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Allocasuarina (Casuarinaceae) Invasion of an Unburnt Coastal Woodland at Ocean Grove, Victoria: Structural Changes 1971–1996

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Abstract

Changes in vegetation structure in a long-unburnt (> 115 years) woodland at Ocean Grove, Victoria, were assessed by comparing density data collected in 1971 by Withers and Ashton (1977) with comparable data from 1996. The changes in structure outlined by Withers and Ashton (1977) continued to operate over the 25 year period, namely, a dramatic increase in the density of *Allocasuarina littoralis* (Salisb.) L.A.S.Johnson, and a continued decline in the once-dominant eucalypts, especially *Eucalyptus ovata* Labill. The density of *A. littoralis* increased from 911 trees ha^{-1} in 1971 to 3565 trees ha^{-1} in 1996. Most of the surviving *E. ovata* displayed extensive crown dieback, and appear likely to die in the near future. Many eucalypt seedlings which were planted into burnt and unburnt experimental plots in 1971 were still alive in 1996, but most were less than 0.5 m tall and suppressed by tall regrowth of *A. littoralis* and *Acacia pycnantha* Benth. In the continued absence of fire and other disturbances, it is predicted that *A. littoralis* will continue to dominate the reserve, leading to further declines in eucalypts. It appears unlikely that a single fire will prevent *A. littoralis* dominance, and frequent burning at short intervals may be required to reinstate an open woodland structure.

Introduction

Two decades ago, Withers and Ashton (1977) began a paper on an unburnt coastal woodland in southern Victoria with the words: ‘In the drier regions of Victoria, it is rare to find vegetation which has remained unburnt for substantial periods of time’. Nowadays, large areas of coastal and lowland Victoria are rarely burnt (Victorian Government 1983; Meredith 1988; Lunt 1995), and numerous instances of shrub encroachment and declines of threatened species and ecosystem diversity may be attributed, at least in part, to long-term fire exclusion (e.g. Gleadow and Ashton 1981; Day *et al*. 1984; Molnar *et al*. 1989; Offor 1990; Scarlett and Parsons 1990; Bennett 1994; Lunt 1995; Fisher 1996; McMahon *et al*. 1996; Middleton *et al*. 1996).

The Ocean Grove Education Reserve, which was studied by Withers and Ashton (1977), is one of the few vegetation remnants in lowland Victoria which is known to have remained unburnt for over 100 years (Withers and Ashton 1977; Lunt 1998). Withers and Ashton (1977) documented a change in the reserve’s vegetation from *Eucalyptus*-dominated woodland to *Allocasuarina* scrub, and concluded that, ‘Ultimately, the poor regeneration of the eucalypt woodland is almost certainly due to the absence of fire … *Casuarina* [now *Allocasuarina*] *littoralis* scrub … is considered to be a climax condition ... in the long-continued absence of fire.’ (Withers and Ashton 1977, p. 623). The Ocean Grove plots have remained unburnt and largely undisturbed over the past 25 years. In 1996, they were reassessed to determine (1) how the vegetation has changed since Withers and Ashton’s studies, (2) whether these changes were predicted by their successional models, and (3) what modifications (if any) need to be made to their conclusions. Since many coastal conservation reserves are now managed in a similar way to the Ocean Grove reserve, an accurate appraisal of vegetation processes at Ocean Grove is directly relevant to the management of many important reserves in south-eastern Australia.

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Materials and Methods

The Ocean Grove Education Reserve occupies 144 ha on the outskirts of Ocean Grove (38°15′S, 144°31′E), 60 km south-west of Melbourne, Victoria. It is situated 3 km from the sea and *c*. 20 m above sea level, on an almost flat plain of Tertiary marine sediments (Land Conservation Council Victoria 1985). The climate at Ocean Grove is mild and maritime, and the average annual rainfall at Barwon Heads, 4 km south-west of the reserve, is 631 mm (Bureau of Meteorology, unpublished data).

In 1971, Withers and Ashton (1977) documented tree densities in a 1.9-ha plot (96 m × 192 m) in the north-eastern corner of the reserve. In 1996, the original plot was relocated as accurately as possible, although the exact boundaries of the new plot probably differ slightly from the original. Only 1.38-ha of the original 1.9-ha plot was sampled in 1996 as a 30 m wide cleared strip was excluded. The number of trees per hectare in 1971 and 1996 was calculated from the 1.38-ha portion of the 1.9-ha plot which was sampled in 1996. Following Withers and Ashton (1977), all standing trees in the plot were identified to species (or genus if species could not be positively identified), and girth over bark at breast height (GBBH) was recorded. The health of each tree was assigned to a four point scale: 1 = no crown dieback, 2 = partial crown dieback (< 25%), 3 = extensive crown dieback (> 25%), 4 = dead.

Six fenced, experimental plots were also established in 1971 to assess seedling regeneration after burning. Three plots (each 5 m × 10 m) were established in open woodland areas, and three smaller plots (2 m × 2 m) beneath mature *Allocasuarina* scrub. Half of each of the larger plots was burnt to assess recruitment, and seeds and seedlings were added to each plot (Withers 1978). The experimental plots were re-assessed in December 1996, and all trees were identified and measured for GBBH and health (as above). In addition, the height of all eucalypts was measured (or, for tall trees, estimated to the nearest metre), as was the average canopy height of *Allocasuarina* and *Acacia* trees in each plot.

Results

The results show a dramatic increase in tree density over the past 25 years, from 3223 plants ha^{-1} in 1971 to 5648 plants ha^{-1} in 1996. This increase was largely due to abundant recruitment by *Allocasuarina littoralis*, which almost quadrupled in numbers (Table 1). Withers and Ashton (1977) found no evidence of root suckering in *A. littoralis*, and it is assumed that all new plants were seedlings. The increase in *Allocasuarina* density is the result of the invasion of areas which previously supported open *Eucalyptus* woodland, as well as substantial increases in density within *Allocasuarina*-dominated areas. The invasion of open *Eucalyptus* woodland by *Allocasuarina* species has resulted in the closure of many open, ‘gap’ areas which existed in 1971.

As predicted by Withers and Ashton (1977), eucalypt densities have continued to decline (Table 1). The density of *Eucalyptus ovata* trees (excluding seedlings < 3 cm GBBH) has declined by over 40% since 1971. The apparent small increase in *E. leucoxylon* density in

Table 1. Density of seedlings and trees ha^{-1} for the six major tree species in 1971 and 1996
Following Withers and Ashton (1977), plants less than 30 mm GBBH are termed seedlings, although many may be older, suppressed individuals. Total sample area = 1.38 ha

Species	Seedlings		Trees		Total	
	1971	1996	1971	1996	1971	1996
Acacia pycnantha	936	432	686	722	1623	1154
Allocasuarina littoralis	572	1420	339	2145	911	3565
Allocasuarina verticillata	66	175	93	247	158	422
Banksia marginata	407	182	56	273	463	455
Eucalyptus leucoxylon	1	1	7	11	8	12
Eucalyptus ovata	14	14	46	27	60	41
Total	1996	2224	1227	3424	3223	5648

Table 1 is an artefact of slight differences in plot location. The decline in eucalypt density is also reflected in the health of surviving trees (Fig. 1). In 1971 there were roughly similar numbers of *E. ovata* in all crown condition classes (Fig. 1*f*). In 1996, by contrast, 70% of trees displayed serious crown decline, and only 5% of trees (mostly small saplings) showed no signs of canopy dieback (Fig. 1*f*). *Acacia* and *Banksia* trees also declined in health over the 25 year period (Fig. 1). In contrast to the generally poor health of eucalypts (especially *E. ovata*), most *Allocasuarina* trees appeared healthy in 1971 and 1996, with no sign of crown dieback (Fig. 1).

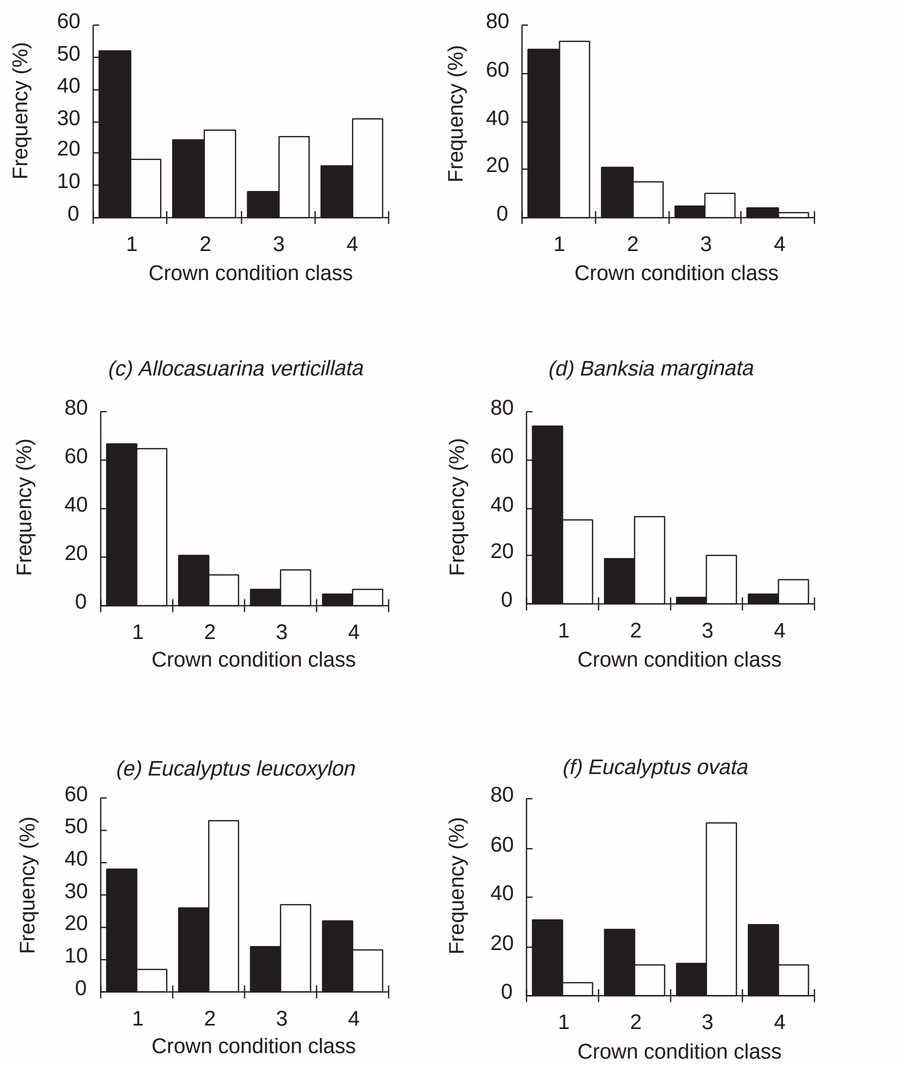

Fig. 1. Percentage frequency of individuals of the six major tree species in the four crown condition classes in 1971 (■) and 1996 (□). 1, no dieback; 2, partial (< 25%) dieback; 3, extensive (> 25%) dieback; 4, dead. Trees < 30 mm GBBH are omitted, following Withers and Ashton (1977). 1971 data from fig. 1.7 in Withers (1976).

Experimental Plots

The three small (2 m × 2 m) regeneration plots which were established in *Allocasuarina* low forest in 1971 all supported very few trees in 1996 (Table 2). Plot 4, which contained the most trees (eight small saplings), was adjacent to a relatively recent (< 10 years) tree fall, which provided a gap above the plot. The three larger plots, established in the *Eucalyptus* woodland in 1971, all supported dense stands, 5–8 m tall, of *Allocasuarina littoralis* and *Acacia pycnantha* (Table 2). There were dramatic differences in the numbers of *A. pycnantha* in different halves of two of the three plots: the halves with abundant *A. pycnantha* regeneration were assumed to have been burnt in 1971. Both halves of plot 2, which was burnt by a low-intensity fire in 1971 (Withers 1978), contained similar numbers of *A. pycnantha* in 1996, and it was not possible to tell which half had been burnt.

In total, 34 live eucalypts were recorded from the three woodland regeneration plots in 1996 (there was none in the three *Allocasuarina* forest plots). There were no obvious

Table 2. Number of trees in 1996 in the 1971 experimental plots

Figures show the total number of stems, dead and alive and, in parentheses, the number of live stems. Plots 1–3, each 5 m × 10 m, were established in open *Eucalyptus* woodland. Half of each plot was burnt (b) and half left unburnt (u). Plot 2 was ‘lightly fired’ in 1971; in 1996 it was impossible to tell which half was burnt. Plots 4–6, each 2 m × 2 m, were established in closed *Allocasuarina* low forest, and remained unburnt. *Acacia baileyana* is not endemic to the region

Plot	1		2		3		4	5	6
Treatment	b	u	?	?	b	u	u	u	u
Acacia baileyana		2 (2)		1 (1)					
Acacia pycnantha	52 (25)	8 (4)	6 (5)	9 (6)	65 (29)	9 (6)	1 (0)	1 (1)	
Allocasuarina littoralis	48 (48)	20 (20)	23 (22)	24 (23)	14 (14)	26 (23)	5 (5)	1 (1)	
Allocasuarina species	1 (0)	3 (0)	1 (0)	2 (0)	1 (0)	2 (0)			
Allocasuarina verticillata	1 (1)	6 (5)	5 (5)	4 (3)	1 (0)	3 (2)	2 (2)		
Banksia marginata				2 (1)		1 (1)			
Eucalyptus species	17 (7)	10 (10)	3 (3)	8 (8)	5 (4)	2 (2)			
Total	119 (81)	49 (41)	38 (35)	50 (42)	86 (47)	43 (34)	8 (7)	2 (2)	0 (0)

Table 3. Number of eucalypts in each height class, and maximum eucalypt height in 1996, in three experimental plots established in open woodlands in 1971

Plot numbers and treatments follow Table 2

Plot	1		2		3	
Treatment	b	u	?	?	b	u
< 1 m	3	6	2	4	3	0
1–2 m	1	3	0	2	0	1
> 2 m	3	1	1	2	1	1
Max. height (m)	10	5	5	3.2	2.5	2.7

differences in eucalypt survival or growth between burnt and unburnt halves of the experimental plots (Table 3). Most eucalypts (53%) were less than 1 m tall. Virtually all of these plants had a basal lignotuber, from which stems had repeatedly resprouted, before dying back again. Only nine eucalypts exceeded 2 m in height, and only five exceeded 4 m. Many of these were weak and spindly, with substantial crown decline, and few appear likely to survive (as mature trees) in the long term. Nevertheless, it should be noted that the density of eucalypt saplings over 4 m tall in these small plots far exceeded that in the larger monitoring plot.

Discussion

The substantial changes in stand structure between 1971 and 1996 continue the trends documented in 1971 by Withers and Ashton (1977), namely a major increase in the density of *Allocasuarina* species, especially *A. littoralis*, and a substantial decline in *Eucalyptus* species. The decline of eucalypts has progressed further since 1971. Many large trees have died in the past 25 years, and many remaining trees (especially *E. ovata*) appear close to death, with recurrent resprouting from epicormic buds on the upper branches or trunk. Since hardly any recruitment has occurred, the decline of *E. ovata* seems likely to continue, if current conditions persist.

It is possible that some of the apparent differences in stand structure between the 1971 and 1996 studies may be due to different plot locations in the two surveys. However, while this explanation might contribute to minor differences, it seems unlikely to account for the major trends observed. The 1.9-ha plot encompasses the obvious variation in vegetation patterning in the surrounding area, and subtle differences in plot placement are unlikely to affect the general results. The permanent staking of plot boundaries in 1996 will eliminate this problem in future surveys.

Repeat monitoring of the 1971 regeneration plots, 23 years after the previous assessment, revealed some unexpected results. First, whilst Withers (1978, p. 479) found that 'a greater percentage of *E. ovata* and *E. leucoxylon* seedlings survived on the fired sites than in the non-fired sward', this difference was not apparent 23 years later, by which stage similar numbers of eucalypts survived under both treatments. Similarly, even though eucalypt seedlings grew significantly taller than *A. littoralis* seedlings in the first 2 years after fire (Withers 1978), this initial advantage was not maintained over the longer term; by 1996, *A. littoralis* and *A. pycnantha* dominated the plots and most eucalypts were less than 1 m tall. A surprisingly large number of eucalypt seedlings survived as small and suppressed seedlings (< 0.5 m tall), 25 years after planting. Other studies have noted considerable mortality of suppressed seedlings, either by fungal attack or browsing (Ashton 1981; Ashton and Chappill 1989). The relatively dry conditions at Ocean Grove (compared to moist eucalypt forests) might minimise fungal attack, and plot fencing prevented browsing by large mammals.

The 'decline' of eucalypts should, however, be viewed in a longer term, historical perspective. At the time of European colonisation, the vegetation appears to have been a very open grassy woodland, co-dominated by eucalypts, *Allocasuarina* species and *Banksia marginata* (Lunt 1998). Despite massive eucalypt mortality in recent decades, the low density of surviving eucalypts is probably similar to that in the early 1800s, when the total density of all tree species may have been less than 20 trees ha^{-1} (Lunt 1998). From this initial low density, eucalypt densities increased substantially in the late 1800s and early- to mid-1900s, and Withers (1971) recorded nearly 100 eucalypt stumps and trees ha^{-1} in 1971. However, whilst eucalypt densities continue to fall, the densities of most other tree species continue to rise; the present densities of the other major tree species (*A. littoralis*, *A. verticillata*, *A. pycnantha* and *B. marginata*) are all dramatically greater than at the time of European settlement. The long-term absence of fire is the most plausible explanation for this marked increase in tree densities (Withers and Ashton 1977; Lunt 1998).

Fire Management

Allocasuarina littoralis recruits after fire from canopy-stored seed, and does not resprout from the base, stem or root suckers (Withers and Ashton 1977; Morrison 1995). Morrison (1995) found that plants of less than 17-cm stem circumference were killed by a single low-intensity fire, and suggested that larger plants would be killed by higher intensity fires. Withers (1976, p. 260) speculated that, ‘if the area is severely fired before the remaining eucalypts die, [*Allocasuarina*] may be relegated to an understorey role again because it is less fire resistant than *E. ovata*’. For a number of reasons, this scenario would seem unlikely. Given the poor health of many eucalypts (especially *E. ovata*), a high-intensity fire is likely to kill many eucalypts as well as *Allocasuarina* and *Acacia* trees. Post-fire recruitment is likely to be dominated by *A. littoralis* and *Acacia pycnantha*, given the sparsity of healthy, seed-supplying, mature eucalypts, and the abundance of soil-stored seed of *A. pycnantha* and canopy-stored seed of *A. littoralis*. Furthermore, the long-term results from the 1971 experimental fire plots demonstrate that *A. littoralis* and *Acacia pycnantha* can outcompete eucalypt seedlings over the long term. Post-fire recruitment is likely to be dominated initially by *A. littoralis* and *Acacia pycnantha* seedlings, and progressively thereafter by *A. littoralis*, as the shorter-lived acacias senesce. Thus, it seems most unlikely that a single fire (of any intensity) would have any substantial impact on preventing long-term dominance by *A. littoralis*. A closed scrub of *Allocasuarina verticillata* developed within 15 years of a single fire near Hobart (Kirkpatrick 1991), and Kirkpatrick (1986) suggested that frequent burning would be required to maintain an open woodland vegetation. If an open-woodland structure is desired at Ocean Grove, and burning is to be used to achieve it, then repeated fires at short intervals (e.g. every 5–10 years) may be required, although further experimental work is obviously required to test this scenario.

Coastal Management

Fire management of woodland and coastal areas appears to have changed dramatically throughout this century. As noted earlier, Withers and Ashton’s (1977) paper began with the words: ‘In the drier regions of Victoria, it is rare to find vegetation which has remained unburnt for substantial periods of time’. Nowadays, large areas of coastal and lowland Victoria, and virtually all grassy woodlands in the state, are rarely burnt (Victorian Government 1983; Meredith 1988; Lunt 1995). The Ocean Grove reserve remains unique, perhaps, because of the very long absence of fire, but many coastal and woodland areas have suffered few fires or grazing stock for at least the last 20 to 30 years (e.g. Bennett 1994). As a consequence, many fire-sensitive native shrubs, such as *Acacia sophorae*, *Kunzea ambigua*, *K. ericoides*, *Leptospermum continentale*, *L. laevigatum* and *Pittosporum undulatum*, are invading coastal and sub-coastal environment in Victoria, to the detriment of rare plants, ecosystem diversity, and small mammal habitat (Day *et al*. 1984; Molnar *et al*. 1989; Offor 1990; Carr 1993; Bennett 1994; McMahon *et al.* 1996). Considerable work is required to develop ecologically sensitive burning regimes for these ecosystems.

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References

Ashton, D. H. (1981). Tall open-forests. In 'Australian Vegetation'. (Ed. R. H. Groves.) pp. 121–151. (Cambridge University Press: Canberra.)

Ashton, D. H., and Chappill, J. A. (1989). Secondary succession in post-fire scrub dominated by *Acacia verticillata* (L'Herit.) Willd. at Wilsons Promontory, Victoria. *Australian Journal of Botany* **37**, 1–18.

Bennett, L. T. (1994). The expansion of *Leptospermum laevigatum* on the Yanakie Isthmus, Wilson's Promontory, under changes in the burning and grazing regimes. *Australian Journal of Botany* **42**, 555–564.

Carr, G. W. (1993). Exotic flora of Victoria and its impact on indigenous biota. In 'Flora of Victoria. Vol. 1. Introduction'. (Eds D. B. Foreman and N. G. Walsh.) pp. 256–297. (Inkata Press: Melbourne.)

Day, J. C., McGregor, G. A., and Johnstone, P. D. (1984). Grampians National Park—Inventory of resources and uses. National Parks Service Victoria and the Australian National Parks and Wildlife Service, Canberra.

Fisher, J. T. (1996). Fire in flora and fauna management. In 'Fire and Biodiversity. The Effects and Effectiveness of Fire Management'. Biodiversity Series Paper No. 8, pp. 241–246. (Biodiversity Unit, Department of the Environment, Sport and Territories: Canberra.)

Gleadow, R. M., and Ashton, D. H. (1981). Invasion by *Pittosporum undulatum* of the forests of central Victoria. I. Invasion patterns and plant morphology. *Australian Journal of Botany* **29**, 705–720.

Kirkpatrick, J. B. (1986). The viability of bush in cities—ten years of change in an urban grassy woodland. *Australian Journal of Botany* **34**, 691–708.

Kirkpatrick, J. B. (1991). Grassy vegetation. In 'Tasmanian Native Bush: A Management Handbook'. (Ed. J. B. Kirkpatrick.) pp. 92–109. (Tasmanian Environment Centre: Hobart.)

Land Conservation Council Victoria (1985). Report on the Melbourne area, district—review. Land Conservation Council Victoria, Melbourne.

Lunt, I. D. (1995). European management of remnant grassy forests and woodlands in south-eastern Australia—past, present and future? *Victorian Naturalist* **112**, 239–249.

Lunt, I. D. (1998). Two hundred years of land use and vegetation change in a remnant coastal woodland in southern Australia. *Australian Journal of Botany* **46**, 629–647.

McMahon, A. R. G., Carr, G. W., Bedggood, S. E., Hill, R. J., and Pritchard, A. M. (1996). Prescribed fire and control of coast wattle (*Acacia sophorae* (Labill.) R.Br.) invasion in coastal heath, south-west Victoria. In 'Fire and Biodiversity. The Effects and Effectiveness of Fire Management'. pp. 87–96. Biodiversity Series, Paper No. 8. (Biodiversity Unit, Department of the Environment, Sport and Territories: Canberra.)

Meredith, C. (1988). Fire in the Victorian Environment. A discussion paper. (Conservation Council of Victoria: Melbourne.)

Middleton, N. D., Ladiges, P. Y., and Enright, N. J. (1996). Population ecology of *Banksia saxicola* (Proteaceae). *Proceedings of the Royal Society of Victoria* **108**, 43–56.

Molnar, C. D., Fletcher, D., and Parsons, R. F. (1989). Relationships between heath and *Leptospermum laevigatum* scrub at Sandringham, Victoria. *Proceedings of the Royal Society of Victoria* **101**, 77–87.

Morrison, D. A. (1995). Some effects of low-intensity fires on populations of co-occurring small trees in the Sydney region. *Proceedings of the Linnaean Society of New South Wales* **115** , 109–119.

Offor, T. (1990). What future for the sandy heaths of Wilson's Promontory? *Victorian Naturalist* **107**, 120–123.

Scarlett, N. H., and Parsons, R. F. (1990). Conservation biology of the southern Australian daisy *Rutidosis leptorrhynchoides*. In 'Management of Small Populations'. (Eds T. W. Clark and J. H. Seebeck.) pp. 195–205. (Chicago Zoological Society: Illinois.)

Victorian Government (1983). Submission for inquiry into environmental impact of bushfires by the House of Representatives Standing Committee on Environment and Conservation.

Withers, J. R. (1971). The structure and regeneration of unburnt *Eucalyptus* woodland at Ocean Grove, Victoria. BSc Hons Thesis, Botany Department, University of Melbourne, Melbourne.

Withers, J. R. (1976). The structure and regeneration of unburnt *Eucalyptus* woodland at Ocean Grove, Victoria. PhD Thesis, Botany Department, University of Melbourne, Melbourne.

Withers, J. R. (1978). Studies on the status of unburnt *Eucalyptus* woodland at Ocean Grove, Victoria. II. The differential seedling establishment of *Eucalyptus ovata* Labill. and *Casuarina littoralis* Salisb. *Australian Journal of Botany* **26**, 465–483.

Withers, J. R., and Ashton, D. H. (1977). Studies on the status of unburnt *Eucalyptus* woodland at Ocean Grove, Victoria. I. The structure and regeneration. *Australian Journal of Botany* **25**, 623–637.

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