigenous *Leptospermum laevigatum* and *Acacia longifolia* var. *sophorae* appeared at both sites in the first year post-fire and were still present at year 10 post-fire (F. Anderson, pers. comm.; M. D. White, pers. comm.; Carr et al. 1992). On the cliff tops at Aireys Inlet, many seedling shrubs of indigenous species from New South Wales and Western Australia, and South African and European exotics also appeared in the first year post-fire and remained till year 10, including **Erica lusitanica*, **Genista linifolia*, *Hakea laurina*, *Hakea suaveolens*, *Melaleuca armillaris*, *Melaleuca diosmifolia*, *Melaleuca hypericifolia* and *Paraserianthes lopantha* (F. Anderson, pers. comm.).

In many cases **C. monilifera* ssp. *monilifera*, **Polygala myrtifolia*, **Erica lusitanica* and **Genista linifolia* flowered and seeded during the first year post-fire producing a second crop of seedlings by 3 years post-fire (F. Anderson, pers. comm.)

(iii) Floristic diversity of communities. The dune communities were floristically diverse. Species numbers per sub-community ranged from 54–111 (Table 3). Seventy-nine to 86% of sand dune species in each sub-community were sampled in the permanent quadrats by year 3, giving a species richness in quadrats of 43–95 species (Table 3).

Nine species were found in all sand dune sub-communities including *Melaleuca lanceolata*, *Leucopogon parviflorus*, *Hibbertia sericea*, *Poa poiformis*, *Lepidosperma gladiatum* and several species of herbs.

Computer analysis of combined year 1 and year 3 data, by Dr D. J. Robertson, Charles Sturt University, using both classification and ordination techniques (data not presented here), confirmed the presence of four distinct sand dune sub-communities all with a dominant shrub layer (subsites D1–D4), and identified floristic differences between them (Tables 1, 3).

Computer analysis also showed that the species composition of each sub-community changed little in the first three years after fire. Ninety-five per cent of all dune species present by the third year appeared in the first year after fire (Table 3).

(iv) Changes in species richness with time. Maximum post-fire species richness occurred in the early years after fire (Table 3, Figs 2A–2F). In dune communities, the species richness of vascular plants in quadrats decreased (Figs 2A, 2C, 2E) as vascular plant cover increased (Figs 2B, 2D, 2F). In contrast, on the dunes the species richness of non-vascular plants either increased or increased then plateaued (Figs 2A, 2C, 2E) as vascular plant cover increased (Figs 2B, 2D, 2F).

(v) Dominant species (Table 1). The approximate density of *Melaleuca lanceolata* on the dunes pre-fire varied from 10–1000 shrubs/ha (approx. 5 stems/shrub), and ranged in habit from 4.5 m multi-stemmed large shrubs of GBH 34 cm (subsite D2; Table 1, Figs 3A–3C), to low sprawling 1.5 m salt-pruned shrubs in exposed areas (subsites D3, D4; Table 1). Densities of *M. lanceolata* shrubs pre-fire were very low (10/ha) on the landward dune (subsite D1) and highest on the lee side of the seaward dune (subsite D2).

The approximate density of *Leucopogon parviflorus* pre-fire varied from 10–3000 shrubs/ha (approx. 2.5 stems/shrub) and ranged in habit from 2.5 m tall multi-stemmed large shrubs of GBH 18 cm (subsite D1; Table 1) to low sprawling

Subsite	D1			D2			D3			D4 §		
Vegetation formation	Open scrub			Open scrub			Open heath			Open heath		
Tall Shrubs†												
Myrtaceae												
Melaleuca lanceolata	1	3	(10)	1	3	10	(1)	3	10	1	3	10
Shrubs†												
Asteraceae												
Ozothamnus ferrugineus	(1)	(3)	10						(10)			
" *turbinatus*							(1)	(3)	(10)	1	(3)	(10)
Olearia axillaris							(1)	(3)	(10)	(1)	(3)	(10)
" *ramulosa*	(1)	3										
Calocephalus brownii							1	(3)	(10)	1	3	10
**Chrysanthemoides monilifera* ssp. *monilifera*	(1)	(3)	(10)	(1)		(10)	(1)		(10)	1		
Chenopodiaceae												
Rhagodia candolleana			(10)	(1)	3	10	(1)	3	(10)	1	3	10
Epacridaceae												
Leucopogon parviflorus	(1)	3	10	(1)	3	(10)	1	3	10	1	3	10
Goodeniaceae												
Goodenia ovata	(1)											
Mimosaceae												
Acacia longifolia var. *sophorae*	1	3	10	1	3	10			10			
" *verticillata*	(1)											
**Paraserianthes lopantha*	(1)											
Pittosporaceae												
Bursaria spinosa	(1)											
Myoporaceae												
Myoporum insulare	1	3	(10)		(3)	(10)						
" *(viscosum)* sp.	(1)											
Myrtaceae												
Leptospermum laevigatum	(1)	(3)	(10)									
" *continentale*	(1)	3	10									
Fabaceae												
Indigofera australis	(1)											
Dilleniaceae												
Hibbertia sericea	1	3	(10)	1	3	(10)	(1)	3	10	1	3	(10)
" *riparia*	(1)											
Polygalaceae												
**Polygala myrtifolia*	(1)	(3)	(10)			(10)			(10)			
Proteaceae												
Banksia marginata	(1)	3	(10)									
Rutaceae												
Correa alba							(1)	(3)	(10)	1	3	10
Rhamnaceae												
Spyridium vexilliferum										1	(3)	
Solanaceae												
Solanum laciniatum	(1)	(3)		(1)	(3)							
Thymeliaceae												
Pimelea humilis	1											
" *serpyllifolia*					3	(10)	1	3	10	1	3	10
Lichens†												
Cladia aggregata			10			(10)			10			10
Parmelia spp.									10			10
Teloschistes chrysophthalmus												10
Usnea ? confusa						(10)			10			10
Unidentified spp.												10

Table 3 continued next page (see legend on page 184)

Subsite	D1			D2			D3			D4 §		
Vegetation formation	Open scrub			Open scrub			Open heath			Open heath		
Liverworts†												
Cephaloziella exiliflora			10									
Lophocolea semiteres		3	10			10		3	10	1	3	10
Marchantia berteroana	(1)								10	(1)		
Unidentified spp.			10			10			10			
Mosses†												
Barbula calycina								3	10	(1)	3	
Barbula crinita									10			
Barbula torquata		3						3	(10)	1	3	(10)
Bartramidula pusilla		3						3				
Brachythecium rutabulum								3				
Bryum billardieri		3	10			10		3	10	(1)	3	
Bryum capillare			10						(10)			(10)
Bryum spp.			10									
Campylopus introflexus			10									
Campylopus spp.			10			(10)						
Ceratodon purpureus	1											
Fissidens tenellus			10									
Funaria hygrometrica	(1)	3					(1)					
Polytrichum juniperinum			10									
Rhacopilum convolutaceum			(10)			10			(10)			
Rhynchostegium tenuifolium						10			(10)			
Sematophyllum amoenum			10									
Tayloria octoblepharis			10									
Thuidium furfurosum								3	10	1	3	10
Tortella cirrhata									(10)			(10)
Tortula antarctica								3	(10)	1	3	(10)
Tortula papillosa									10			
Zygodon minutus						(10)			(10)			
Unidentified spp.	1	3	10	1	3		1	3		1	3	
Fungi†												
Unidentified spp.		(3)	(10)		(3)	(10)		(3)	(10)	(1)	(3)	(10)
Ferns†												
Lindsaea linearis	(1)	(3)		1	3							
Pteridium esculentum	1	3	10			10						
Grasses†												
Poaceae												
Agrostis avenacea	1	3			3			3	10			
" *billardieri*				1	3		1	3	(10)		3	10
Austrostipa flavescens				1	3		1	3	10	1	3	
" *semibarbata*	1	3										
**Briza maxima*	1	3										
* " *minor*	1	3										
**Catapodium rigidum*					3		1	3				
Danthonia caespitosa							(1)	(3)		1	3	
Deyeuxia quadriseta	1	3										
Dichelachne crinita	(1)	3									3	
**Ehrharta erecta*		(3)										
**Holcus lanatus*	(1)											
Imperata cylindrica	1	3	(10)									
**Lagurus ovatus*				(1)	3		1	3	10	1	3	10
Microlaena stipoides	1											

Table 3 continued next page (see legend on page 184)

Subsite	D1			D2			D3			D4 §		
Vegetation formation	Open scrub			Open scrub			Open heath			Open heath		
Poa poiformis	1	3		1	3	10	1	3	10	1	3	10
Spinifex hirsutus										1	3	10
Themeda triandra	1	3										
**Vulpia myuros*								3			3	
Unidentified spp.	1	3	10		3	10		3	10	1	3	10
Lilies & irises '												
Hypoxidaceae												
Hypoxis glabella							1					
Liliaceae												
Chamaescilla corymbosa	(1)											
Dianella brevicaulis				(1)					(10)			(10)
Wurmbea dioica							(1)					
Xanthorrhoeaceae												
Lomandra filiformis	(1)											
" *micrantha*	(1)											
Lomandra spp.			(10)									
Sedges & rushes '												
Cyperaceae												
Gahnia radula	1	3	10			10						
Isolepis marginata	1						1					
" *nodosa*	(1)	3		(1)			(1)	(3)	10	1	3	10
Lepidosperma gladiatum	1	3	10	1	3	10	1	3	10	(1)	3	(10)
Schoenus agopon	1	3			3			3	10			
Juncaceae												
Juncus pallidus	(1)	(3)		(1)	(3)							
Orchids '												
Orchidaceae												
Caladenia latifolia							1	3	10	1	3	10
Corybas incurvis							1	3	10			
Cyrtostylis reniformis							(1)	(3)	(10)			
Pterostylis alata							(1)					
Microtis unifolia	(1)						(1)					
Herbs '												
Asteraceae												
**Arctotheca calendula*	(1)			1								
Argentipallium leucopsideum							(1)					
**Carduus tenuiflorus*	(1)	3			3	(10)		3	(10		3	(10)
**Cirsium vulgare*	(1)				3			(3)	(10)			
**Conyza bonariensis*	1	3	(10)	1	3	10						
Cymbonotus priessianus				1								
**Dittrichia graveolens*	(1)											
Euchiton sphaericus	(1)											
Helichrysum leucopsideum							(1)					
" *scorpioides*	(1)											
**Hypochoeris radicata*	(1)											
**Senecio elegans*							(1)		(10)			(10)
" *hispidulus*	(1)			(1)								10
" *odoratus*	(1)	(1)										
" spp.	(1)	3		(1)		(10)						
**Sonchus oleraceus*	1			1	3	(10)		3	(10)			

Table 3 continued next page (see legend on page 184)

Subsite	D1			D2			D3			D4 §		
Vegetation formation	Open scrub			Open scrub			Open heath			Open heath		
Aizoaceae												
Tetragonia implexicoma			(10)	(1)	(3)	(10)						
Boraginaceae												
Cynoglossum suaveolens							1					
Campanulaceae												
Wahlenbergia gracilenta	1	3										
" *stricta*	(1)											
Caryophyllaceae												
**Cerastium glomeratum*		3			3		(1)	3			3	
Parietaria debilis				1		10			10			
**Polycarpan tetraphyllum*				(1)								
**Stellaria media*							1	3	(10)	1	3	(10)
Chenopodiaceae												
Threlkeldia diffusa				(1)								
Convolvulaceae												
Convolvulus erubescens	1	3										
Dichondra repens	1	3	10		3	10		3	10			
Crassulaceae												
Crassula decumbens				(1)			(1)					
" *sieberiana*				(1)	3		(1)	3	10	1	3	(10)
" spp.	(1)											
Cruciferae												
**Cokile maritima*										(1)		
Fabaceae												
**Melilotus* spp.	(1)											
**Vicia sativa*	(1)											
**Vicia* spp.	(1)											
Droseraceae												
Drosera peltata ssp. *auriculata*	(1)											
Drosera peltata	(1)											
Gentianaceae												
Centaurium spicatum	1	3			3		(1)	3	10		3	(10
Sebaea ovata							1	3				
Geraniaceae												
Geranium solanderi	1	3		1	3	(10)		3	10		3	10
Pelargonium australe	(1)	3										
" *inodorum*	(1)											
Goodeniaceae												
Scaevola albida	(1)										3	
Haloragaceae												
Gonocarpus tetragynus	1	3										
Labiatae												
Scutellaria humilis				(1)								
Oxalidaceae												
**Oxalis corniculata*	1	3						3				
Polygonaceae												
Rumex brownii	(1)	3										
Plantaginaceae												
Plantago varia	(1)	3										
Primulaceae												
**Anagallis arvensis*	1			1	3			3	10			
Rosaceae												
Acaena novae-zelandiae	(1)	(3)	(10)									

Table 3 continued next page (see legend on page 184)

Subsite Vegetation formation	D1 Open scrub			D2 Open scrub			D3 Open heath			D4 [§] Open heath		
Rubiaceae												
**Galium divaricatum*				(1)								
" *murale*		3		1							3	(10)
" spp.	(1)											
Opercularia varia	(1)											
Scrophulariaceae												
Veronica calycina	1	3										
Solanaceae												
**Solanum douglasii*	1			1								
Umbelliferae												
Apium prostratum							(1)		(10)			(10)
Daucus glochidiatus					3		1	3	10	1	3	10
Hydrocotyle hirta	1	3					(1)	3	10	1	3	10
Violaceae												
Viola hederacea	1	3										
Zygophyllaceae												
Zygophyllum billardierei	1											
Creepers & climbers [†]												
Aizoaceae												
Carpobrotus rossii				(1)	3	(10)				1	3	10
Fabaceae												
Swainsona lessertiifolia	1			1			1	3	10	1		(10)
Lauraceae												
Cassytha glabella	(1)	3	(10)									
Pittosporaceae												
Billardiera scandens	1	3										
Polygonaceae												
Muehlenbeckia adpressa	1	3	(10)	(1)	3	(10)						
Rosaceae												
Rubus parviflorus	(1)	3	(10)									
**Rubus ulmifolius*	(1)	(3)	(10)									
Ranunculaceae												
Clematis microphylla					3	(10)	1	3	10	(1)	3	10
Seedlings [†]												
Dicotyledon	1			1			1					
Monocotyledon	1			1			1		10			
Sub-total vascular species in quadrats Year 1, Year 3, Year 10	37	43	9	17	29	10	19	31	24	23	30	17
Sub-total additional vascular species at site Year 1, Year 3, Year 10	51	10	17	20	4	14	21	8	16	4	3	13
Total vascular species [δ] Year 1, Year 3, Year 10	88	53	26	37	33	24	40	39	40	27	33	30

Table 3 continued next page (see legend on page 184)

Subsite Vegetation formation	D1 Open scrub			D2 Open scrub			D3 Open heath			D4 § Open heath		
Sub-total non-vascular species in quadrats Year 1, Year 3, Year 10	1	5	11	-	1	4	1	8	9	4	6	6
Sub-total additional non-vascular species at site Year 1, Year 3, Year 10	2	-	1	-	-	4	1	-	7	2	-	4
Total non-vascular species δ Year 1, Year 3, Year 10	3	5	12	-	1	8	2	82	16	6	6	10
Total species δ Year 1, Year 3, Year 10	91	58	38	37	34	32	41	47	56	33	39	40
Total species δ Years 1-3 Combined	95			50			59			43		
Total species δ Years 1-10 Combined	111			60			75			54		
Total species δ Years 1-10 Combined	152 species 124 species vascular plants 28 species non-vascular plants											

Table 3. Floristic comparisons between sand dune subsites 1, 3 and 10 years after fire. *Key:* 1 = present in quadrats year 1; 3 = present in quadrats year 3; 10 = present in quadrats year 10; (1) = present at site year 1; (3) = present at site year 3; (10) = present at site year 10; §not burnt; *introduced species; †1 × 3 m quadrats; δtotal species present in quadrats plus additional species present at site.

1.0–1.5 m salt-pruned shrubs in exposed areas (subsites D3, D4; Table 1). Densities of *L. parviflorus* were 3000/ha at subsites D1 and D3, and very low (10/ha) at subsite D2.

The mean density of *Acacia longifolia* var. *sophorae* on the landward dune (subsite D1) pre-fire was approximately 275 shrubs/ha (range 50–500 ha). Most were mature sprawling shrubs 3.5 m tall by 4.0–7.0 m wide. No *A. longifolia* var. *sophorae* was present pre-fire at any other subsites; though occasional plants occurred on the coastal heathland inland from the dunes.

(vi) Non-vascular plants. Non-vascular plants were uncommon. The number of species present gradually increased with time post-fire (Table 3). Three species appeared in year 1, an additional 8 species by year 3, and an additional 17 species by year 10, making a total of 28 species of non-vascular plants for the 10 years post-fire. The burnt subsites, subsites D1–D3, were colonised in succession by different species of non-vascular plants. Post-fire colonisers, *Funaria hygrometrica*, *Ceratodon purpureus* and *Marchantia berteroana*, appeared during year 1 post-fire and were rarely seen after year 3. The liverwort *Lophocolea semitieres* and another seven species of moss appeared by year 3; and a further species of liverwort, 14 additional species of moss and 3 species of lichens by year 10.

Less than 50% of the non-vascular plant species which appeared at subsites D1–D3 during the 10 years post-fire, were recorded on the unburnt subsite, subsite D4.

(b) Swamp thicket (site S, Table 4)

(i) Number of species. A total of 94 species of vascular plants were recorded prior to the fire. Seventy-eight per cent reappeared in the first year after fire, and all reappeared by 3 years post-fire (Table 4). One additional species, the orchid *Burnettia cuneata,* not previously recorded in the district, appeared in the swamp ecotone (subsite S4) six months after fire.

No additional species of vascular plants appeared between 3 and 10 years post-fire. In contrast, 9 species of non-vascular plants appeared by year 3 and an additional 1 non-vascular plant species between years 3 and 10.

A total of 2 tree species, 18 shrubs, 6 species of ferns, 64 species of herbs, 3 creepers and climbers, 2 water plants and 19 species of non-vascular plants were present, giving a total species-list of 114 for the 10 years post-fire at site S (Table 4).

(ii) Introduced species. Only three introduced species, **Centaurium spicatum*, **Cotula coronopifolia* and **Cyperus tenellus*, were found in the swamp ecotone adjacent to the Harrison Track (subsite S4, Table 4).

(iii) Floristic diversity of communities. The *Melaleuca squarrosa* swamp thicket/closed scrub plant sub-communities (subsites S1–S3) were floristically similar. Species numbers per sub-community ranged from 29–42 (Table 4). In contrast, the heath woodland/closed scrub ecotone sub-community (subsite S4) was floristically richer (98 species—Table 4). Ninety-one to 95% of species in each sub-community were sampled in the permanent quadrats by year 3 giving a species richness in quadrats of 29–98 species (Table 4).

Seven species of shrubs and 1 tree species were found in all swamp sub-communities. They were *Eucalyptus ovata, Melaleuca squarrosa, Leptospermum continentale, Leptospermum lanigerum, Viminaria juncea, Epacris obtusifolia, Sprengelia incarnata, Comesperma ericinum* and *Pimelea flava.*

Computer analysis by Dr D. J. Robertson, Charles Sturt University, confirmed the presence of four distinct swamp sub-communities and identified floristic differences between them. Computer analysis also showed that the species composition of each sub-community changed little in the first three years after fire. Eighty-two per cent of all swamp species present by the third year appeared in the first year after fire (Table 4).

The floristic differences between the swamp communities appeared to reflect variations in soils, drainage and topography. Communities on peaty soils in depressions or along drainage lines always contained the shrub *Leptospermum lanigerum* (subsites S1, S2) whilst communities on drier transitional soils, which were seasonally waterlogged, contained the sedge *Baumea acuta* (subsites S3, S4).

The proportion of sedges and rushes was greater in swamp communities than in the sand dune communities (Tables 3, 4).

(iv) Changes in species richness with time. Maximum post-fire species richness occurred in the early years after fire (Table 4, Figs 2G, 2H). In swamp communities, the species richness of vascular plants in quadrats decreased (Fig. 2G) as vascular plant cover increased (Fig. 2H). In contrast, the species richness of non-vascular plants increased with time then plateaued (Fig. 2G) as vascular plant cover increased (Fig. 2H).

Combining site and quadrat data, maximum post-fire species richness of vascular plants in the *M. squarrosa* swamp (subsites S1–S3 combined) occurred during years 1–3, decreasing by year 10 to 70% of the year 1–3 level (40 species years 1–3 combined; 28 species year 10—Table 4). Similarly, maximum post-fire species richness of non-vascular plants (subsites S1–S3 combined) occurred during years 1–3 and then decreased by year 10 to 50% of the year 1–3 level (10 species years 1–3 combined; 5 species year 10—Table 4).

(v) Dominant species (Table 1). *Melaleuca squarrosa* formed dense thickets often 0.5 km wide along the length of the Anglesea River Valley. The approximate density of *M. squarrosa* shrubs pre-fire ranged from 30 000 shrubs/ha (5–10 stems/shrub; subsites S2, S3; Figs 4A–4C); to dense thickets of 100 000–250 000 shrubs/ha (subsite S1 and other sites along the Anglesea River). The approximate pre-fire height of *M. squarrosa* ranged from 3.5 m (subsites S1–S3, Table 1) to 4.8 m at Edwards Creek, a westerly tributary of the Anglesea River.

Eucalyptus ovata multi-stemmed emergents occurred at low density (eg. 15 trees/ha; 5 stems/tree at subsite S2, Figs 4A–4C), usually in the centre of the thickets of *M. squarrosa* near permanent water. Pre-fire height at both Harrison Track and Edwards Creek was approximately 6.5 m (range 6.25–6.75 m; GBH 56.0 cm).

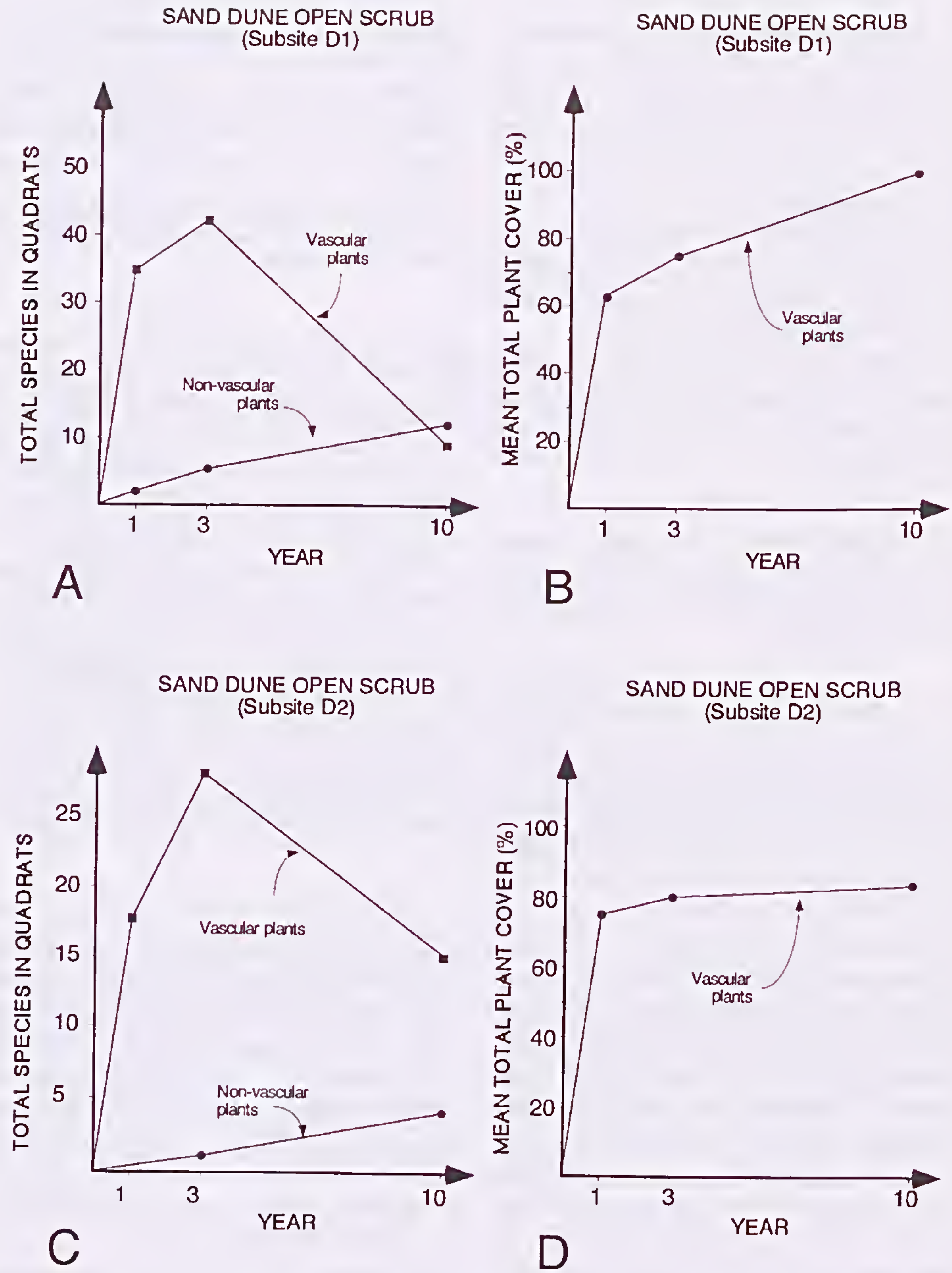
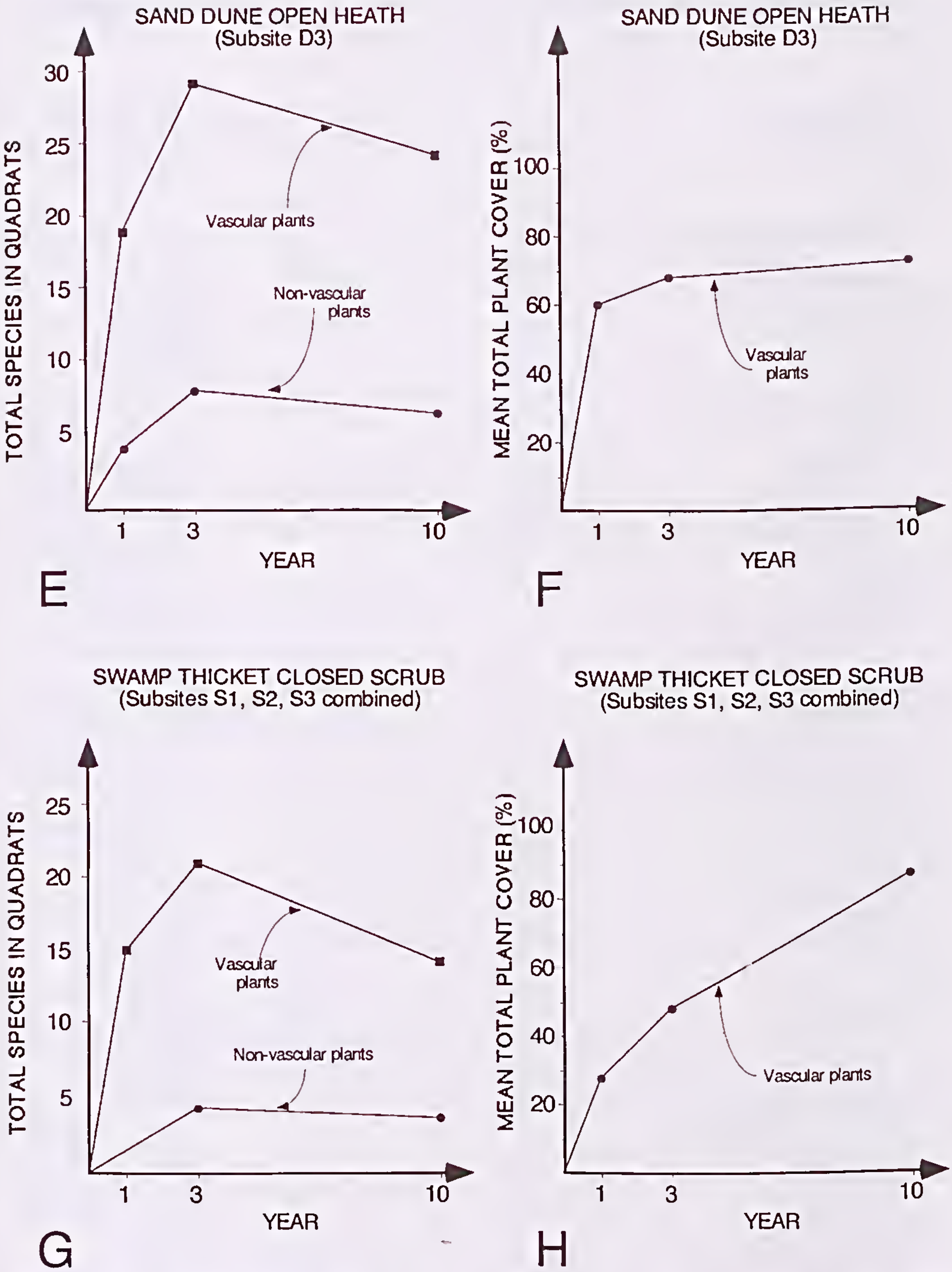


Fig. 2. Species richness and plant cover (%) 1, 3 and 10 years post-fire. A, Species richness in sand dune open-scrub (subsite D1). B, Cover (%) in sand dune open-scrub (subsite D1). C, Species richness in sand dune open-scrub (subsite D2). D, Cover (%) in sand dune open-scrub (subsite D2). E, Species richness in



sand dune open-heath (subsite D3). F, Cover (%) in sand dune open-heath (subsite D3). G, Species richness in swamp thicket closed-scrub (subsites S1–S3 combined). H, Cover (%) in swamp thicket closed-scrub (subsites S1–S3 combined).

Subsite Vegetation formation	S1§ Closed scrub		S2§ Closed scrub		S3 Closed heath			S4 Heath woodland/ Closed scrub		
Trees										
Myrtaceae										
Eucalyptus obliqua								(1)	(3)	(10)
" *ovata*	(3)	(10)	(3)	(10)	1	(3)	(10)	(1)	(3)	(10)
Tall Shrubs †										
Myrtaceae										
Leptospermum continentale	3	10	3	10	1	3	10	1	3	10
" *lanigerum*	3	10	3	10	(1)	3				
Melaleuca squarrosa	3	10	3	10	1	3	10	1	3	10
Fabaceae										
Viminaria juncea	3	10	3	10	(1)	(3)	(10)			
Shrubs †										
Asteraceae										
Ozothamnus rosmarinifolius								(1)	(3)	(10)
Epacridaceae										
Epacris impressa								1	3	10
" *obtusifolia*	3	10	3	(10)	1	3	10	1	3	10
Leucopogon australis								1	3	10
Sprengelia incarnata	3	10	3	10	1	3	10	1	3	10
Leucopogon virgatus								(1)	(3)	(10)
Goodeniaceae										
Goodenia ovata			3	10		3	10	(1)	(3)	(10)
Dilleniaceae										
Hibbertia fasciculata var. *prostrata*								(3)		
Fabaceae										
Pultenaea dentata						(3)	(10)		3	10
" *stricta*			3			3	(10)		(3)	(10)
Sphaerolobium vimineum									(3)	
Mimosaceae										
Acacia verticillata								(1)	(3)	(10)
Polygalaceae										
Comesperma ericinum	3	(10)	(3)			3		1	3	10
Proteaceae										
Banksia marginata								1	3	10
Thymelaceae										
Pimelea flava	3	10	3	(10)		3	10	(1)	3	(10)
Fungi †										
Gerronema postii					(1)			(1)		
Unidentified spp.	3	10	3	10		3	10		3	10
Liverworts †										
Cephaloziella exiliflora						3				10
Goebelobryum unguiculatum										10
Hyalolepidozea longisypha									3	10
Kurzia compacta									3	10
Kurzia ? reversa							10			10
Lethocolea pansa						3	10			10
Marchantia berteroana	3									
Riccardia aequicellularis										10
Unidentified spp.	3	10	3	10		3	10		3	10

Table 4 continued next page (see legend on page 192)

Subsite	S1§			S2§			S3			S4		
Vegetation formation	Closed scrub			Closed scrub			Closed heath			Heath woodland/ Closed scrub		
Lichens †												
Cladia aggegata		3	10		3	10		3	10		3	10
Thysanothecium scutellatum												10
Usnea sp.												10
Unidentified spp.												10
Mosses †												
Barbula calycina											(3)	
Bryum spp.								3				
Campylopus clavatus								3	10			
" *introflexus*								3	10			10
Ceratodon purpurens								3				
Funaria hygrometrica										(1)		
Polytrichum juniperinum											(3)	
Unidentified spp.		3	10			(3)	1	3	10			
Ferns & allies †												
Unidentified spp.					3							
Gleicheniaceae												
Gleichenia dicarpa		3	10		(3)		1	3	10	1	3	10
Schizaeaceae												
Schizaea fistulosa										1	3	
Selaginellaceae												
Selaginella uliginosa								3	10	1	3	10
Centrolepidaceae												
Centrolepis aristata										(1)		
" *strigosa*										(1)		
Dennstaedtiaceae												
Pteridium esculentum										(1)		
Sedges & rushes †												
Unidentified spp.						10			10		3	10
Cyperaceae												
Baumea acuta							1	3		1		
" *juncea*		3			3		1	3	10	1	3	(10)
" *tetragona*		3				10	1	3	10	1	3	(10)
**Cyperus tenellus*											(3)	
Gahnia sieberiana		(3)	(10)		3	(10)	1	3	10			
" *trifida*		3			3	(10)	(1)	3	10			
" *radula*										(1)	(3)	(10)
Isolepis inundata										(1)		
" *marginata*										(1)		
Lepidosperma longitudinale		3	10									
Schoenus apogon											(3)	
" *brevifolius*		3			3		1	3	10	1	3	10
" *tenuissimus*											(3)	10
Juncaceae												
Juncus planifolius		3										
" *pauciflorus*										(1)	(3)	(10)
Restionaceae												
Eurodisma minus		3	10		3	10	1	3	10		3	10

Table 4 continued next page (see legend on page 192)

Subsite Vegetation formation	S1§ Closed scrub		S2§ Closed scrub	S3 Closed heath			S4 Heath woodland/ Closed scrub		
Water plants									
Juncaginaceae									
Triglochin procerum	3	10	3						
Menyanthaceae									
Villarsia reniformis	(3)		(3)				(1)	(3)	
Grasses									
Poaceae									
Agrostis avenacea									3
Deyeuxia densa							(1)		
" *quadriseta*							(1)		
Poa morrisii							(1)	(3)	
Microlaena stipoides							(1)		
Phragmites australis	(3)	10							
Tetrarrhena acuminata	3								
Lilies & irises†									
Xanthorrhoeaceae									
Lomandra longifolia							(1)		(10)
Iridaceae									
Patersonia fragilis							1	3	10
" *occidentale*				(1)	3		1	3	10
Xyridaceae									
Xyris operculata	3	10	(3)		(3)		1	3	10
Orchids†									
Orchidaceae									
Burnettia cuneata				(1)			(1)		
Calochilus campestris							(1)		
Corybas fordhamii							(1)		
Cryptostylis subulata			3						
Orthoceras strictum				(1)			(1)		
Prasophyllum australe							1		
Herbs†									
Asteraceae									
**Cotula coronopifolia*							(1)		
Euchiton sphaericus							(1)		
Lagenifera gracilis							(1)		
Droseraceae									
Drosera peltata var. *auriculata*				1			1		10
" *binata*	3		(3)	1	3	10	1	3	10
" *glanduligera*							(1)		
" *macrantha*							(1)		
" *peltata*							1	3	
" *pygmaea*					(3)		1	(3)	
" *whittakeri*							1	3	
Euphorbiaceae									
Poranthera microphylla							(1)		
Gentineaceae									
**Centaurium spicatum*							(1)		
Goodeniaceae									
Goodenia humilis							(1)	(3)	
" *lanata*							(1)	(3)	
Selliera radicans							(1)	(3)	

Table 4 continued next page (see legend on page 192)

Subsite Vegetation formation	S1[§] Closed scrub			S2[§] Closed scrub			S3 Closed heath			S4 Heath woodland/ Closed scrub		
Haloragaceae												
Gonocarpus tetragynus										(1)	(3)	
" *micranthus*											(3)	
Lentibulariaceae												
Utricularia lateriflora										1		
Lobeliaceae												
Lobelia alata										(1)	(3)	
Loganiaceae												
Mitrasacme pilosa											(3)	
Rosaceae												
Acaena novae-zelandiae											(3)	
Rubiaceae												
Galium binifolium		3	10							(1)	(3)	
Opercularia varia										1		
Tremandraceae												
Tetratheca ciliata											(3)	(10)
Stylidiaceae												
Stylidium perpusillum											(3)	
Umbelliferae												
Centella cordifolia								3		(1)		
Xanthosia dissecta							1	3	10	1	3	10
" *pusilla*										(1)	3	
Violaceae												
Viola cleistogamoides										(1)	(3)	
Primulaceae												
Samolus repens										(1)	(3)	
Creepers & excclimbers [†]												
Lauraceae												
Cassytha glabella		3	10		3			3	10		3	10
" *melantha*								(3)				
Pittosporaceae												
Billardiera scandens										1	3	
Seedlings [†]												
Dicotyledon							1			1		
Monocotyledon							1			1		
Sub-total vascular species in quadrats Year 1, Year 3, Year 10	-	25	19	-	18	10	15	24	19	28	27	22
Sub-total additional vascular species at site Year 1, Year 3, Year 10	-	2	3	-	6	5	6	6	4	42	28	12
Total vascular species [δ] Year 1, Year 3, Year 10	-	27	22	-	24	15	21	30	23	70	55	24

Table 4 continued next page (see legend on page 192)

Subsite Vegetation formation	S1§ Closed scrub			S2§ Closed serub			S3 Closed heath			S4 Heath woodland/ Closed scrub		
Sub-total non-vascular species in quadrats Year 1, Year 3, Year 10	-	3	3	-	2	2	1	7	5	-	3	1
Sub-total additional non-vascular species at site Year 1, Year 3, Year 10	-	-	-	-	1	-	1	-	-	2	2	-
Total non-vascular species δ Year 1, Year 3, Year 10	-	3	3	-	3	2	2	7	5	2	5	11
Total species δ Year 1, Year 3, Year 10	§	30	25	§	27	17	23	37	28	72	60	35
Total species δ Years 1-3 Combined		29			27			40			90	
Total species δ Years 1-10 Combined		30			29			42			98	
Total species δ Years 1-10 Combined	114 species 95 species vascular plants 19 species non-vascular plants											

Table 4. Floristic comparisons between swamp subsites 1, 3 and 10 years after fire. *Key:* 1 = present in quadrats year 1; 3 = present in quadrats year 3; 10 = present in quadrats year 10; (1) = present at site year 1; (3) = present at site year 3; (10) = present at site year 10; δtotal species present in quadrats plus additional species present at site; §only surveyed years 3 and 10; *introduced species; **12 × 13 m quadrats; †1 × 3 m quadrats.

(vi) Non-vascular plants. As on the sand dunes, non-vascular plants were uncommon and appeared in a definite sequence with time. The total number of species recorded at years 1, 3 and 10 was 2, 13 and 11, respectively. The early colonisers, *Funaria hygrometrica*, *Marchantia berteroana* and *Gerronema postii*, were present in very low numbers. Liverworts were relatively plentiful in damp ecotonal areas (subsite S4).

Structure. The structure of the plant sub-communities 1, 3 and 10 years post-fire are presented in Table 5 and Figs 3–6.

At both dune and swamp sites, the fire completely incinerated the herb and ground stratum and killed all above-ground portions of the shrub stratum. Very small shrubs were burnt to the ground.

(a) Coastal dunes (site D; Table 5, Figs 3A–3C, 5A–5C, 6A–6C)

(i) Melaleuca lanceolata *recovery post-fire.* All *Melaleuca lanceolata* shrubs at subsite D3 (pre-fire GBH 22 cm) and 98% *M. lanceolata* shrubs at subsite D2 (pre-fire GBH 34 cm) survived the fire, sprouting from lignotubers 2–4 months post-fire (Figs 3A–3C). Shrubs which did not survive and resprout showed severe fire scarring at the base, and the cambial layer had apparently been damaged by the fire. The ash bed, at subsite D2 on the lee side of the dunes, was 30–45 cm deep post-fire (Figs 3A–3C).

Huge numbers of *M. lanceolata* seedlings appeared on the dunes in the first year after fire. Mean densities of *Melaleuca* seedlings after 3 years at subsites D1, D2 and D3 were 8000/ha, 280 000/ha and 57 500/ha, respectively. Very few

Subsite Vegetation type	D1 OS	D2 OS	D3 OH	D4 OH §	S1 OH	S2 CS	S3 CS	S4 HW/CS
Shrub stratum								
Melaleuca species	Ml (rare)	Ml*	Ml*	Ml (rare)	Ms*	Ms*	MS*	Ms
Other species	*As (rare),Lp	Lp	Lp	*Lp,Ca	Ll,Lc	Ll, Lc	Lc	Lc*
Cover %								
Prefire (approx.)	30-70	30-70	30-70	30-70	70-100	70-100	70-100	30-70
3 years	6	40	12	30-70 §	60 (73)	60 (65)	70 (37)	30 (40)
10 years	75	63	48	30-70 §	95 (100)	85	83	80
Height (m) (main species)	(As) (Lp)	(Ml)	(Ml)	(Lp)	(Ms)	(Ms)	(Ms)	(Ms)
Prefire (approx.)	3.5 2.5	4.5	1.9	1.25	3.5	3.5	3.5	2.0
Live stem height after fire (year 0)	0 0	0	0	1.25 §	0	0	0	0
3 years	1.2 0.6	2.0	1.0	1.25 §	1.5	2.3	2.0	1.0
10 years	3.9 2.0	3.7	1.9	1.25 §	3.2	3.7	3.4	2.1
Ground & herb stratum								
Cover %								
Prefire (approx.) - all plants	30-70	30-70	30-70	30-70	70-100	70-100	70-100	30-70
3 years - all plants	69	†51	68	30-70 §	25	8	16	32
- bare ground/litter	25	9	20	30-70 §	2.0	27	47	28
10 years - all plants	1	36	26	30-70 §	99	85	79	85
- bare ground/litter	24	1	26	30-70 §	1.0	15	21	15
Height (m)								
Prefire - approx.	1.5	1.5	1.0	1.0	2.0	2.0	2.0	1.5
Live stem height after fire (year 0)	0	0	0	1.0 §	0	0	0	0
3 years	1.0	0.8	0.4	1.0§	1.0 §	2.0	2.0	1.5
10 years	1.7	1.8	1.0	1.0 §	2.0	2.0	2.0	1.3
Tallest understorey species*	Lg	Lg	Il	Il	Gs,Gt	Gs,Gt	Gs,Gt	Gr

Table 5. Structure of sand dune (D) and swamp (S) communities 3 and 10 years after fire. *Key:* *tallest species prior to the fire; Ml = *Melaleuca lanceolata*; Ms = *Melaleuca squarrosa*; As = *Acacia longifolia* var. *sophorae*; Lp = *Leucopogon parviflorus*; Ca = *Correa alba*; Ll = *Leptospermum lanigerum*; Lc = *Leptospermum continentale*; Il = *Isolepis nodosus*; Lg = *Lepidosperma gladiatum*; Gs = *Gahnia sieberiana*; Gt = *Gahnia trifida*; Gr = *Gahnia radula*; §area not burnt; †*Melaleuca* seedlings; OS = open scrub; OH = open heath; CS = closed scrub; HW/CS = heath woodland/closed scrub (ecotone).

of these seedlings survived till year 10. Huge numbers of seedlings also germinated at year 1 under *M. lanceolata* in saline swamps beside the Anglesea River, but most did not survive (M. D. White, pers. comm.).

The rate of recovery of *M. lanceolata* was most rapid at subsite D3 (Table 5, Fig. 5C), approximate pre-fire height and cover being attained by 10 years post-fire. However, the rate of shrub height and cover recovery at this site was affected at least twice during the 10 year period by salt-spray-induced chloride toxicity which killed young regrowth on the seaward side of *M. lanceolata*. *Leucopogon parviflorus* was less affected.

The rate of recovery of *M. lanceolata* was slower in the drier conditions at site D2 (Table 5, Figs 3A–3C, 5B) though vigorous sprouting from basal epicormics occurred in the early years post-fire and recovery of cover was initially rapid, only 82% of approximate pre-fire height was reached by year 10 (Fig. 5B). A few seedling shrubs of *Myoporum insulare* and *Acacia longifolia* var. *sophorae* established in this area in the early years post-fire, and by year 10 had reached heights of 5.0 m and 3.7 m, respectively (Figs 3A–3C).

(ii) Leucopogon parviflorus *recovery post-fire.* Vegetative regeneration of *L. parviflorus* shrubs (GBH 18–22 cm) was very slow; basal regrowth gradually appearing from lignotubers over a 19-month period (6–24 months post-fire).

The percentage viability of *L. parviflorus* shrubs varied, ranging from 100% at subsite D3; 75% in *L. parviflorus* open heath on the cliff tops at Aireys Inlet; to 20% at subsite D1. Some fire scarring of *L. parviflorus* lignotubers was observed at subsite D1, and plants with such scarring did not resprout.

Rate of recovery of *L. parviflorus* height and cover was slow in comparison with other species which grew more vigorously in the early years post-fire (Table 5, Figs 5A, 6A). At subsite D1 by year 3, 0.8 m tall *Pteridium esculentum* and 1.2 m tall *Acacia longifolia* var. *sophorae* seedlings, formed a dense cover over 0.6 m *L. parviflorus* regrowth. At subsite D1, *L. parviflorus* was rank and spindly at year 10 and height and cover values were only 76% and 12% of the approximate pre-fire levels (Fig. 5A).

Few *Leucopogon* seedlings appeared at any of the subsites in the first 10 years after fire and most did not survive. The only *Leucopogon* seedlings noted at year 10 were at subsites D3 and D4 (0.12 m, 0.72 m tall, respectively).

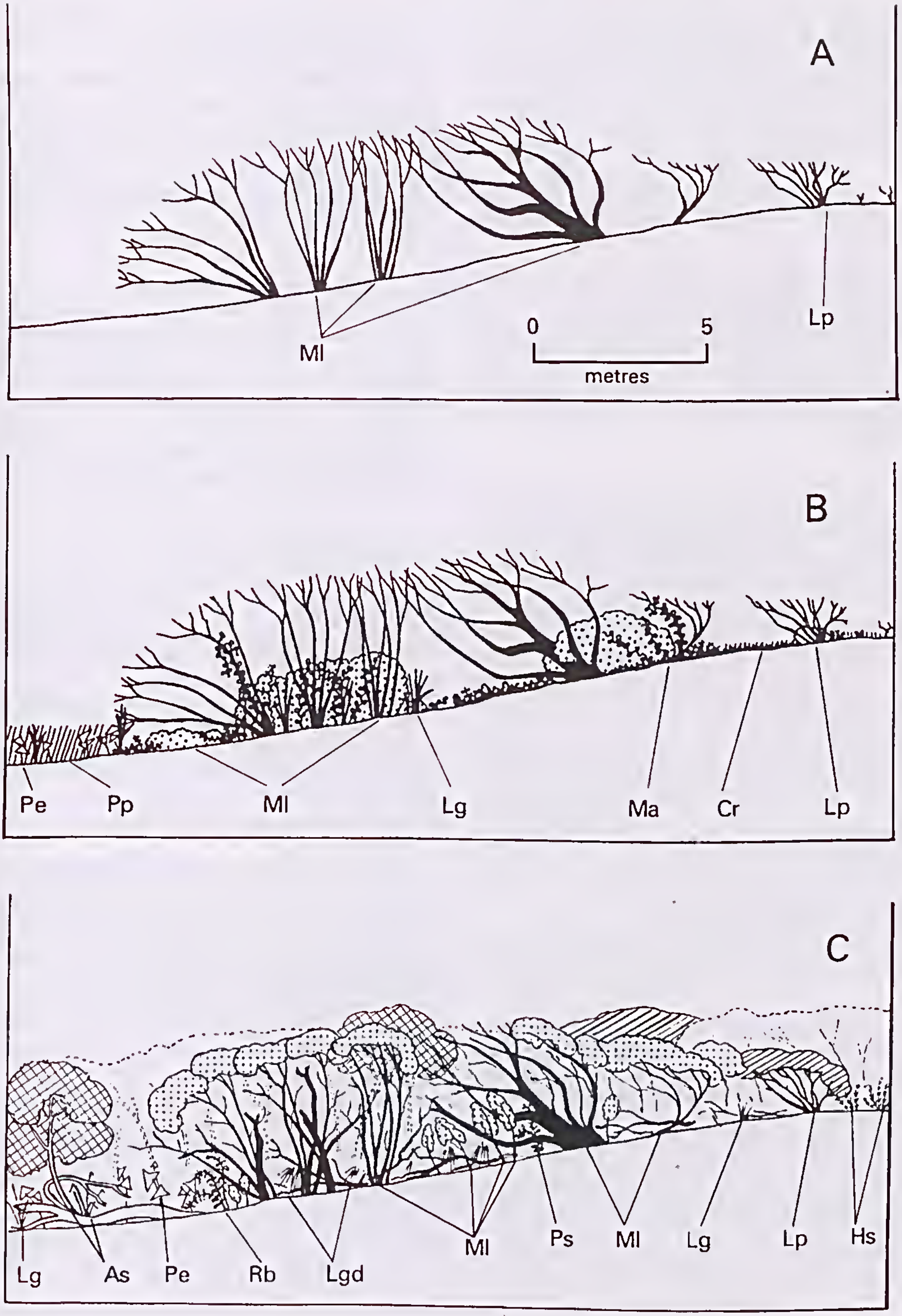
(iii) Acacia longifolia *var.* sophorae *recovery post-fire.* All shrubs of *A. longifolia* var. *sophorae* were killed by the fire (Table 5). Many seedlings germinated at 6–8 months post-fire (subsite D1), the greatest numbers usually occurring under the dead *A. longifolia* var. *sophorae* shrubs. Some seedlings also germinated on other parts of the dunes (subsite D2) and on the nearby coastal heathland.

Seedling heights were 0.4 m, >1.0 m and 3.9 m at years 1, 3 and 10, respectively. Seedling density (at subsite D1) was greatest at year 2 (approx. 2700 shrubs/ha); many seedling deaths occurring during the third year.

The rate of height and cover recovery of *A. longifolia* var. *sophorae* at subsite D1 was rapid, reaching approximate pre-fire levels by 7–8 years post-fire (Table 5, Fig. 5A). By year 10, height and density of *A. longifolia* var. *sophorae* was 3.9 m and 225/ha, respectively (ranges 3.4–4.4; 140–350/ha, respectively). *A. longifolia* var. *sophorae* shrubs comprised >90% of the total shrub cover at year 10, along with a few large isolated plants of *Myoporum insulare* and *Ozothamnus ferrugineus*. Width of the *A. longifolia* var. *sophorae* shrubs ranged from 2.4–6.0 m. By year 13 post-fire, some *A. sophorae* shrubs were 5 m tall and 10 m wide with a GBH of 45 cm.

(iv) Cover of shrubs and herbs 1–10 years post-fire. Both the shrub stratum and the herb and ground stratum began to recover in the first year after fire (Figs 6A–6C). At all subsites herbs and grasses were the main cover component during years 1–3. Grazing of grasses, orchids and other herbs by European rabbits (*Oryctolagus cuniculus*) was common, especially at subsites D3 and D4. Some species such as *Agrostis billardieri* were selectively grazed each year.

Fig. 3. Vegetation profiles at subsite D2 immediately after fire and 2 and 14 years later. Horizontal and vertical scales are the same. Stippling and hatching indicates the extent of canopy regrowth. A, Open scrub of *Melaleuca lanceolata* (Ml) and *Leucopogon parviflorus* (Lp) immediately after fire (subsite D2). B, Subsite D2, 2 years after fire. *Carpobrotus rossii* (Cr), *Lepidosperma gladiatum* (Lg), *Pteridium esculentum* (Pe), *Poa poiformis* (Pp). C, Subsite D2, 14 years after fire. *Acacia sophorae* (As), *Hibbertia sericea* (Hs), *Lepidosperma gladiatum* dead (Lgd), *Rhagodia baccata* (Rb).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By year 10, woody shrubs were the main cover component at all subsites and herb cover was reduced to about 30–44% at subsites D2 and D3 (Table 5, Figs 6B–6C), and to <1% at subsite D1 (Table 5, Fig. 6A), where *Acacia longifolia* var. *sophorae* had been the dominant shrub since years 1–3 post-fire.

(*b*) *Swamp thicket* (site S; Table 5, Figs 4A–4C, 5D, 6D)

The fire incinerated the herb and ground stratum and killed all above ground portions of the *Melaleuca squarrosa* shrub stratum. Above-ground portions of *Eucalyptus ovata* were also killed. The litter layer between the *M. squarrosa* shrubs was also incinerated exposing huge lignotubers of the plants, raised 0.3–0.5 m above the surface of the peat.

(*i*) Melaleuca squarrosa *recovery post-fire.* All *M. squarrosa* shrubs on the swamp (subsites S1–S3) and about 99% *M. squarrosa* shrubs in the swamp ecotone (subsite S4) survived the fire, sprouting from lignotubers 6–8 weeks post-fire (Figs 4A–4C). Shrubs which did not survive showed severe fire scarring of the base, suggesting that the fire may have been extremely hot or long lasting in these areas. Germination of hard-seeded swamp species such as *Pultenaea stricta* was often observed in such locations.

Recovery of 3.5 m *M. squarrosa* (subsites S1–S3) is presented in Table 5 and Fig. 5D. Though recovery of cover was faster in the early years post-fire, by year 10 all sub-communities had reached their approximate pre-fire height and cover levels (Fig. 5D). Recovery height and cover of 4.8 m *M. squarrosa* at Edwards Creek also occurred by 10 years post-fire.

In the swamps, possible fungal infection was observed on young *M. squarrosa* regrowth in the first year after fire. No pathogens were isolated.

(*ii*) Eucalyptus ovata *recovery post-fire.* Most (~98%) mature *E. ovata* (pre-fire height 6.5 m, GBH 56 cm) survived the fire, sprouting from the base at 6–9 weeks. Smaller trees which were burnt to the ground did not resprout till 11 months post-fire. Trees which did not regenerate showed severe fire-scarring of the lignotuber.

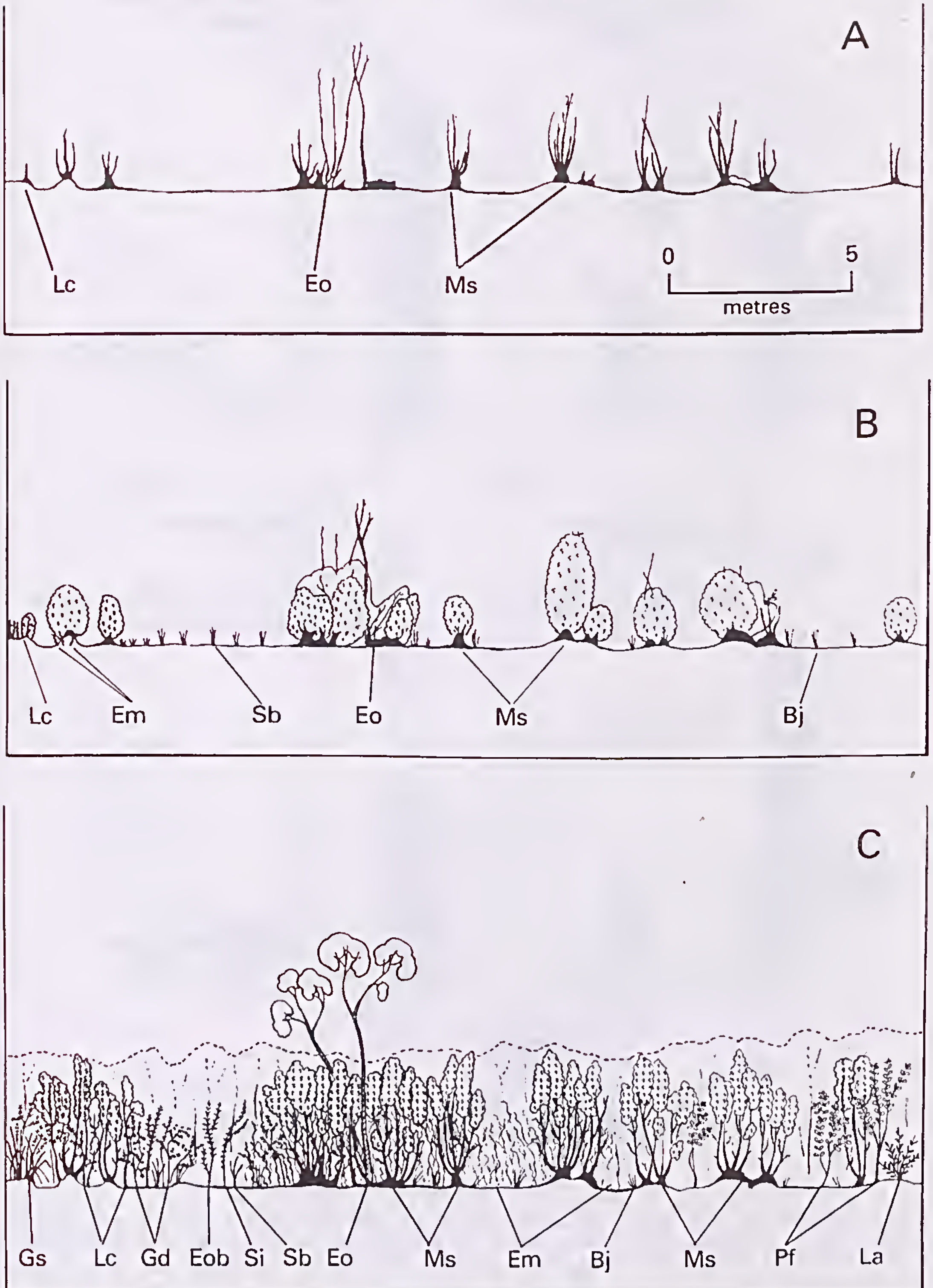
At the Harrisons Track and Edwards Creek tributaries, the rate of height recovery of multi-stemmed *E. ovata* (6.5 m pre-fire) was faster than the rate of height recovery of the *M. squarrosa* thicket (Fig. 5D); regrowth from *E. ovata* lignotubers reaching 73% of pre-fire height by year 3 (range 4.3–5.2 m) and 110% of pre-fire height by year 10 (range 6.8–7.4 m; Fig. 5D).

(*iii*) Leptospermum continentale *recovery post-fire.* *L. continentale* was found mainly around the edge of the swamps, often on raised rootstocks with *M. squarrosa*. All *L. continentale* shrubs appeared to survive the fire, sprouting from lignotubers 6–8 weeks post-fire (Figs 4A–4C). Regeneration was almost entirely by regrowth, pre-fire heights of 2.5 m (range 1.4–4.7 m; subsites S1–S3 combined) being reached by 10 years post-fire. Seedlings of *L. continentale* were rare.

(*iv*) *Cover of shrubs and herbs 1–10 years post-fire.* Both the shrub stratum and the herb and ground stratum began to recover in the first year after fire (Fig. 6D), though woody plants remained the main cover component throughout the 10-year period. By year 10, sedges and ferns, especially the climbing species *Empodisma minus* and *Gleichenia dicarpa*, often formed an impenetrable barrier through and between the woody shrubs and with other sedges and rushes contributed significantly to vegetation cover (Fig. 6D). No grasses and few herbs were found in the swamp subsites throughout the 10 year period.

(*v*) *Recovery following death of lignotubers.* In small areas in drier parts of the swamp (20–40 m^2; subsites S3, S4), the wildfire appeared to have been exceptionally intense, and severe fire-scarring and death of lignotubers of *E. ovata*, *M. squarrosa* and *L. continentale* occurred. In these areas, very small in-ground fires (peat fires) were ignited by the wildfire, and the top 0.1–0.15 m of the peaty loam was burnt leaving areas of red 'burnt peat' on the 'black' peat. All above-ground and in-ground vegetation was killed.

Fig. 4. Vegetation profiles at subsite S3 immediately after fire and 2 and 14 years later. A, Closed scrub of *Melaleuca squarrosa* (Ms) and *Leptospermum continentale* (Lc) with *Eucalyptus ovata* (Eo) immediately after fire (subsite S3). B, Subsite S3, 2 years after fire. *Baumea juncea* (Bj), *Empodisma minus* (Em), *Shoenus brevifolius* (Sb). C, Subsite S3, 14 years after fire. *Epacris obtusifolia* (Eob), *Gleichenia dicarpa* (Gd), *Gahnia sieberiana* (Gs), *Leucopogon australis* (La), *Pimelia flava* (Pf), *Sprengelia incarnata* (Si).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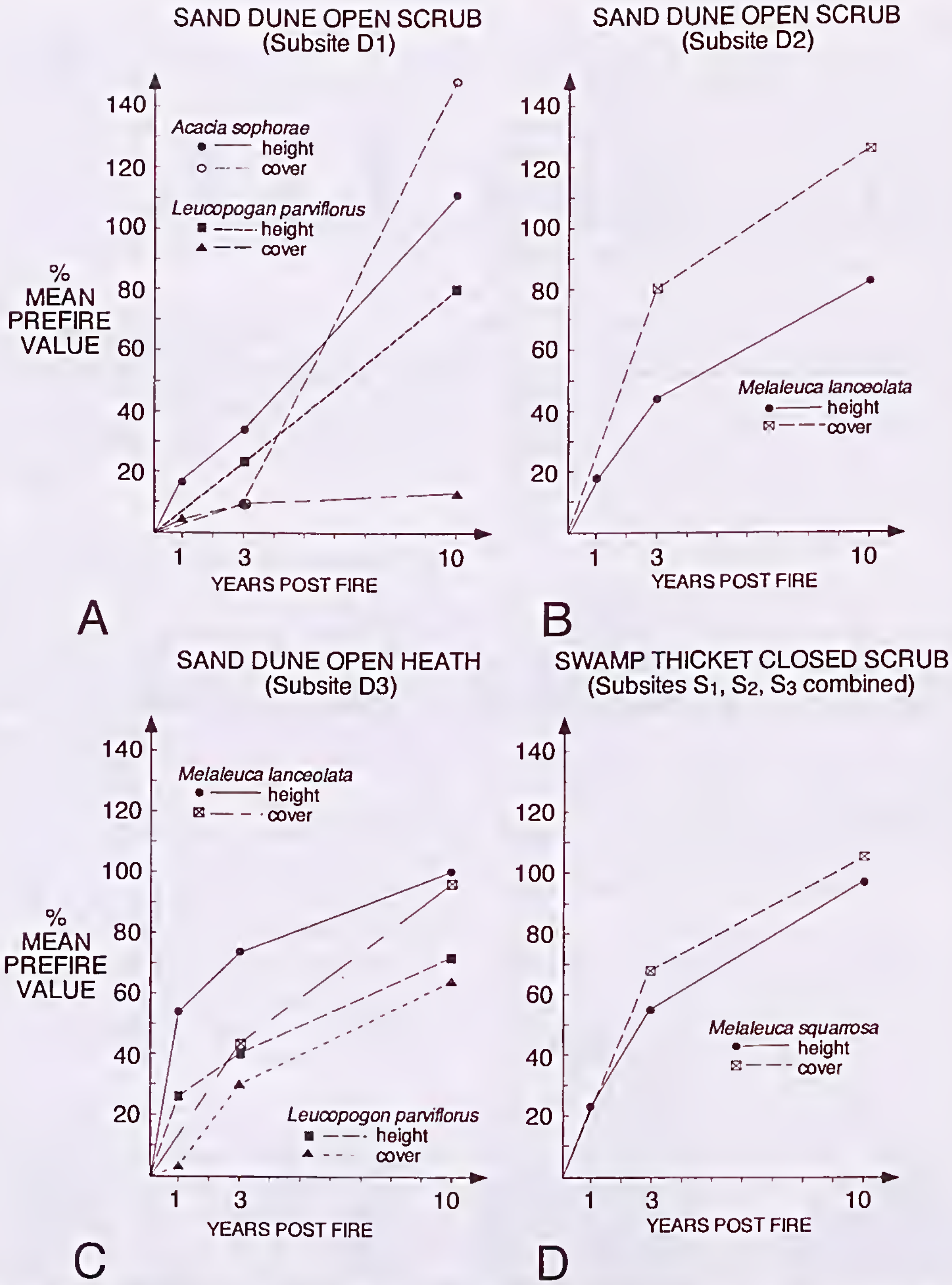

Fig. 5. Shrub stratum recovery in dune and swamp communities 1–10 years post-fire. A, Dunes, subsite D1—*Leucopogon parviflorus–Acacia longifolia* var. *sophorae* open scrub community. B, Dunes, subsite D—*Melaleuca lanceolata* open scrub community. C, Dunes, subsite D3—*Melaleuca lanceolata, Leucopogon parviflorus* open heath community. D, Swamps, subsites S1–S3 combined—*Melaleuca squarrosa–Leptospermum continentale* closed scrub community.

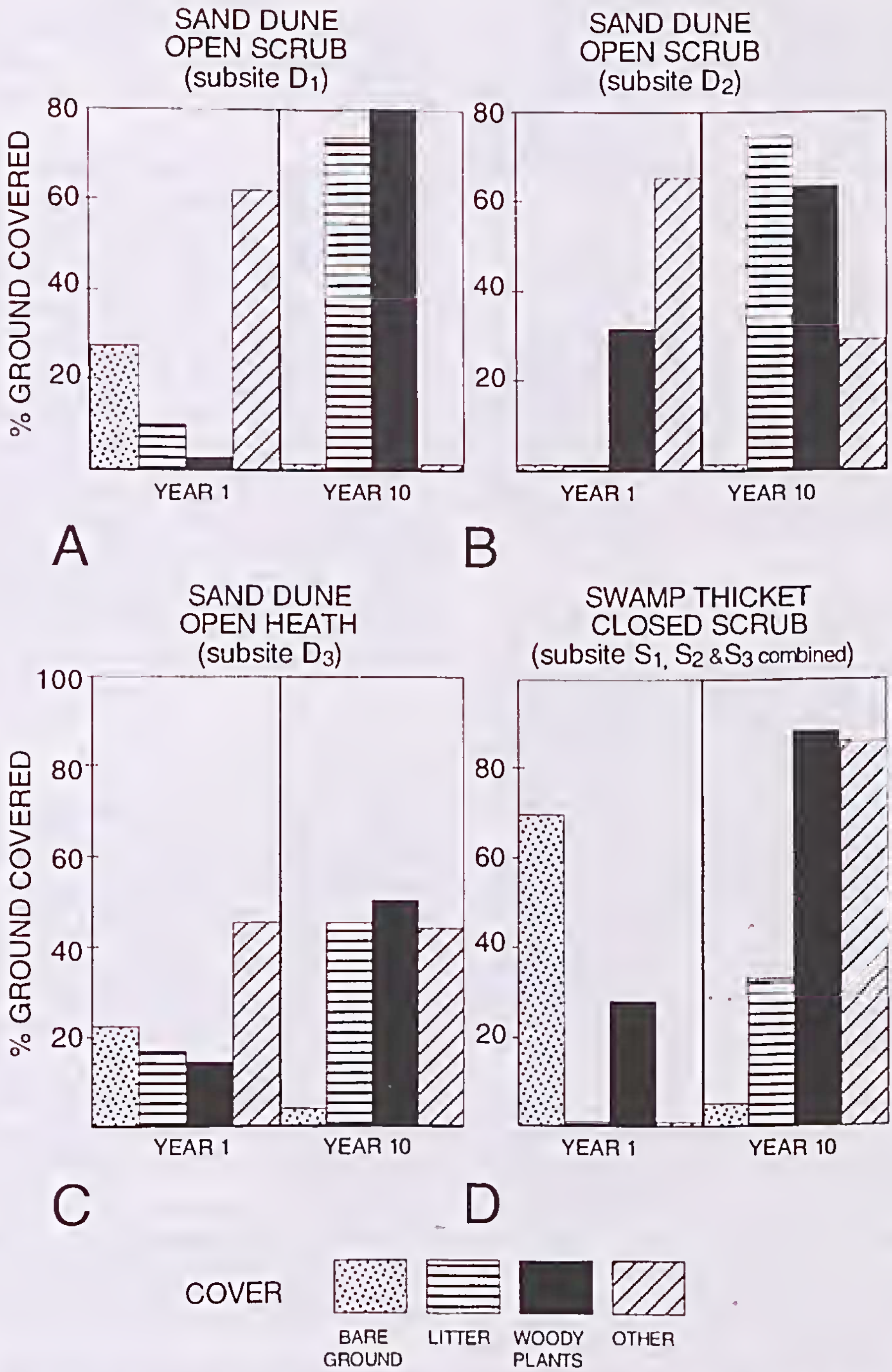

Fig. 6. Projective cover of shrub stratum in open scrub and open heath on the dunes and in closed scrub in the swamp communities 1 and 10 years post-fire. A, Dunes, subsite D1—*L. parviflorus*–*A. longifolia* var. *sophorae* open scrub. B, Dunes, subsite D2—*M. lanceolata* open scrub. C, Dunes, subsite D3—*M. lanceolata*–*L. parviflorus* open heath. D, Swamp, subsites S1–S3 combined—*M. squarrosa*–*L. continentale* closed scrub.

Vegetation regeneration in these areas was extremely slow and by 10 years post-fire plants present included a few mosses which colonised in the early years post-fire, and an occasional 'hard seeded' shrub (eg. *Pultenaea stricta*). No seedlings of *M. squarrosa* or *E. ovata* established in these areas in the 10 years post-fire; and no further colonisation was observed at 15 years.

Regeneration strategies

Regeneration strategies for species appearing in the first 3 years post-fire are presented in Tables 6 and 7. Life-form groups of all species regenerating in the first 3 years and still present at year 10 are presented in Tables 8 and 9. Regeneration was either by regrowth, from dormant buds, in stems, lignotubers, root tussocks, roots, rhizomes, tubers and tuberoids; from seed; or by both means.

(a) Coastal dunes (site D; Tables 6, 8, Fig. 3)

(i) Regeneration mechanisms and timing. On the dunes, *Pteridium esculentum*, *Imperata cylindrica* and *Muehlenbeckia adpressa* sprouted at 4–6 weeks from underground roots or rhizomes. As mentioned earlier, sprouting of *Melaleuca lanceolata* shrubs occurred by 2–4 months, whilst *Leucopogon parviflorus* did not resprout till 6–24 months.

Huge numbers of monocotyledon and dicotyledon seedlings appeared on the dunes from 2–3 months; including many grasses, especially *Poa poiformis* and *Stipa flavescens*, and introduced weeds. Hundreds of seedlings of *M. lanceolata* appeared in the deep ash at subsite D2, at 6 months, whilst germination of *Acacia sophorae* seedlings at subsite D1 occurred 6–8 months post-fire.

(ii) Regeneration strategies and life-form groups. All species of vascular plants present before the fire reappeared during the first year post-fire. Sixty-one per cent were OSR regenerators and included mainly shrubs and herbs. Fifteen per cent were ORR and included sedges, rushes, and orchids; and the remaining 24% were FRR and included both shrubs and herbs.

Approximately 61% of all species present at years 1–3 post-fire, and still remaining 10 years post-fire, had regenerated from seed only. The two main exotic shrub species, and two indigenous shrub species classified as 'environmental weeds', were all OSR regenerators and survived the first 10 years post-fire; **Chrysanthemoides monilifera*, **Polygala myrtifolia*, *Parasieranthes lopantha*, *Leptospermum laevigatum*. The vigorous shrub of the landward dunes, *Acacia longifolia* var. *sophorae*, was also an OSR regenerator and survived till year 10.

(iii) Regeneration strategies of dominant shrubs. The main shrubs, *Melaleuca lanceolata* and *Leucopogon parviflorus*, were both FRR regenerators. A high degree of both rootstock and seedling regeneration was shown by *M. lanceolata* in comparison with *L. parviflorus* which produced few seedlings. However, by year 10, *M. lanceolata* had largely re-established by vegetative means. Though massive germination of *M. lanceolata* seedlings occurred under established shrubs at subsite D2, most seedlings did not survive to year 10. At years 1, 3 and 10 seedling numbers were 230/m^2, 28/m^2, 2.3/m^2, respectively; and seedling heights 0.2 m, 0.5 m and 2.6 m. Seedling mortality was highest where the seed-bed appeared dry or was shaded by ferns, grasses or herbs including *Pteridium esculentum*, *Poa poiformis* and *Conyza bonariensis*. Seedling height and density at 3 years in open areas was 0.6 m and 170 m^2, respectively.

(b) Swamp thicket (site S; Tables 7, 9, Fig. 4)

(i) Regeneration mechanisms and timing. In the swamps, sedges and rushes including *Baumea juncea*, *Empodisma minus* and *Schoenus brevifolius*, regenerated from rhizomes by 4–6 weeks. Sprouting of the main shrubs, *Melaleuca squarrosa* and *Leptospermum continentale*, occurred from lignotubers by 6–8 weeks, as did most *Eucalyptus ovata* at 2–4 months. Seedlings of *Sprengelia incarnata* and *Pimelea flava* appeared by 6 months.

At a swamp on the Salt Creek, north of Aireys Inlet, with floristics similar to site S, *Drosera binata* was the first plant to regenerate following the fire, sprouting in thousands at 3 weeks. Another herb, *Utricularia uniflora*, also appeared at this site at 6–8 weeks.

By year 1, all vascular plant species present before the fire had reappeared with the exception of three species of hard-seeded shrubs, *Pultenaea dentata*, *P. stricta* and *Sphaerolobium vimineum*, which germinated from seed 2 years post-fire.

(ii) Regeneration strategies and life form groups. Sixty-one per cent of species present at years 1–3 regenerated by vegetative means (35% ORR regenerators, 26% FRR regenerators); and 39% from seed only (Table 9).

Obligate seed regenerators † (from seed or spore or propagules only)	Regen. Strategy	First Flowering
Shrubs		
Acacia longifolia var. *sophorae*	S1	F3
" *verticillata*	S1	F2
**Chrysanthemoides monolifera*	S1	F1
Correa alba	S1	F2
Goodenia ovata	S1	F1
Indigofera australis	S1	F2
Leptospermum continentale	S1	F3
" *laevigatum*	S1	F3
Myoporum insulare	S1	
" *(viscosum)* sp.	S1	
Olearia axillaris	S1	F1
" *ramulosa*	S1	F2
Ozothamnus ferrugineus	S1	F2
" *turbinatus*	S1	F1
**Paraserianthes lopantha*	S1	F3
Pimelea humilis	S1	F2
**Polygala myrtifolia*	S1	F1
Rhagodia candolleana	S1	F1
Solanum laciniatum	S1	F2
Spyridium vexilliferum	S1	F2
Liverworts		
Lophocolea semiteres	S2	F2
Marchantia berteroana	S1	F1
Mosses		
Barbula calycina#	S3	F2
Barbula torquata #	S3	F3
Bartramidula pusilla	S3	F3
Brachythecium rutabulum	S3	F3
Bryum billardieri #	S3	F3
Ceratodon purpureus	S2	F2
Funaria hygrometrica	S1	F1
Polytrichum juniperium	S3	F2
Thuidium furfurosum #	S3	F2
Tortella antarctica #	S3	F2
Grasses		
**Briza maxima*	S1	F1
* " *minor*	S1	F1
**Catapodium rigidum*	S1	F1
**Lagurus ovatus*	S1	F1
**Vulpia myuros*	S1	F1
Herbs		
Acaena novae-zealandii	S1	F1
**Anagallis arvensis*	S1	F1
Apium prostratum	S1	F1
**Arctotheca calendula*	S1	F2?
* *Cakile maritima*	S1	F1
Centaurium spicatum	S1	F1
**Cerastium glomeratum*	S1	F1

Facultative regrowth regenerators † (by regrowth, and from seed or propagules)	Regeneration Strategy		First Flowering
Tall shrubs			
Melaleuca lanceolata	L1	S1	F3
Shrubs			
Banksia marginata	L1	S?	F2
Bursaria spinosa	L1	S1	F1
Calocephalus brownii	St1, L1	S1	F2
Hibbertia riparia	L1	S1	F3
" *sericea*	L1	S1	F2
Leucopogon parviflorus	L1	S1	F3
Pimelea serpyllifolia	St1, L1	S1	F2
Ferns			
Pteridium esculentum	R1	S1	F1
Grasses			
Agrostis avenacea	R1	S1	F1
" *billardieri*	R1	S1	F1
Austrostipa flavescens	R1	S1	F1
" *semibarbata*	R1	S1	F1
Danthonia caespitosa	R1	S1	F1
Deyeuxia quadriseta	R1	S1	F1
Dichelachne crinita	R1	S1	F1
**Ehrharta erecta*	R1	S1	F1
**Holcus lanatus*	R1	S1	F1
Imperata cylindrica	R1	S1	F1
Microlaena stipoides	R1	S1	F1
Poa poiformis	R1	S1	F1
Spinifex hirsutus	R1	S1	F?
Themeda triandra	R1	S1	F1
Herbs			
Helichrysum leucopsideum	R1	S1	F2
" *scorpioides*	R1	S1	F1
Oxalis corniculata	R1	S1	F1
Pelargonium australe	R1	S1	F1
" *inodorum*	R1	S1	F1
Plantago varia	R1	S1	F1
Veronica calycina	R1	S1	F2
Zygophyllum billardieri	R1?	S1	F1
Creepers & climbers			
Muehlenbeckia adpressa	R1	S1	F2
Rubus parviflorus	R1	S1	F1
**Rubus ulmifolius*	R1	S1	F1

Table 6 continued next page (see legend on page 202)

Obligate seed regenerators † (from seed or spore or propagules only)	Regen. Strategy	First Flowering
**Carduus tenuifolius*	S1	F1
**Cirsium vulgare*	S1	F1
**Conyza bonariensis*	S1	F2?
**Crassula decumbens*	S1	F1
* " *sieberiana*	S1	F1
**Cymbonotus priessiana*	S1	F1
Convolvulus erubescens	S1	F1
Cynoglossum suaveolens	S1	F1
Daucus glochidautus	S1	F1
Dichondra repens	S1	F2
**Dittrichia graveolens*	S1	F1
Euchiton sphaericus	S1	F1
**Galium divaricatum*	S1	F1
* " *murale*	S1	F1
Geranium solanderi	S1	F1
Gonocarpus tetragynus	S1	F1
Hydrocotyle hirta	S1	F2
**Melilotus* spp.	S1	F1?
Opercularia varia	S1	F1
**Polycarpon tetraphyllum*	S1	F2?
Parietaria debilis	S1	F2
Rumex brownii	S1	F1
Sebaea ovata	S1	F2
Scaevola albida	S1	F2
Scutellaria humilis	S1	F2
**Senecio elegans*	S1	F1
" *hispidulus*	S1	F1
" *odoratus*	S1	F1
**Solanum douglasii*	S1	F1
**Sonchus oleraceus*	S1	F1
**Stellaria media*	S1	F1
Tetragona implexicoma	S1	F1
Threlkeldia diffusa	S1	F2
Viola hederacea	S1	F1
**Vicia sativa*	S1	F3?
Wahlenbergia gracilenta	S1	F1
" *stricta*	S1	F1
Creepers & climbers		
Billardiera scandens	S1	F3
Cassytha glabella	S1	F2
Carpobrotus rossii	S1	F2
Clematis microphylla	S1	F2
Swainsona lessertiifolia	S1	F1

Obligate regrowth regenerators † (by regrowth only)	Regen. Strategy	First Flowering
Ferns		
Lindsaea linearis	R1	F2
Lilies & irises		
Chamaescilla corymbosa	T1	F1
Dianella brevicaulis	T1	F1
Hypoxis glabella	C1?	F1
Lomandra filiformis	T1	F1
" *micrantha*	T1	F1
Wurmbea dioica	T1	F1
Sedges & rushes		
Gahnia radula	R1	F2
Isolepis marginata	R1	F1
" *nodosa*	R1	F1
Juncus pallidus	R1	F1
Lepidosperma gladiatum	R1	F2
Schoenus apogon	R1	F1
Orchids		
Caladenia latifolia	Tu1	F1
Corybas incurvis	Tu1	F1
Cyrtostylis reniformis	Tu1	F1
Microtis unifolia	Tu1	F1
Pterostylis alata	Tu1	F1
Herbs		
Drosera peltata var. *auriculata*	T1	F1
" *peltata*	T1	F1
**Hypochoeris radicata*	R1	F1

Table 6. Regeneration strategies and flowering of sand dune communities 1–3 years after fire. *Key:* Regeneration strategy/year—S1 = germinated from seed year 1; S2 = germinated from seed year 2; S3 = germinated from seed year 3; R1 = regrowth from rhizomes year 1; R2 = regrowth from rhizomes year 2; T1 = regrowth from tubers year 1; Tu = regrowth from tuberoids year 1; L1 = regrowth from lignotubers year 1; St1 = regrowth from stems year 1; C1 = regrowth from corms year 1; RSt1 = regrowth from rhizostolons year 1; Rsk1 = regrowth from root suckers year 1. Flowering/year—F1 = first flowered year 1; F2 = first flowered year 2; F3 = first flowered year 3; #S1F1 in unburnt areas; *introduced species. †Terminology follows Purdie (1977a, 1977b). Seed is used to mean both seeds and spores.

Obligate seed regenerators † (from seed or spores or propagules only)	Regeneration Strategy	First Flowering
Mosses		
Barbula calycina	S3	F3
Bryum spp.	S3	F3
Campylopus clavatus	S3	F3
" *introflexus*	S3	F3
Ceratodon purpureus	S2	F2
Funaria hygrometrica	S1	F1
Polytrichum juniperinum	S3	F3
Lichens		
Cladia aggregata	S2	F2
Liverworts		
Cephaloziella exiliflora	S2	F3
Hyalolepidozia longiscypha	S2	F2
Kurzia compacta	S2	F2
Lethocolea pansa	S3	F3
Marchantia berteroana	S1	F1
Fungi		
Gerronema postii	S1	F1
Shrubs		
Acacia verticillata	S1	F1
Comesperma ericinum	S1	F2
Epacris impressa	S1	F1
" *obtusifolia*	S1	F2
Goodenia ovata	S1	F1
Hibbertia fasicularis var. *prostrata*	S1	F1
Ozothamnus rosmarinifolius	S1	F2
Pimelea flava	S1	F2
Pultenaea dentata	S2	F2
" *stricta*	S2	F2
Sphaerolobium vimineum	S2	F2
Spreugelia incarnata	S1	F1
Tetratheca ciliata	S1	F1
Grasses		
Agrostis avenacea	S2	F2
Herbs		
Acaena novae-zelandiae	S1	F1
**Centarium spicatum*	S1	F1
Galium binifolium	S1	F2
" *gaudichaudii*	S1	F2
Gonocarpus micranthus	S1	F2
" *tetragynus*	S1	F1
Euchiton sphaericus	S1	F1
Mitrasacme pilosa	S1	F1
Opercularia varia	S1	F1
Poranthera microphylla	S1	F1
Viola cleistogamoides	S1	F2
Xanthosia dissecta	S1	F2
" *pusilla*	S1	F2
Creepers & climbers		
Billardiera scandens	S1	F3
Cassytha glabella	S1	F2
" *melantha*	S1	F2

Facultative regrowth regenerators † (by regrowth, and from seed or propagules)	Regeneration Strategy		First Flowering
Trees			
Eucalyptus obliqua	L1	S1	?
" *ovata*	L1	S1	?
Tall shrubs			
Leptospermum continentale	L1	S1	F2
" *lanigerum*	L1	S1	F2
Melaleuca squarrosa	L1	S1	F2
Viminaria juncea	L1	S1	F2
Shrubs			
Banksia marginata	L1	S1	?
Leucopogon australis	L1	S1	F2
" *virgatus*	L1	S2	F2
Ferns & allies			
Centrolepis aristata	R1	S1	F1
" *strigosa*	R1	S1	F1
Gleichenia dicarpa	R1	S1	F2
Water plants			
Triglochin procera	R1	S1	?
Villarsia reniformis	R1	S1	F1
Lilies & irises			
Patersonia fragilis	R1	S2	F1
" *occidentalis*	R1	S2	F1
Xanthorrhoea minor	St1	S1	F1
Xyris operculata	R1	S1	F1
Grasses			
Deyeuxia densa	R1	S1	F1
" *quadriseta*	R1	S1	F1
Microlaena stipoides	R1	S1	F1
Phragmites australis	R1	S1	F1
Poa morrisii	R1	S1	F1
Tetrarrhena acuminata	R1	S1	F1
Herbs			
Centella cordifolia	R1	S1	F1
Goodenia humilis	R1	S1	F1
" *lanata*	R1	S1	F1
Lagenifera gracilis	R1	S1	F1
Selliera radicans	R1	S1	F1

Obligate regrowth regenerators † (by regrowth only)	Regeneration Strategy	First Flowering
Ferns & allies		
Lycopodium laterale	R1	F2
Schizaea fistulosa	R1	F2
Selaginella uliginosa	R1	F2

Table 7 continued next page (see legend on page 204)

Obligate regrowth regenerators † (by regrowth only)	Regeneration Strategy	First Flowering
Sedges & rushes		
Baumea acuta	R1	F1
" *juncea*	R1	F1
" *tetragona*	R1	F1
Cyperus tenellus	R1	F1
Empodisma minus	R1	F2
Gahnia radula	R1	F2
" *sieberiana*	R1	F2
" *trifida*	R1	F2
Isolepis inundata	R1	F1
" *marginata*	R1	F1
Juncus planifolius	R1	F2
" *pauciflorus*	R1	F1
Lepidosperma longitudinale	R1	F2
Schoenus apogon	R1	F1
" *brevifolius*	R1	F2
" *lepidosperma*	R1	F2
Lilies & irises		
Lomandra longifolia	T1	F1
Orchids		
Burnettia cuneata	Tu1	F1
Calochilus campestris	Tu1	F1
Corybas fordhamii	Tu1	F1
Cryptostylis subulata	Tu1	F1
Orthoceras strictum	Tu1	F1
Prasophyllum australe	Tu1	F1
Herbs		
Cotula coronopifolia	R1	F2
Drosera peltata ssp. *auriculata*	T1	F1
" *binata*	T1	F1
" *glanduligera*	T1	F1
" *macrantha*	T1	F1
" *peltata*	T1	F1
" *pygmaea*	T1	F1
" *whittakeri*	T1	F1
Lobelia alata	R1	F1
Samolus repens	R1	F1
Stylidium perpusillum	R1	F1
Utricularia lateriflora	R1	F1

Table 7. Regeneration strategies and flowering of swamp communities 1–3 years after fire. *Key:* Regeneration strategy/year—S1 = germinated from seed year 1; S2 = germinated from seed year 2; S3 = germinated from seed year 3; R1 = regrowth from rhizomes year 1; R2 = regrowth from rhizomes year 2; T1 = regrowth from tubers year 1; Tu = regrowth from tuberoids year 1; L1 = regrowth from lignotubers year 1; St1 = regrowth from stems year 1; RSt1 = regrowth from rhizostolons year 1; Rsk1 = regrowth from root suckers year 1. Flowering/year—F1 = first flowered year 1; F2 = first flowered year 2; F3 = first flowered year 3. †Terminology follows Purdie (1977a, 1977b).

By year 10, 57% of the species present at years 1–3 and still remaining were capable of regenerating vegetatively (Table 9).

(iii) Regeneration strategies of dominant shrubs. The dominant shrubs *Melaleuca squarrosa* and *Leptospermum continentale*, though both FRR regenerators, showed a high degree of rootstock regeneration producing very few seedlings. At subsite S3, *M. squarrosa* seedling density at year 2 post-fire was <200/ha and no *Melaleuca* seedlings were seen at year 10 post-fire.

Some seedlings of *L. continentale* established at the edge of the swamp in the ecotone (subsite S4).

In contrast, the FRR regenerator *Viminaria juncea* regenerated both by regrowth and from seed and flowering plants originating by both means were seen in the swamp by year 2 post-fire.

Flowering response after fire

(a) Coastal dunes (site D; Table 6)

(i) Response during first spring. There was spectacular flowering on the dunes 6–8 months after the fire, about 70% of all species which had regenerated during year 1 flowering during the first spring (Table 6).

Most species flowering at 6 months were ORR herbs, *Hypoxis pusilla*, *Wurmbea dioica* and *Drosera peltata* ssp. *auriculata*, and orchids.

Flowering plants of *Swainsona lessertifolia* were the most conspicuous herb on the dunes 7–8 months post-fire. Patches of *Helichrysum leucopsideum*, *Cynoglossum suaveolens* and *Pelargonium inodorum* also appeared, flowered, and were not seen in later years.

By 8 months post-fire, 19 grass species (including 13 native and 6 introduced species) and 20 species of introduced weeds (including 10 members of Asteraceae) were in flower. Some introduced herbs (eg. *Anagallis arvensis*) had a brief juvenile phase, flowering when only a few centimetres high and less than a year old.

(ii) Orchid flowering. Five species of orchids, *Caladenia latifolia*, *Corybas incurvis*, *Cyrtostylis reniformis*, *Microtis unifolia* and *Pterostylis alata*, flowered on the dunes 6–8 months post fire; *C. latifolia* appeared in large numbers and observers commented that the flower color appeared more intense than in non-fire years.

Three of the 5 orchid species, *Caladenia latifolia*, *Corybas incurvis* and *Cyrtostylis reniformis*, reappeared (in reduced numbers) at both 3 and 10 years post-fire on the first dune (subsite D3).

Species present Regeneration strategy post-fire	Years 1-3 OSR	 FRR	 ORR	Year 10 OSR	 FRR	 ORR
Tall shrubs (1)*	-	1	-	-	1	-
Shrubs(27)	20	7	-	13	6	-
Dicotyledon herbs (51)	44	8	3	18	-	-
Monocotyledon herbs (35)						
Orchids (5)	-	-	5	-	-	3
Lilies & irises (5)	-	-	6	-	-	2
Grasses (19)	5	14	-	1	6	-
Sedges & rushes (6)	-	-	6	-	-	4
Creepers & climbers (8)	5	3	-	4	3	-
Ferns(2)	-	1	1	-	1	-
Non-vascular plants (12) $^{\delta}$	12	-	-	4	-	-
Subtotal	86	34	21	40	17	9
% Total species †	61%	24%	15%	61%	26%	13%
Total species $^{\dagger\,\delta}$		136			66	

Table 8. Regeneration strategies and life form groups of all species appearing in sand dune communities 1–3 years post-fire, and still present 10 years post-fire. *Key:* OSR = obligate seed regenerators; FRR = facultative regrowth regenerators; ORR = obligate regrowth regenerators. Terminology follows Purdie (1977a, 1977b). *Numbers in brackets show total species present years 1–3; $^{\delta}$16 species of non-vascular plants (mosses, lichens, liverworts) which appeared after year 3, and were present at year 10, have not been included in these data; †total species = total number of species recorded (quadrat and site data combined).

(iii) Grazing and seed harvesting. Grasses grew and flowered prolifically during the first spring, especially in the deep ash at subsite D2. Intensive seed harvesting of *Poa poiformis*, *Stipa flavescens* and *S. semibarbata* by introduced house mice, *Mus musculus*, was observed at this subsite at 8–10 months, but not during later years when growth and flowering of grasses was less luxuriant.

Grazing of orchids and some herbs and grasses by European rabbits, *Oryctolagus cuniculus*, also occurred from years 1–10. Many of the hundreds of *Caladenia latifolia* and *Corybas incurvis* which appeared at subsite D3 during year 2 were grazed both before and after flowering. Selective grazing of the grass *Agrostis billardieri* also occurred during years 1–10. During the 10 years post-fire, digging by rabbits often appeared to prevent seedling establishment on the top of the dunes.

(iv) Flowering of dominant shrubs. Flowering of resprouting *Melaleuca lanceolata* and *Leucopogon parviflorus* shrubs first occurred during year 3 post-fire. Little seed set was observed at this time.

Species present Regeneration strategy post fire	Years 1-3 OSR	 FRR	 ORR	Year 10 OSR	 FRR	 ORR
Trees (2)*	-	2	-	-	2	-
Shrubs(19)	12	7	-	10	7	-
Dicotyledon herbs (31)	14	5	12	3	-	2
Monocotyledon herbs (33)						
Orchids (6)	-	-	6	-	-	-
Lilies & irises (4)	-	3	1	-	3	1
Grasses (7)	1	6	-	-	1	-
Sedges & rushes (16)	-	-	16	-	-	10
Creepers & climbers (2)	2	-	-	1	-	-
Ferns (7)	-	4	3	-	1	-
Water plants (2)	-	2	-	-	1	-
Non-vascular plants (14) $^{\delta}$	14	-	-	7	-	-
Subtotal	43	29	38	21	15	13
% Total species †	39%	26%	35%	43%	31%	26%
Total species $^{\dagger\,\delta}$		110			49	

Table 9. Regeneration strategies and life form groups of all species appearing in swamp communities 1–3 years post-fire, and still present 10 years post-fire. *Key:* OSR = obligate seed regenerators; FRR = facultative regrowth regenerators; ORR = obligate regrowth regenerators. Terminology follows Purdie (1977a, 1977b). *Numbers in brackets show total species present years 1–3; $^{\delta}$5 species (mosses, lichens, liverworts) which appeared after year 3, and were present at year 10, have not been included in these data; †total species = total number of species recorded (quadrat and site data combined).

In contrast, flowering of exotic shrubs such as **Chrysanthemoides monilifera* spp. *monilifera* and **Polygala myrtifolia* occurred by year 1 and was often accompanied by seed set.

(b) Swamp thicket (site S; Tables 7, 9, Fig. 4)

(i) Response during first spring. About 60% of the swamp species which regenerated during year 1, flowered that year (Table 7). Many were ORR or FRR herbs, including *Drosera binata* and *Utricularia lateriflora* which both flowered, at wet sites, by 2 months and at drier swamp sites from 4–12 months.

The tall yellow eye *Xyris operculata*, some sedges, *Baumea juncea* and *Schoenus brevifolius*, the comb fern *Schizaea fistulosa*, and the marsh flower *Villarsia reniformis*, all flowered at 6–8 months, along with six species of orchids, and several other species of *Drosera*.

Herbs of the swamps which flowered during the early summer included *Lobelia alata*, *Samolus repens* and *Cotula coronopifolia*.

Most of the 16 species of sedges or rushes present flowered in the first or second year post-fire. Few grass species were present, compared with the dune communities and no spectacular flowering of grasses was observed at year 1.

(ii) Orchid flowering. The orchid species, *Burnettia cuneata*, *Calochilus campestris*, *Corybas fordhamii*, *Cryptostylis subulata*, *Orthoceras strictum* and *Prasophyllum australe*, flowered at 6–8 months, in closed scrub or the swamp ecotone.

About 100 plants of the rare *Burnettia cuneata*, not previously recorded in the district, appeared and flowered in the ecotone (subsite S4) at 7 months. None of these plants appeared to set seed. Two plants appeared at the same subsite at year 2, and none in subsequent years.

Observations suggest that the density of flowering of some swamp orchids, *Prasophyllum australe*, *Calochilis campestris* and *Corybas fordhamii*, was greater the year after the fire than in normal years. In one damp swamp ecotone near the Anglesea River, thousands of plants of *Microtis atrata* appeared and flowered at 7 months. Time of flowering was also affected by moisture levels in the swamps. In damp sites *P. australe* flowered at 6 months post-fire, whilst in drier areas flowers did not appear until 10–11 months post-fire.

With the exception of *Cryptostylis subulata*, no species of orchids were seen after year 2 post-fire.

(iii) Grazing. Grazing of shrubs and herbs of the swamp ecotone and swamp by black wallabies, *Wallabia bicolor*, was observed from year 3 onwards.

(iv) Flowering of dominant shrubs and trees. Flowering of most shrubs, including the dominant species *Melaleuca squarrosa* and *Leptospermum continentale*, occurred during the second year post-fire. The only species which had not flowered by year 3 was the swamp gum, *Eucalyptus ovata*, which flowered and set seed between 4–7 years post-fire.

DISCUSSION

Species richness post-fire

This study has shown that the *Melaleuca* scrub communities of both the coastal dunes and the river valleys of the Anglesea district were, in general, resilient to a severe single summer surface wildfire, confirming the observations of Specht et al. (1958) and Gill (1975, 1981) for other dry sclerophyll communities in southern Australia.

The regeneration patterns described comply with the 'initial floristic composition' models of Egler (1954) and Purdie & Slatyer (1976) as all species of vascular plants present prior to the fire re-established during the first three years post-fire; and no additional species appeared between 3 and 10 years post-fire.

The species richness of vascular plants in both dune and swamp communities decreased with time post-fire as reported for heath and heath woodland communities in other parts of Australia (Specht et al. 1958) and as previously described for the heaths, heath woodlands and open forest communities of the Anglesea area (Wark et al. 1987; Wark 1996, 1997). In contrast, the species richness of non-vascular plants either stayed constant or increased with time post-fire and a floristic change was also observed. Similar changes have also been observed in the heaths, heath woodlands and forest communities near Anglesea (Wark et al. 1987; Wark 1996, 1997).

In both swamp and dune communities, sclerophyllous shrubs became increasingly dominant with time, and species richness of the understorey decreased as the overstorey canopy cover (shrub cover) increased, as reported for heath woodlands in Australia (Specht & Morgan 1981; Specht & Specht 1989; Wark 1996).

Structure recovery post-fire

The rate of recovery of vegetation structure on the dunes probably reflects the intensity of the fire and local climate, moisture, and competitive factors post-fire.

The low post-fire viability (20%) of *Leucopogon parviflorus* shrubs on the landward dunes reflects both the extreme heat of the fire (as fire-scarred lignotubers of *L. parviflorus* did not regenerate), and competition for light, moisture and nutrients by vigorous resprouters (*Pteridium esculentum*, *Gahnia radula* and *Muehlenbeckia adpressa*) and rapidly growing seedling shrubs such as *Acacia longifolia* var. *sophorae*. On a cliff top near Aireys Inlet, where little or no *Pteridium*, *Gahnia*, *Muehlenbeckia* or *Acacia* was present, recovery rate of *L. parviflorus* shrubs of similar girth was >75%.

The slow regrowth recovery of *M. lanceolata* shrubs on the lee side of the dunes (80% of pre-fire height and cover by year 10) may reflect the drier conditions there and also explain the low level of *M. lanceolata* seedling survival after 10 years. Competition from the large shrubs, *Myoporum insulare* and *Acacia longifolia* var. *sophorae*, may also have affected rates of *M. lanceolata* regrowth and seedling survival.

In the *Melaleuca lanceolata–Leucopogon parviflorus* open heath of the seaward dune, death of young *M. lanceolata* regrowth occurred 2–3 times during the early years post-fire, following prolonged on-shore winds. Parsons & Gill (1968) and Parsons (1979) showed that chloride toxicity from salt spray caused stunting of coastal heath and scrub at Pillar Point, Wilsons Promontory National Park, Victoria; similar effects were seen in coastal heath at Point Addis, east of Anglesea, where young regrowth of *Leptospermum myrsinoides*, *Monotoca scoparia* and *Eucalyptus obliqua* was killed (Wark et al. 1987; Wark 1996).

The rapid structural and floristic change observed 3–5 years post-fire when *A. longifolia* var. *sophorae* shrubs began to dominate the open scrub of the landward dunes is similar to that observed during *A. longifolia* var. *sophorae* invasion of coastal heathland at Deans Heath, western Victoria (McMahon et al. 1996). Both there and in the present study, invasion by this vigorous species resulted in apparent elimination or supression of other shrub and herb species within 10 years, probably due to competition for light, nutrients, moisture and space.

It has been observed (Clarke 1994) that both the floristics and structure of dune communities may be modified and simplified by fire frequency. Such modification has occurred at Urquhart Bluff about 1.5 km west of the dune site, where a series of three dune fires within 10 years during the 1980s resulted in simplification of the *Melaleuca lanceolata–Leucopogon parviflorus* coastal heath and loss of most of its sclerophyllous component with a major change in floristics (M. D. White, pers. comm.). The modified community on the seaward dune is now largely dominated by introduced grasses and herbs and *Pteridium esculentum*.

Recovery rates in *Melaleuca squarrosa* closed scrub of the swamps were the same at all sites monitored, the greater height of the stands at Edwards Creek reflecting the presence of permanent rather than semi-permanent streams.

The structural and floristic change seen when small in-ground fires occurred within the *M. squarrosa* closed scrub, shows that these swamp communities are not totally resilient to fire, and that vegetation recovery may take many years.

Regeneration strategies

The high degree of vegetative regeneration (61%) seen in the swamp communities is similar to that reported for the heaths, heath woodlands and dry sclerophyll open-forest of the district following wildfire (Wark et al. 1987; Wark 1996, 1997), and for other heaths and dry sclerophyll woodlands in southern Australia (Gill & Groves 1981; Specht 1981).

Although the dominant shrubs of the swamps (*Melaleuca squarrosa–Leptospermum continentale*) and of the dunes (*Melaleuca lanceolata–Leucopogon parviflorus*) and were all FRR regenerators, sprouting was the main post-fire regeneration strategy observed. Few of the many seedlings (<2.0%) produced by *M. lanceolata* on the lee side of the dunes survived to year 10; and seedling production by *Leucopogon parviflorus*, *Melaleuca squarrosa* and *Leptospermum continentale* was rare.

In contrast to the swamp communities, regeneration from seed was the main post-fire regeneration strategy on the dunes, where 60% of species were OSR regenerators.

The high proportion of both introduced and 'environmental weed' species (as defined by Carr 1993) on the dunes is not unexpected considering the proximity to the Great Ocean Road and the Anglesea township. It is well documented that weeds may be spread by motor vehicles (Clifford 1959) as well as by water, wind, soil, birds, animals and man. Most of the shrubs on the dunes defined as 'environmental weeds' were OSR garden escapes of either exotic, **Chrysanthemoides monilifera* var. *monilifera* and **Polygala myrtifolia*, or indigenous origin, *Leptospermun laevigatum* and *Parasieranthes lopantha*, present outside their natural range (Parsons et al. 1977; Barson & Calder 1981; Carr 1993). Others, such as *Acacia longifolia* var. *sophorae*, were indigenous species of the coastal complex (Parsons et al. 1977; Barson & Calder 1981), which Carr (1993) considers may, under certain circumstances, become 'ecologically out of balance'.

It is known that all these species can establish on low nutrient soils and may eliminate smaller native species through competition (Parsons 1973).

Flowering response post-fire

The spectacular flowering of grasses, lilies, orchids and herbs seen on the dunes during year 1 is similar to that observed post-fire in heaths and heath woodlands in southern Australia (Specht et al. 1958; Gill 1981) and in the Anglesea area (Wark et al. 1987; Wark 1996).

The appearance of the rare lizard orchid *Burnettia cuneata* (Gullan et al. 1990) in the swamps of the Anglesea River post-fire confirms observations (Meredith 1986; McMahon et al. 1990; Carr et al. 1995) of the floristic uniqueness of these *Melaleuca* swamp communities (Australian Heritage Commission 1993). Management strategies are required to prevent degradation of these swamps by off-road vehicles, which introduce environmental weeds and accelerate the spread of water- and soil-borne plant pathogens such as *Phytophthora cinnamomi* (Weste 1974; Carr et al. 1995).

Phytophthora cinnamomi

Earlier studies have shown that *P. cinnamomi* is present in the heaths and heath woodlands adjacent to the Anglesea swamps (Wark et al. 1987; Wark 1996). Extensive infestation could possibly result in elimination of sclerophyllous OSR shrub species of the swamp, such as *Sprengelia incarnata*, and a change in the species richness and diversity of the swamp communities. However, recent long-term studies by Weste (1997) and Weste & Kennedy (1997) in the Grampians, Wilsons Promontory and Brisbane Ranges National Parks, indicate that pathogen incidence may vary over a 20–30-year period and that a decline in *P. cinnamomi* distribution may be accompanied by regeneration of susceptible OSR species, if seed is available.

Environmental weeds

The prolific germination of the fire-sensitive OSR shrub species **Chrysanthemoides monilifera* ssp. *monilifera* (boneseed), **Polygala myrtifolia* (Myrtle-leaf milkwort), *Leptospermum laevigatum* (coast tea-tree) and *Acacia longifolia* var. *sophorae* (coast wattle) in the first year post-fire supports previous findings that fire may stimulate seedling establishment and spread of these 'environmental weeds' (Burrell 1981; Weiss 1984; Weiss & Milton 1984; Wark et al. 1987; Molnar et al. 1989; Carr 1993). Post-fire field observations showed an increase in range and density of all four species on the dunes; and some invasion of coastal heathland by boneseed, coast tea-tree and coast wattle; and of gullies and slumps close to the coast by Myrtle-leaf milkwort (M. D. White, pers. comm.). Inland, the range of **Chrysanthemoides monilifera* ssp. *monilifera* increased following the fire, seedlings appearing in isolated areas away from pre-existing plants, roads or settlements (Wark et al. 1987), including heath woodland and dry sclerophyll forest communities. It has been shown that boneseed may be dispersed by both native and exotic birds including rosellas (*Platycercus elegans*), pied currawongs (*Strepa graculina*) and blackbirds (*Turdus merula*) (Weiss & Noble 1984a, 1984b; Dodkin & Gilmore 1985; Lane 1985) and our observations would support this.

A decreased incidence of fire since the time of European settlement may be responsible for the spread of 'environmental weeds' such as *Leptospermum laevigatum* and *Acacia longifolia* var. *sophorae* into heathlands (Burrell 1981; McMahon et al. 1996). Both are fire-sensitive species which may be eliminated by consecutive fires at short intervals and a decrease in fire frequency would allow their establishment, seeding and invasion (Burrell 1981; McMahon et al. 1996), with subsequent suppression of native species. This supression may occur quite rapidly. Recently, McMahon et al. (1966) showed that invasion of coastal heathlands by *Acacia longifolia* var. *sophorae* occurred within a fire-free period of less than 10 years. Major structural modifications occurred in the invaded heathlands within 3–5 years; and floristic changes, resulting in a 60% drop in apparent species richness, within 10–15 years, with dominants such as *Banksia marginata* decreasing in abundance.

Such floristic and structural changes which follow invasion of heathlands by 'environmental weeds' may, in part, be reversed by elimination of these weeds by fire. However, in Sandringham, Victoria, Molnar et al. (1989) showed that, though the fire may be used to reverse *Leptospermum laevigatum* invasion of heathlands after 70 years (resulting in the return of a significant subset of plants, from soil-stored seed), no regeneration of the three dominant shrubs of area, *Allocasuarina pusilla*, *Banksia marginata* and *Leptospermum myrsinoides*, occurred in the absence of an adjacent seed source, with subsequent changes in vegetation and species richness.

Because 'environmental weeds' such as **C. monilifera* ssp. *monilifera*, **P. myrtifolia*, *L. laevigatum* and *A. longifolia* var. *sophorae* are all fire-sensitive OSR species, their spread may be controlled by prescribed burning (Burrell 1981; Weiss 1984, 1986; Carr 1993; McMahon et al. 1996). There is urgent need to implement environmentally appropriate control programmes, including biological control, use of herbicides and prescribed burning, to further reduce the spread of these four species of weeds in the Anglesea Aireys Inlet region and protect its local flora.

Peat fires

The *Melaleuca squarrosa–Leptospermum continentale* closed scrub on the Anglesea River, Salt Creek and their tributaries, is one of the largest of such swamp communities in Victoria, and contains several rare species including *Burnettia cuneata*, *Corybas fordhamii* and *Pimelea flava* (Carr et al. 1995).

The soils of the river valleys are humus-rich and in-ground (peat) fires have occurred in the past both on the Salt Creek (Gill 1993; White 1994) and on the Anglesea River (G. Carr, pers. comm.; M. D. White, pers. comm.) causing major changes in hydrology and vegetation structure and floristics.

In 1980, a wildfire ignited the peat in a 1.5-ha strip of *M. squarrosa* closed scrub on the Salt Creek in the Angahook–Lorne State Park about 5 km west-north-west of Anglesea. It burnt for several months destroying all above-ground and in-ground vegetation and the soil seedbank, leaving a red 'burnt' peat'. A succession of 'fire mosses' colonised the area in the early years post-fire, including *Funaria hygrometrica*, *Ceratodon purpureus* and *Polytrichum juniperinum*, and a few shrubs, mainly species with windborne seed (eg. *Olearia phlogopappa)*, appeared at the edge of the 'burnt peat' during years 2 and 3 (White 1994).

The area was burnt a second time by the Ash Wednesday wildfire (1983), incinerating all above-ground vegetation. The creek cut a new course through the 'burnt peat', and some which was washed away. Seedlings of *Eucalyptus ovata* and *E. aromaphloia* appeared in damper areas and seedlings of *Allocasuarina litoralis* throughout the site. Patches of uncolonised 'burnt peat' still remained.

Fifteen years after the second fire, the area has become a *Eucalyptus* woodland dominated by trees of *Eucalyptus ovata* and *E. aromaphloia*. Patches of uncolonised red 'burnt peat' still remain and the area appears drier than in 1980. The ground has sunk and much of the 'burnt peat' has been washed away (Gill 1993).

Similar changes in vegetation structure and floristics occurred in a gully near Aireys Inlet where, in 1983, a peat fire developed and destroyed a *Eucalyptus obliqua*, *Cyathea australis*, *Prostanthera lasianthos* gully community (Wark 1997). Here the gully species were replaced by a woodland of *E. obliqua* and *E. willisii* which germinated from seed shed onto the site post-fire. Few understorey plants were present 14 years after the fire, and, as at Salt Creek, the hydrology of the area changed, and the site appears drier than in the past (Wark 1997).

Though no peat fires of any size established in the *Melaleuca squarrosa* swamps of the Anglesea River and Salt Creek following the 1983 wildfire, the occurrence of small (20 m^2) in-ground fires on drier parts of the *M. squarrosa* thickets, with subsequent death of all above-ground and in-ground vegetation and seed stores, indicates that these swamp communities are not resilient to such events.

Almost no recolonisation of these badly burnt areas occurred in the 15 years following the fire, the only exceptions being a few fire mosses in early years and, on one occasion, a shrub of the 'hard-seeded' swamp species *Pultenaea stricta*.

The slow rate of recovery of such areas suggests that in these seasonally waterlogged swamps recovery from an in-ground fire may take many years.

A mosaic of dense *Melaleuca squarrosa* swamp thicket and open waterlogged sedgeland occurs along the Anglesea River. It has been suggested that this mosaic reflects the past fire history of the area (G. Carr, pers. comm.), the sedgelands of the mosaic being most recently burnt and the *M. squarrosa* swamp thicket (closed scrub) the climax community.

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	Authority	
	Ross (1993)†	Ross (1996)
Shrubs	*Acacia sophorae*	*Acacia longifolia* var. *sophorae*
	Hibbertia prostrata	*Hibbertia fasciculata* var. *prostrata*
Herbs	**Inula graveolens*	**Dittrichia graveolens*
Grasses	*Rytidosperma caespitosum*	*Danthonia caespitosa*
	Stipa semibarbata	*Austrostipa semibarbata*

Appendix. Nomenclature of vascular plants—name changes since the second paper in this series. †Ross (1993) and other authorities listed in Wark (1996).