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COVER

Ben Halls Gap National Park *Sphagnum* Moss Cool Temperate Rainforest Community — listed as an Endangered Ecological Community under the NSW *Threatened Species Conservation Act 1995*.
Photographer: Nicki Chilcott.

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Floristic description and environmental relationships of *Sphagnum* communities in NSW and the ACT and their conservation management

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Whinam, J. and Chilcott, N. (Nature Conservation Branch, Department of Primary Industries, Water and Environment GPO Box 44, Hobart, Tas, Australia 7001. Corresponding author, email: Jennie.Whinam@dpiwe.tas.gov.au*)* *2002. Floristic description and environmental relationships of* Sphagnum *communities in NSW and the ACT and their conservation management.* Cunninghamia *7(3): 463–500.*

Investigations were conducted at 49 sites in New South Wales (NSW) and the Australian Capital Territory (ACT) to map the location and extent of *Sphagnum* peatland communities, some of which no longer contained *Sphagnum* moss. Nine floristic groups were identified for the *Sphagnum* peatlands based on data from 39 of the surveyed sites. The data were ordinated by hybrid multi-dimensional scaling. The strongest floristic gradients corresponded to changes in altitude, climate and geology and were strongly related to the geographic distribution of sites. While some groups are on land reserved for conservation, others occur on forestry and private land tenures. Reservation has not protected some sites from threatening processes, with most *Sphagnum* peatland communities surveyed being moss remnants or peatlands in poor condition with invading weed species. The main factors that have led to this degradation are fire, grazing, clearing, feral animals (pigs and brumbies), forestry operations and peat mining.

This paper is dedicated to the memory of my friend and colleague, Don Adamson (JW).

Introduction

Sphagnum peatlands are an unusual and infrequent component of the Australian landscape, and are often associated with drainage basins and watercourses (Campbell 1983, Whinam et al., in press). They are found primarily at montane and alpine altitudes in poorly drained, relatively infertile sites. Australian peatlands dominated by *Sphagnum* are generally small in area, restricted in distribution, and have relatively few *Sphagnum* species — six taxa (*Sphagnum cristatum, S. perichaetiale, S. australe, S. falcatulum, S. fuscovinosum* and *S. novo-zelandicum*) being recognised in a recent taxonomic revision (Seppelt 2000). *Sphagnum cristatum* is the most common species and is economically important in both Australia and New Zealand, as the main species harvested for horticultural use.

The majority of peat deposits in eastern Australia are sedge peats, mostly derived from the plant families Restionaceae or Cyperaceae. *Sphagnum* peatlands are defined as areas where the peatland is greater than 1000 m^2 and forms a distinct ecosystem and where *Sphagnum* species are the dominant peat formers (Whinam et al. in press). They occur in Australia most frequently between 600–1000 m altitude. However they can occur down to sea level, for example a small hanging swamp on top of a seacliff in Sydney (Bridgman et al. 1995), and in coastal dune swales (P. Adam pers. comm.). The bulk of Australian *Sphagnum* peatlands are found in Tasmania (Whinam et al. 2001).

In New South Wales (NSW) and the Australian Capital Territory (ACT) several regional peatland studies have been undertaken, including an inventory of significant mires in southern montane NSW and the ACT (Hope & Southern 1983). However this inventory did not distinguish *Sphagnum* peatlands from the more common sedge peatlands. The montane/sub-alpine bogs (above 1000 m) of the ACT, with and without *Sphagnum*, have been described (Helman & Gilmour 1985). Several *Sphagnum* peatlands in the ACT have also been described as part of the Mountain Occupation Project (Hope 1997, 1999, Saunders et al. 1996), and in local surveys, for example Ginini Flats (Clark 1980) and Tinderry Nature Reserve (Doherty 1997). Nationally significant peatlands, including mires with *Sphagnum* moss are included in *A Directory of Important Wetlands in Australia* (ANCA 1996).

There have been some regional studies of *Sphagnum* peatlands, notably the *Sphagnum* peatlands of New England (Millington 1954), Boyd Plateau (Black 1982) and the bogs of the Snowy Mountains (Costin 1954, Clarke & Martin 1999). Some vegetation descriptions of mires do not record *Sphagnum* moss, even though it is present e.g. Hanging Rock Swamp (Klaphake 1994) and the classification of sub-alpine bogs of the south-east forests (Keith & Bedward 1999) as these surveys did not record bryophytes.

The distribution of *Sphagnum* peatlands is largely limited by evapotranspiration in the warmest months (Whinam et al. 1989). They occur in areas where there is a seasonally stable high watertable, where there is a constant supply of surface or seepage water (Millington 1954). The geographic extent and conservation status of *Sphagnum* peatlands are affected by *Sphagnum* moss harvesting, peat mining, burning, grazing and forestry operations (Whinam et al. in press). In addition the impacts of feral animals, particularly pigs and brumbies, have also affected the condition of *Sphagnum* peatlands in NSW and the ACT (Helman & Gilmour 1985, Dyring 1990). In future, the increased temperatures and altered rainfall patterns predicted with global warming may result in the demise of *Sphagnum* peatlands at the hottest and driest margins of their distribution (Whinam et al. in press).

The aim of this survey was to collect data on the current extent and floristics of *Sphagnum* peatlands in NSW and the ACT, to describe their floristic variation and the environmental factors influencing them, to determine their conservation status, and to identify threats to their survival.

Methods

Site selection

Potential survey sites were identified from Herbarium records, *A Directory of Important Wetlands in Australia* (ANCA 1996), previous publications and on the advice of our botanical colleagues. Floristic surveys were conducted during the 2000–01 field season. Revisiting of some sites identified in the past (e.g. Millington 1954) has meant that some fieldwork has necessarily resulted in 'negative data' — i.e. removal of *Sphagnum* records or recording data at very degraded sites.

Field methods

Species cover abundance data were collected in 10 × 10 m quadrats. Species nomenclature follows Harden (1990–93) and the Australian National Botanic Gardens *Australian Plant Names Index* (ANBG 2001). Site descriptions included species recorded outside the quadrat, aspect and slope. Peat depth was measured with a stainless steel probe, with three measurements taken in each quadrat to obtain a mean peat depth. Three measurements were also taken to calculate the mean height between hummocks and hollows for each quadrat. A soil pH test kit was used to test the pH of the peat in each quadrat. Moss tendril length was recorded for *Sphagnum* at each site. Grid references were recorded with a GPS (accuracy ± 10 m), with altitudes determined from topographic maps.

Analytical methods

The data consisted of 39 sites and 355 taxa of vascular plants and *Sphagnum* species, from which singleton species (i.e. species found at only one site) were then deleted. Other mosses and lichens were recorded but not identified to species level. Owing to the high number of taxa with less than 5% cover, all data were converted to presence/absence prior to the analyses. The Bray-Curtis coefficient (Faith et al. 1987) was used to represent floristic dissimilarity between sites, and all clustering and ordination analyses were performed on this dissimilarity matrix.

Because floristic variation was anticipated to be relatively continuous, ordination was used initially, with cluster analysis used to dissect the data for ease of description. Sites were ordinated by hybrid multidimensional scaling (Faith et al. 1987) with the semi-strong algorithm (Belbin 1991a) implemented in PATN (Belbin 1995). Multidimensional scaling has been shown to be most robust method for ordinating community data (Kenkel & Orlóci 1986, Minchin 1987).

Ordinations were performed for the first six dimensions with 50 different random starting configurations for each dimension, in order to minimise the chance of entrapment at a local minimum. A plot of minimum stress versus number of dimensions suggested that a three-dimensional ordination adequately summarised the data. The three-dimensional solution yielded a stress of 0.2200, which was substantially better than the best two-dimensional solution (stress = 0.3113). The four-dimensional solution revealed no further structure in the data beyond that already apparent in the three-dimensional solution. Groups were clustered by β-flexible weighted arithmetic average clustering (WPGMA) with β = -0.1 in PATN (Belbin 1995).

Floristic characteristics of the groups in the resulting hierarchy were investigated with the indicator value index of Dufrêne and Legendre (1997). There are two components to this index for presence/absence data — 'specificity' and 'fidelity' (Dufrêne 1999). The two components are multiplied together and then multiplied by 100 to give the indicator value for that species.

For any given partition of a dendrogram, the indicator values of all the species can be computed for each site group; in a set of hierarchical partitions a species is allocated to the node in the hierarchy where its indicator value reaches a maximum. The statistical significance of the indicator values is assessed by a randomisation procedure, and these results can be used as a guide to establish the number of groups that should be discriminated in the final dendrogram (Dufrêne & Legendre 1997). The indicator values were calculated by IndVal 2.0 (Dufrêne 1999) with equal weightings for the two components of the index, and 499 randomisations to assess significance at the 0.05 level.

Bioclimatic variables were predicted by the BIOCLIM component of the ANUCLIM package (CRES 1999). BIOCLIM uses bioclimatic parameters derived from monthly climatic estimates to approximate energy and water balances at a given location (Nix and Bushby 1986). Based on the climatic variables of maximum temperature, minimum temperature, rainfall, solar radiation and pan evaporation BIOCLIM can produce up to 35 bioclimatic parameters (Houlder et al. 1999). The BIOCLIM variables included in these analyses are defined in Table 1. Interpretation of the statistical significance for climate variables is however limited as they are modelled data derived from a relatively sparse distribution of climate stations. Median values are given for environmental variables for each floristic group (Table 2), as they are more resistant to outlying values than means (Fowler & Cohen 1990).

The continuous environmental variables were fitted to the ordination space by a vector-fitting approach (Bowman & Minchin 1987, Dargie 1984). The statistical significance of the resulting correlations (Table 1) was determined by randomly permuting the values of the variables amongst the sites (Faith & Norris 1989) 100 times using Monte-Carlo testing of environmental attributes (MCAO) in PATN. These analyses were performed by the principal axis correlation (PCC) routines in PATN (Belbin 1991b).

Table 1. Codes and descriptions of bioclimatic variables from BIOCLIM (Houlder et al. 1999) and results of vector fitting of environmental variables and species richness to the three-dimensional ordination space with the number of observations (n), multiple correlation coefficient (R) and range of each variable. All correlations were significant to P < 0.05.

Code	Variable name	*n*	*R*	Range
Alt	Altitude (m)	39	0.7265	630–2048
Geol	Geology	39	0.6677	Sandstone, granite, shale, basalt, trachyte
SRich	Species richness	39	0.6835	9–38
AnMeTemp	Annual mean temperature (°C): The annual mean of weekly mean temperatures. Each weekly mean temperature is the mean of that week's maximum and minimum temperature.	39	0.8823	3.3–14.2
MeTWaQ	Mean temperature of the warmest period (°C): The highest temperature of any weekly maximum temperature.	39	0.8919	9.4–21.9
MeTCo	Mean temperature of the coldest period (°C).	39	0.8379	-2.5–6.7
AnnPrec	Annual mean precipitation (mm): the sum of all the monthly precipitation estimates.	39	0.7744	464–2496
PrecDP	Precipitation of the driest period (mm): the precipitation of the driest week.	39	0.7501	0–29
AMMI	Mean moisture index of the warmest quarter: The warmest quarter of the year is determined (to the nearest week), and the average moisture index value is calculated.	39	0.8338	0.39–1
MICV	Moisture index seasonality (C of V): The Coefficient of Variation (C of V) is the standard deviation of the weekly moisture index values expressed as a percentage of the mean of those values (i.e. the annual mean).	39	0.7449	0–63

Table 2. *Sphagnum* communities in New South Wales and Australian Capital Territory. Ranges and median values (bold type) of environmental variables and species richness (with group numbers from the clustering in brackets).

Floristic Community	No. of plots	Altitude (m)	Mean annual temperature (°C)	Mean annual precipitation (mm)	pH	Mean peat depth (cm)	Species richness
Seepage *Sphagnum* moss beds	2	650–900	12.4–13.7	464–542	4.5	1	9–13
(Group 1)		**775**	**13**	**503**	**4.5**	**1**	**11**
Rainforest *Sphagnum* peatlands	2	1300–1460	11.4–11.7	654–915	4.5–7	5–43	12–26
(Group 2)		**1380**	**11.6**	**785**	**5.8**	**24**	**19**
Tea tree *Sphagnum* peatlands	2	763–786	11.2	1088–1094	6.0	85–87	22–26
(Group 3)		**775**	**11.2**	**1091**	**6.0**	**86**	**24**
Shrubby herbaceous *Sphagnum* peatlands	11	796–1210	9.0–10.5	648–1413	4.5–6.0	20–7200	18–38
(Group 4)		**1040**	**9.5**	**1100**	**6.0**	**61**	**28**
Shrubby-sedgey *Sphagnum* peatlands	7	985–1740	4.8–10.3	1056–2184	5.5–6.5	65–235	15–29
(Group 5)		**1430**	**7.0**	**1317**	**6.0**	**157**	**25**
Heathy *Sphagnum* peatlands	6	1050–1300	12.4–14.2	711–839	5.0–6.0	23–87	21–34
(Group 6)		**1280**	**12.6**	**831**	**6.0**	**37.5**	**31**
Sphagnum swamps	4	1300–1500	10.3–11.4	668–750	4.5–6.0	37–147	22–37
(Group 7)		**1300**	**11.4**	**668**	**4.8**	**62.5**	**29**
Degraded *Sphagnum* moss beds	3	630–680	12.8–13.1	484–512	4.5–6.0	19–70	28–33
(Group 8)		**680**	**12.9**	**501**	**5.0**	**38**	**31**
Alpine *Sphagnum* moss beds	2	1900–2048	3.3–4.0	2343–2496	4.5–6.0	38–42	22–32
(Group 9)		**1974**	**3.7**	**2420**	**5.3**	**40**	**27**

Results

Locations of *Sphagnum* peatlands surveyed in NSW and the ACT, identified by their floristic groups (and two additional sites over the Victorian border) are shown Fig. 1. The majority of *Sphagnum* peatlands tend to be regionally clumped, and only small *Sphagnum* moss beds occur at the highest altitude sites. A summary of environmental variables for each floristic group is presented in Table 2.

A total of 196 singleton species were recorded at 39 sites, varying from one singleton per site (Mongarlowe River) to 16 singletons (The Sentinel at Pippit Creek, Kosciuszko National Park). The number of singleton species at sites is not correlated with species richness. Mean species richness (native and weed species) of all sites (26 taxa) is generally high, as is the number of weed species recorded when compared with Tasmanian *Sphagnum* peatlands (Whinam et al. 2001). Only two species of *Sphagnum* were recorded: *S. cristatum* and *S. novo-zelandicum*.

Community classification

A comparison of the dendrogram (Fig. 2) with the HMDS ordination suggested that nine groups would be sufficient to describe the data set. Further dissection of the diagram was not supported by indicator values for species at lower nodes in the hierarchy because most of these nodes did not have significant ($P < 0.05$) indicator species associated with them. A notable feature of the classification was the presence of several groups that consist of only a few sites. There was a tendency for these groups to be characterised by sites with low numbers of taxa. While the group with highest species diversity also contained the most weed species, there is no trend correlating diversity with weed occurrence within groups.

The community classification including significant ($P < 0.05$) indicator species for each of the final groups is shown in Figs 2 and 3, and the full hierarchically arranged two-way table of species by site groups together with indicator values, is given in Appendix 1. These analyses yield the nine identifiable *Sphagnum* peatland types and their environmental attributes which are described below. A list of all species recorded (native and weed species) is given in Appendix 2.

The dendrogram (Fig. 2) suggests a major division of these *Sphagnum* communities into those with *Blechnum nudum* as the principal discriminatory species (i.e. Groups 1–3 in Figs 2 and 3 and in Appendix 1) and those with *Empodisma minus* (Groups 4–8 in Figs 2 and 3 and in Appendix 1). As well, one group of species (including *Chionogentias muelleriana, Deschampsia caespitosa* and *Astelia alpina*) separates at a high level of the ordination (Group 9, Figs 2 and 3 and in Appendix 1). This apparent division of Group 9 is not as marked in the ordination (Fig. 4).

Groups 1–3 are small, each group having only 2 plots. However, these groups are distinct floristically — demonstrated by the indicator species in Fig. 3 and Appendix 1. Groups 4–8 include most of the plots surveyed and include a diversity of species, reflecting the structural and altitudinal variety of some of the groups, but all have *Empodisma minus* as a discriminatory species. Group 9 contains grasses and herbs found only at higher altitudes (e.g. *Poa hiemalis, Deschampsia caespitosa, Chionogentias muelleriana,* and *Celmisia tomentella*).

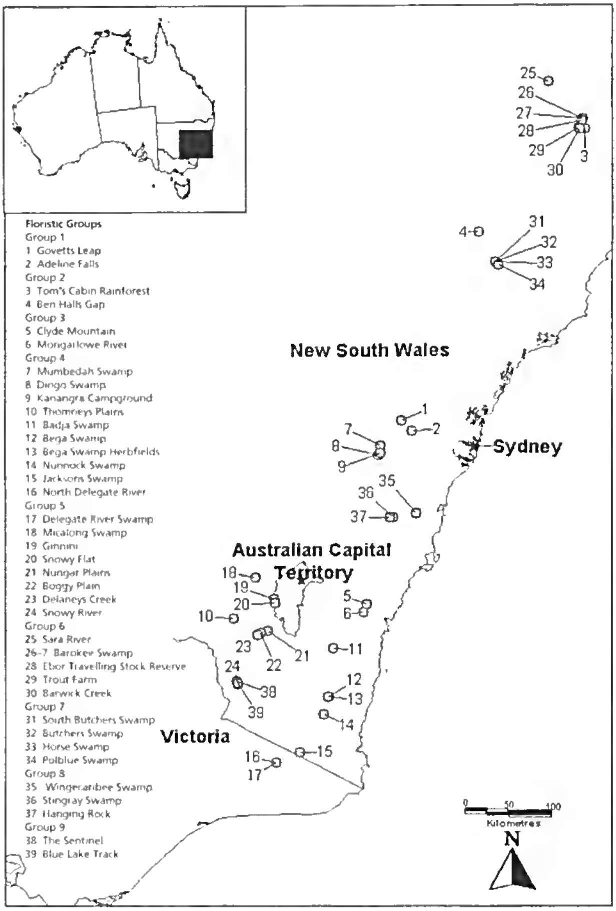

Fig. 1. Distribution of *Sphagnum* peatlands in NSW and ACT See text for descriptions of floristic groups.

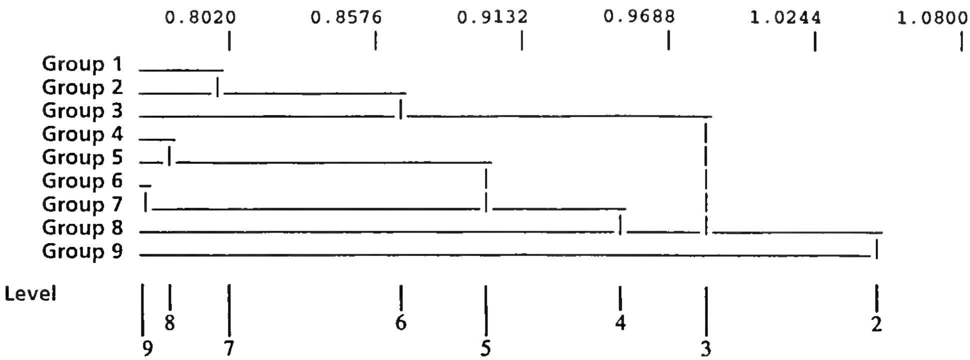

Fig. 2. Dendrogram from the WPGMA clustering of *Sphagnum* plots in NSW and ACT The dissimilarity is displayed on the top edge of the dendrogram, while 'Level' (displayed) along the bottom edge of the dendrogram denotes the fusions for reference to the two-way table of indicator species displayed in Appendix 1.

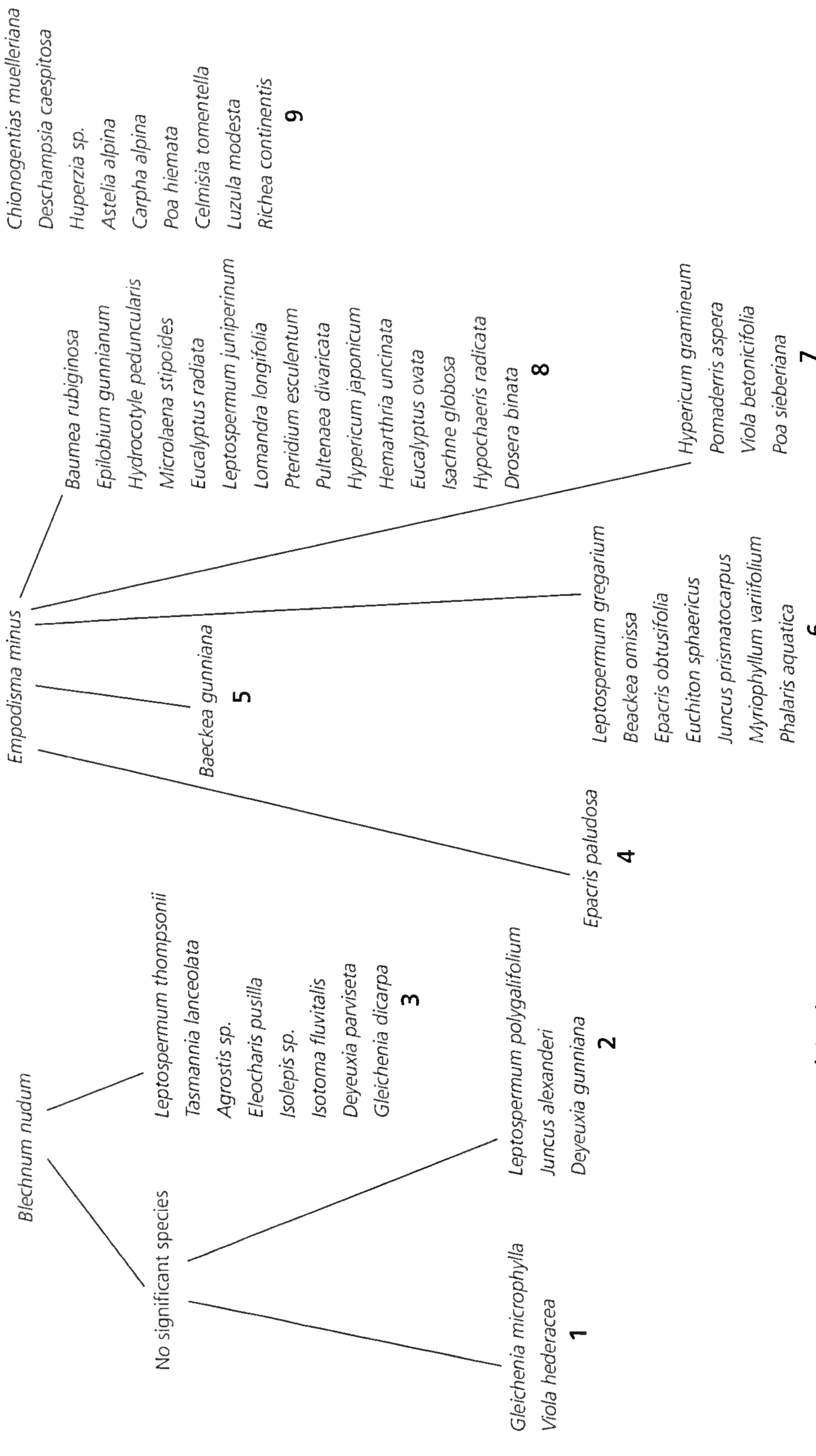

Fig. 3. Diagram of indicator species at each level of split in PATN. Bold text denotes the nine floristic groups (see text for group definitions).

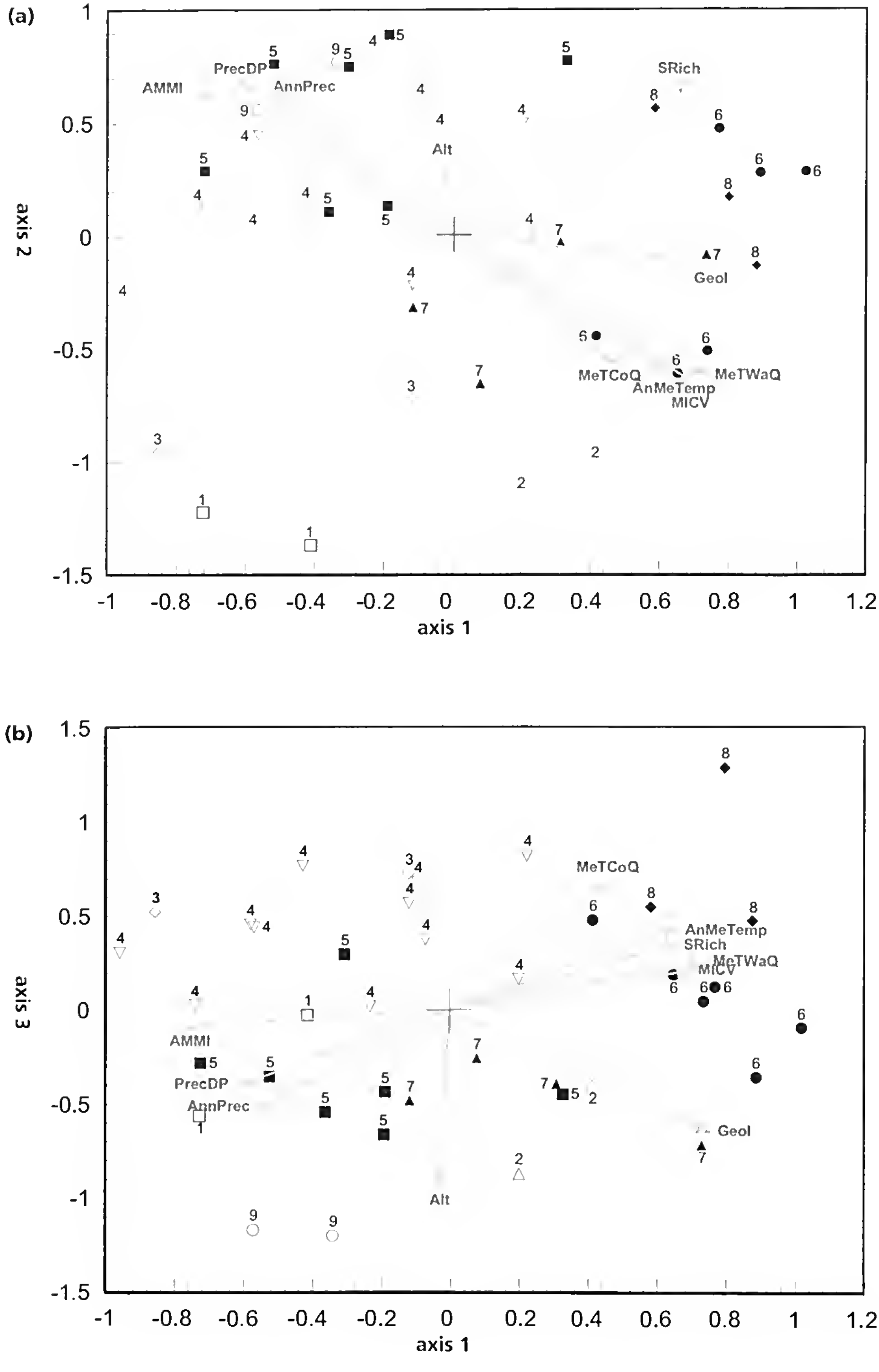

Fig. 4. HMDS in three dimensions, showing sites and significant ($p < 0.05$) fitted vectors for environmental variables and species richness with respect to (a) axis 1 v 2, and (b) axis 1 v 3. Abbreviations for environmental variables are: Alt = altitude, Geol = Geology, SRich = species richness, AnMeTemp = annual mean temperature, MeTCoQ = Mean temperature coldest quarter, MeTWaQ = Mean temperature warmest quarter, AnnPrec = annual precipitation, PrecDP = precipitation of driest period, AMMI = mean moisture index of warmest quarter, MICV = moisture index seasonality (Coefficient of Variation).

Floristic Group 1. Seepage *Sphagnum* moss beds – Blue Mountains Sandstone

This group of seepage *Sphagnum* moss beds is characterised by the ferns *Gleichenia microphylla* and *Blechnum nudum* and the herb *Viola hederacea*. A small group (represented by 2 plots), these sites are moss beds on seepage lines at the bottom of cliffs. These moss beds occur on sandstone in the Blue Mountains area, at altitudes ranging from 650–900 m, and are acidic (median pH 4.5). Mean annual temperature ranges from 12.4–13.7°C and mean annual precipitation ranges from 464–542 mm. Species richness of sites in this group ranges from 9–13, and mean peat depth is extremely shallow (1 cm). The flat moss beds, while small, are in good condition and occur in the reserve system.

Floristic Group 2. Rainforest *Sphagnum* peatlands – Northern Tablelands

Rainforest *Sphagnum* peatlands occur under a rainforest canopy at moderately high altitude (range 1300–1460 m). The community is distinguished by four metre tall *Leptospermum polygalifolium* subsp. *montanum*, with *Blechnum nudum, Juncus alexanderi* and *Deyeuxia gunniana* as the understorey. These rainforest *Sphagnum* peatlands, with large hummocks of *Sphagnum* moss (median 34.5 cm) occur on basalt and trachyte. Mean annual temperature ranges from 11.4–11.7°C and mean annual precipitation ranges from 654–915 mm. Species richness of this group ranges from 12–26, and mean peat depth ranges from 5–43 cm. The two quadrats surveyed are in good condition and occur in Ben Halls Gap National Park. This community — the Ben Halls Gap National Park *Sphagnum* Moss Cool Temperate Rainforest Community — is listed as an Endangered Ecological Community under the *NSW Threatened Species Conservation Act 1995*.

Floristic Group 3. Tea tree *Sphagnum* peatlands – Monga

Tea tree *Sphagnum* peatlands occur along drainage channels at altitudes ranging from 763–786 m. This group is distinguished by an overstorey of the vulnerable shrub *Leptospermum thompsonii*, with *Tasmannia lanceolata*, *Agrostis* sp., *Eleocharis pusilla*, *Isolepis* sp., *Isolepis fluvitalis*, *Deyeuxia parviseta* and *Gleichenia dicarpa*. Mean annual temperature is 11.2°C and mean annual precipitation ranges from 1088–1094 mm. Species richness of this group ranges from 22–26 species. Mean peat depth ranges from 85–87 cm. The two peatlands in this group are in good condition and are in Monga National Park.

Floristic Group 4. Shrubby herbaceous *Sphagnum* peatlands

This largest group of sites (11 plots) includes the indicator shrub *Epacris paludosa*. The herbs vary regionally but include *Asperula gunnii*, *Hydrocotyle* spp., *Brachyscome* spp., *Wahlenbergia* spp. and *Hypericum japonicum*. The majority of sites have a number of weed species including *Hypochaeris radicata*, *Rubus fruticosus*, *Taraxacum* spp. and *Holcus lanatus*. The number of weeds reflects the highly disturbed nature of many of the sites, caused by cattle grazing, feral pig damage and past fires. While some of the sites have substantial areas of *Sphagnum* moss, the condition of the peatlands is deteriorating from disturbance. The sites vary geographically from Jacksons Swamp near the NSW border north to the Kanangra-Boyd National Park and altitudinally from 796–1210 m (median 1040 m). While sites in the Kanangra-Boyd National Park are reserved, they are not protected from the feral pig damage currently occurring. Mean annual temperature ranges from 9.0–10.5°C (median 9.5°C) and mean annual precipitation ranges from 648–1413 mm (median 1100 mm). Species richness of sites in this group ranges from 18–38 (median 28), and mean peat depth ranges from 20–7200 cm (median 61 cm). The pH of this group tends towards neutral (median pH 6.0).

Floristic Group 5. Shrubby-sedgey *Sphagnum* peatlands

Shrubby-sedgey *Sphagnum* peatlands with large undulating moss hummocks (median 50 cm) are characterised by the shrub *Baeckea gunniana*. They occur at altitudes from 985–1740 m, from subalpine Kosciuszko National Park through to the ACT border and have a variety of sedges including *Empodisma minus, Baloskion australe, Luzula* spp., as well as the grass *Poa costiniana*. Several of the sites in Kosciuszko National Park contain weeds, again reflecting the past grazing history of some mid-altitude sites near the Snowy River, as well as the encroachment of pine plantations at Micalong Swamp. Many of these sites appear to be remnants, confined to drainage lines or peatland margins. Mean annual temperature ranges from 4.8–10.3 °C (median 7°C) and mean annual precipitation ranges from 1056–2184 mm (median 1317 mm). Species richness of sites in this group ranges from 15–29, and mean peat depth ranges from 65–235 cm (median 157 cm).

Floristic Group 6. Heathy *Sphagnum* peatlands – Northern Tablelands granite and basalt

Heathy *Sphagnum* peatlands are characterised by *Leptospermum gregarium, Baeckea omissa, Epacris obtusifolia, Eucliton sphaericus, Juncus prismatocarpus, Myriophyllum variifolium* and *Phalaris aquatica*. Mean annual temperature ranges from 12.4–14.2°C and mean annual precipitation ranges from 711–839 mm. Species richness of this group ranges from 21–34 (median 31), and mean peat depth ranges from 23–87 cm (median 37.5 cm). These poorly drained sites (6 plots) are on granite and basalt at altitudes from 1050–1300 m. Some of the sites occur in Travelling Stock Reserves, degraded by cattle trampling. The degraded condition of these New England sites subject to cattle grazing is reflected by the presence of weed species including *Hypochaeris radicata, Holcus lanatus, Taraxacum* sp. *Rubus fruticosus* and *Sonchus oleracens*.

Floristic Group 7. Barrington drainage line *Sphagnum* swamps

This group is distinguished by the species *Pomaderris aspera, Hypericum gramineum, Viola betonicifolia* and *Poa sieberiana*. The four sites occur on drainage lines through acidic swamps (median pH 4.75), primarily on basalt at altitudes from 1300–1500 m, with *Sphagnum* confined to drainage lines. No weeds were recorded in the *Sphagnum* swamps, reflecting their good condition. All the sites are in Barrington Tops National Park. Mean annual temperature ranges from 10.3–11.4°C and mean annual precipitation ranges from 668–750 mm. Species richness of this group ranges from 22–37, and mean peat depth ranges from 37–147 cm (median 62.5 cm).

Floristic Group 8. Degraded *Sphagnum* moss beds — Southern Highlands

These montane (630–680 m) *Sphagnum* moss beds occur as remnants restricted to drainage margins of peatlands on the Southern Highlands. The three sites in this group are all suffering degradation and weed species were recorded in the moss beds at each of the sites. None are in conservation areas. The characteristic species include *Baumea rubiginosa, Epilobium gunnianum, Hydrocotyle peduncularis, Microlaena stipoides, Eucalyptus radiata, Leptospermum juniperinum, Lomandra longifolia* and *Pteridium esculentum*. Mean annual temperature ranges from 12.8–13.1°C and mean annual precipitation ranges from 484–512 mm. Species richness of sites in this group ranges from 28–33, and mean peat depth ranges from 19–70 cm (median 38 cm). This floristic group had the highest mean number of weed species (4 taxa). One site is suffering major weed invasion (e.g. willows and blackberries) after extensive changes associated with peat mining (Wingecarribee Swamp), while another appears to be a remnant affected by changes in drainage and sedimentation due to forestry operations (e.g. Hanging Rock).

Floristic Group 9. Alpine *Sphagnum* moss beds

Two high altitude sites (1900–2048 m) make up these alpine *Sphagnum* moss beds, with the distinguishing species being *Chionogentias muelleriana, Deschampsia caespitosa, Hypericum* sp., *Astelia alpina, Carpha alpina, Poa hiemata, Celmisia tomentella, Luzula modesta* and *Richea continentis*. Both these sites have shown recent expansion of the moss beds, indicating successful recovery in the catchment after long-term erosion control works following the cessation of grazing (R. Good, pers. comm.). Mean annual temperature ranges from 3.3–4.0°C and mean annual precipitation ranges from 2343–2496 mm. Species richness of sites in this group ranges from 22–32 (median 27), and mean peat depth ranges from 38–42 cm. These sites are within Kosciuszko National Park.

Ordination and correlation with environmental variables

Overlaying the site groups derived from the clustering on the ordination (Figs 4a and 4b) shows that most peripheral plots are represented by the smallest groups, with lower species diversity, and a higher number of singletons. They tend to be highly dissimilar from the bulk of the data (as indicated in Appendix 1). Groups 1, 2 and 3 (all groups with low species richness) have high negative scores on axis 2 (Fig. 4a) while Group 9 (high altitude sites) has a high negative score on both axis 1 and 3 (Fig. 4b). Groups 6 and 8 have high positive scores on axis 1 (Fig. 4a). Sites in these two groups have high species richness and are the most disturbed sites with higher numbers of introduced species and singletons.

Patterns in the environmental variables across this ordination are evident. The strongest gradient contrasts the generally higher altitude, cooler and wetter sites (upper left corner of Fig.4a — predominantly sites from Groups 5 and 9), with sites from lower altitude, warmer areas and higher seasonal variation (sites on the lower right portion of axis 1 v 2 — predominantly from Groups 2 and 6; see also Table 2) (all correlations significant at $P < 0.05$). On the plot of axes 1 v 3 (Fig. 4b), sites tend to be grouped regionally and are correlated with geology. Sandstone geology (associated with Group 1) separates from granite (associated with Groups 5 and 9) and basalt (Group 7) rock types.

Discussion

Many of the alpine and sub-alpine *Sphagnum* peatlands of NSW and all the montane/sub-alpine *Sphagnum* peatlands of the ACT are in nature reserves (Groups 1, 2, 3, 7 and 9). However few of the lowland and highland *Sphagnum* peatlands are reserved (Group 8 is unreserved and Groups 4 and 6 are poorly reserved). Unfortunately, reservation has not equated with protection from the many activities that currently threaten the survival of *Sphagnum* peatlands.

The majority of *Sphagnum* peatlands surveyed are either *Sphagnum* remnants or severely degraded peatlands. The most potent threats to their survival are posed by fire, grazing, peat mining, clearing, feral animals (both pigs and brumbies), and forestry operations. The most disturbed sites contain the highest number of introduced species, and have a high native species richness, as well as a high number of species occurring at single sites. These disturbed sites also tend to have a neutral pH (6.0), indicating an absence of the acidity commonly associated with *Sphagnum* bogs (Clymo 1973). This suggests that whilst *Sphagnum* is present, these sites can only be considered as marginal (restricted to peatland or drainage margins) or remnant *Sphagnum* peatlands, where *Sphagnum* moss now constitutes only a small percentage of the peatland vegetation cover.

The remnants of *Sphagnum* moss in areas where larger mossbeds were previously described, combined with pollen data (Clark 1986), confirm the detrimental impacts of fire on *Sphagnum* peatlands (Whinam et al. 1989, 2001). An increase in either the frequency or intensity of fire is likely to favour fire-tolerant rhizomotous sedges at the expense of *Sphagnum* moss, and its associated herbs and fire sensitive shrubs (Whinam 1995). Fire, along with grazing and logging, can also lead to increased sedimentation, particularly when peatlands are in the bottom of valleys and in topographic depressions. Increased sedimentation may affect the organic content of the site and make re-establishment by *Sphagnum* moss less likely. *Sphagnum* moss is also thought to provide some protection from fire for fire sensitive species, such as *Athrotaxis selaginoides* in Tasmania (Whinam et al. 2001), because there are few days when the wet moss will carry fires. However field evidence suggests that during dry periods when the buffering ability of *Sphagnum* is reduced, intense fires are able to burn at least the margins of *Sphagnum* peatlands (Whinam et al. 2001). The impacts of fire on *Sphagnum* peatlands in the ACT have included burning through the moss hummocks into the peat (Helman & Gilmour 1985, Clark 1980). Once drier conditions are established, future fires can destroy remaining areas of *Sphagnum* (Clark 1980). Fire or associated changes alter the ecological role that *Sphagnum* moss beds play in a water catchment. *Sphagnum* moss stabilises both the soil surface and stream banks, and acts as a filter, removing suspended sediment. *Sphagnum* peatlands impede flow and return water, maintaining a more even moisture regime between rainfall events.

We observed extensive damage by feral pigs (notably in sub-alpine areas of Kosciuszko National Park and in Kanangra-Boyd National Park) and brumbies (in the ACT). The severe impacts of these feral animals on bogs in the ACT have been noted previously (Helman & Gilmour 1985, Clark 1980). Trampling by feral animals, grazing animals and people, causes channelling, leading to changes in water flow, which may completely alter the drainage pattern (Helman & Gilmour 1985), and result in drier conditions (Clark 1986). Preferential grazing of palatable herbs and grasses in *Sphagnum* bogs, combined with browsing of new growth of shrubs (J. Whinam, unpublished data) can lead to increased dominance by unpalatable species. Several of the surveyed sites, with a history of either feral animals or cattle grazing, included weed species, such as blackberries. Some of the New England region sites described by Millington (1954) and subject to grazing have changed significantly with nutrient influx from aerial fertiliser spraying and altered drainage patterns.

Australia is a net importer of peat, with supplies coming primarily from Canada, New Zealand, Germany and Ireland (in descending order of amount supplied) and, compared to northern hemisphere operations, the scale of peat mining in Australia is very small. However, where peat mining occurs, the hydrologic and ecosystem changes are catastrophic for peatland communities (Kodela et al. 1992). Changes in the hydrology and ecology of Wingecarribee Swamp, following a collapse of the peats in 1998, as a consequence of peat mining (Arachchi & Lambkin 1999), have left only one *Sphagnum* moss bed surviving, where three had previously been recorded (P. Kodela, pers. comm.).

Logging operations and associated changes in drainage and sedimentation have left only remnant *Sphagnum* moss patches along drainage margins, with *Sphagnum* now rare or absent throughout the bulk of the peatland. This is especially noticeable where *Pinus radiata* has escaped from plantations and invaded *Sphagnum* moss beds (e.g. Hanging Rock Swamp, Southern Highlands and Micalong Swamp, ACT border).

The only area that has shown a recent increase in the amount of *Sphagnum* moss present is the higher area of Kosciuszko National Park, which is thought to be due to recovery resulting from rehabilitation works and the cessation of grazing (Clarke & Martin 1999, Wimbush & Costin 1979a, 1979b). Much of the expansion in *Sphagnum* moss has only occurred in the past 5 years (R. Good, pers. comm). While both healthy and expanding, these moss beds are still quite small and it will be some time before they form fully functioning *Sphagnum* ecosystems.

An outstanding example of a rainforest-*Sphagnum* community in good condition is in Ben Halls Gap National Park. Its conservation significance has been recognised by its listing as a Threatened Ecological Community under the *NSW Threatened Species Conservation Act 1995*. Unfortunately many of the remaining *Sphagnum* peatlands sites surveyed are in a severely degraded state suggesting that there is a strong case for listing some *Sphagnum* peatlands as threatened communities in New South Wales, particularly shrubby herbaceous *Sphagnum* peatlands, shrubby-sedgey *Sphagnum* peatlands and heathy *Sphagnum* peatlands. Two plant species recorded in our survey, *Leptospermum thompsonii* and *Gentiana wingecarribiensis* (Kodela et al. 1994), are listed under the *NSW Threatened Species Conservation Act 1995* and nationally under the *Environment Protection and Biodiversity Conservation Act 1999*. None of the species recorded are restricted to *Sphagnum* communities.

Conclusion

Our analyses of *Sphagnum* peatlands throughout NSW and the ACT have shown a strong regional distribution of floristic communities (at least partially related to geology, altitude and climate). The survey has documented the degradation and demise of many *Sphagnum* peatlands and has identified past and ongoing threatening processes. The future for many of these *Sphagnum* peatlands is bleak, especially when the impacts of increased temperatures and altered rainfall patterns predicted with global warming are considered (Whinam et al. in press). Without management actions that mitigate against trampling, fire, drainage and sedimentation impacts, many of the sites surveyed are likely to continue to deteriorate.

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References

Arachchi, B.K. & Lambkin, K.L. (1999) Wingecarribee Reservoir swamp failure. *ANCOLD Bulletin* 113: 37–45.

Australian National Botanic Gardens (2001) *Australian Plant Names Index*. At http://www.anbg.gov.au/cgi-bin/apni

Australian Nature Conservation Agency (1996) *A Directory of Important Wetlands in Australia. Second Edition* (Australian Nature Conservation Agency: Canberra).

Belbin, L. (1991a) Semi-strong hybrid scaling: a new ordination algorithm. *Journal of Vegetation Science* 2: 491–496.

Belbin, L. (1991b) *PATN: Technical reference* (CSIRO Wildlife Research: Canberra).

Belbin, L. (1995) *PATN Pattern Analysis Package* (CSIRO Division of Wildlife Ecology: Canberra).

Black, D. (1982) The vegetation of the Boyd Plateau, N.S.W. *Vegetatio* 50: 93–111.

Bowman, D. M. J. S. & Minchin, P. R. (1987) Environmental relationships of woody vegetation patterns in the Australian monsoon tropics. Ambio. *Australian Journal of Botany* 35: 151–169.

Bridgman, H.A., Warner, R.F. & Dodson, J.R. (1995) *Urban biophysical environments* (Oxford University Press: Melbourne).

Campbell, E.O. (1983) Mires of Australasia. Mires: Swamp, Bog, Fen and Moor. In: *Ecosystems of the World. Vol. 4B* (Ed. A.J.P. Gore) (Elsevier Scientific, Amsterdam).

Clarke, P.J. & Martin, A.R.H. (1999) *Sphagnum* peatlands of Kosciuszko National Park in relation to altitude, time and disturbance. *Australian Journal of Botany* 47: 519–536.

Clark, R.L. (1980) *Sphagnum* growth on Ginini Flats, A.C.T. Unpublished report to Department of Biogeography and Geomorphology, (Australian National University: Canberra).

Clark, R.L. (1986) The fire history of Rotten Swamp, A.C.T. Unpublished report to A.C.T. Parks and Conservation Service.

Clymo. R.S. (1973) The growth of *Sphagnum*: methods of measurements: some effects of environment. *Journal of Ecology* 61: 849–69.

Costin, A.B. (1954) *A study of the ecosystems of the Monaro Region of New South Wales.* (Government Printer: Sydney).

CRES (1999) *ANUCLIM Version 5.0.* Canberra, Centre for Resource and Environmental Studies, (Australian National University: Canberra).

Dargie, T. C. D. (1984) On the integrated interpretation of indirect site ordinations: a case study using semi-arid vegetation in south-eastern Spain. *Vegetatio* 55: 37–55.

Doherty, M. (1997) Vegetation survey and mapping of Tinderry Nature Reserve. Unpublished report to New South Wales National Parks and Wildlife Service, Queanbeyan District.

Dufrêne, M. (1999) *IndVal or how to identify indicator species of a sample typology ?* Direction générale des Ressources naturelles et de l'Environnement — Région wallonne: Serveur d'informations sur la biodiversité en Wallonie.

Dufrêne, M. & Legendre, P. (1997) Species assemblages and indicator species: the need for a flexible asymmetrical approach. *Ecological Monographs* 67: 345–366.

Dyring, J. (1990) The impact of feral horses (*Equus caballus*) on sub-alpine and montane environments in Australia. Masters of Applied Science thesis. Department of Resource and Environmental Studies, University of Canberra.

Faith, D.P., Minchin, P.R., & Belbin, L. (1987) Compositional dissimiliarity as a robust measure of ecological distance: a theoretical model and computer simulations. *Vegetatio* 69: 57–68.

Faith, D. P. & Norris, R. H. (1989) Correlation of environmental variables with patterns of distribution and abundance of common and rare freshwater macroinvertebrates. *Biological Conservation* 50: 77–98.

Fowler, J. & Cohen, L. (1990) *Practical Statistics for Field Biology.* John Wiley & Sons Ltd. West Sussex, England.

Harden, G. (1990–93) *Flora of New South Wales.* (Gwen Harden, Ed.) 4 Volumes. New South Wales University Press, Sydney.

Helman, C.E. & Gilmour, P.M. (1985) Treeless vegetation above 1000 metres altitude in the A.C.T. Unpublished report to the Conservation Council of the Southeast Region and Canberra.

Hope, G. (1997) Mountain Occupation Project: Report on additional field investigations on Mt Scabby and Mt Bimberi in the Australian Capital Territory. Unpublished report.

Hope, G. (1999) Mountain Occupation Project: Report Little Creamy, Rock Flats and Lower Cotter Source Bogs in the Australian Capital Territory and Yaouk Swamp, New South Wales. Unpublished report.

Hope, G.S. & Southern, W. (1983) Peatlands of the Southern Tablelands of New South Wales. Unpublished report to NSW National Parks and Wildlife Service.

Houlder, D., Hutchinson, M., Nix, H. & McMahon, J. (1999) *ANUCLIM Version 5.0 User Guide*. Centre for Resource and Environmental Studies (Australian National University: Canberra).

Keith, D.A. & Bedward, M. (1999) Native vegetation of the South East Forests Region. *Cunninghamia* 6: 1–218.

Kenkel, N. C. & Orlóci, L. (1986) Applying metric and non-metric multidimensional scaling to ecological studies: some new results. *Ecology* 67: 919–928.

Klaphake, V (1994) Plant survey of Hanging Rock Swamp and surrounding area, Penrose, Central Tablelands, NSW Unpublished report.

Kodela, P., Adam, P. & Wright, P. (1992) Protecting upland wetlands: Mining swamps for organic sediments — the need for State Government environmental planning policies. *National Parks Journal* October, 7–12.

Kodela, P.G., James, T.A. & Hind, P.D. (1994) Observations on the ecology and conservation status of the rare herb, *Gentiana wingecarribiensis*. *Cunninghamia* 3: 535–541.

Millington, R.J. (1954) *Sphagnum* bogs of the New England Plateau, New South Wales. *Journal of Ecology* 42: 328–344.

Minchin, P. R. (1987) An evaluation of the relative robustness of techniques used for ecological ordination. *Vegatatio* 69: 89–107.

Nix, H. A. & Busby, J. (1986) *BIOCLIM — A bioclimatic analysis and prediction system*. Division of Water and Land Resources: Canberra. Research Report No. 1983–85.

Saunders, P., Buckle, D., Hope, G. & Spooner, N. (1996) Namadgi National Park Mountain Occupation Project: A Multi-disciplinary investigation of an Aboriginal site complex in the Mount Scabby Range, ACT. Unpublished report to Namadgi National Park.

Seppelt, R.D. (2000) The Sphagnopsida (Sphagnaceae; Ambuchananiaceae) in Australia. *Hikobia* 13: 163–183.

Whinam, J. (1995) Effects of fire on Tasmanian *Sphagnum* peatlands. In: Papers presented at Bushfire '95, an Australian Bushfire Conference, Hobart, Tasmania, 27–29 September 1995.

Whinam, J., Eberhard, S., Kirkpatrick, J. & Moscal, T. (1989) *Ecology and conservation of Sphagnum peatlands in Tasmania* (Tasmanian Conservation Trust Inc.: Hobart).

Whinam, J. & Buxton, R. (1997) *Sphagnum* peatlands of Australasia: an assessment of harvesting sustainability. *Biological Conservation* 82: 21–29.

Whinam, J., Barmuta, L.A. & Chilcott, N. (2001) Floristic descriptions and environmental relationships of Tasmanian *Sphagnum* communities and their conservation management. *Australian Journal of Botany* 4: 673–685.

Whinam, J., Hope, G. S., Adam, P., Clarkson, B. R., Alspach, P. A. & Buxton, R. P. (in press) *Sphagnum* peatlands of Australasia: the resource, its utilisation and management. *Wetlands Ecology and Management*.

Wimbush, D.J. & Costin, A.B. (1979a) Trends in vegetation at Kosciuszko. I. Grazing trials in the subalpine zone, 1957–1971. *Australian Journal of Botany* 27: 741–787.

Wimbush, D.J. & Costin, A.B. (1979b) Trends in vegetation at Kosciuszko. II. Subalpine range transects, 1959–1978. *Australian Journal of Botany* 27: 789–831.

Appendices

Appendix 1. Two-way table of indicator species (INDVAL 2.0) for NSW and ACT *Sphagnum* peatlands.

Species	**Final Group**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**IndVal**
	Group size	**2**	**2**	**2**	**11**	**7**	**6**	**4**	**3**	**2**	
	Level										
Gleichenia microphylla	7	2									100
Viola hederacea	7	2			1		3	2	1		52.94
Leptospermum polygalifolium	7		2				1				90.91
Juncus alexandri	7		2					2			83.33
Deyeuxia gunniana	7		2				4	2			62.50
Blechnum nudum	3	2	2	2					1		96.88
Bursaria spinosa	6			2							100
Leptospermum thompsonii	6			2							100
Tasmannia lanceolata	6			2							100
Agrostis sp.	6			2	1						94.74
Eleocharis pusilla	6			2	1						94.74
Isolepis sp.	6			2	2	1					85.71
Isotoma fluvitalis	6			2	2		1				82.57
Deyeuxia parviseta	6			2			1	3			71.43
Gleichenia dicarpa	6			2			2		1		65.22
Epacris paludosa	5				9	4					72.22
Baekea gunniana	8				1	6				1	50.74
Leptospermum gregarium	9						6				100
Baeckea omissa	9						4				66.67
Epacris obtusifolia	9						3				50.00
Euchiton sphaericus	9						3				50.00
Juncus prismatocarpus	9						3				50.00
Myriophyllum variifolium	9						3				50.00
Phalaris aquatica	9						3				50.00

Species	**Final Group**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**IndVal**
	Group size	**2**	**2**	**2**	**11**	**7**	**6**	**4**	**3**	**2**	
	Level										
Baloskion stenocoleum	5						5	2			70.00
Epacris microphylla	5				1		3	3			54.92
Hakea microcarpa	5				4	1	5	2			50.11
Hypericum gramineum	9							2			50.00
Pomaderris aspera	9							2			50.00
Viola betonicifolia	9							2			50.00
Poa sieberiana	9		1			3	2	4			44.21
Empodisma minus	3				10	7	4	1	1		74.19
Baumea rubiginosa	4						2		3		93.33
Epilobium gunnianum	4					2		1	3		90.32
Hydrocotyle peduncularis	4		1		2		3	1	3		72.41
Microlaena stipoides	4								2		66.67
Eucalyptus radiata	4								2		66.67
Leptospermum juniperinum	4								2		66.67
Lomandra longifolia	4								2		66.67
Pteridium esculentum	4								2		66.67
Pultenaea divaricata	4								2		66.67
Hypericum japonicum	4			1	7	1	3		3		64.12
Hemarthria uncinata	4				1				2		63.28
Eucalyptus ovata	4				2				2		60.22
Isachne globosa	4						2		2		60.22
Hypochaeris radicata	4			1	9	2	4		3		58.74
Drosera binata	4	1		1					2		44.44
Chionogentias muelleriana	2									2	100
Deschampsia caespitosa	2									2	100
Huperzia sp.	2									2	100
Astelia alpina	2					1				2	97.37
Carpha alpina	2					1				2	97.37
Poa hiemata	2					1				2	97.37
Celmisia tomentella	2					2				2	94.87
Luzula modesta	2				2	1				2	92.50
Richea continentis	2					4				2	90.24

Appendix 2. Occurrence of species at *Sphagnum* peatland sites in NSW and ACT.
*** indicates introduced species.**

Family	Species Name	No. of sites	Adeline Falls	Badja Swamp	Barokee Swamp 1	Barokee Swamp 2	Barwick Creek	Bega Swamp	Bega Swamp Herbfields	Ben Halls Gap	Blue Lake Track	Boggy Plain	Butchers Swamp	Clyde Mountain	Delaney's Creek	Delegate River Swamp	Dingo Swamp	Ebor TSR	Ginnini	Govett's Leap	Hanging Rock Swamp	Horse Swamp	Jackson's Swamp	Kanangra Campground	Micalong Swamp	Mongarlowe River	Mumbedah Swamp	North Delegate River	Nungar Plains	Nunnock Swamp	Polblue Swamp	Sara River	Sentinel at Pippit Creek	Snowy Flat	Snowy River	South Butchers Swamp	Stingray Swamp	Thomeleys Plains	Tom's Cabin Rainforest	Trout Farm	Wingecaribee
Dicotyledonae																																									
APIACEAE																																									
	Centella asiatica	1												x																											
	Centella cordifolia	2																													x										x
	Diplaspis nivis	1																																x							
	Diplaspis sp.	1									x																														
	Hydrocotyle peduncularis	9			x	x	x	x													x							x									x		x		x
	Hydrocotyle rivularis	1																								x															
	Hydrocotyle sp.	15		x					x			x	x		x		x					x	x	x			x		x	x	x	x						x			
	Oreomyrrhis argentea	1																	x																						
	Oreomyrrhis brevipes	1																																x							
	Oreomyrrhis ciliata	6		x								x			x																x					x		x			
	Oreomyrrhis eriopoda	3						x																									x				x				
	Trachymene humilis	1						x																																	
	Trachymene sp.	1																					x																		
APOCYNACEAE																																									
	Parsonsia brownii	1																																					x		
ARALIACEAE																																									
	Polyscias sambucifolia	1																																					x		

	No. of sites	Adeline Falls	Badja Swamp	Barokee Swamp 1	Barokee Swamp 2	Barwick Creek	Bega Swamp	Bega Swamp Herbfields	Ben Halls Gap	Blue Lake Track	Boggy Plain	Butchers Swamp	Clyde Mountain	Delaney's Creek	Delegate River Swamp	Dingo Swamp	Ebor TSR	Ginnini	Govett's Leap	Hanging Rock Swamp	Horse Swamp	Jackson's Swamp	Kanangra Campground	Micalong Swamp	Mongarlowe River	Mumbedah Swamp	North Delegate River	Nungar Plains	Nunnock Swamp	Polblue Swamp	Sara River	Sentinel at Pippit Creek	Snowy Flat	Snowy River	South Butchers Swamp	Stingray Swamp	Thomeleys Plains	Tom's Cabin Rainforest	Trout Farm	Wingecaribee
ASTERACEAE																																								
*Achillea millefolium**	1																															x								
Brachyscome graminea	1		x																																					
Brachyscome obovata	1									x																														
Brachyscome ptychocarpa	1																					x																		
Brachyscome scapigera	1					x																																		
Brachyscome sp.	5				x		x	x																					x								x			
Brachyscome spathulata	1																																		x					
Bracteantha bracteata	5						x									x	x										x			x										
Celmisia sp.	1							x																																
Celmisia tomentella	5									x				x										x					x				x							
*Cirsium vulgare**	1																												x											
*Conyza bonariensis**	1																x																							
Cotula alpina	4						x																		x							x	x							
Craspedia aurantia	1										x																													
Craspedia costiniana	2																																x		x					
Craspedia lucantha	1																																x							
Erigeron pappocromus	2																							x								x								
Erigeron setosus	1																																		x					
Erigeron sp.	1																										x													
Euchiton argentifolius	1																																x							
Euchiton collinus	1																															x								
Euchiton fordianus	1																																		x					
Euchiton involucratus	5		x				x																		x	x											x			

	No. of sites	Adeline Falls	Badja Swamp	Barokee Swamp 1	Barokee Swamp 2	Barwick Creek	Bega Swamp	Bega Swamp Herbfields	Ben Halls Gap	Blue Lake Track	Boggy Plain	Butchers Swamp	Clyde Mountain	Delaney's Creek	Delegate River Swamp	Dingo Swamp	Ebor TSR	Ginnini	Govett's Leap	Hanging Rock Swamp	Horse Swamp	Jackson's Swamp	Kanangra Campground	Micalong Swamp	Mongarlowe River	Mumbedah Swamp	North Delegate River	Nungar Plains	Nunnock Swamp	Polblue Swamp	Sara River	Sentinel at Pippit Creek	Snowy Flat	Snowy River	South Butchers Swamp	Stingray Swamp	Thomeleys Plains	Tom's Cabin Rainforest	Trout Farm	Wingecaribee
ASTERACEAE cont.																																								
Euchiton poliochlorus	1																												x											
Euchiton sp.	5						x					x			x							x														x				
Euchiton sphaericus	3			x													x																						x	
Gnaphalium gymnocephalum	1																			x																				
Gnaphalium sp.	1																					x																		
Helichrysum rutidolepis	3		x									x																								x				
*Hypochoeris radicata**	17		x	x			x	x					x	x	x		x			x		x					x	x	x	x							x		x	x
Lagenifera stipitata	6		x				x																				x		x						x		x			
Microseris scapigera	2				x	x																																		
Olearia algida	1																																		x					
Olearia oppositifolia	1											x																												
Ozothamnus rosmariniifolius	1															x																								
Pseudognaphalium luteoalbum	2																			x	x																			
*Senecio hispidulus**	1																			x																				
Senecio sp.	3										x														x												x			
*Sonchus oleraceus**	1																x																							
*Taraxacum officinale**	1																																				x			
Taraxacum sp.*	2			x													x																							
Telfordia obovata	1																																					x		
Telfordia sp.	1																																						x	
BORAGINACEAE																																								
Myosotis australis	1																x																							

	No. of sites	Adeline Falls	Badja Swamp	Barokee Swamp 1	Barokee Swamp 2	Barwick Creek	Bega Swamp	Bega Swamp Herbfields	Ben Halls Gap	Blue Lake Track	Boggy Plain	Butchers Swamp	Clyde Mountain	Delaney's Creek	Delegate River Swamp	Dingo Swamp	Ebor TSR	Ginnini	Govett's Leap	Hanging Rock Swamp	Horse Swamp	Jackson's Swamp	Kanangra Campground	Micalong Swamp	Mongarlowe River	Mumbedah Swamp	North Delegate River	Nungar Plains	Nunnock Swamp	Polblue Swamp	Sara River	Sentinel at Pippit Creek	Snowy Flat	Snowy River	South Butchers Swamp	Stingray Swamp	Thomeleys Plains	Tom's Cabin Rainforest	Trout Farm	Wingecaribee
BRASSICACEAE																																								
Cardamine gunnii	1										x																													
Cardamine lilacina	1																																x							
Rorippa sp.	1			x																																				
CAMPANULACEAE																																								
Isotoma fluvitalis	5			x				x					x													x				x										
Lobelia sp.	1																													x										
Pratia pedunculata	3		x																																	x			x	
Pratia purpurascens	2																													x	x									
Pratia sp.	1																																				x			
Pratia surrepens	1						x																																	
Wahlenbergia ceracea	10		x	x			x				x			x		x											x				x						x		x	
Wahlenbergia gloriosa	1																																	x						
Wahlenbergia sp.	2																x					x																		
Stellaria angustifolia	1			x																																				
Stellaria flaccida	1																																						x	
Stellaria pungens	2		x																						x															
CLUSIACEAE																																								
Hypercium gramineum	2																				x										x									
Hypericum japonicum	14			x			x	x					x	x		x	x			x		x					x	x				x					x			x
Hypericum sp.	5		x									x											x			x				x										
CONVOLVULACEAE																																								
Dichondra repens	1																																			x				
CUNONIACEAE																																								
Ceratopetalum apetalum	1	x																																						

	No. of sites	Adeline Falls	Badja Swamp	Barokee Swamp 1	Barokee Swamp 2	Barwick Creek	Bega Swamp	Bega Swamp Herbfields	Ben Halls Gap	Blue Lake Track	Boggy Plain	Butchers Swamp	Clyde Mountain	Delaney's Creek	Delegate River Swamp	Dingo Swamp	Ebor TSR	Ginnini	Govett's Leap	Hanging Rock Swamp	Horse Swamp	Jackson's Swamp	Kanangra Campground	Micalong Swamp	Mongarlowe River	Mumbedah Swamp	North Delegate River	Nungar Plains	Nunnock Swamp	Polblue Swamp	Sara River	Sentinel at Pippit Creek	Snowy Flat	Snowy River	South Butchers Swamp	Stingray Swamp	Thomeleys Plains	Tom's Cabin Rainforest	Trout Farm	Wingecaribee
DROSERACEAE																																								
Drosera arcturi	2																							x									x							
Drosera binata	4												x						x	x																				x
Drosera peltata	1																																							x
ELAEOCARPACEAE																																								
Elaeocarpus holopetalus	1								x																															
EPACRIDACEAE																																								
Acrotriche sp.	1																			x																				
Dracophyllum secundum	1																		x																					
Epacris breviflora	9						x	x							x			x				x			x			x						x			x			
Epacris celata	2													x															x											
Epacris glacialis	2																							x								x								
Epacris gunnii	3		x								x																			x										
Epacris impressa	1												x																											
Epacris microphylla	6			x								x															x				x					x			x	
Epacris obtusifolia	3				x	x											x																							
Epacris paludosa	14		x				x	x							x			x					x	x	x		x	x		x				x	x		x			
Epacris petrophila	2																															x		x						
Epacris pulchella	1											x																												
Leucopogon lanceolatus	2												x																									x		
Leucopogon sp.	2																											x		x										
Pentachondra pumila	1																																		x					
Richea continentis	7									x	x							x						x									x	x	x					
Sprengelia incarnata	1																		x																					
Trochocarpa sp.	1																																					x		

	No. of sites	Adeline Falls	Badja Swamp	Barokee Swamp 1	Barokee Swamp 2	Barwick Creek	Bega Swamp	Bega Swamp Herbfields	Ben Halls Gap	Blue Lake Track	Boggy Plain	Butchers Swamp	Clyde Mountain	Delaney's Creek	Delegate River Swamp	Dingo Swamp	Ebor TSR	Ginnini	Govett's Leap	Hanging Rock Swamp	Horse Swamp	Jackson's Swamp	Kanangra Campground	Micalong Swamp	Mongarlowe River	Mumbedah Swamp	North Delegate River	Nungar Plains	Nunnock Swamp	Polblue Swamp	Sara River	Sentinel at Pippit Creek	Snowy Flat	Snowy River	South Butchers Swamp	Stingray Swamp	Thomeleys Plains	Tom's Cabin Rainforest	Trout Farm	Wingecaribee
FABACEAE																																								
Lotus australis	1																																						x	
Lotus uliginosus	1																																							x
Oxylobium ellipticum	1																						x																	
Pultenaea capitellata	1																													x										
Pultenaea divaricata	2																			x																				x
Pultenaea polifolia	1																										x													
Pultenaea sp.	1																						x																	
Trifolium repens	6			x							x	x										x										x							x	
GENTIANACEAE																																								
Chionogentias diemensis	1						x																																	
Chionogentias muelleriana	2									x																							x							
GERANIACEAE																																								
*Geranium dissectum**	1																					x																		
Geranium neglectum	11		x	x		x	x									x	x					x	x					x									x			x	
Geranium potentilloides	2										x															x														
Geranium sp.	1											x																												
GOODENIACEAE																																								
Scaevola hookerii	1					x																																		
Scaevola sp.	1																														x									
Velleia montana	2																						x				x													

	No. of sites	Adeline Falls	Badja Swamp	Barokee Swamp 1	Barokee Swamp 2	Barwick Creek	Bega Swamp	Bega Swamp Herbfields	Ben Halls Gap	Blue Lake Track	Boggy Plain	Butchers Swamp	Clyde Mountain	Delaney's Creek	Delegate River Swamp	Dingo Swamp	Ebor TSR	Ginnini	Govett's Leap	Hanging Rock Swamp	Horse Swamp	Jackson's Swamp	Kanangra Campground	Micalong Swamp	Mongarlowe River	Mumbedah Swamp	North Delegate River	Nungar Plains	Nunnock Swamp	Polblue Swamp	Sara River	Sentinel at Pippit Creek	Snowy Flat	Snowy River	South Butchers Swamp	Stingray Swamp	Thomeleys Plains	Tom's Cabin Rainforest	Trout Farm	Wingecaribee
HALORAGACEAE																																								
Gonocarpus micranthus	16		x		x	x	x					x	x	x	x	x					x		x				x				x			x	x		x			
Gonocarpus oreophilus	1																																					x		
Gonocarpus sp.	3							x														x						x												
Gonocarpus teucrioides	1												x																											
Myriophyllum pedunculatum	4		x																			x								x			x							
Myriophyllum sp.	3						x					x																								x				
Myriophyllum variifolium	3			x													x																						x	
Myriophyllum verrucosum	1																				x																			
LAMIACEAE																																								
Prunella vulgaris	3			x																																x			x	
LENTIBULARIACEAE																																								
Utricularia dichotoma	5															x			x	x						x				x										
Utricularia sp.	3				x																	x									x									
LILIACEAE																																								
Arthropodium milleflorum	5				x	x						x				x											x													
Astelia alpina	4									x														x									x		x					
Astelia psychrocheris	1																																		x					
Burchardia umbellata	1				x																																			
Caesia parviflora	1							x																																
Dianella odorata	1																x																							
Dianella tasmanica	2												x																									x		
Herpolirion novae-zelandiae	1																																		x					
Hypoxis hygrometrica	1				x																																			
Thelionema caespitosum	1		x																																					

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LOGANIACEAE																																								
Mitrasacme serpyllifolia	1																			x																				
LYTHRACEAE																																								
Lythrum salicaria	3		x																						x															x
MENYANTHACEAE																																								
Villarsia exaltata	1																			x																				
MIMOSACEAE																																								
Acacia melanoxylon	1																																					x		
Acacia rubida	1												x																											
MYRTACEAE																																								
Baeckea gunniana	10									x	x			x				x						x	x							x		x	x		x			
Baeckea omissa	3			x	x	x																																		
Baeckea sp.	1											x																												
Baeckea utilis	12		x				x	x							x	x							x				x	x		x						x		x		x
Callistemon pallidus	1								x																															
Callistemon pityoides	3															x											x										x			
Callistemon sp.	1																																				x			
Eucalyptus dalrympleana	1											x																												
Eucalyptus niphophila	1																											x												
Eucalyptus nitens	1																																					x		
Eucalyptus nova-anglica	1				x																																			
Eucalyptus ovata	3																											x									x			x
Eucalyptus pauciflora	5		x	x								x											x																x	
Eucalyptus radiata	1																																							x

	No. of sites	Adeline Falls	Badja Swamp	Barokee Swamp 1	Barokee Swamp 2	Barwick Creek	Bega Swamp	Bega Swamp Herbfields	Ben Halls Gap	Blue Lake Track	Boggy Plain	Butchers Swamp	Clyde Mountain	Delaney's Creek	Delegate River Swamp	Dingo Swamp	Ebor TSR	Ginnini	Govett's Leap	Hanging Rock Swamp	Horse Swamp	Jackson's Swamp	Kanangra Campground	Micalong Swamp	Mongarlowe River	Mumbedah Swamp	North Delegate River	Nungar Plains	Nunnock Swamp	Polblue Swamp	Sara River	Sentinel at Pippit Creek	Snowy Flat	Snowy River	South Butchers Swamp	Stingray Swamp	Thomeleys Plains	Tom's Cabin Rainforest	Trout Farm	Wingecaribee
MYRTACEAE cont.																																								
Eucalyptus viminalis	1																													x										
Leptospermum argenteum	1																																			x				
Leptospermum grandifolium	2															x							x																	
Leptospermum gregarium	5			x	x	x											x																						x	
Leptospermum juniperinum	1																																							x
Leptospermum lanigerum	4														x													x		x							x			
Leptospermum myrtifolium	3						x								x										x															
Leptospermum obovatum	3																						x				x													x
Leptospermum polygalifolium	2								x																													x		
Leptospermum sp.	2											x						x																						
Leptospermum thompsonii	2												x													x														
ONAGRACEAE																																								
Epilobium billardierianum	5						x														x					x			x							x				
Epilobium curtisiae	1																															x								
Epilobium gunnianum	5																			x	x				x										x					x
Epilobium sp.	8		x								x	x		x								x									x			x			x			
PITTOSPORACEAE																																								
Billardiera scandens	1																													x										
Bursaria spinosa	2												x													x														
PLANTAGINACEAE																																								
Plantago alpestris	1									x																														
Plantago glacialis	1									x																														
Plantago muelleri	1																																x							

	No. of sites	Adeline Falls	Badja Swamp	Barokee Swamp 1	Barokee Swamp 2	Barwick Creek	Bega Swamp	Bega Swamp Herbfields	Ben Halls Gap	Blue Lake Track	Boggy Plain	Butchers Swamp	Clyde Mountain	Delaney's Creek	Delegate River Swamp	Dingo Swamp	Ebor TSR	Ginnini	Govett's Leap	Hanging Rock Swamp	Horse Swamp	Jackson's Swamp	Kanangra Campground	Micalong Swamp	Mongarlowe River	Mumbedah Swamp	North Delegate River	Nungar Plains	Nunnock Swamp	Polblue Swamp	Sara River	Sentinel at Pippit Creek	Snowy Flat	Snowy River	South Butchers Swamp	Stingray Swamp	Thomeleys Plains	Tom's Cabin Rainforest	Trout Farm	Wingecaribee
POLYGALACEAE																																								
Comesperma retusum	1																										x													
POLYGONACEAE																																								
*Acetosella vulgaris**	1																			x																				
PORTULACACEAE																																								
Montia sp.	1														x																									
Neopaxia australasica	3			x											x																		x							
Neopaxia sp.	1																					x																		
PROTEACEAE																																								
Banksia integrifolia	1								x																															
Hakea microcarpa	11			x	x	x	x								x			x			x									x						x	x		x	
Hakea nodosa	1										x																													
Lomatia fraseri	1																																					x		
RANUNCULACEAE																																								
Caltha introloba	1																																x							
Caltha sp.	1									x																														
Ranunculus collinus	4		x								x			x												x														
Ranunculus gunnianus	1																																x							
Ranunculus niphophilus	1																																x							
Ranunculus papulentus	1															x																								
Ranunculus pimpinellifolius	6						x							x							x										x					x			x	
Ranunculus sp.	6			x			x				x											x			x												x			
Ranunculus trifolium	1																					x																		
Ranunculus victoriensis	1																															x								

	No. of sites	Adeline Falls	Badja Swamp	Barokee Swamp 1	Barokee Swamp 2	Barwick Creek	Bega Swamp	Bega Swamp Herbfields	Ben Halls Gap	Blue Lake Track	Boggy Plain	Butchers Swamp	Clyde Mountain	Delaney's Creek	Delegate River Swamp	Dingo Swamp	Ebor TSR	Ginnini	Govett's Leap	Hanging Rock Swamp	Horse Swamp	Jackson's Swamp	Kanangra Campground	Micalong Swamp	Mongarlowe River	Mumbedah Swamp	North Delegate River	Nungar Plains	Nunnock Swamp	Polblue Swamp	Sara River	Sentinel at Pippit Creek	Snowy Flat	Snowy River	South Butchers Swamp	Stingray Swamp	Thomeleys Plains	Tom's Cabin Rainforest	Trout Farm	Wingecaribee
RHAMNACEAE																																								
Pomaderris aspera	2											x																								x				
ROSACEAE																																								
Acaena anserinifolia	1																								x															
Acaena novae-zelandiae	1																																			x				
Acaena ovina	1																																						x	
Acaena sp.	3										x																									x	x			
Geum urbanum	1										x																													
*Rubus fruticosus aggregate**	3																x								x														x	
RUBIACEAE																																								
Asperula gunnii	17		x	x	x		x	x				x	x	x		x		x			x								x	x				x		x	x			x
Asperula sp.	4										x				x							x			x															
Coprosma quadrifida	1																																					x		
Coprosma reptans	1																																					x		
Nertera granadensis	3	x																									x				x									
RUTACEAE																																								
Leionema phylicifolium	1																													x										
Nematolepis ovatifolia	1																																		x					
SALICACEAE																																								
*Salix cinerea**	1																																							x
SCROPHULARIACEAE																																								
Chionohebe densifolia	1																															x								
Chionohebe sp.	1								x																															
Euphrasia sp.	1																															x								

	No. of sites	Adeline Falls	Badja Swamp	Barokee Swamp 1	Barokee Swamp 2	Barwick Creek	Bega Swamp	Bega Swamp Herbfields	Ben Halls Gap	Blue Lake Track	Boggy Plain	Butchers Swamp	Clyde Mountain	Delaney's Creek	Delegate River Swamp	Dingo Swamp	Ebor TSR	Ginnini	Govett's Leap	Hanging Rock Swamp	Horse Swamp	Jackson's Swamp	Kanangra Campground	Micalong Swamp	Mongarlowe River	Mumbedah Swamp	North Delegate River	Nungar Plains	Nunnock Swamp	Polblue Swamp	Sara River	Sentinel at Pippit Creek	Snowy Flat	Snowy River	South Butchers Swamp	Stingray Swamp	Thomeleys Plains	Tom's Cabin Rainforest	Trout Farm	Wingecaribee
SCROPHULARIACEAE cont.																																								
Gratiola peruviana	3											x																								x			x	
Gratiola sp.	1																									x														
*Mimulus moschatus**	2										x														x															
Parahebe sp.	1																																		x					
Veronica serpyllifolia	1																								x															
Veronica species B	3										x																		x							x				
STYLIDIACEAE																																								
Stylidium graminifolium	5				x	x																					x								x					x
THYMELAEACEAE																																								
Pimelea alpina	1																																		x					
Pimelea bracteata	1													x																										
Pimelea sp.	1																																				x			
VIOLACEAE																																								
Viola betonicifolia	2											x																								x				
Viola caleyana	4								x								x				x										x									
Viola hederacea	7	x			x	x						x							x			x									x									
Viola sp.	3	x						x							x																									
WINTERACEAE																																								
Tasmannia glaucifolia	1			x																																				
Tasmannia lanceolata	2												x													x														
Tasmannia xerophila	2														x													x												
PINACEAE																																								
*Pinus radiata**	1																			x																				

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Monocotyledonae																																								
CYPERACEAE																																								
Baumea rubiginosa	4				x	x														x																				x
Carex appressa	5										x														x	x										x		x		
Carex gaudichaudiana	26		x	x			x			x	x	x		x	x		x	x			x	x		x	x			x	x	x	x	x	x	x	x	x	x		x	x
Carex jackiana	3		x											x															x											
Carex lobolepis	1			x																																				
Carex sp.	4											x		x								x						x												
Carpha alpina	4									x				x										x									x							
Chorizandra sphaerocephala	1																			x																				
Cladium sp.	2			x								x																												
Cyperus sanguinolentus	2																																						x	x
Cyperus sphaeroideus	2																																		x				x
Eleocharis acuta	1																																							x
Eleocharis pusilla	3		x									x													x														
Eleocharis sp.	2																				x								x										
Gahnia grandis	1																												x										
Gymnoschoenus sphaerocephalus	1																			x																				
Isolepis aucklandica	8						x	x							x							x			x			x				x		x						
Isolepis cernua	1			x																																				
Isolepis crassiuscula	1																															x							
Isolepis habra	1																																						x	
Isolepis sp.	5												x	x									x			x				x										
Isolepis subtilissima	1																													x									

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CYPERACEAE cont.																																								
Lepidosperma filiforme	4															x			x				x				x													
Lepidosperma limicolum	1																			x																				
Lepidosperma sp.	5											x	x		x							x															x			
Oreobolus distichus	1																							x																
Oreobolus pumilio	1																																x							
Oreobolus sp.	3							x		x																									x					
Schoenus calyptratus	2									x																									x					
Schoenus sp.	1																										x													
Scirpus polystachyus	1																																						x	
IRIDACEAE																																								
Libertia pulchella	1	x																																						
JUNCACEAE																																								
Juncus alexandri	4								x			x																								x		x		
*Juncus articulatus**	1																																							x
Juncus australis	1																				x																			
Juncus continuus	2		x																	x																				
*Juncus effusus**	1																															x								
Juncus falcatus	1		x																																					
Juncus phaeanthus	1						x																																	
Juncus prismatocarpus	3			x													x																						x	
Juncus sp.	7		x											x							x	x			x				x							x			
Juncus subsecundus	2			x																																		x	
Luzula australasica	1																								x															

	No. of sites	Adeline Falls	Badja Swamp	Barokee Swamp 1	Barokee Swamp 2	Barwick Creek	Bega Swamp	Bega Swamp Herbfields	Ben Halls Gap	Blue Lake Track	Boggy Plain	Butchers Swamp	Clyde Mountain	Delaney's Creek	Delegate River Swamp	Dingo Swamp	Ebor TSR	Ginnini	Govett's Leap	Hanging Rock Swamp	Horse Swamp	Jackson's Swamp	Kanangra Campground	Micalong Swamp	Mongarlowe River	Mumbedah Swamp	North Delegate River	Nungar Plains	Nunnock Swamp	Polblue Swamp	Sara River	Sentinel at Pippit Creek	Snowy Flat	Snowy River	South Butchers Swamp	Stingray Swamp	Thomeleys Plains	Tom's Cabin Rainforest	Trout Farm	Wingecaribee
JUNCACEAE cont.																																								
*Luzula campestris**	1																	x																						
Luzula flaccida	1																			x																				
Luzula modesta	5						x			x				x		x																	x							
Luzula sp.	8		x					x			x										x								x		x			x			x			
ORCHIDACEAE																																								
Acianthus fornicatus	1																																					x		
Chiloglottis sp.	1																																			x				
Prasophyllum tadgellianum	1																																		x					
Pterostylis furcata	2		x									x																												
Spiranthes australis	1																																						x	
Spiranthes sinensis	2																					x	x																	
Spiranthes sp.	2							x																						x										
POACEAE																																								
Agrostis avenacea	1																			x																				
Agrostis billardierei	1																													x										
Agrostis hiemalis	3		x				x							x																										
Agrostis sp.	3												x													x		x												
Agrostis sp. *aff parviflora*	1																													x										
*Anthoxanthum odoratum**	1																																							x
Australopyrum pectinatum	2																											x									x			
Austrodanthonia penicillata	1																													x										
Deschamsia caespitosa	2									x																							x							
Deschamsia sp.	1																																		x					

	No. of sites	Adeline Falls	Badja Swamp	Barokee Swamp 1	Barokee Swamp 2	Barwick Creek	Bega Swamp	Bega Swamp Herbfields	Ben Halls Gap	Blue Lake Track	Boggy Plain	Butchers Swamp	Clyde Mountain	Delaney's Creek	Delegate River Swamp	Dingo Swamp	Ebor TSR	Ginnini	Govett's Leap	Hanging Rock Swamp	Horse Swamp	Jackson's Swamp	Kanangra Campground	Micalong Swamp	Mongarlowe River	Mumbedah Swamp	North Delegate River	Nungar Plains	Nunnock Swamp	Polblue Swamp	Sara River	Sentinel at Pippit Creek	Snowy Flat	Snowy River	South Butchers Swamp	Stingray Swamp	Thomeleys Plains	Tom's Cabin Rainforest	Trout Farm	Wingecaribee
POACEAE cont.																																								
Deyeuxia carinata	2									x																									x					
Deyeuxia gunniana	7				x	x			x			x																								x		x	x	
Deyeuxia parviseta	6					x						x	x								x					x					x									
Deyeuxia quadriseta	2																			x										x										
Deyeuxia sp.	3						x	x																													x			
Dichelachne crinita	1																				x																			
Dichelachne sp.	1																													x										
Ehrharta stipoides	1																			x																				
Hemarthria uncinata	2																													x										x
Hierochloe redolens	1										x																													
*Holcus lanatus**	13		x	x													x			x	x	x			x			x			x	x					x		x	x
Isachne globosa	2																x																							x
Microlaena sp.	2																																			x		x		
Microlaena stipoides	3					x						x																		x										
Panicuum buncei	1																x																							
*Paspalum dilatatum**	1																																							x
Phalaris aquatica	3			x													x																						x	
Poa costiniana	8						x				x			x				x						x					x			x	x							
Poa hiemata	3									x																			x				x							
Poa sieberiana	10				x							x					x	x			x				x						x			x		x		x		
Poa sp.	6						x	x	x							x																				x	x			
Rytidosperma nudiflorum	1																																x							
Tetrarrhena sp.	1														x																									
Tetrarrhena turfosa	2																										x													x
Trisetum spicatum	1																								x															

	No. of sites	Adeline Falls	Badja Swamp	Barokee Swamp 1	Barokee Swamp 2	Barwick Creek	Bega Swamp	Bega Swamp Herbfields	Ben Halls Gap	Blue Lake Track	Boggy Plain	Butchers Swamp	Clyde Mountain	Delaney's Creek	Delegate River Swamp	Dingo Swamp	Ebor TSR	Ginnini	Govett's Leap	Hanging Rock Swamp	Horse Swamp	Jackson's Swamp	Kanangra Campground	Micalong Swamp	Mongarlowe River	Mumbedah Swamp	North Delegate River	Nungar Plains	Nunnock Swamp	Polblue Swamp	Sara River	Sentinel at Pippit Creek	Snowy Flat	Snowy River	South Butchers Swamp	Stingray Swamp	Thomeleys Plains	Tom's Cabin Rainforest	Trout Farm	Wingecarribee
RESTIONACEAE																																								
Baloskion australe	12						x	x			x		x	x		x		x			x						x			x				x			x			
Baloskion longipes	1												x																											
Baloskion stenocoleum	7			x	x	x											x				x										x								x	
Empodisma minus	24		x	x	x	x	x	x			x			x	x	x		x					x	x	x		x	x	x	x	x	x		x	x		x			x
Lepyrodia anarthria	5				x	x						x					x			x																				
SMILACACEAE																																								
Smilax australis	1																																						x	
XANTHORRHOEACEAE																																								
Lomandra longifolia	1																																							x
Lomandra sp.	1											x																												
Lomandra spicata	1																																					x		
XYRIDACEAE																																								
Xyris operculata	1				x																																			
Xyris ustulata	1																										x													
Pteridophyta																																								
OSMUNDACEAE																																								
Leptopteris fraseri	1	x																																						
POLYPODIACEAE																																								
Microsorum astralasicum	1																																					x		
Microsorum diversifolium	1								x																															

	No. of sites	Adeline Falls	Badja Swamp	Barokee Swamp 1	Barokee Swamp 2	Barwick Creek	Bega Swamp	Bega Swamp Herbfields	Ben Halls Gap	Blue Lake Track	Boggy Plain	Butchers Swamp	Clyde Mountain	Delaney's Creek	Delegate River Swamp	Dingo Swamp	Ebor TSR	Ginnini	Govett's Leap	Hanging Rock Swamp	Horse Swamp	Jackson's Swamp	Kanangra Campground	Micalong Swamp	Mongarlowe River	Mumbedah Swamp	North Delegate River	Nungar Plains	Nunnock Swamp	Polblue Swamp	Sara River	Sentinel at Pippit Creek	Snowy Flat	Snowy River	South Butchers Swamp	Stingray Swamp	Thomeleys Plains	Tom's Cabin Rainforest	Trout Farm	Wingecaribee
BLECHNACEAE																																								
Blechnum cartilagineum	1			x																																				
Blechnum fluviatile	2								x			x																												
Blechnum nudum	6	x							x				x						x							x												x		
Blechnum penna-marina	6											x					x					x			x											x			x	
Blechnum wattsii	2	x																								x														
DENNSTAEDTIACEAE																																								
Pteridium esculentum	1																			x																				
DICKSONIACEAE																																								
Dicksonia antarctica	1	x																																						
GLEICHENIACEAE																																								
Gleichenia dicarpa	3												x													x													x	
Gleichenia microphylla	2	x																	x																					
Sticherus tener	1	x																																						
HYMENOPHYLLACEAE																																								
Hymenophyllum sp.	1												x																											
LYCOPODIACEAE																																								
Huperzia sp.	2									x																							x							
Lycopodium fastigiatum	1																																x							
Lycopodium sp.	1									x																														
Bryophytes																																								
SPHAGNACEAE																																								
Sphagnum cristatum	38	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Sphagnum novo-zelandicum	2										x									x																				

Vegetation and floristics of Mount Canobolas State Recreation Area, Orange, New South Wales

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[*Previously published under Thomas D. McGann]

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The vegetation of Mount Canobolas State Recreation Area (1673 ha), 14 km south-west of Orange (33°21'S, 154°59'E) in the Shire of Cabonne on the Central Tablelands of New South Wales is described. A floristic survey of 50 × 0.04 ha plots was conducted in November 1999. Seven communities are defined based on flexible UPGMA analysis of abundance scores of vascular plant taxa. Mapping of these communities is based on ground truthing, air photo interpretation and substrate.

A total of 309 taxa was recorded including two species listed under the *NSW Threatened Species Conservation Act 1995*: *Eucalyptus canobolensis* and *Eucalyptus saxicola*. Additionally the reserve contains the Mount Canobolas *Xanthoparmelia* lichen community recently listed on the *NSW Threatened Species Conservation Act 1995*. This paper describes the seven communities and discusses their significance and distribution within the Recreation Area. A vegetation map and species list are provided.

Introduction

Mt Canobolas State Recreation Area (1673 ha in area), is approximately 14 km south west of Orange (33°21'S, 154°59'E) within the Shire of Cabonne. It is within the Central Tablelands Botanic Subdivision and the South East Highlands Bioregion (Figure 1). Mt Canobolas (elevation 1397 m) is a significant feature of the landscape and is one of the most highly visited sites in the Central West of New South Wales. The population centres of nearby Orange and Bathurst create a significant visitor pressure on the State Recreation Area and surrounds.

Much of the land that abuts the State Recreation Area is highly modified and under plantation (*Pinus* or stone fruit) or is used for grazing. The western and southern boundaries are shared with land under the control of State Forests of New South Wales, much of which is *Pinus radiata* plantation. All other reserve boundaries are shared with freehold land. There is a freehold in-holding within the eastern portion of the reserve.

This paper is based on a flora survey for the Central West Region of the NSW National Parks and Wildlife Service to provide information for developing appropriate management strategies (Hunter 2000).

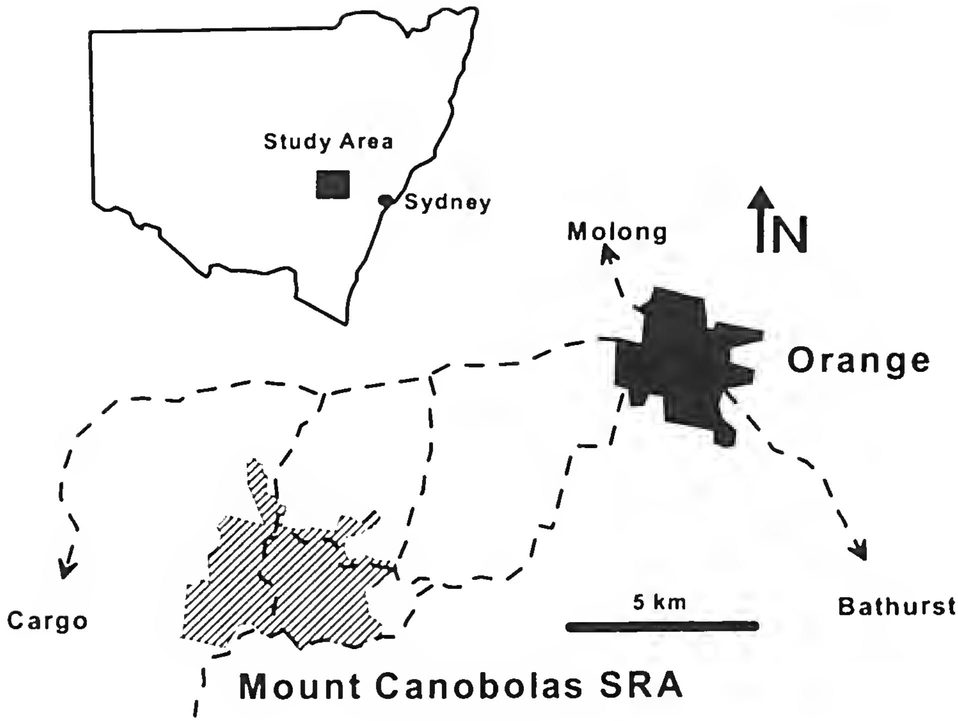

Figure 1: Map of locality of the Mount Canobolas State Recreation Area.

Climate

The rainfall patterns of Mt Canobolas are strongly orographic. The mountain itself rises over 500 m above the surrounding plains. Rainfall is 950 mm MAR which is 200–400 mm a year greater rainfall than the closely adjacent surrounding plains. The summit region has snowfalls in winter. Even during dry periods, much of the summit region may be clothed in cloud thus reducing transpiration and increasing the effective rainfall by dew formation.

Geology and geomorphology

Mount Canobolas is the highest mountain directly west of the Blue Mountains and is the highest and most significant topographic feature within the Central West of New South Wales. Elevation within the State Recreation Area ranges from around 900 m to 1397 m. Gum Ridge forms the approximate southern boundary. Within the reserve this ridge is of significance, as it is almost entirely over 1200 m, with many parts over 1300 m, and effectively modifies the climate of the rest of the reserve from the southerly climatic patterns.

All creeks flowing through the reserve originate from within its boundaries though none achieve any great size. Internal to the reserve is a small relatively broad valley enclosed by Mt Canobolas, Gum Ridge and a small ridge associated with the eastern boundary. This valley has a small and narrow outlet to the east via Towac Creek. Although water flows in all directions from the summit most water exits via Towac Creek (east: Macquarie River Catchment) and Boree Creek (west: Lachlan River Catchment).

Mount Canobolas lies within the Canobolas Volcanic Centre, part of the Orange Province (Meakin et al. 1997). This province occurs directly south-east and west of Orange extending in a west northwesterly direction. It was formed during the Tertiary when extensive volcanic activity was occurring along what is now the eastern highlands of Australia. This region was at that time in a continental intraplate setting and the resultant volcanic activity produced intrusions and flows of basalts, alkali rhyolite and trachyte, and volcani-clastics in the Orange area. These outcrop as domes, dykes, cones, plugs and extensive lava flows.

Tertiary sediments and gravels and Quaternary alluvium are also reported in the area. Sub-basaltic sediments, for example those that are situated about 20 km SSW of Orange, occur below the basalts of the Canobolas Volcanic Centre and are Middle Miocene in age. Tertiary gravels in the area range in age from Miocene to Pliocene.

The Tertiary rocks and sediments are unconformably underlain by Ordovician units — the Oakdale Formation of the Cabonne Group and the older Fairbridge Volcanics of the Kenilworth Group. Rocks of the Oakdale Formation include mafic volcanic sandstone, basalt, siltstone, black shale, chert, breccia and conglomerate and the Fairbridge Volcanics comprise porphyritic augite basalt, hornblende basaltic andesite, and volcaniclastics (Meakin et al. 1997).

History, conservation and landuse

In 1815 Governor Lachlan Macquarie sent surveyor George Evans on an expedition south-west of Bathurst to find the direction of flow of the Macquarie River (Cannon 1987). On 23 May 1815 Evans viewed what was to become Mt Canobolas and named it Jamieson's Table Mountain (Milton 1997). Major Thomas Mitchell was the first to scale Mt Canobolas searching for the course of the Darling River. Due to the altitude and subsequent orographic rainfall, reduced temperatures and highly fertile basaltic soils, most of the flanks of the mountain have long been used for agricultural purposes, in particular for growing stone fruit and *Pinus radiata* plantations.

In 1876 Mt Canobolas was set aside as a water reserve for travelling stock and has been under some form of reservation to the present time. In 1997 Mt Canobolas was placed under the control of the National Parks and Wildlife Service as a State Recreation Area (SRA), after the dissolution of the Canobolas Regional Parklands Reserve Trust, which had administered Mt Canobolas and a further 35 crown reserves within the Central West of New South Wales until then. Milton (1997) chronicles the changes associated with the control and reservation of the Mt Canobolas.

Within the Central West National Parks and Wildlife District 76% of the native vegetation has been cleared, and more than 90% of the remaining vegetation is in fragmented remnants of five square kilometers or less (ERM Mitchell McCotter 1996). Significant large reserves within the region include Goobang National Park to the west and Winburndale Nature Reserve to the east.

Previous investigations

Allan Cunningham, through his involvement with the Oxley expeditions (Oxley 1820), and Mitchell (1839) give broad statements on the surrounding landscapes but make no specific mention of the vegetation on Mt Canobolas. In 1899 R.H. Cambage, a surveyor for the Department of Lands and Mines with a keen interest in botany, appears to have made the first major plant collections from Mt Canobolas. J.H. Maiden, Director of the Sydney Botanic Gardens and J.L. Boorman, botanical collector made collections for the National Herbarium of NSW from Mt Canobolas in 1908.

R.H. Cambage produced the first detailed description of the vegetation in the vicinity of Orange (Cambage 1909). The Soil Conservation Service of NSW (1978) produced broad scale vegetation maps for the Orange district indicating the entirety of Mt Canobolas being of *Eucalyptus dalrympleana – Eucalyptus viminalis* Association. Kenna et al. (1998) produced a checklist of some of the more common plants along walking tracks in the State Recreation Area and Hunter (1998) surveyed the populations of *Eucalyptus canobolensis*.

Methods

Fifty, 20 × 20 m quadrats were surveyed for vascular plants scored using the Braun-Blanquet (1982) six point cover abundance scale. Quadrats were placed using a stratified random method using Physiography (Crest, Hill-slope, Open Depressions) and altitude (< or > 1200 m) were used to stratify survey sites. The survey was conducted over five days in November 1999.

Good quality material of species were retained as vouchers by the Central West Region of the NSW NP&WS and duplicates of significant collections submitted to the National Herbarium of NSW. Nomenclature follows that of Harden (1990–1993) except where recent changes have been made.

Analyses and data exploration were performed using options available in the PATN Analysis Package (Belbin 1995a, b). For final presentation of results all species and their relative abundance scores were used and the analysis performed using Kulczynski association measure which is recommended for ecological applications (Belbin 1995a, b) along with flexible Unweighted Pair Group arithmetic Averaging (UPGMA) and the default PATN settings.

Delineation of community boundaries in Fig. 2 was based on the location of sites and their position within the multivariate analysis, air photograph interpretation, substrate and ground truthing. The vegetation map is based on a 1: 25 000 scale. Structural names follow Specht et al. (1995) and are based on the most consistent uppermost stratum.

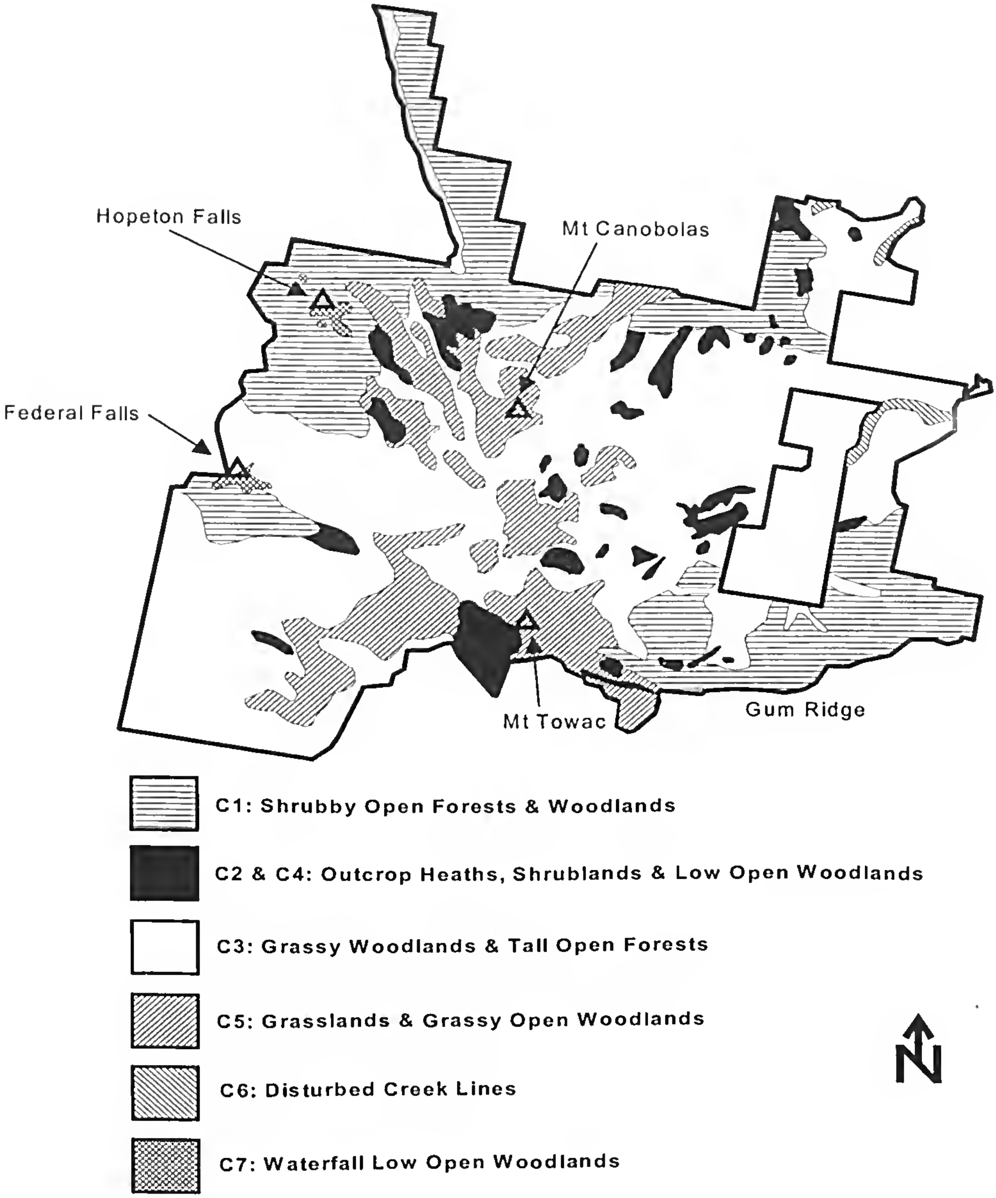

Fig. 2. Map of vegetation communities for Mount Canobolas State Recreation Area. Note Community 2 & 4 have been combined as they cannot be distinguished using API and both occur on rock outcrops.

Table 1: Selected attributes of the seven defined communities at Mount Canobolas State Recreation Area.

Community	Number of Sites	Richness per 400 m^2 (average)	Number of Species	Number of Introduced Species	Proportion of Reserve	Number of Hectares
C1: Stringybark – Peppermint	12	22–39 (29)	107	10	26%	427
C2: Outcrop Heaths & Shrublands	1	21 (21)	21	5	2%	10
C3: Snow Gum – Mountain Gum	20	18–34 (27)	133	27	52%	846
C4: Outcrop Low Open Woodlands	6	23–31 (25)	66	7	4%	24
C5: Grasslands & Grassy Open Woodlands	8	22–40 (31)	94	20	15%	242
C6: Disturbed Creek Lines	1	34 (34)	34	17	1%	11
C7: Waterfall Low Open Woodlands	2	29–31 (30)	48	5	< 1%	7

Results

Seven communities were recognised at the dissimilarity measure of c. 0.8. A summary of the community relationships is given by the dendrogram (Fig. 3). The first major division on the dendrogram is the separation of the riparian areas. The next major division separates communities with a strong shrub component from those more forb dominated. In all 309, vascular plant taxa, from 69 families and 93 genera, were recorded from the collation of existing site data and subsequent sampling (Appendix). Approximately 14% (46) of all taxa were introduced to NSW.

Vegetation communities

The vegetation communities within Mount Canobolas SRA are broadly similar to those found in southern NSW, though dominance of the endemic *Eucalyptus canobolensis* is unique. Most of the vegetation communities are of woodland formation with a distinct grassy component. Tall open forests also occur in valleys, heaths and shrublands on shallow soils and rock outcrops, and grasslands within the matrix of other structural forms. Table 1 gives a summary of relevant statistics for each community. Within the following descriptions of communities extreme values are given in brackets.

Community 1: Stringybark – Peppermint Shrubby Open Forests and Woodlands

Distribution: Primarily on shallow but moist soils on red brown to chocolate brown soils (occasionally dark brown). Found from 1000 m to 1340 m particularly if sites are exposed.

Structure: Upper (5–) 15–25 (–30) m tall; (10–) 30–40% cover. Mid shrub not always present 3–8 m tall; 10–30% cover. Low shrub mostly present 1–2 m tall; 20–80% cover. Ground layer < 1 m tall; 30–100% cover.

Trees: *Eucalyptus macrorhyncha, Eucalyptus canobolensis, Eucalyptus dives, Acacia irrorata, Eucalyptus dalrympleana* subsp. *dalrympleana, Exocarpos cupressiformis, Eucalyptus pauciflora, Eucalyptus goniocalyx, Eucalyptus bridgesiana, Eucalyptus rubida* subsp. *rubida, Eucalyptus radiata* subsp. *radiata, Eucalyptus blakelyi, Acacia melanoxylon.*

Shrubs: *Cassinia uncata, Hibbertia obtusifolia, Mirbelia oxylobioides, Cassinia longifolia, Pultenaea cunninghamii, Melichrus urceolatus, Leucopogon attenuatus, Hibbertia riparia, Pultenaea polifolia, Pultenaea subternata, Monotoca scoparia, Leptospermum myrtifolium, Daviesia leptophylla, Leucopogon fletcheri* subsp. *brachysepalus, Indigofera australis.*

Climbers & trailers: *Hardenbergia violacea, Glycine clandestina, Desmodium varians, Rubus parviflorus, Desmodium gunnii, Billardiera scandens.*

Ground cover: *Poa sieberiana, Themeda triandra, Hydrocotyle laxiflora, Stackhousia monogyna, Lomandra multiflora, Luzula flaccida, Geranium solanderi* subsp. *solanderi, Senecio diaschides, Bossiaea neo-anglica, Viola betonicifolia, Veronica calycina, Gonocarpus tetragynus, Cymbonotus lawsonianus, Echinopogon ovatus, Acaena ovina, Euchiton gymnocephalus, Scutellaria humilis, Pteridium esculentum, Galium gaudichaudii, Brachyscome spathulata, Senecio biserratus, Scleranthus biflorus, Euchiton sphaericus, Dianella revoluta, Centaurium tenuiflorum, Asperula conferta.*

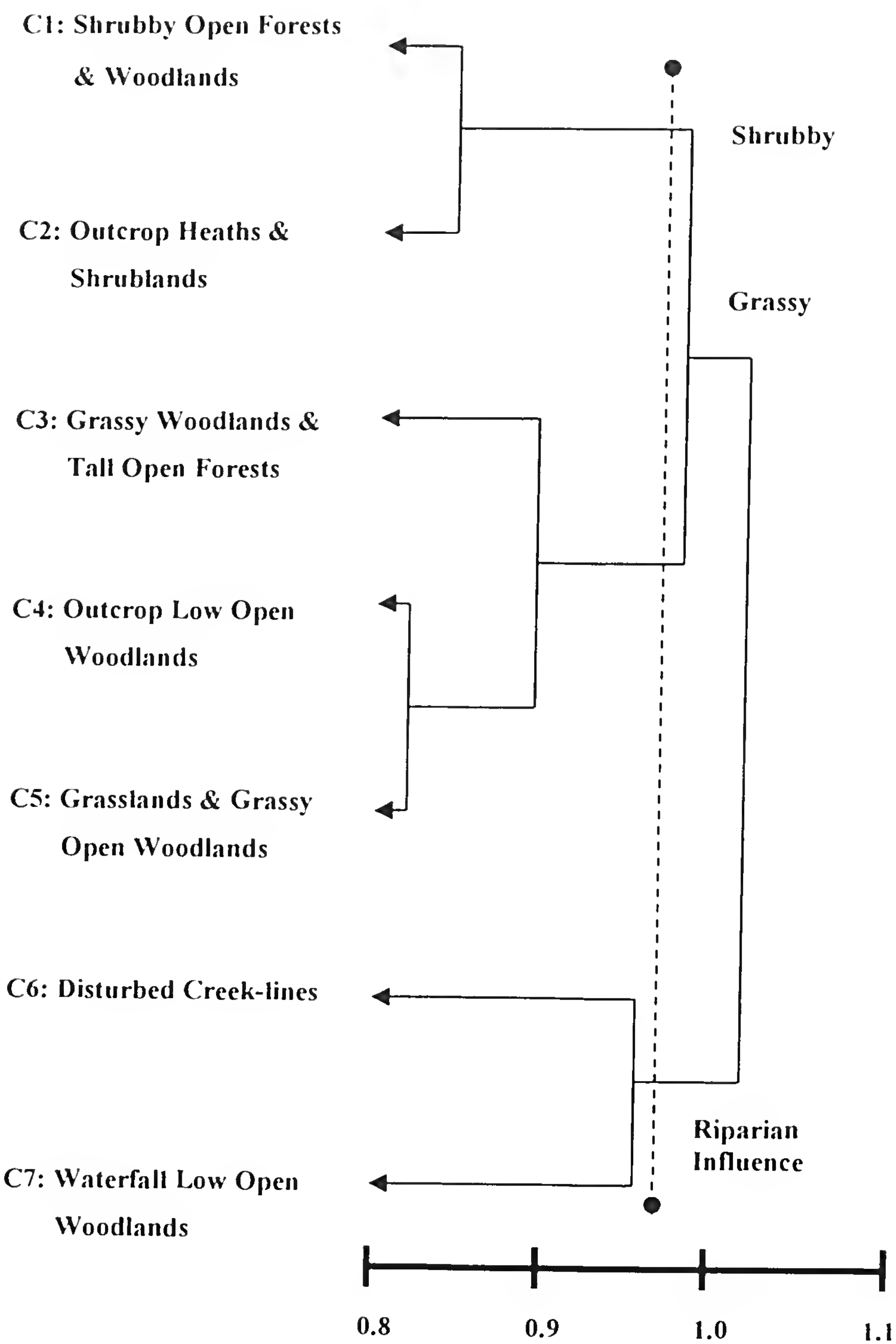

Fig. 3. Summary dendrogram of the full floristic dataset of sites using the Kulczynski association and flexible UPGMA fusion strategy and a β value of –0.1. Communities have been defined at a dissimilarity level of c. 0.8.

Variability: Two sub-assemblages are distinguished on overstorey dominants and the height of the trees. On less exposed sites, primarily on upper and lower slopes, *Eucalyptus dives* dominated forests occur that commonly obtain heights of 20–30 m and usually have an upper and lower shrub layer. The upper shrub layer often contains *Acacia irrorata*. The second sub-assemblage occurs on drier more exposed sites and is commonly dominated by *Eucalyptus macrorhyncha*. This sub-assemblage is generally shorter and commonly only obtains a height of 15–20 m. Generally only a lower shrub layer is present.

Conservation and management issues: Specht et al. (1995) considered that the assemblage was adequately conserved across its range with occurrences within the Blue Mountains, Kanangra Boyd and Kosciuszko National Parks in NSW and numerous reserves in Victoria. Keith and Bedward (1990) indicate that around 30% of the remaining lands containing a similar community are reserved in the southeast. This community is adequately conserved across its range but that the occurrence within Mt Canobolas SRA is significant due to the unusual assortment of associated species and the community being at its north-western geographic limit of occurrence.

Community 2: Outcrop Heaths and Shrublands

Distribution: Found as highly disjunct and small patches throughout the reserve on skeletal soils.

Structure: Upper 1–3 m tall; 40–100% cover. Ground layer < 0.5 m tall; 20–80% cover.

Shrubs: *Calytrix tetragona, Mirbelia oxylobioides, Leucopogon attenuatus, Cassinia uncata, Hibbertia riparia.*

Ground cover: *Poa sieberiana, Themeda triandra, Cheilanthes austrotenuifolia, Stellaria flaccida, Senecio diaschides, Pterostylis pedunculata, Paspalidium constrictum, Haloragis heterophylla, Gonocarpus tetragynus, Crassula colorata* subsp. *acuminata, Brachyscome spathulata.*

Variability: Where little or no soil development occurs, or where there are no substantial cracks in the exposed rock, shrubs do not develop or at least do not form dense stands. The community may be become sub-assemblage of Community 4 if fire frequencies are too high by decreasing the cover of shrubs and increasing more fire tolerant herbaceous vegetation (Hunter 1999).

Conservation and management issues: Likely to be wholly or restricted to Mt Canobolas and surrounds. This community is likely to be vulnerable to attrition from inappropriate fire regimes and attrition from disturbance due to visitor pressure. Community 2 is limited in extent, highly fragmented, and as such has a number of unique management problems. Such rock outcrop communities contain unique bryophyte communities (including the endangered Mt Canobolas *Xanthoparmelia* lichen community) and herbs that are easily disturbed by trampling. This endangered lichen community consists of *Xanthoparmelia canobolasensis* and *X. metastrigosa*, which are known only from Mt Canobolas, and *X. sulcifera* and *C. fuliginosa* each known from only one other locality in New South Wales (NSW Scientific Committee Final Determination 5 October 2001). The community occurs on rock faces and shallow soils on rock pavements and is threatened by road and drainage works, and collection of bushrock (NSW Scientific Committee

Final Determination 5 October 2001). Tourist visitation of the slopes and summit of Mt Canobolas increases risks of trampling and disturbance to the community. There is also potential for loss of lichen habitat from increased urban encroachment and rural development such as vineyards and orchards on the north and east flanks of Mt Canobolas. Unfortunately, rock outcrops are magnets for visitors as they are open and easy to walk on and often have good views.

Community 3: Snow Gum – Mountain Gum Grassy Woodlands and Tall Open Forests

Distribution: Found at higher altitudes or in protected areas dominating the central portion of the reserve. Soils are variable but primarily chocolate brown and are deep to shallow. The community is distributed from 900–1397 m altitude.

Structure: Upper (5–) 15–35 (–50) m tall; 20–40% cover. Upper shrub layer usually present 4–10 m tall; 10–60% cover. Lower shrub layer usually not present 1–3 m tall; 10–30% cover. Ground cover < 1 m tall; 80–100% cover.

Trees: *Eucalyptus pauciflora, Acacia melanoxylon, Eucalyptus dalrympleana* var. *dalrympleana, Acacia irrorata* subsp. *irrorata, Eucalyptus canobolensis, Eucalyptus viminalis, Eucalyptus mannifera, Eucalyptus radiata* subsp. *radiata, Eucalyptus polyanthemos* subsp. *polyanthemos, Eucalyptus goniocalyx, Eucalyptus dives.*

Shrubs: *Cassinia uncata, Hibbertia obtusifolia, Pultenaea polifolia, Pimelea ligustrina* var. *hypericina, Daviesia latifolia, Cassinia longifolia, Olearia stellulata, Mirbelia oxylobioides.*

Climbers & trailers: *Desmodium varians, Rubus parvifolius, Glycine tabacina, Desmodium gunnii, Hardenbergia violacea, Glycine* sp. A.

Ground cover: *Poa sieberiana, Acaena ovina, Pteridium esculentum, Geranium solanderi* subsp. *solanderi, Ranunculus lappaceus, Hydrocotyle laxiflora, Senecio quadridentatus, Luzula flaccida, Senecio diaschides, Scleranthus biflorus, Cymbanotus lawsonianus, Brachyscome spathulata, Microlaena stipoides, Echinopogon ovatus, Asperula conferta, Dichondra repens, Carex gaudichaudiana, Urtica incisa, Lomandra filiformis, Euchiton gymnocephalus, Derwentia derwentiana* var. *glauca, Rumex brownii, Pterostylis pedunculata, Wahlenbergia stricta* subsp. *stricta, Craspedia variabilis, Blechnum nudum, Wahlenbergia victoriensis, Viola hederacea, Viola betonicifolia, Senecio lautus* subsp. *lanceolatus, Poa labillardieri, Plantago varia, Lagenifera stipitata, Juncus remotiflorus, Gonocarpus tetragynus, Epilobium billardierianum, Chrysocephalum apiculatum.*

Variability: Sub-assemblages are distinguished primarily by physiography. Tall open forests dominated by *Eucalyptus dalrympleana* subsp. *dalrympleana* and *Eucalyptus viminalis* associated with open depressions (creek lines) with deep soils with trees up to 50 m tall. Grassy woodlands dominated by *Eucalyptus pauciflora* and *Eucalyptus canobolensis* from 5–25 m tall occur on upper slopes and crests on primarily shallow soils are also within this assemblage. There is a high degree of overlap between understorey species in these sub-assemblages and even the dominants of each occur commonly in both. These two sub-assemblages would likely separate out as distinct communities if the creek lines were far more developed, but since they are only barely incised they intergrade too much for separation.

Conservation and management issues: Benson and Keith (1990) indicate that the understorey of many remnants of these type of assemblages are heavily disturbed particularly by grazing. This community is probably adequately conserved across its range. Likely to be at the north-western limit of its distribution within the Mt Canobolas SRA. It is evident that the intense fire that occurred in 1985 has dramatically affected these woodland communities by causing massive germination of a cohort of young *Eucalyptus pauciflora*.

Community 4: Outcrop Low Open Woodlands

Distribution: Found scattered and disjunct across the entire reserve at altitudes from 1100–1360 m. Soils are always skeletal and generally red brown to chocolate or dark brown in colour.

Structure: Upper not always present 5–10 m tall; cover usually 10% but up to 30%. Shrub layer 1–3 m tall; 20–40% cover. Ground layer < 1 m tall; 50–80% cover.

Trees: *Eucalyptus canobolensis, Acacia irrorata* subsp. *irrorata, Eucalyptus saxicola.*

Shrubs: *Cassinia uncata, Phebalium squamulosum, Mirbelia oxylobioides, Dodonaea viscosa, Calytrix tetragona, Leptospermum myrtifolium, Leucopogon attenuatus, Hibbertia obtusifolia, Cassinia longifolia.*

Climbers & trailers: None apparent.

Ground cover: *Poa sieberiana, Centaurium tenuiflorum, Geranium solanderi* var. *solanderi, Cheilanthes sieberi, Carex gaudichaudiana, Luzula flaccida, Schoenus apogon, Austrodanthonia eriantha, Wurmbea dioica* subsp. *dioica, Senecio diaschides, Scleranthus biflorus, Dichelachne micrantha, Crassula colorata* var. *acuminata, Asplenium flabellifolium, Senecio quadridentatus, Oreomyrrhis eriopoda, Hypericum japonicum, Cardamine gunnii, Austrostipa racemosa* subsp. *racemosa, Rumex brownii, Oreobolus pumilio* var. *pumilio, Montia fontana* subsp. *chondrosperma, Hydrocotyle peduncularis, Hydrocotyle laxiflora, Digitaria brevigluмis, Crassula sieberiana, Austrodanthonia penicellata, Acaena novae-zelandiae.*

Variability: Much variation appears to be associated with soil development and time since of fire. Where little or no soil development occurs, or where there are no substantial cracks in exposed rock, shrubs do not develop or at least do not form dense stands. Where soil development increase substantially trees are able to invade. Rock outcrops with a lowered frequency of fires have a greater proportion of shrubs with an occasional overstorey of *Eucalyptus saxicola*. Mt Towac, which has been burned more frequently, has fewer shrub taxa and is dominated by *Cassinia uncata* and *Acacia irrorata*, and a greater density of herbaceous taxa.

Conservation and management issues: Due to the restricted distribution and most of the community occurring within the SRA this community is probably adequately reserved locally. It should be considered vulnerable, particularly due to inappropriate fire regimes and visitor pressure.

Community 5: Grasslands and Grassy Open Woodlands

Distribution: Found above 1200 m altitude on shallow moist soils of a chocolate brown colour. Usually small and patchily distributed within Community 3.

Structure: Upper not always present (5–) 10–15 (–25) m tall; (5–) 10–20 (–40)% cover. Shrub layer not always present 2–5 m tall; 10–20 (-30)% cover. Ground cover < 1 m tall; 80–100% cover.

Trees: *Eucalyptus pauciflora, Eucalyptus canobolensis, Acacia irrorata* subsp. *irrorata, Eucalyptus dalrympleana* subsp. *dalrympleana, Acacia melanoxylon, Acacia deanei.*

Shrubs: *Cassinia uncata, Pimelea latifolia, Hibbertia obtusifolia, Acrotriche serrulata, Lespedeza juncea* subsp. *sericea, Pultenaea cunninghamii, Melichrus urceolatus, Leptospermum myrtifolium, Hibbertia riparia, Cassinia arcuata.*

Climbers & trailers: *Desmodium varians, Hardenbergia violacea, Desmodium gunnii.*

Ground cover: *Poa sieberiana, Geranium solanderi* subsp. *solanderi, Carex gaudichaudiana, Hydrocotyle laxiflora, Scutellaria humilis, Cheilanthes austrotenuifolia, Scleranthus biflorus, Acaena ovina, Hypericum japonicum, Senecio quadridentatus, Ranunculus lappaceus, Oreomyrrhis eriopoda, Euchiton gymnocephalus, Cymbonotus lawsonianus, Centaurium tenuiflorum, Hypericum gramineum, Veronica calycina, Rumex brownii, Oxalis chnoodes, Asperula conferta, Acaena novae-zelandiae, Viola betonicifolia, Urtica incisa, Stellaria flaccida, Schoenus apogon, Lomandra multiflora, Hydrocotyle pedicellosa, Epilobium billardierianum, Crassula sieberiana.*

Variability: Trees are a minor component of the community but can occur in low densities and change the community visually but not the overall floristic composition. Shrubs occasionally occur such as *Cassinia,* but are scarce or low to the ground. Intergradation occurs with Community 4 where soils are more skeletal and where fires are frequent.

Conservation and management issues: Keith and Benson (1988) stated that assemblages such as these were mostly cleared for agriculture. Costin (1970) describes them as being degraded to shrublands due to grazing and fire. Keith and Bedward (1999) indicated that 86% of this community was depleted in the Monaro area with only around 0.03% of that not depleted being reserved. It is likely that this community is poorly conserved across its range and that the occurrence within the Mount Canobolas SRA is highly significant.

Community 6: Disturbed Creek-lines

Distribution: Highly disturbed lower creek lines occur in the lower reaches of Towac Creek and a minor creek line that leaves the north eastern corner of the reserve.

Structure: Upper 30–35 m tall; 20% cover. Middle layer 10–20 m tall; 20% cover. Ground layer < 1m tall; 80% cover.

Trees: *Eucalyptus viminalis, Eucalyptus stellulata, Eucalyptus pauciflora, Eucalyptus dalrympleana.*

Shrubs: *Acacia falciformis, Leptospermum polygalifolium, Pimelea ligustrina* var. *hypericina, Phebalium squamulosum, Mirbelia oxylobioides, Cassinia uncata.*

Ground cover: *Urtica incisa, Pteridium esculentum, Geranium solanderi* subsp. *solanderi, Scleranthus biflorus, Blechnum nudum, Acaena ovina, Ranunculus lappaceus, Adiantum aethiopicum.*

Variability: This community is worth distinguishing despite its derived nature, due to disturbance and weed invasion, as it will need separate consideration and management requirements beyond what is needed in other creek line areas within the reserve.

Conservation and management issues: Of little conservation importance, but if rehabilitated would be a valuable asset to the reserve as it is the only location where *Eucalyptus stellulata* is found. *Eucalyptus stellulata* assemblages in general are considered adequately reserved across their range by Specht et al. (1995), being found in numerous National Parks and other reserves within New South Wales and Victoria.

Community 7: Waterfall Low Open Woodlands

Distribution: Federal and Hopeton Falls.

Structure: Highly variable. Upper 5–30 m tall; 10% cover. Shrub layer 1–2 m tall; 30–90% cover. Ground layer < 1 m tall; 20–40% cover.

Trees: *Eucalyptus goniocalyx, Eucalyptus viminalis, Acacia melanoxylon, Eucalyptus canobolensis.*

Shrubs: *Exocarpus strictus, Cassinia uncata, Indigofera adesmiifolia, Dodonaea viscosa, Acacia verniciflua.*

Climbers & trailers: *Billardiera scandens.*

Ground cover: *Senecio lautus* subsp. *lanceolatus, Lepidosperma laterale, Pellaea falcata* var. *nana, Bulbine bulbosa, Stypandra glauca, Senecio hispidulus* var. *hispidulus, Galium migrans, Austrostipa racemosa, Wurmbea dioica* var. *dioica, Vittadinia cuneata, Veronica calycina, Themeda triandra, Pteridium esculentum, Poa sieberiana, Pleurosorus subglandulosus, Plantago varia, Imperata cylindrica, Gonocarpus tetragynus, Geranium solanderi* subsp. *solanderi, Dianella caerulea* var. *caerulea, Cymbopogon refractus, Austrodanthonia eriantha, Asplenium flabellifolium, Aristida ramosa, Sigesbeckia australis, Scleranthus biflorus, Echinopogon ovatus, Drosera peltata, Crassula sieberiana, Cheilanthes distans, Cheilanthes austrotenuifolia, Carex gaudichaudiana.*

Variability: Primarily of an open shrubland with an assortment of herbs of equal cover. Stunted *Eucalyptus goniocalyx* may occur where soil development is greater, particularly on the margins of the exposed rock face. The scree slopes at the bottom of the falls has few shrubs but a dense *Senecio* ground cover and the odd taller tree such as *Eucalyptus viminalis.*

Conservation and management issues: Considered adequately reserved but of very limited extent. Specht et al. (1995) considered communities with similar dominants to be reasonably conserved across its range. Blackberry (*Rubus*) is a serious problem at present.

Discussion

The plant communities within Mt Canobolas SRA, on a 0.04 ha quadrat basis, have nearly two-to three-fold greater species richness than comparable communities surveyed elsewhere in the South Eastern Highlands Bioregion (Keith & Bedward 1999), however generally less than what was found in communities from lower altitudes (Lembit 1996, Porteners 1997). For example Keith and Bedward (1999) describe a Dry Grassy Woodland (*E. dives – E. dalrympleana – E. pauciflora – E. rubida*) with 13 spp./0.04 ha, a Dry Grass Forest (*E. pauciflora – E. rubida – E. viminalis*) with 16 spp./0.04 ha and a Basalt Grassland (*E. pauciflora – E. viminalis* with scattered *Acacia melanoxylon*) with 17 spp./0.04 ha on average. Comparable communities here include Community 1 with 29 spp./0.04 ha, Community 3 with 27 spp./0.04 ha and Community 5 with 31 spp./0.04 ha on average.The richness of all communities was relatively uniform, being in general between 25–35 species./0.04 ha (28 average).

Milton (1997) stated that (due to the rapid climb in altitude) the vegetation of Mt Canobolas SRA changed '*as if a line were drawn on a map*'. The results of this survey indicate that this is not the case. There is considerable overlap between communities, particularly with those that are widespread within the SRA. Communities within the SRA have affinities with those described as intermediate in the literature (Beadle 1981, Keith & Bedward 1999). This may be partly due to the small and isolated nature of the remnant.

The occurrence of grasslands and low open grassy woodlands are likely to be natural. These patches may be derived from past fire regimes but are more likely to have formed due to the climate. Ripley (1992) and Benson (1994) discuss that under low rainfall (c. 850 mm MAR) it is likely that dense herbaceous vegetation would exhaust the available moisture in the top layer of soil. Tree seedlings are out-competed. If sites become wetter, the grasslands may become gradually recolonised by shrub and tree species that survive the dry conditions, but in such situations frequent frosts may restrict seedling development (Benson 1994).

Mt Canobolas State Recreation Area is placed within the South Eastern Highlands (SHE) Bioregion and the community descriptions here support this. Within the SEH Bioregion, Mt Canobolas is an outlier at the extreme north and west. In particular, Communities 1, 3 and 5, which are the most extensive within the SRA (92.3% of SRA) show strong affinities with high altitude assemblages, primarily on basalt on the western parts of the Blue Mountains, the western parts of the Southern Tablelands, as well as the Monaro region and central Victoria. Communities 2 and 4, which are restricted to skeletal soils on rock outcrops, are primarily associated with flora of the Southern Tablelands of New South Wales. The stronger herbaceous component of Community 4 shows affinities to the Southern Tablelands but with a distinct relationship with the flora of the North Western Slopes. In contrast, Community 7, which occurs on the most exposed sites within the SRA (i.e. on shallow soils, fully exposed, western facing), has strong relationships with the floras of the northeast and the Central Western parts of the state.

The flora of Mt Canobolas SRA is comparatively cosmopolitan. Milton (1997) quotes Jenny Kenna, president of the Orange Field Naturalist Club, as stating '*Mount Canobolas is a sub-alpine climate which by its location has been isolated from other sub-alpine areas and has allowed plants to evolve in isolation*'. Such beliefs are, probably largely based on the distinctness of the Mt Canobolas flora from the immediately adjacent vegetation. This survey has shown that there is very little support for such beliefs. The flora of Mt Canobolas is distinctly widespread and typical of other high altitude floras; it is possibly even depauperate in terms of high altitude specialists. Only two true endemics exist in Mt Canobolas SRA, both of which are *Eucalyptus* species — *Eucalyptus canobolensis*, the first endemic to be recognised and recently a second endemic species, *Eucalyptus saxicola* (Hunter 2001). Certainly, Mt Canobolas is a disjunct remnant of sub-alpine habitat. However, it is likely that due to its long isolation and very small overall area it has lost, or never obtained, many high altitude specialists.

Conclusion

Mt Canobolas State Recreation Area is a significant isolated high altitude conservation reserve with a comparatively little disturbed habitat. It conserves some of the major and widespread communities found within the South East Highland Bioregion and the vegetation associated with high altitude basaltic soils. Many of the associated communities and species are at the north-western limit of their known distribution; some are highly significant.

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References

Beadle, N.C.W. (1981) *The vegetation of Australia* (Cambridge University Press: Cambridge).

Belbin, L. (1995a) *Users guide: PATN Pattern Analysis Package* (Division of Wildlife & Ecology CSIRO: Canberra).

Belbin, L. (1995b) *Technical Reference: PATN Pattern Analysis Package* (Division of Wildlife & Ecology CSIRO: Canberra).

Benson, D.H. & Keith, D.A. (1990) The natural vegetation of Wallerawang 1: 100 000 map sheet. *Cunninghamia* 2: 305–336.

Benson, J.S. (1994) The native grasslands of the Monaro region: Southern Tablelands of NSW. *Cunninghamia* 3: 609–650.

Braun-Blanquet, J. (1982) *Plant sociology: the study of plant communities* (McGraw Hill: New York).

Cambage, R.H. (1909) Notes on the botany of the interior of New South Wales. VII. From Forbes to Bathurst. *Proceedings of the Linnean Society of New South Wales* 27: 561–591.

Cannon, M. (1987) *The exploration of Australia* (Reader's Digest: Surry Hills).

Costin, A.B. (1970) Sub-alpine and alpine communities. In R.M. Moore (Ed.) *Australian Grasslands*. (Australian National University Press: Canberra).

ERM Mitchell-McCotter (1996) *Bathurst Vegetation Survey*. Unpublished Report to the Central West Region NSW NP&WS.

Faulkner, W. (1996) *Canobolas Regional Parkland Reserves — an Assessment of Conservation Values*. Unpublished Report to the Central West Region NSW NP&WS.

Harden, G.J. (1990–1993) *Flora of New South Wales Vol. 1–4* (UNSW Press: Sydney).

Hunter, J.T. (2001) *Eucalyptus saxicola* (Myrtaceae), a new species from the Central Tablelands of New South Wales (Section Maidenaria series Bridgesianae). *Telopea* 9: 403–407.

Hunter, J.T. (2000) *Vegetation and Floristics of the Mount Canobolas State Recreation Area*. Unpublished Report to the Central West Region of the NSW NP&WS.

Hunter, J.T. (1998) *Threatened endemic eucalypts of the Central Tablelands*. Unpublished Report to the Central West Region NSW NP&WS.

Keith, D.A. & Bedward, M. (1999) Native vegetation of the south-east forests region, Eden. *Cunninghamia* 6: 1–218.

Keith, D.A. & Benson, D.H. (1988) The natural vegetation of Katoomba 1:100 000 map sheet. *Cunninghamia* 2: 107–144.

Kenna, J.I., Medd, R.W. & Bower, C.C. (1998) *Flora of the walking tracks of Mt Canobolas State Recreation Area* (Orange Field Naturalists & Conservation Society Inc.: Orange).

Lembit, R. (1996) *Vegetation survey of Evans Crown Nature Reserve*. Unpublished Report to the Central West Region NSW NP&WS.

Meakin, S., Spackman, J.M., Scott, M.M., Watkins, J.J., Warren, A.Y.E., Moffitt, R.S. & Krynen, J.P. (1997) *Orange*. 1st Edn (1: 100 000 geological map 8731) (Geological Survey of NSW & Australian Geological Survey: Canberra).

Milton, N. (1997) *Mount Canobolas (The journey towards State Recreation Area status)*. Unpublished PKM 160 Natural Resource Management Assignment Bathurst Campus, University of Sydney (held in NP&WS Bathurst district office).

Mitchell, T.L. (1839) *Three Expeditions into the Interior of Eastern Australia with the descriptions of the recently explored region of Australia Felix, and the present colony of New South Wales*. Vol. 1 (2nd Edn) (T. & W. Boone: London).

Oxley, J. (1820) *Journals of two Expeditions into the Interior of New South Wales* (John Murray: London).

Porteners, M.F. (1997) *Vegetation survey of Goobang National Park*. Unpublished Report to the Central West NSW NP&WS.

Ripley, E.A. (1992) Grassland climate. In R.T. Coupland *Ecosystems of the World. 8A: Natural Grasslands: Introduction and Western Hemisphere* (Elsevier: Amsterdam).

Soil Conservation Service of New South Wales (1978) *Orange District Technical Manual* (Soil Conservation Service: Sydney).

Specht, R.L., Specht, A., Whelan, M.B. & Hegarty, E.E. (1995) *Conservation atlas of plant communities in Australia* (Centre for Coastal Management & Southern Cross University Press: Lismore).

Appendix: Flora of Mount Canobolas SRA. Nomenclature follows that of Harden (1990–1993) except where recent changes have occurred. Taxa found within the survey sites are scored according to their occurrence in each of the seven communities defined. Some taxa were found in previous surveys and have not been verified by the author or opportunistically and therefore are not assigned to a specific community. C1 = Shrubby Open Forests & Woodlands; C2 = Outcrop Heaths & Shrublands; C3 = Grassy Woodlands & Tall Open Forests; C4 = Outcrop Low Open Woodlands; C5 = Grasslands & Grassy Open Woodlands; C6 = Disturbed Creek Lines; C7 = Waterfall Low Open Woodlands. Introduced species are indicated by *.

Taxon	C1	C2	C3	C4	C5	C6	C7	Opportunistic
Adiantaceae								
Adiantum aethiopicum			C3			C6		
Cheilanthes austrotenuifolia	C1	C2	C3		C5		C7	
Cheilanthes distans							C7	
Cheilanthes sieberi subsp. *sieberi*	C1		C3	C4				
Pellaea nana							C7	
Pteris tremula								O
Amygdalaceae								
**Prunus laurocerasus*			C3					
Anthericaceae								
Arthropodium milleflorum				C4	C5			
Thysanotus tuberosus								O
Apiaceae								
Actinotus helianthi								O
Hydrocotyle laxiflora	C1		C3	C4	C5			
Hydrocotyle pedicellosa					C5			
Hydrocotyle peduncularis	C1		C3	C4	C5			
Lilaeopsis polyantha					C5			
Oreomyrrhis eriopoda	C1		C3	C4	C5			
Araliaceae								
Astrotricha linearis								O
**Hedera helix*			C3			C6		
**Tetrapanax papyrifer*								O
Asphodelaceae								
Bulbine bulbosa	C1		C3				C7	
Aspleniaceae								
Asplenium flabellifolium				C4	C5		C7	
Pleurosorus subglandulosus							C7	
Asteraceae								
**Bidens pilosa*			C3					
Brachyscome spathulata	C1	C2	C3					
Bracteantha bracteata								O
Cassinia arcuata					C5			
Cassinia laevis			C3					
Cassinia longifolia	C1		C3	C4				
Cassinia uncata	C1	C2	C3	C4	C5	C6	C7	
Chrysocephalum apiculatum			C3					

Taxon	C1	C2	C3	C4	C5	C6	C7	Opportunistic
Asteraceae cont.								
Chrysocephalum semipapposum								O
**Cirsium vulgare*	C1	C2	C3	C4	C5	C6		
**Conyza albida*	C1		C3	C4	C5		C7	
**Conyza bonariensis*			C3					
Craspedia variabilis			C3		C5			
Cymbanotus lawsonianus	C1		C3	C4	C5			
Cymbanotus preissianus	C1							
Euchiton gymnocephalus (DC.) Holub	C1		C3	C4	C5			
Euchiton sphaericus (Willd.) Holub	C1				C5			
**Hypochaeris radicata*	C1	C2	C3	C4	C5		C7	
Lagenifera stipitata			C3					
Microseris lanceolata								O
Olearia chrysophylla								O
Olearia stellulata			C3					
Senecio biserratus	C1							
Senecio diaschides	C1	C2	C3	C4	C5			
Senecio glossanthus			C3					
Senecio hispidulus var. *hispidulus*							C7	
Senecio lautus subsp. *dissectifolius*								O
Senecio lautus subsp. *lanceolatus*	C1		C3				C7	
Senecio linearifolius								O
Senecio quadridentatus	C1		C3	C4	C5			
Senecio sp. E			C3		C5			
Sigesbeckia australis							C7	
Sonchus oleraceus			C3		C5	C6		
**Taraxacum afficinale*	C1		C3		C5	C6		
Vittadinia cuneata var. *cuneata*							C7	
Blechnaceae								
Blechnum nudum			C3			C6		
Boraginaceae								
**Amsinckia intermedia*			C3			C6		
Brassicaceae								
Cardamine gunnii			C3	C4				
**Hirschfeldia incana*						C6		
Callitrichaceae								
Callitriche stagnalis			C3			C6		
Campanulaceae								
Wahlenbergia ceracea								O
Wahlenbergia communis								O
Wahlenbergia luteola								O
Wahlenbergia stricta subsp. *stricta*	C1		C3	C4				
Wahlenbergia victoriensis	C1		C3		C5			

Taxon	C1	C2	C3	C4	C5	C6	C7	Opportunistic
Caprifoliaceae								
**Lonicera japonica*								O
Caryophyllaceae								
**Cerastium glomeratum*			C3		C5			
**Petrorhagia nanteuilii*					C5		C7	
Scleranthus biflorus	C1		C3	C4	C5	C6	C7	
Stellaria angustifolia				C4				
Stellaria flaccida		C2	C3	C4	C5			
Stellaria multiflora								O
Stellaria pungens								O
Celastraceae								
Maytenus silvestris								O
Clusiaceae								
**Hypericum androsaemum*								O
Hypericum gramineum	C1				C5			
Hypericum japonicum	C1		C3	C4	C5			
**Hypericum perforatum*			C3					
Colchicaceae								
Burchardtia umbellata								O
Wurmbea dioica subsp. *dioca*	C1			C4	C5		C7	
Commelinaceae								
Commelina cyanea								O
Convolvulaceae								
Convolvulus erubescens								O
Dichondra repens			C3		C5			
Crassulaceae								
Crassula colorata var. *acuminata*		C2		C4	C5			
Crassula sieberiana				C4	C5		C7	
Cupressaceae								
Callitris endlicheri								O
Cyperaceae								
Carex appressa			C3					
Carex breviculmis					C5			
Carex gaudichaudiana	C1		C3	C4	C5		C7	
Carex inversa			C3					
Eleocharis acuta								O
Fimbristylis dichotoma								O
Gahnia aspera			C3					
Lepidosperma laterale	C1						C7	
Oreobolus pumilio subsp. *pumilio*				C4				
Schoenus apogon	C1		C3	C4	C5			

Taxon	C1	C2	C3	C4	C5	C6	C7	Opportunistic
Davalliaceae								
Rumohra adiantiformis								O
Dennstaedtiaceae								
Pteridium esculentum	C1		C3			C6	C7	
Dilleniaceae								
Hibbertia obtusifolia	C1		C3	C4	C5			
Hibbertia riparia	C1	C2			C5			
Hibbertia sericea								O
Droseraceae								
Drosera auriculata								O
Drosera peltata							C7	
Dryopteridaceae								
Polystichum proliferum			C3					
Epacridaceae								
Acrotriche serrulata					C5			
Brachyloma daphnoides subsp. *glabrum* (Blakely) J.T.Hunter								O
Leucopogon attenuatus	C1	C2		C4				
Leucopogon fletcheri subsp. *brachysepalus*	C1		C3					
Leucopogon fraseri								O
Leucopogon virgatus								O
Melichrus urceolatus	C1		C3		C5			
Monotoca scoparia	C1							
Euphorbiaceae								
Phyllanthus virgatus								O
Poranthera microphylla			C3		C5			
Fabaceae								
Acacia brownei	C1							
Acacia buxifolia								O
Acacia dealbata								O
Acacia deanei subsp. *paucijuga*					C5			
Acacia falciformis						C6		
Acacia irrorata subsp. *irrorata*	C1		C3	C4	C5			
Acacia lanigera								O
Acacia melanoxylon	C1		C3		C5		C7	
Acacia verniciflua							C7	
Bossiaea buxifolia								O
Bossiaea neo-anglica	C1			C4				
**Cytisus scoparius* subsp. *scoparius*						C6		
Daviesia latifolia			C3					
Daviesia leptophylla	C1		C3					
Desmodium gunnii	C1		C3		C5			
Desmodium varians	C1		C3		C5			

Taxon	C1	C2	C3	C4	C5	C6	C7	Opportunistic
Fabaceae cont.								
Glycine clandestina	C1		C3					
Glycine sp. A			C3					
Glycine tabacina	C1		C3					
Hardenbergia violacea	C1		C3		C5			
Hovea heterophylla	C1							
Indigofera adesmiifolia							C7	
Indigofera australis	C1		C3					
Lespedeza juncea								O
Medicago polymorpha	C1		C3	C4	C5	C6	C7	
Mirbelia oxylobioides	C1	C2	C3	C4		C6		
Oxylobium ellipticum			C3					
Pultenaea cunninghamii	C1				C5			
Pultenaea polifolia	C1		C3					
Pultenaea sp. F			C3					
Pultenaea subternata	C1							
**Trifolium arvense*								O
**Trifolium dubium*			C3		C5			
**Trifolium repens*	C1	C2	C3		C5			
**Ulex europaeus*					C5			
Vicia villosa subsp. *varia*			C3			C6		
Gentianaceae								
**Centaurium erythraea*								O
**Centaurium tenuiflorum*	C1		C3	C4	C5			
Geraniaceae								
Geranium homeanum								O
Geranium potentilloides var. *potentilloides*								O
Geranium solanderi var. *solanderi*	C1		C3	C4	C5	C6	C7	
Pelargonium australe								O
Goodeniaceae								
Goodenia hederacea subsp. *hederacea*	C1							
Haloragaceae								
Gonocarpus elatius								O
Gonocarpus tetragynus	C1	C2	C3				C7	
Haloragis heterophylla		C2		C4				
Juncaceae								
Juncus australis								O
Juncus remotiflorus			C3		C5			
Juncus subsecundus					C5			
Luzula densiflora	C1							
Luzula flaccida	C1		C3	C4	C5			
Luzula ovata								O

Taxon	C1	C2	C3	C4	C5	C6	C7	Opportunistic
Lamiaceae								
Ajuga australis								O
Mentha satureioides								O
**Marrubium vulgare*		C2		C4	C5			
**Prunella vulgaris*			C3					
Scutellaria humilis	C1		C3	C4	C5			
Lomandraceae								
Lomandra confertifolia subsp. *pallida*								O
Lomandra filiformis			C3	C4	C5			
Lomandra longifolia								O
Lomandra multiflora subsp. *multiflora*	C1		C3		C5			
Loranthaceae								
Amyema miquelii	C1		C3					
Malaceae								
**Cotoneaster glaucophyllus*								O
**Crataegus monogyna*			C3					
Myrtaceae								
Angophora floribunda								O
Calytrix tetragona		C2		C4				
Eucalyptus blakelyi	C1							
Eucalyptus bridgesiana	C1							
Eucalyptus canobolensis (L.A.S.Johnson & K.D.Hill) J.T.Hunter	C1		C3	C4	C5		C7	
Eucalyptus dalrympleana subsp. *dalrympleana*	C1		C3		C5	C6		
Eucalyptus deanei								O
Eucalyptus dives	C1		C3					
Eucalyptus goniocalyx	C1		C3				C7	
Eucalyptus macrorhyncha	C1							
Eucalyptus mannifera			C3					
Eucalyptus pauciflora	C1		C3		C5	C6		
Eucalyptus polyanthemos subsp. *polyanthemos*			C3					
Eucalyptus radiata subsp. *radiata*	C1		C3					
Eucalyptus rubida subsp. *rubida*	C1							
Eucalyptus saxicola J.T.Hunter				C4				
Eucalyptus stellulata						C6		
Eucalyptus viminalis			C3			C6	C7	
Kunzea parvifolia								O
Leptospermum myrtifolium	C1		C3	C4	C5			
Leptospermum polygalifolium subsp. *transmontanum*						C6		
Onagraceae								
Epilobium billardierianum var. *cinereum*	C1		C3	C4	C5			

Taxon	C1	C2	C3	C4	C5	C6	C7	Opportunistic
Ophioglossaceae								
Ophioglossum lusitanicum subsp. *coriaceum*				C4				
Orchidaceae								
Caladenia congesta								O
Caladenia fuscata								O
Caladenia gracilis								O
Caladenia phaeoclavia								O
Caladenia tentaculata								O
Calochilus campestris								O
Calochilus robertsonii								O
Chiloglottis trilabra								O
Chiloglottis valida								O
Corybas hispidus								O
Dipodium punctatum								O
Dipodium roseum					C5			
Diuris punctata								O
Diuris semilunulata								O
Diuris sulphurea								O
Eriochilus cucullatus								O
Gastrodia procera								O
Genoplesium sagittiferum								O
Thelymitra megcalyptra								O
Microtus uniflora								O
Prasophyllum brevilabre								O
Prasophyllum odoratum								O
Pterostylis alata								O
Pterostylis coccina								O
Pterostylis longifolia								O
Pterostylis nutans								O
Pterostylis parviflora								O
Pterostylis pedunculata		C2	C3					O
Oxalidaceae								
Oxalis chnoodes	C1		C3	C4	C5			
Oxalis perennans	C1		C3		C5			
Phormiaceae								
Dianella caerulea var. *caerulea*	C1		C3				C7	
Dianella longifolia var. *longifolia*								O
Dianella revoluta	C1		C3					
Dianella tasmanica			C3					
Stypandra glauca							C7	
Pinaceae								
**Pinus radiata*	C1		C3					
Pittosporaceae								
Billardiera scandens	C1						C7	
Rhytidosporum procumbens								O

Taxon	C1	C2	C3	C4	C5	C6	C7	Opportunistic
Plantaginaceae								
**Plantago lanceolata*	C1		C3					
Plantago varia	C1		C3		C5		C7	
Poaceae								
Aira cupaniana					C5			
Aristida ramosa var. *scaberula*							C7	
Austrodanthonia eriantha (Lindl.) H.P.Linder				C4	C5		C7	
Austrodanthonia penicellata (Labill.) H.P.Linder	C1			C4				
Austrodanthonia pilosa (R.Br.) H.P.Linder							O	
Austrodanthonia racemosa (R.Br.) H.P.Linder			C3					
Austrostipa densiflora (R.Br.) S.W.L.Jacobs & H.P.Linder				C4			C7	
Austrostipa scabra (Lindl.) S.W.L.Jacobs & J.Everett	C1							
**Briza maxima*								O
**Bromus sterilis*								O
Cymbopogon refractus							C7	
Dactylis glomerata						C6		
Dichelachne micrantha				C4				
Digitaria breviglumis				C4				
Digitaria brownii								O
Echinopogon ovatus	C1		C3		C5		C7	
Elymus scaber var. *scaber*								O
Imperata cylindrica var. *major*			C3				C7	
Microlaena stipoides	C1		C3	C4	C5			
Paspalidium constrictum		C2						
Paspalum dilatatum			C3			C6		
Poa annua								O
Poa labillardieri			C3					
Poa sieberiana	C1	C2	C3	C4	C5		C7	
Themeda triandra	C1	C2		C4	C5		C7	
Tripogon loliiformis			C3		C5		C7	
Polygonaceae								
**Acetosella vulgaris*	C1	C2	C3	C4	C5			
Rumex brownii			C3	C4	C5			
Portulacaceae								
Montia fontana subsp. *chondrosperma*				C4				
Ranunculaceae								
Ranunculus inundatus				C4				
Ranunculus lappaceus	C1		C3		C5	C6		
Rhamnaceae								
Cryptandra amara var. *amara*			C3					

Taxon	C1	C2	C3	C4	C5	C6	C7	Opportunistic
Rosaceae								
Acaena novae-zelandiae	C1		C3	C4	C5			
Acaena ovina	C1		C3		C5	C6		
**Rosa rubiginosa*					C5	C6		
**Rubus chloocladus*	C1		C3	C4	C5		C7	
Rubus parvifolius	C1		C3					
Rubiaceae								
Asperula conferta	C1		C3		C5			
Coprosma quadrifida			C3					
Galium aparine			C3		C5	C6		
Galium gaudichaudii	C1			C4				
Galium migrans							C7	
Pomax umbellata				C4				
Nertera granadensis								O
Rutaceae								
Correa reflexa var. *reflexa*								O
Phebalium squamulosum subsp. *squamulosum*				C4		C6		
Salicaceae								
**Salix fragilis*						C6		
Santalaceae								
Exocarpos cupressiformis	C1		C3					
Exocarpos strictus							C7	
Sapindaceae								
Dodonaea viscosa subsp. *angustissima*	C1			C4			C7	
Scrophulariaceae								
Derwentia derwentiana subsp. *subglauca*	C1		C3		C5			
**Orobanche minor*								O
**Verbascum thapsus*			C3		C5			
Veronica calycina	C1		C3		C5		C7	
Solanaceae								
**Datura stramonium*						C6		
Stackhousiaceae								
Stackhousia monogyna	C1			C4	C5			
Stackhousia viminea								O
Stylidiaceae								
Stylidium graminifolium	C1							

Taxon	C1	C2	C3	C4	C5	C6	C7	Opportunistic
Thymelaeaceae								
Pimelea curviflora var. *gracilis*			C3					
Pimelea latifolia subsp. *hirsuta*			C3		C5			
Pimelea ligustrina subsp. *ligustrina*			C3			C6		
Urticaceae								
Urtica incisa			C3	C4	C5	C6		
Violaceae								
Viola betonicifolia	C1		C3		C5			
Viola hederacea	C1		C3					
Xanthorrhoeaceae								
Xanthorrhoea glauca subsp. *angustifolia*								O

Mosses, Liverworts and Hornworts of Mount Canobolas, New South Wales

Alison Downing, Ron Oldfield and Eleanor Fairbairn-Wilson

Downing, Alison[1], Oldfield, Ron[1] and Fairbairn-Wilson, Eleanor[2] ([1]Department of Biological Sciences, Macquarie University NSW 2109; [2]Orange Agricultural Institute, Forest Road, Orange NSW 2800) *2002. Mosses, Liverworts and Hornworts of Mount Canobolas, New South Wales.* Cunninghamia *7(3): 527–537.*

A surprising number of endemic species of plants and animals are found within Mount Canobolas State Recreation Area (33°21′ S, 148°59′ E, 1395 m asl) 15 km SW of Orange in the Central West of New South Wales. During this survey of bryophytes on Mount Canobolas, 75 species, including 60 moss species, 13 liverwort species and two hornwort species were identified. Although no endemic bryophyte species were recorded, the assemblage included an unusual combination of alpine, arid zone and rainforest species. Areas of exposed rock on the upper flanks of the mountain are particularly species rich. The geology of the area is complex and the presence of certain species at particular locations is probably determined by the chemical composition of the substrate rock. *Polytrichastrum alpinum*, a rare species in New South Wales previously recorded only above 1500 metres in alpine areas of Kosciuszko National Park, was collected on Mount Canobolas at 1206 m asl. A number of uncommon species were recorded in Mount Canobolas State Recreation Area, including the mosses *Bryoerythrophyllum jamesonii, Leptodontium paradoxum, Hymenostomum microstomum* var. *brachycarpa, Orthotrichum assimile, Tortula anderssonii, Tortula rubella* and *Tortula ruralis*, the liverwort *Riccia crozalsii* and the hornwort *Anthoceros* cf. *punctatus*.

Introduction

Mosses, liverworts and hornworts together comprise the three Classes of the Division Bryophyta of the Plant Kingdom. They are often referred to as 'lower plants' and are regularly overlooked in biological surveys although they are usually an important component of the vegetation. This study documents the bryophytes that occur in the Mount Canobolas State Recreation Area in central-western New South Wales. Mount Canobolas is most unusual in the many endemic species of a wide range of organisms that are found in its vicinity. The unique *Xanthoparmelia* lichen flora of rocky outcrops has recently been listed as an Endangered Ecological Community under the New South Wales *Threatened Species Conservation Act 1995.*

Mount Canobolas is located approximately 15 km southwest of Orange in the Central West of New South Wales (Fig. 1). The summit is 1395 m asl, approximately 500 m higher than Orange and the surrounding area. The State Recreation Area has an area of 1673 hectares, incorporating much of the natural vegetation of the mountain. Rather than one mountain, the area comprises a complex of peaks made up of both volcanic and intrusive rocks. Volcanic activity occurred over about 700 000 years, from Middle

Miocene to Late Miocene. Numerous volcanic vents — Young Man Canobolas, Old Man Canobolas, The Pinnacle, Mount Towac and Johnsons Pinnacle — erupted at different times; Old Man Canobolas was the last to erupt and is the youngest volcanic vent of the complex. The lavas vary from trachytes to andesitic basalts to basalts; the intrusive rocks include porphyries and dolerites. There are also large quantities of agglomerate and tuff associated with the various lava flows (Branagan & Packham 2000).

Meteorological data is available from several local observatories, Orange (Post Office, 33°28′ S, 149°10′ E, 863 metres asl) has warm to hot summers and cold winters. The mean annual rainfall is 878 mm, distributed relatively evenly throughout the year, but with slightly higher recordings during the cooler months. The temperature recordings for Mount Canobolas State Forest (33°39′ S, 149°02′ E, 987 metres asl), are cooler year round than those of Orange, and the rainfall (1097.5 mm per annum) is higher than that of Orange. Since Mount Canobolas is higher than the surrounding countryside, the summit is likely to have temperatures significantly cooler than Orange, and rainfall significantly higher. Snow is not uncommon on Mount Canobolas in winter. (Bureau of Meteorology 2002).

Mount Canobolas is located near the western boundary of the Central Tablelands Botanical Division. The vascular flora has been well documented, for example by Kenna, Medd and Bower (1998) and includes a surprising number of species with affinities to the alpine flora of southern New South Wales, Victoria and Tasmania. Much of the summit of Mount Canobolas has been cleared and is now topped by communications installations, public car parks and lookouts. Naturally occurring rock rubble and rocky outcrops surround these constructions. Soil in the crevices in and between the rocks support grasses, herbs and low shrubs. The open area of the summit is adjoined by sub-alpine *Eucalyptus pauciflora* (Snow Gum) woodland with a dense cover of *Poa sieberiana* (Snow Grass). Further down the mountain there is a mixed *Eucalyptus* woodland, merging into tall *Eucalyptus* forest on the moist and sheltered eastern and southern flanks of the mountain. There are occasional broad expanses of rock, for example at Orange View Lookout and at the Walls Nature Trail, on which there are low heaths associated with rich lichen communities.

There is very little information available on the distribution of bryophytes in this western sector of the Central Tablelands Botanical Division. The closest area for which there is a comprehensive bryophyte collection is in the vicinity of the Abercrombie River, well to the south-east, made by Robert Coveny in 1995 and held by the National Herbarium of New South Wales. Eldridge & Tozer (1997) have contributed significantly to the knowledge of bryophytes from the drier areas of semi-arid western New South Wales, but their collections held at the National Herbarium of NSW do not include specimens from Mount Canobolas. Many of the species documented by Eldridge and Tozer in semi-arid western New South Wales also occur on Mount Canobolas. Downing (1993) collected bryophytes from numerous, small, isolated limestone outcrops between Wellington and Molong, and more recently in 2000 and 2001, collected bryophytes at Borenore Caves, west of Orange (Downing, unpublished records).

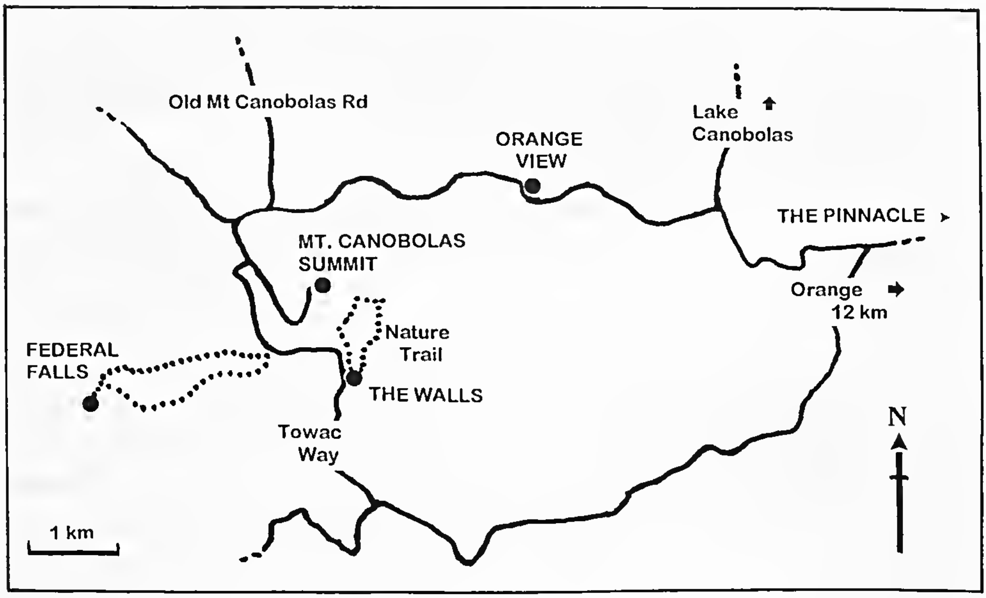

Fig. 1. Mt. Canobolas – bryophyte collecting sites.

Methods

In November 2001, mosses, liverworts and hornworts were collected from within the Mount Canobolas State Recreation Area, from sites reflecting differences in altitude, aspect, vegetation type and substrate. These collection sites included rocky outcrops, constructed car parks, stone walls and paths of the summit, *Eucalyptus* woodland and forest of the flanks of the mountain, and areas of low heath on exposed rock. Additional collections were made in the vicinity of The Pinnacle Lookout, an Orange City Council reserve close to the boundary of the State Recreation Area.

The collections were returned to the laboratory and identified using references, including Scott and Stone (1976), Beever, Allison and Child (1992), Catcheside (1980) and Scott (1985). Authorities for species mentioned in the text for the most part follow the Index of Mosses Database (W^3MOST) which is part of the TROPICOS data base of the Missouri Botanical Garden (2002) and are included in Table 1.

Judith Curnow from Australian National Botanic Gardens Herbarium in Canberra provided a list of species from Mount Canobolas from their records. These are marked # in Table 1. The Canberra collections of Heinar Streimann, August, 1979, came from two sites: *Eucalyptus* woodland (at 1390 m asl just below the summit) of Mount Canobolas and from Federal Falls, a moister area of *Eucalyptus* woodland at 910 m asl. Only one record from Mount Canobolas was found in the National Herbarium of NSW, *Bryum creberrimum*, collected in 1988 by Brooks & Pilgrim.

Vouchers for each species collected from Mount Canobolas have been lodged with the National Herbarium of NSW, Mrs Macquaries Road, Sydney, NSW 2000. Duplicates of unusual species have been lodged with Macquarie University Herbarium, Department of Biological Sciences, Macquarie University, North Ryde, NSW 2109.

Table 1 Bryophytes collected from the Mount Canobolas State Recreation Area

Summit = species collected above 1380 m asl. Walls = Walls Nature Trail, Towac includes a number of locations in the vicinity of the junction of the Towac Road with the Summit Road, Pinnacle = The Pinnacle, an isolated knoll east of the State Recreation Area, OrangeV = Orange View Lookout, Old Rd = Old Mount Canobolas Road, Fed Falls = Federal Falls.
# = Records of Australian National Herbarium, Canberra.

MOSSES	Summit	Walls	Towac	Pinnacle	OrangeV	Old Rd	Fed Falls
Bartramiaceae							
Bartramia hampeana Müll. Hal.	*		*				
Bartramia ithyphylla Brid.	#						
Breutelia affinis (Hook.) Mitt.	*	*	*	*	*	*	
Philonotis scabrifolia (Hook.f. & Wilson) Braithw.							#
Philonotis tenuis (Taylor) Reichardt		*	*			*	
Brachytheciaceae							
Brachythecium rutabulum (Hedw.) Schimp.		*	*				
Brachythecium paradoxum (Hook.f. & Wilson) Jaeger			*	*			
Bryaceae							
Bryum apiculatum Schwaegr.	#						
Bryum argenteum Hedw.	*,#				*	*	
Bryum caespiticium Hedw.	*						
Bryum campylothecium (Taylor) J.R.Spence		*					
Bryum creberrimum Taylor		*			*		
Bryum dichotomum Hedw.			*		*	*	
Bryum radiculosum Brid.	#						
Rosulabryum billarderi (Schwaegr.) J.R.Spence	*						#
Rosulabryum torquescens (Bruch ex De Not) J.R.Spence	*						
Dicranaceae							
Campylopus australis Catches. & J.P.Frahm	#						
Campylopus introflexus (Hedw.) Brid.		*			*	*	

MOSSES	Summit	Walls	Towac	Pinnacle	OrangeV	Old Rd	Fed Falls
Ditrichaceae							
Ceratodon purpureus (Hedw.) Brid.	*			*	*	*	
Ditrichum difficile (Duby) M.Fleisch.		*		*			
Eccremidium pulchellum (Hook.f. & Wilson) Müll. Hal.					*		
Pleuridium nervosum (Hook.) Mitt.		*	*				
Encalyptaceae							
Encalypta vulgaris Hedw.						*	
Fabroniaceae							
Fabronia australis Hook.	#						
Fissidentaceae							
Fissidens asplenioides Hedw.	#	*					#
Fissidens leptocladus Müll. Hal. ex Rodway				*			
Fissidens megalotis (Hook. & Wilson) Stone					*		
Fissidens pungens Hampe & Müll. Hal.							#
Fissidens taylorii Müll. Hal.		*	*			*	#
Funariaceae							
Entosthodon muhlenbergii (Turner) Fife			*				
Entosthodon subnudus (Taylor) Fife var. *gracilis*		*					
Funaria apophysata (Taylor) Broth.			*				
Grimmiaceae							
Grimmia laevigata (Brid.) Brid.						*	
Grimmia longirostris Hook.			*				
Grimmia pulvinata (Hedw.) Sm.	*,#				*		
Grimmia trichophylla Grev.	#	*		*			
Schistidium apocarpum (Hedw.) Bruch & Schimp.	*		*		*	*	
Hedwigiaceae							
Hedwigidium integrifolium (P.Beauv.) Dixon		*		*			

MOSSES	Summit	Walls	Towac	Pinnacle	OrangeV	Old Rd	Fed Falls
Hypnaceae							
Hypnum cupressiforme Hedw.		*		*	*		
Orthotrichaceae							
Orthotrichum assimile Muell. Hal.	#						
Zygodon intermedius Bruch & Schimp.	#						#
Polytrichaceae							
Polytrichastrum alpinum (Hedw.) G.L.Sm.		*					
Polytrichum juniperinum Hedw.	*	*		*	*	*	
Pottiaceae							
Barbula calycina Schwaegr.	*				*		
Barbula crinita Schultz	*				*		
Bryoerythrophyllum jamesonii (Taylor) H.A.Crum			*				
Didymodon subtorquatus (Müll. Hal. & Hampe) Catches.			*				
Hymenostomum microstomum (Hedw.) R.Br. var. *brachycarpa*			*				
Leptodontium paradoxum I.G. Stone & G.A.M. Scott		*				*	
Tortula anderssonii Ångström	#						
Tortula antarctica (Hampe) Wilson	*	*			*	*	
Tortula muralis Hedw.	*		*				
Tortula pagorum (Milde) De Not.	*				*		
Tortula papillosa Wilson ex Spruce	*						
Tortula rubella Hook. & Wilson	#						
Tortula ruralis (Hedw.) P. Gaertn, B. Mey & Scherb.	#						
Triquetrella papillata (Hook.f. & Wilson) Broth.	*	*		*		*	
Racopilaceae							
Racopilum cuspidigerum (Schwaegr.) Ångström			*				#

MOSSES	**Summit**	**Walls**	**Towac**	**Pinnacle**	**OrangeV**	**Old Rd**	**Fed Falls**
Splachnaceae							
Tayloria octoblepharum (Hook.) Mitt.		*					
Thuidiaceae							
Thuidium sparsum (Hook.f. & Wilson) Jaeger	*						
LIVERWORTS							
Aytoniaceae							
Asterella drummondii (Hook.f. & Taylor) R.M.Schust.		*	*		*		
Cephaloziellaceae							
Cephaloziella exiliflora (Taylor) R.M.Schust.		*					
Cephaloziella arctica Bryhn & Douin subsp. *subantarctica*					*		
Codoniaceae							
Fossombronia sp.			*				
Frullaniaceae							
Frullania pentapleura Taylor	#						#
Frullania wildii Stephani	#						
Frullania probosciphora Taylor				*			
Geocalycaceae							
Chiloscyphus fissistipus (Hook.f. & Taylor) Taylor ex Gottsche et al.				*			
Chiloscyphus semiteres (Lehm.) Lehm. & Lindenb.		*		*	*		
Metzgeriaceae							
Metzgeria decipiens (C.Massal.) Schiffner		*					
Metzgeria furcata (L.) Dumort.							#
Ricciaceae							
Riccia crozalsii Levier					*		
Riccia rorida Na –Thalang		*					
HORNWORTS							
Anthocerotaceae							
Anthoceros cf. *punctatus* L.			*	*			
Phaeoceros laevis L.			*				

Results and Discussion

Seventy-five bryophyte species were recorded from Mount Canobolas, including 60 species of moss from 18 families, 13 species of liverworts from seven families, and two species of hornworts from one family (Table 1). New records for the Central Tablelands Botanical Division of NSW are: the mosses, *Polytrichastrum alpinum, Eccremidium pulchellum, Hymenostomum microstomum* var. *brachycarpa, Leptodontium paradoxum, Orthotrichum assimile, Tortula anderssonii, Tortula rubella* and *Tortula ruralis,* the liverwort *Riccia crozalsii* and the hornwort *Anthoceros* cf. *punctatus.*

It would be helpful to compare the bryophyte species richness at Mount Canobolas with surrounding areas, but the lack of collections from the western slopes of the Great Dividing Range casts doubt on the validity of such comparisons. Many of the bryophytes that grow on Mount Canobolas are also found in the Blue Mountains and the hills of the Great Dividing Range to the east. Coveny collected 53 bryophytes (39 mosses and 14 liverworts) along the Abercrombie River; of these, 28 mosses and five liverworts, were also recorded on Mount Canobolas. However, just a few kilometres further west of Mount Canobolas in the Central Western Slopes Botanical Division, there are significanly fewer bryophyte species.

A particularly unusual aspect of the distribution of mosses, liverworts and hornworts on Mount Canobolas has been the difficulty in assigning species to particular habitats. On the sandstones of the Sydney area and the Blue Mountains, it is relatively easy to predict where certain species will occur. Some species occur only on the ridge tops, others on the valley sides, and yet others occur only in the shelter of closed forest in gullies. However, on Mount Canobolas it was almost impossible to predict occurrences and we have had to review our findings carefully. It seems probable that distribution of many species is very closely related to the chemical composition of the substrate rock — rather than to altitude, aspect, or vegetation type. The geology of the area is quite complex, and it appears likely that bryophyte distribution can be correlated with the considerable acidic/basic variability of the underlying rock. For example, a small, rocky outcrop in *Eucalyptus* woodland on the Old Mount Canobolas Road yielded an unusual combination of two species, *Encalypta vulgaris,* a calcicole (i.e. a species found only on calcareous substrates), and *Campylopus introflexus,* a calcifuge (i.e. a species never found growing on calcareous substrates). The occurrence of these two species growing in such close proximity suggested that species distribution could be more closely correlated with the chemical nature of the substrate rock rather than with any other factor.

Bryophytes on rock exposures

Mosses and liverworts are most conspicuous in areas of bare rock or soil, in particular the rocky areas of the summit, and in the heath/lichen communities on broad rock exposures. Thirty species of mosses and two liverworts were collected on or just below the Mount Canobolas summit. Here they grow in abundance on rock and on soil, both in the developed areas of roads, walking tracks, car parks and buildings, and also in the adjoining open areas of naturally occurring rock rubble and bare rock.

Ramsay et al. (1986) document *Grimmia laevigata, Grimmia pulvinata* and *Schistidium apocarpum* as alpine species in NSW, although all three are found elsewhere in Australia at much lower altitude. Mosses from the family Pottiaceae are abundant on and near the summit. Some rare finds include *Tortula anderssonii, Tortula ruralis* and *Tortula rubella. Tortula anderssonii* was until recently known in Australia only from Yarrangobilly Caves in the northern end of Kosciuszko National Park. *Tortula ruralis* and *Tortula rubella* are also not common and more usually collected at higher altitudes. *Orthotrichum assimile* and *Zygodon intermedius*, both from the family Orthotrichaceae, are also more usually collected at higher altitudes in southern NSW. Some more common species including *Barbula crinita, Tortula antarctica, Tortula pagorum, Tortula papillosa* and *Triquetrella papillata*, probably reflect the occasional aridity of the summit, as they are a common component of arid and semi-arid areas of southern Australia (Eldridge & Tozer 1997) They have anatomical characteristics that enable them to survive extreme desiccation resulting from high temperatures, lack of moisture, exposure to wind, and damage to photosynthetic tissue from high light intensities.

Another group of mosses, including *Bryum argenteum, Ceratodon purpureus, Polytrichum juniperinum* and *Tortula muralis* are cosmopolitan, with a worldwide distribution. Although they occur naturally in Australia, and are present elsewhere on Mount Canobolas in undisturbed areas of natural vegetation, their abundance at the summit appears to be associated with the construction of the roads, parking areas, stone walls and buildings.

The Walls Nature Trail is another very rich area; 20 species of moss and five species of liverwort were collected along the trail. Here species richness is probably related to the diversity of habitats — including both wet and dry heath/lichen communities on the exposed metamorphosed sandstone, wet, seeping, trackside banks at the junction of the heath and *Eucalyptus* woodland, and a cool, moist and shaded gully with terrestrial ferns. *Metzgeria decipiens*, a thallose epiphytic liverwort more usually associated with rainforest gullies of the coast and coastal ranges, was found along this gully. *Metzgeria furcata* from Federal Falls, is also more usually associated with rainforests.

The presence of *Polytrichastrum alpinum* on Mount Canobolas was unexpected. This species was collected at the start of the Walls Nature Trail (1206 m asl) growing through clumps of other mosses and lichens. It is recorded by Scott and Stone (1976 p. 68) as 'almost exclusively alpine in habitat ... a rare plant, growing on bare soil and in wet crevices mostly above about 5000 ft' (about 1500 metres). The National Herbarium of NSW holds two specimens of *Polytrichastrum alpinum* (as *Polytrichum alpinum* L. ex Hedw.) both collected in 1899 from Mount Kosciuszko.

On exposed rock, in microphytic soil crusts a few mm deep, tiny mosses such as *Pleuridium nervosum* and the minute liverwort *Cephaloziella exiliflora* were collected. Also present are *Riccia rorida* and *Asterella drummondii*, thallose liverworts more usually associated with arid and semi-arid areas of southern Australia. *Breutelia affinis* is abundant on damp seepage areas over the rock, forming dense, golden banks.

Another area of particular interest is the heath community on exposed rock at the Orange View Lookout, on the north-eastern side of the mountain (1154 metres asl); 20 species were recorded, including 16 mosses and four liverworts. On seepage areas on the broad, rocky exposures, there is an abundant growth of *Breutelia affinis*, together with *Bryum creberrimum* and *Campylopus introflexus*.

Bryophytes in Eucalyptus woodland and forest

Where grasses grow as a dense ground cover in *Eucalyptus* woodland or forest, bryophytes are virtually non-existent. However, bryophytes do successfully colonise roadside banks, the margins of walking trails, rough basal bark of eucalypts, fallen logs and exposed rocks. The ubiquitous *Breutelia affinis* forms golden cushions along some sections of road. Both hornworts, *Anthoceros* cf. *punctatus* and *Phaeoceros laevis* were collected from a damp, roadside bank in *Eucalyptus* forest with a south-easterly aspect. Some unusual species are also present, including *Bryoerythrophyllum jamesonii*, *Didymodon subtorquatus* and *Hymenostomum microstomum* var. *brachycarpa*. *Bryoerythrophyllum jamesonii* (syn. *B. binnsii*) is a rare species, recorded by Scott and Stone (1976) from Tasmania and Victoria; however, a small population was recently reported from a volcanic outcrop at Mount Wilson in the Blue Mountains (Graham Bell, pers. comm.). *Leptodontium paradoxum* is not uncommon along the southern coast of Australia, from Western Australia through South Australia to Victoria, but there are no records at the National Herbarium of NSW of this species occurring in the Central Tablelands. *Hymenostomum microstomum* var. *brachycarpa* is listed by Catcheside (1980) as rare in South Australia and Victoria and this is the first record of its occurrence in NSW.

Bryophytes at The Pinnacle

The Pinnacle Lookout is not included within the Mount Canobolas State Recreation Area. However, the bryophyte flora is particularly interesting and includes a number of species either not recorded from, or not common in, the State Recreation Area. These are the liverworts *Frullania probosciphora* and *Chiloscyphus fissistipus*, and the moss *Fissidens leptocladus*. *Brachythecium paradoxum* is a bryophyte frequently found in alpine and sub-alpine environments; it is common and abundant on the rough bark at the base of snow gums in the sub-alpine *Eucalyptus pauciflora* woodlands of Kosciuszko National Park. *Chiloscyphus fissistipus* and *Frullania probosciphora* are both species more usually associated with moist, rainforest gullies of the coast and coastal ranges.

Conclusion

The bryoflora of Mount Canobolas is an unusual assemblage of moss, liverwort and hornwort species. The distribution of bryophytes is unpredictable and the presence of certain species at particular locations can probably be correlated with the chemical composition of the substrate rock. The bryoflora includes some species with alpine affinities, others more common in the arid or semi-arid areas of Australia, and some species more usually associated with rainforest environments. Areas of exposed rock, at the summit, in the vicinity of the Orange View Lookout, and at the beginning of the Walls Nature Trail, are particularly species rich. *Polytrichastrum alpinum*, collected at

1206 m asl on Mount Canobolas, is a rare species in New South Wales where it has previously only been recorded from alpine areas above 1500 metres. The bryoflora of The Pinnacle Reserve includes a number of species that do not commonly occur within the Mount Canobolas State Recreation Area.

Time constraints limited the number of locations that could be visited during the course of this survey, and further collections from the Federal and Hopetoun Falls could add significantly more species. Collections at other times of the year may well include other annual and/or ephemeral species.

The lack of bryophyte collections and the paucity of information available on bryophyte distribution in areas west of the Great Dividing Range has highlighted the urgent need for bryological surveys of the natural areas of the western sector of the Northern, Central and Southern Tablelands Botanical Divisions, and the North Western, Central Western and South Western Botanical Divisions of New South Wales.

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References

Beever, J., Allison, K.W. & Child, J. (1992) *The Mosses of New Zealand* (University of Otago Press: Dunedin: New Zealand).

Branagan, D. F. & Packham, G. H. (2000) *Field geology of New South Wales* (NSW Department of Mineral Resources: Sydney).

Bureau of Meteorology, Australia (2002) *Climatic averages for Australian sites* (www.bom.gov.au/climate/averages/)

Catcheside, D.G. (1980). *Mosses of South Australia* (Government Printer: Adelaide).

Downing, A.J. (1993) Bryophytes on calcareous substrates in south eastern Australia. M.Sc. Thesis (unpublished).

Eldridge, D. & Tozer, M.E. (1997) *A practical guide to soil lichens and bryophytes of Australia's dry country* (Department of Land & Water Conservation: Sydney).

Kenna, J.I., Medd, R.W. & Bower, C.C. (1998) *Flora of the walking tracks of Mt Canobolas State Recreation Area* (Orange Field Naturalist and Conservation Society Inc.).

Missouri Botanical Garden (2002) Index of Mosses Database (W^3MOST). (www.mobot.org/MOBOT/TROPICOS/most/iom/shtml)

Ramsay, H.P., Streimann, H., Ratkowsky, A.V., Seppelt, R. & Fife, A. (1986) Australasian alpine bryophytes. Pp. 300–335 in: Barlow, B.A. *Flora and fauna of alpine Australasia, ages and origins.* (CSIRO: Melbourne).

Scott, G.A.M. (1985) *Southern Australian liverworts* (Australian Government Publishing Service: Canberra).

Scott, G.A.M. & Stone, I.G. (1976) *The mosses of Southern Australia* (Academic Press: London).

Vegetation and floristics of Burnt Down Scrub Nature Reserve, North Coast, New South Wales

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The vegetation of Burnt Down Scrub Nature Reserve, 15 km south west of Baryugil in the Parish of Carnham on the North Coast of New South Wales is described. A floristic survey of 28 × 0.04 ha plots was conducted in December of 1999. Five communities are defined based on flexible UPGMA analysis of abundance scores of vascular plant taxa. These communities are mapped based on ground truthing, air photo interpretation and substrate.

A total of 355 vascular plant taxa was recorded including four species listed as rare or threatened: *Marsdenia liisae, Olearia heterocarpa, Sarcochilus weinthalii* and *Tinospora smilacina*. This paper describes the communities and discusses their significance and distribution within the Nature Reserve. A vegetation map and species list are provided.

Introduction

Burnt Down Scrub Nature Reserve is located 8 km north-north-west of the junction of the Mann and Clarence Rivers and 15 km south west of Baryugil (Fig. 1). The Nature Reserve is within the North Coast Botanical Subdivision and the New South Wales North Coast (NNC) Bioregion. The reserve includes 338 ha incorporating Portions 94 and 99 of the Parish of Carnham and the County of Drake. Freehold land currently used for grazing purposes surrounds the Nature Reserve. Burnt Down Scrub NR was dedicated under the *Forestry and National Park Estate Bill 1998* and was gazetted on 1 January 1999.

This paper gives part of the results of a flora survey conducted for the Northern Tablelands Region of the NSW National Parks and Wildlife Service (NSW NP&WS). The aims of this study were to provide a vegetation map of communities to assist in fire management of the Nature Reserve and to provide information on the distribution of rare, geographically restricted or disjunct taxa within the conservation area. This information will be used to develop appropriate management strategies (Hunter 2000).

Geology and geomorphology

Burnt Down Scrub Nature Reserve is in undulating to rugged terrain associated with the upper reaches of the Clarence River catchment. Aspects are predominantly southern and western. Burnt Down Creek is a lesser tributary of the Mann River, and drains the reserve towards the south. The sedimentary basement rock has been deeply eroded and the reserve falls from 520 m to 200 m altitude over its length.

The basement rock types of the area are of argillites, phyllites, slates, limestone and intermediate volcanics which are of Ordovician to Silurian age (Floyd 1981). Just to the south west of the corner of the reserve is an outcrop of dioritic and gabbroic intrusives of Permian age.

History and landuse

The area of Portions 94 and 99 show some significant evidence of past clearing in patches and associated grazing. Some selective logging is evident in the closed forest patches along with greater selective logging in the open forest areas. When these operations occurred and for how long are not known. Following inspection in 1976 the area was gazetted as State Forest. Floyd (1981) recommended that Portion 99 be handed over to the management of the NSW NP&WS. However, it was considered that Portion 99 could be adequately managed within State Forests as a Flora Reserve. Burnt Down Scrub remained part of the Washpool State Forest after the Environmental Impact Statement of the Casino District (State Forests of NSW 1995) with the recognised Dry Rainforest assemblages reserved indefinitely from logging as a State Forest Reserve. The western boundary areas and most of Portion 94 were gazetted for logging in 2000–2002. Much of the western boundary of the reserve was, until gazettal, held under on occupational grazing permit.

Fires have been used as a management tool by the holders of grazing permits and by State Forests themselves, for both reduced fuel loads and green pick for cattle. A major fire swept through much of the reserve in 1985 (State Forests of NSW 1995). Previous information on fires is not currently available, however evidence during this field investigation indicated that some major fires have occurred over much of the reserve.

Previous investigations

Although few site-based data were available for Burnt Down Scrub, sufficient ground-based work had been conducted. The area covered by the reserve was originally checked by the Forestry staff Pople, Graham and Owens in 1976 and Owens later produced a sketch map of the vegetation. Alex Floyd visited the area in March 1981 to evaluate the rainforest contained in portion 99 (Floyd 1981). Floyd spent two days investigating the area and described two closed forest communities: a viney scrub on previously cleared areas that had been overgrown with *Lantana* and a myrtle scrub. Floyd considered the latter to be a remnant of a much larger rainforest (Floyd 1981). Floyd considered the Dry Rainforest was of considerable interest as it was a southern outlier of similar forests from the Richmond Valley, linking that region with similar associations in the Macleay, Guy Fawkes and Kangaroo Rivers regions. In 1994 Doug Binns placed three sites within what is now Burnt Down Scrub Nature Reserve in order to assess the vegetation for the EIS of the Casino District forestry operations (Binns 1995).

Methods

This survey was conducted over three days in December 1999. Twenty eight, 20 × 20 m quadrats were surveyed for vascular plants scored using the Braun-Blanquet (1982) cover abundance scale. Quadrats were placed using a stratified random method using past vegetation mapping to delineate strata in which random quadrats were placed.

Good quality plant material was retained as vouchers by the Northern Tablelands Region of the NSW NP&WS and duplicates of significant collections submitted to the Herbarium of the North Coast Botanic Gardens (COFFS). Nomenclature follows that of Harden (1990–1993) except where recent changes have been made.

Analyses and data exploration were performed using options available in the PATN Analysis Package (Belbin 1995a, b). For final presentation of results all species and their relative abundance scores were used and the analysis performed using Kulczynski association measure which is recommended for ecological applications (Belbin 1995a, b) along with flexible UPGMA and the default PATN settings.

Delineation of community boundaries in Fig. 2 was based on the location of sites and their position within the multivariate analysis, air photograph interpretation and ground truthing. The vegetation map is based on a 1: 25 000 scale. Structural names follow Specht et al. (1995) and are based on the most consistent uppermost stratum.

Results and Discussion

Five communities were recognised at the dissimilarity measure of c. 0.9. A summary of the community relationships is given by the dendrogram (Fig. 3). The first major division on the dendrogram separates open forests from closed or mixed forests. The next major division separates closed forests from mixed forests. In all 355 vascular plant taxa from 106 families and 252 genera, were recorded from the collation of existing site data and subsequent sampling (Appendix). Approximately 3.5% (12) of all taxa were exotic. Four species are listed as rare or threatened within Briggs and Leigh (1996) or on the *Threatened Species Conservation Act 1995* and include: *Marsdenia liisae* (3RC–), *Olearia heterocarpa* (2RCa), *Sarcochilus weinthalii* (3VC– & Schedule 2, *Vulnerable TSC Act 1995) and Tinospora smilacina (Schedule 1, Endangered TSC Act 1995)*. All communities are described based on their native flora components.

Vegetation communities

Two broad types of natural community structure were found. Tall open forests were located in the northern half of the reserve and these are dominated by a variety of eucalypt species with a grassy understorey and in some cases a prominent mesic shrub layer. In the rest of the reserve low closed forests are found with eucalypt emergents. In some situations where past clearing has occurred closed forest gives way to dense *Lantana* infestations. A summary of relevant statistics for each community is presented in Table 1. In the following descriptions of communities, extreme values are given in brackets. See Appendix for a species list for the flora of Burnt Down Scrub Nature Reserve.

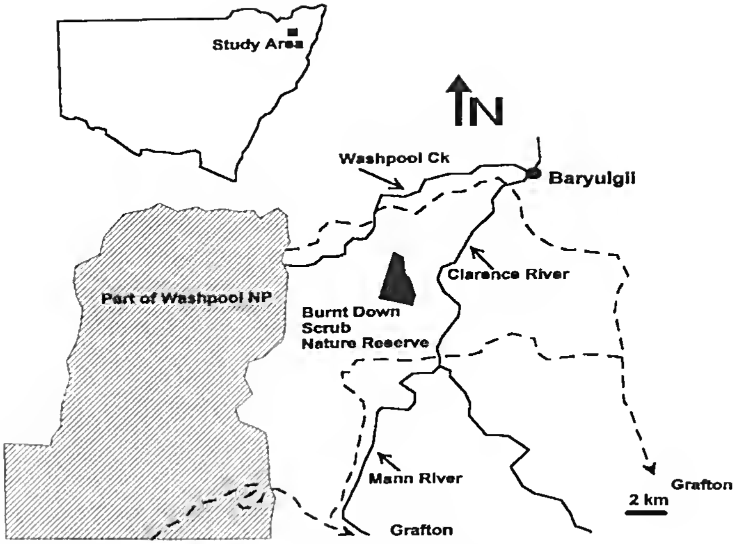

Fig.1. Map of locality of the Burnt Down Scrub Nature Reserve.

Fig. 2. Map of vegetation communities for Burnt Down Scrub Nature Reserve.

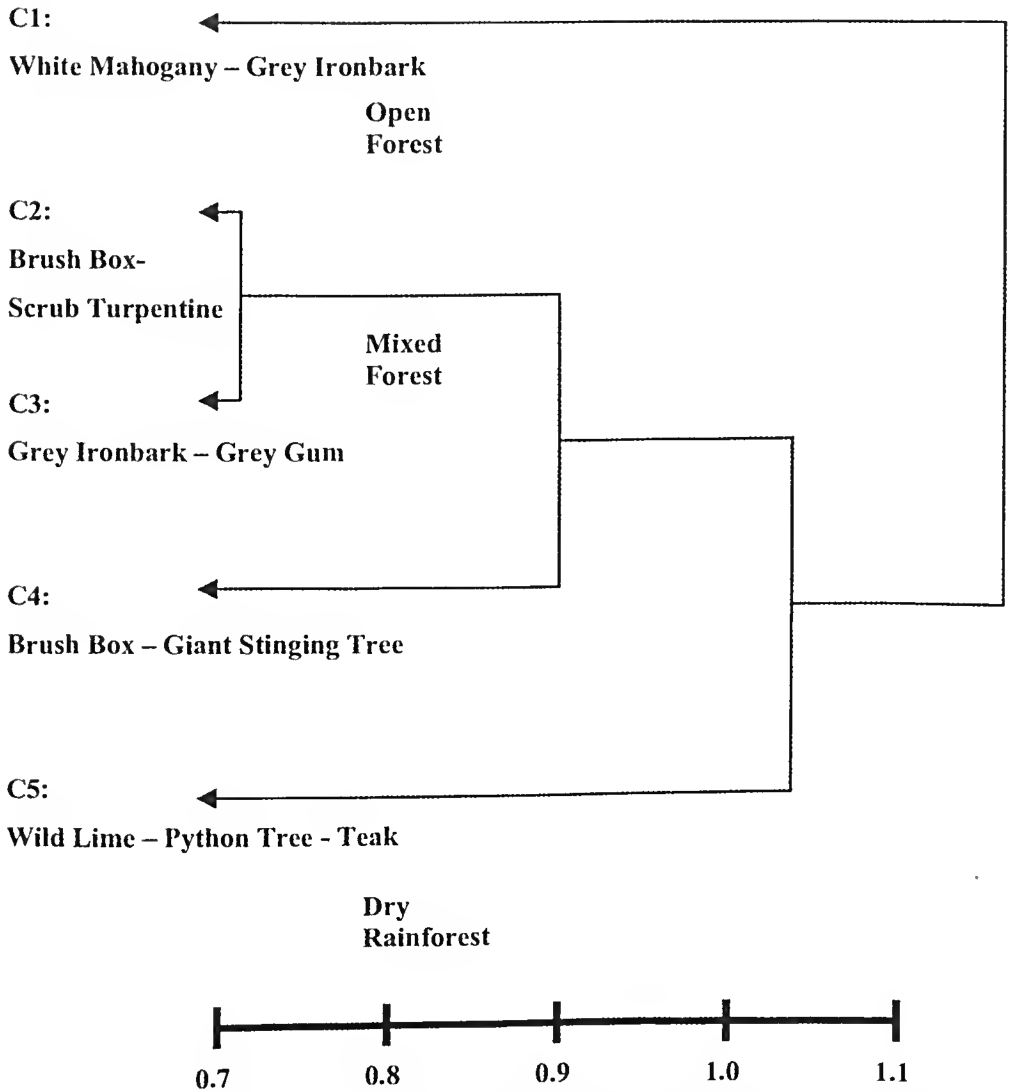

Fig. 3. Summary dendrogram of the full floristic dataset of sites using the Kulczynski association and flexible UPGMA fusion strategy and a β value of -0.1. Communities have been defined at a dissimilarity level of c. 0.9.

Table 1: Selected attributes of the seven defined communities at Burnt Down Scrub Nature Reserve.

Community	Number of Sites	Richness per 400 m² (average)	Number of Species	Number of Introduced Species	Proportion of Reserve	Number of Hectares
C1: White Mahogany – Grey Ironbark	10	16–42 (32)	110	7	19%	72
C2: Brush Box – Scrub Turpentine	5	29–50 (41)	105	2	7%	28
C3: Grey Ironbark – Grey Gum	4	39–48 (42)	92	6	12%	45
C4: Brush Box – Stinging Tree	3	18–35 (28)	59	1	17	66
C5: Wild Lime – Python Tree – Teak	6	13–41 (25)	75	1	45	175

Community 1: White Mahogany – Grey Ironbark Tall Open Forest

White Mahogany (*Eucalyptus acmenoides*) – Grey Ironbark (*Eucalyptus siderophloia*) – Small-fruited Grey Gum (*Eucalyptus propinqua*)

Distribution: Mainly in the northern and south-western sections of the reserve on moist loamy, deep and dark brown soils.

Structure: Upper (20–) 25–30 m tall; (20–) 25–30% cover. Upper middle layer, to 15 m tall, usually not present; to 25 % cover. Lower middle layer 3–5 (–8) m tall; 10–30 (–40)% cover. Ground layer to 1 m tall; 90% cover.

Trees: *Eucalyptus acmenoides, Eucalyptus siderophloia, Eucalyptus propinqua, Eucalyptus microcorys, Allocasuarina torulosa, Eucalyptus moluccana, Corymbia gummifera, Corymbia citriodora* subsp. *variegata, Eucalyptus saligna, Lophostemon confertus, Eucalyptus umbra.*

Shrubs: *Acacia irrorata, Desmodium brachypodum, Breynia cernua, Macrozamia fawcetii, Swainsona brachycarpa, Solanum densevestitum, Lespedeza juncea, Xanthorrhoea glauca, Rapanea variabilis, Jacksonia scoparia, Solanum stelligerum, Polyscias sambucifolia, Indigofera australis, Pimelea neo-anglica, Alpinia caerulea, Acacia longifolia, Acacia falciformis.*

Climbers & trailers: *Hibbertia scandens, Hardenbergia violacea, Desmodium varians, Glycine clandestina, Rubus parvifolius, Rubus rosifolius, Eustrephus latifolius, Clematis glycinoides, Glycine tabacina, Austrosteenisia blackii.*

Ground flora: *Sorghum leiocladum, Imperata cylindrica, Poa sieberiana, Vernonia cinerea, Pteridium esculentum, Dianella caerulea* var. *assera, Viola betonicifolia, Lepidosperma laterale, Hydrocotyle peduncularis, Lomandra longifolia, Dichondra repens, Themeda triandra, Senecio lautus* subsp. *lanceolatus, Proiphys cunninghamii, Plectranthus parviflorus, Oplismenus imbecillis, Lomandra multiflora, Geranium solanderi* subsp. *solanderi, Calochlaena dubia, Viola hederacea, Veronica calycina, Ranunculus lappaceus, Dianella caerulea* var. *caerulea, Cyperus enervis, Chrysocephalum apiculatum, Ajuga australis.*

Variability: Two distinct sub-assemblages are apparent based on overstorey species, but which are similar in their understorey components. Across the north-eastern boundary the community is dominated by *Eucalyptus acmenoides* with *Eucalyptus siderophloia, Eucalyptus propinqua* and a minor component of *Eucalyptus moluccana* this grades to a more *Eucalyptus siderophloia* dominated patch with the addition of *Corymbia gummifera* on the north-western boundary. The second sub-assemblage occurs in the south-west of the reserve; here *Corymbia citriodora* subsp. *variegata* is prominent.

Conservation and management issues: Considered well reserved across its range. The adventive *Lantana* is only a minor component of this community at present. It is possible that this assemblage will undergo some floristic and structural change and that current boundaries may not be stable under different fire regimes.

Community 2: Brush Box – Scrub Turpentine Tall Open Forest

Brush Box (*Lophostemon confertus*) – Scrub Turpentine (*Rhodamnia rubescens*) – Tallowwood (*Eucalyptus microcorys*)

Distribution: Along gullies primarily in the northern section of the reserve. Soils are primarily damp, loamy, deep and dark brown to brown.

Structure: Upper layer 25–30 m tall; 30–40% cover. Upper middle layer often not present 5–15 m tall; about 40% cover. Lower middle layer often not present 2–6 m tall; cover 20%. Ground layer to 1 m tall; ground cover variable 30–90%.

Trees: *Lophostemon confertus, Rhodamnia rubescens, Eucalyptus microcorys, Guioa semiglauca, Quintinia sieberi, Eucalyptus acmenoides, Eucalyptus saligna, Eucalyptus siderophloia, Dendrocnide excelsa, Synoum glandulosum, Rapanea variabilis, Ficus coronata, Euroschinus falcata, Endiandra virens.*

Shrubs: *Alpinia caerulea, Cordyline petiolaris, Citriobatus pauciflorus, Neolitsea dealbata, Pimelea strigosa, Solanum densevestitum, Maytenus bilocularis, Hibiscus heterophyllus, Acacia longifolia, Swainsona brachycarpa, Solanum stelligerum, Senecio amygdalifolius, Livistona australis, Psychotria loniceroides, Melicope erythrococca, Breynia cernua, Alchornea ilicifolia, Acacia irrorata.*

Climbers & trailers: *Rubus rosifolius, Cissus antarctica, Smilax australis, Pandorea pandorana, Desmodium varians, Cayratia clematidea, Austrosteenisia blackii, Marsdenia liisae, Hibbertia scandens, Glycine clandestina, Eustrephus latifolius.*

Ground flora: *Poa sieberiana, Imperata cylindrica, Blechnum cartilagineum, Oplismenus imbecillis, Dianella caerulea* var. *assera, Viola hederacea, Lomandra longifolia, Gahnia sieberiana, Cyperus tetraphyllus, Calochlaena dubia, Adiantum aethiopicum, Typhonium brownii, Senecio lautus* subsp. *lanceolatus, Geranium solanderi* subsp. *solanderi, Doodia aspera, Senecio* sp. E, *Proiphys cunninghamii, Oxalis perennans, Lepidosperma laterale, Galium migrans, Gahnia melanocarpa.*

Variability: Two sub-assemblages may be delineated. Areas upstream with potentially greater incursion of fires have a less well developed mesic understorey and are dominated by trees found in the adjacent Community 1, namely *Eucalyptus acmenoides* and *Eucalyptus microcorys*. Down stream the community has a dense mesic understorey and is dominated by *Lophostemon confertus* and *Eucalyptus saligna*.

Conservation and management issues: An extremely widespread association that is found in the majority of reserves along the escarpment of the North Coast. This community is well reserved both locally and regionally. Development depends on time since last fire and depth of incursion. This community occurs in narrow bands with a large edge to area ratio. If fires occur less frequently this community is likely to expand and develop structurally.

Community 3: Grey Ironbark – Grey Gum Tall Open Forest

Grey Ironbark (*Eucalyptus siderophloia*) – Small-fruited Grey Gum (*Eucalyptus propinqua*) – Brush Box (*Lophostemon confertus*)

Distribution: On steeper slopes in comparably exposed positions. The soils are moist to damp, loamy, dark brown to brown and deep.

Structure: Upper layer (14–) 25–30 m tall; cover 30–35%. Upper mid layer usually present 8–15 m tall; 40% cover. Lower mid layer often not present 2–8 m tall; cover 10–30%. Ground layer, 1–3 m tall; cover variable (30–) 70–90%.

Trees: *Eucalyptus siderophloia, Eucalyptus propinqua, Lophostemon confertus, Eucalyptus acmenoides, Corymbia citriodora* subsp. *variegata, Eucalyptus microcorys, Quintinia sieberi, Eucalyptus moluccana, Eucalyptus fibrosa, Zanthoxylum brachyacanthum, Rhodamnia rubescens.*

Shrubs: *Swainsona brachycarpa, Callistemon salignus, Solanum densevestitum, Pimelea neo-anglica, Hibiscus heterophyllus, Solanum campanulatum, Polyscias sambucifolia, Xanthorrhoea glauca, Psychotria loniceroides, Pimelea strigosa, Neolitsea australiensis, Solanum stelligerum, Senna clavigera, Olearia heterocarpa, Nyssanthes diffusa, Cordyline petiolaris.*

Climbers & trailers: *Desmodium varians, Eustrephus latifolius, Pandorea pandorana, Marsdenia lloydii, Glycine clandestina, Cissus antarctica, Smilax australis.*

Ground flora: *Poa sieberiana, Sorghum leiocladum, Oplismenus imbecillis, Lepidosperma laterale, Senecio lautus* subsp. *lanceolatus, Dichondra repens, Cyperus enervis, Lomandra longifolia, Hydrocotyle peduncularis, Dianella caerulea* var. *assera, Calochlaena dubia, Veronica calycina, Proiphys cunninghamii, Plectranthus parviflorus, Oxalis perennans, Imperata cylindrica, Senecio* sp. E, *Rhytidosporum procumbens, Dianella caerulea* var. *caerulea, Cyperus tetraphyllus, Alocasia brisbanensis.*

Variability: Probably somewhat intermediate between Community 1 and 2. It occurs along the margin of well developed closed forest. While the overstorey was relatively consistent the understorey was highly variable.

Conservation and management issues: Well reserved locally and across its range range. Likely to change over short time periods due to changes in management or incursions of fire. *Lantana* is a serious problem in some localities and is likely to expand into other parts.

Community 4: Brush Box – Stinging Tree Closed Forest

Brush Box (*Lophostemon confertus*) – Giant Stinging Tree (*Dendrocnide excelsa*) – Ivorywood (*Siphonodon australe*)

Distribution: Occurring patchily throughout the reserve where *Lantana* is at its densest.

Structure: Upper layer 20–40; cover 10–20%. Understorey 5–10 m tall; 90–100% cover.

Trees: *Lophostemon confertus, Dendrocnide excelsa, Siphonodon australis, Synoum glandulosum, Flindersia xanthoxyla, Eucalyptus saligna, Cryptocarya obovata, Baloghia inophylla, Wilkiea huegeliana, Rapanea variabilis, Livistona australis, Grevillea robusta, Geijera salicifolia, Endiandra virens, Denhamia celastroides, Bridelia exaltata, Austromyrtus bidwillii.*

Shrubs: *Neolitsea dealbata, Alpinia caerulea, Nyssanthes diffusa, Melicope micrococca, Citriobatus pauciflorus.*

Climbers & trailers: *Austrosteenisia blackii, Cissus antarctica.*

Ground flora: *Polystichum formosum, Proiphys cunninghamii, Pollia crispata, Cyperus tetraphyllus, Cyperus enervis, Lastreopsis munita, Calochlaena dubia, Arthropteris tenella, Alocasia brisbanensis.*

Variability: This is a derived community and variability is largely based on the density of *Lantana* stands.

Conservation and management issues: This is a derived community largely based on the dominance of *Lantana camara*. *Lantana* is particularly prevalent where past clearing activities have occurred and where there has been a mixture of grazing and burning. Despite the density of *Lantana*, a number of significant species where found within this assemblage.

Community 5: Wild Lime – Python Tree – Teak Closed Scrub

Wild Lime (*Capparis arborea*) – Python Tree (*Austromyrtus bidwillii*) – Teak (*Flindersia australis*)

Distribution: Mainly restricted to the southern portion of the reserve. Soils are damp to moist, dark brown, brown to red brown and shallow to deep.

Structure: Upper layer 20–30 (–35) m tall; cover 20–30 (–50%). Mid layer 5–15 m tall; cover 80–90%. Ground layer 1–2 m tall; cover usually c. 10%.

Trees: *Capparis arborea, Austromyrtus bidwillii, Flindersia australis, Siphonodon australis, Diospyros australis, Rapanea variabilis, Eucalyptus fibrosa, Alectryon subcinereus, Alchornea ilicifolia, Scolopia braunii, Grevillea robusta, Flindersia xanthoxyla, Ficus watkinsiana, Backhousia sciadophora, Atalaya salicifolia, Aphananthe philippinensis, Zanthoxylum brachyacanthum, Gmelina leichardtii, Drypetes australasica, Cryptocarya obovata, Bridelia exaltata.*

Shrubs: *Psychotria loniceroides, Canthium vaciniifolium, Cordyline petiolaris, Psychotria daphnoides, Alyxia ruscifolia, Olearia nernstii, Neolitsea dealbata, Maytenus bilocularis.*

Climbers & trailers: *Cissus antarctica, Morinda jasminoides, Austrosteenisia blackii, Marsdenia lloydii, Smilax australis, Pandorea pandorana, Marsdenia liisae.*

Ground flora and epiphytes: *Pellaea nana, Pyrrosia confluens, Platycerium bifurcatum, Dendrobium schoeninum, Sarcochilus weinthlii, Rhinerrhiza divitiflora, Dendrobium tarberi, Dendrobium speciosum, Dendrobium monophyllum, Dendrobium fairfaxii, Dendrobium bowmanii, Oplismenus imbecillis, Dendrobium teretifolium, Dendrobium gracilicaule, Cyperus enervis.*

Variability: Largely based on past fire encroachment and past selective logging. Along the access trail where some tree removal has occurred the community has a dense cover of regrowth and the height of the closed forest under-canopy is low. Along some ridges deep within this community the overstorey is dominated by Ironbarks with a dense and medially tall closed forest under-canopy dominated by *Backhousia sciadophora* and *Austromyrtus bidwillii.* In a few protected sites the assemblage is overtopped by *Flindersia australis* rather than eucalypt species.

Conservation and management issues: This assemblage is adequately reserved across its range, particularly in the north but less so in the south. Burnt Down Scrub Nature Reserve represents the only occurrence of this community type in the local area and as such this community is naturally well reserved locally.

Discussion

Burnt Down Scrub Nature Reserve contains at least 355 vascular plant taxa. On a site basis the number of species is rather low compared to nearby tablelands regions (Hunter 1998, Hunter et al. 1999). However, surveys conducted in the nearby Gibraltar Range and nearby low land coastal areas indicated that site richness is generally lower in these types of communities (Sheringham & Hunter 2002, Binns 1995). Thus, site richness and overall richness are probably indicative of this part of the region.

Floyd (1981) was astute when he considered after two days of ground investigations that the reserve was a southern outlier of communities from the Richmond River basin. Based on the extensive summaries of community relationships published by the Resource and Conservation Assessment Council (1996) and the Comprehensive Resource Assessment (1999) this relationship is upheld. In the broadest sense the communities contained within Burnt Down Scrub have correlates along the eastern escarpment at altitudes between about 300 and 700 m from Gloucester to just over the Queensland border in the north in the Moreton District. Burnt Down does provide a link, as suggested by Floyd (1981), between the Richmond River area and the gorge country of Guy Fawkes and the Macleay. More specifically though the communities of Burnt Down are probably largely restricted to the lowland areas of the upper Clarence and Richmond Rivers. In terms of individual floristics the most recurring feature is the number of taxa known to be at or near the southern distribution within the reserve. This is particularly so for Community 5, which contains a number of taxa not recorded further south.

Conclusion

Burnt Down Scrub Nature Reserve is a significant link between the Richmond River area and those of the gorge country associated with the Guy Fawkes and Macleay Rivers. The communities within the reserve are largely restricted to the lowland areas of the upper Clarence and Richmond basins and many species are at or near their southern limit of distribution. Though all communities are considered to be adequately reserved many are highly significant occurrences. In particular, Community 5 is the only local occurrence of this community type. Despite its small size Burnt Down Scrub has a significant number of species.

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References

Belbin, L. (1995a) *Users guide: PATN pattern analysis package*. (Division of Wildlife & Ecology CSIRO: Canberra).

Belbin, L. (1995b) *Technical Reference: PATN Pattern Analysis Package*. (Division of Wildlife & Ecology CSIRO: Canberra).

Binns, D. (1995) Flora Survey Report Casino Management Area Northern Region State Forests of New South Wales. *Casino management area EIS supporting document No. 7*. (State Forests of New South Wales: Sydney).

Braun-Blanquet, J. (1982) *Plant sociology: the study of plant communities*. (McGraw Hill: New York).

Briggs, J.D. & Leigh, J.H. (1996) *Rare or Threatened Australian Plants*. CSIRO & the Australian Nature Conservation Agency: Canberra.

Comprehensive Resource Assessment (1999) *Forest Ecosystem Classification for Upper and Lower North East CRA Regions*. A report undertaken for the NSW CRA/RFA Steering Committee.

Floyd, A.E. (1981) *Rainforest Vegetation of Portions 94 and 99, Parish Carnham, County Drake Nature Reserve vs State Forest*. Unpublished Report to the NSW NP&WS.

Harden, G.J. (1990–1993) *Flora of New South Wales Vol. 1–4*. (University of New South Wales Press: Sydney).

Hunter, J.T. (2000) *Vegetation and Floristics of Burnt Down Scrub Nature Reserve*. Unpublished Report to the Northern Tablelands Region of the NSW NP&WS.

Hunter, J.T. (1998) *Vegetation Survey of the Washpool National Park Western Additions*. Unpublished report to the Northern Tablelands Region NSW NPWS.

Hunter, J.T., Wyatt, A., Hoffmeyer, D., Brown, L., Barkwell, N. & Beresford-Smith, N.J. (1999) Vegetation and floristics of the Demon Nature Reserve, Tenterfield, New South Wales. *Cunninghamia* 6: 331–350.

Resource and Conservation Assessment Council (1996) *Regional Report of Upper North East New South Wales: Volume 4 Biodiversity Attributes*. (National Parks and Wildlife Service: Sydney).

Sheringham, P. & Hunter, J.T. (2002) *Vegetation and Floristics of Gibraltar Range National Park*. Unpublished report to the Northern Tablelands Region NSW NPWS.

Specht, R.L., Specht, A., Whelan, M.B. & Hegarty, E.E. (1995) *Conservation Atlas of Plant Communities in Australia*. (Centre for Coastal Management and Southern Cross University Press: Lismore).

State Forests of New South Wales (1995) *Tenterfield Management Area Proposed Forestry Operations Main Report*. Vol. A (Research Division, State Forests of New South Wales: Sydney).

Appendix: Flora of Burnt Down Scrub Nature Reserve. Nomenclature follows that of Harden (1990–1993) except where recent changes have occurred. Taxa found within the survey sites are scored according to their occurrence in each of the 5 communities defined. Some taxa were found in previous surveys or opportunistically and therefore are not assigned to a specific community. C1 = White Mahogany – Grey Ironbark; C2 = Brush Box – Scrub Turpentine; C3 = Grey Ironbark – Grey Gum; C4 = Brush Box – Giant Stinging Tree; C5 = Wild Lime – Python Tree – Teak. Introduced species are indicated by '*'. Species at their southern limit are indicated by (S).

Taxon	C1	C2	C3	C4	C5	Opportunistic
Acanthaceae						
Brunoniella australis			C3			
Pseuderanthemum variabile						O
Adiantaceae						
Adiantum aethiopicum	C1	C2	C3			
Adiantum formosum			C3			
Adiantum hispidulum			C3			
Pellaea nana				C4	C5	
Agavaceae						
Cordyline petiolaris						O
Cordyline stricta						O
Alangiaceae						
Alangium villosum subsp. *polyosmoides*						O
Amaranthaceae						
Deeringia arborescens						O
Nyssanthes diffusa			C3	C4	C5	
Amaryllidaceae						
Proiphys cunninghamii	C1	C2	C3	C4	C5	
Anacardiaceae						
Euroschinus falcata var. *falcata*		C2			C5	
Annonaceae						
Rauwenhoffia leichardtii						O
Anthericaceae						
Arthropodium milleflorum						O
Laxmannia gracilis						O
Thysanotus tuberosus						O
Tricoryne elatior						O
Apiaceae						
Hydrocotyle peduncularis	C1		C3			
Daucus glochidiatus						O
Platysace ericoides						O
Apocynaceae						
Alstonia constricta						O
Alyxia ruscifolia				C4	C5	
Parsonsia straminea				C4		

Taxon	C1	C2	C3	C4	C5	Opportunistic
Araceae						
Alocasia brisbanensis		C2	C3	C4		
Gymnostachys anceps		C2				
Typhonium brownii	C1	C2				
Araliaceae						
Polyscias elegans						O
Polyscias murrayi						O
Polyscias sambucifolia subsp. A	C1		C3			
Arecaceae						
Archontophoenix cunninghamiana		C2				
Linospadix monostachya						O
Livistona australis		C2		C4		
Asclepiadaceae						
Gymnema pleiandenium						O
**Gomphocarpus fruticosus*	C1		C3			
Marsdenia liisae		C2			C5	
Marsdenia lloydii		C2	C3		C5	
Aspleniaceae						
Asplenium attenuatum						O
Asplenium australasicum	C1					
Asplenium flabellifolium						O
Asplenium polydon						O
Asteliaceae						
Cordyline petiolaris		C2	C3	C4	C5	
Asteraceae						
**Bidens pilosa*						O
**Bidens subalternans*						O
Chrysocephalum apiculatum	C1					
**Cirsium vulgare*	C1		C3			
**Conyza albida*	C1		C3			
**Conyza bonariensis*						O
Craspedia variabilis	C1					
Euchiton sphaericus	C1					
**Hypochaeris radicata*						O
Olearia argophylla					C5	
Olearia heterocarpa			C3			
Olearia nernstii					C5	
Ozothamnus diosmifolius		C2				
Senecio amygdalifolius		C2				
Senecio lautus subsp. *lanceolatus*	C1	C2	C3			
Senecio sp. E	C1	C2	C3			
**Sigesbeckia orientalis* subsp. *orientalis*	C1		C3			
Vernonia cinerea var. *lanata*	C1	C2				
Vittadinia tenuissima			C3			

Taxon	C1	C2	C3	C4	C5	Opportunistic
Bignoniaceae						
Pandorea jasminoides						O
Pandorea pandorana		C2	C3		C5	
Blechnaceae						
Blechnum cartilagineum		C2				
Blechnum nudum						O
Doodia aspera	C1	C2				
Doodia maxima		C2				
Boraginaceae						
Ehretia acuminata var. *acuminata*						O
Campanulaceae						
Wahlenbergia stricta subsp. *stricta*						O
Capparaceae						
Capparis arborea		C2			C5	
Caryophyllaceae						
Stellaria flaccida						O
Casuarinaceae						
Allocasuarina littoralis						O
Allocasuarina torulosa	C1					
Celastraceae						
Cassine australis var. *australis*						O
Celastrus subspicata						O
Denhamia celastroides		C2		C4		
Maytenus bilocularis	C1	C2	C3		C5	
Siphonodon australis				C4	C5	
Clusiaceae						
Hypericum gramineum						O
Commelinaceae						
Commelina cyanea						O
Pollia crispata			C3	C4	C5	
Convolvulaceae						
Dichondra repens	C1		C3			
Dichondra sp. A						O
Crassulaceae						
Crassula sieberiana						O
Cucurbitaceae						
Diplocyclos palmatus						O
Zehneria cunninghamii	C1					

Taxon	C1	C2	C3	C4	C5	Opportunistic
Cyatheaceae						
Cyathea australis				C4		
Cyperaceae						
Carex declinata		C2				
Carex inversa	C1	C2	C3			
Cyperus enervis	C1	C2	C3	C4	C5	
Cyperus tetraphyllus		C2	C3	C4	C5	
Fimbristylis dichotoma						O
Gahnia aspera					C5	
Gahnia melanocarpa		C2				
Gahnia sieberiana	C1	C2			C5	
Lepidosperma laterale	C1	C2	C3			
Schoenus apogon						O
Davalliaceae						
Arthropteris tenella		C2		C4		
Dioscoraceae						
Dioscorea transversa						O
Dennstaedtiaceae						
Calochlaena dubia	C1	C2	C3	C4		
Pteridium esculentum	C1					
Dilleniaceae						
Hibbertia obtusifolia						O
Hibbertia scandens	C1	C2				
Dryopteridaceae						
Lastreopsis decomposita						O
Lastreopsis munita			C3	C4		
Polystichum formosum		C2	C3	C4		
Ebenaceae						
Diospyros australis		C2		C4	C5	
Diospyros pentamera			C3			
Elaeocarpaceae						
Elaeocarpus obovatus						O
Epacridaceae						
Melichrus urceolatus						O
Escalloniaceae						
Quintinia sieberi		C2	C3			
Euphorbiaceae						
Acalypha capillipes (S)						O
Actephala lindleyi						O

Taxon	C1	C2	C3	C4	C5	Opportunistic
Euphorbiaceae cont.						
Alchornea ilicifolia		C2			C5	
Baloghia inophylla		C2		C4		
Breynia cernua	C1	C2				
Bridelia exaltata		C2		C4	C5	
Claoxylon australe						O
Cleistanthus cunninghamii						O
Croton insularis						O
Croton stigmatosus						O
Croton verreauxii		C2				
Drypetes australasica		C2			C5	
Mallotus philippensis		C2				
Phyllanthus similis	C1				C5	
Phyllanthus virgatus	C1		C3			
Poranthera microphylla			C3			
Eupomatiaceae						
Eupomatia bennettii						O
Eupomatia laurina						O
Fabaceae						
Acacia binervia	C1					
Acacia falciformis	C1					
Acacia irrorata subsp. *irrorata*	C1	C2	C3			
Acacia longifolia	C1	C2	C3			
Austrosteenisia blackii var. *blackii*	C1	C2		C4	C5	
Desmodium brachypodum	C1	C2				
Desmodium nemorosum		C2				
Desmodium rhytidophyllum	C1	C2				
Desmodium varians	C1	C2	C3			
Erythrina vespertilio						O
Glycine clandestina	C1	C2	C3			
Glycine microphylla		C2				
Glycine tabacina	C1					
Hardenbergia violacea	C1					
Hovea heterophylla						O
Indigofera australis	C1					
Jacksonia scoparia	C1					
Lespedeza juncea subsp. *sericea*	C1					
Lotus cruentus		C2				
Pararchidendron pruinosum var. *pruinosum*						O
Senna clavigera			C3			
Swainsona brachycarpa	C1	C2	C3			
Zornia dyctiocarpa subsp. *dyctiocarpa*	C1					
Flacourtiaceae						
Scolopia braunii					C5	
Gentianaceae						
Centaurium erythraea	C1					

Taxon	C1	C2	C3	C4	C5	Opportunistic
Geraniaceae						
Geranium solanderi var. *solanderi*	C1	C2				
Goodeniaceae						
Goodenia hederacea var. *hederacea*						O
Haemodoraceae						
Haemodorum planifolium			C3			
Haloragaceae						
Gonocarpus tetragynus						O
Hypoxidaceae						
Hypoxis exilis	C1					
Icacinaceae						
Citronella moorei						O
Iridaceae						
Patersonia sericea						O
**Sisyrinchium* sp. A	C1					
Juncaceae						
Juncus usitatus			C3			
Luzula flaccida						O
Lamiaceae						
Ajuga australis	C1					
Plectranthus parviflorus	C1		C3			
Lauraceae						
Cassytha glabella						O
Cryptocarya obovata				C4	C5	
Cryptocarya triplinervis						O
Endiandra sieberi				C4		
Endiandra virens		C2	C3	C4		
Neolitsea australiensis			C3	C4		
Neolitsea dealbata	C1	C2		C4	C5	
Lobeliaceae						
Pratia purpurascens			C3			
Lomandraceae						
Lomandra filiformis						O
Lomandra longifolia	C1	C2	C3		C5	
Lomandra multiflora subsp. *multiflora*	C1					
Luzuriagaceae						
Eustrephus latifolius	C1	C2	C3			
Geitonoplesium cymosum		C2				

Taxon	C1	C2	C3	C4	C5	Opportunistic
Malvaceae						
Abutilon oxycarpum		C2	C3			
Hibiscus heterophyllus subsp. *heterophyllus*	C2	C3	C4	C5		
Meliaceae						
Dysoxylum fraserianum						O
Dysoxylum rufum		C2				
Melia azedarach						O
Synoum glandulosum		C2		C4		
Toona ciliata						O
Menispermaceae						
Legnephora moorei						O
Tinospora smilacina		C2		C4	C5	
Monimiaceae						
Daphnandra micrantha						O
Wilkiea huegeliana				C4		
Moraceae						
Ficus coronata		C2				
Ficus fraseri						O
Ficus macrophylla						O
Ficus superba var. *henneana*						O
Ficus watkinsiana				C4	C5	
Myrsinaceae						
Embelia australiana						O
Rapanea variabilis	C1	C2		C4	C5	
Myrtaceae						
Acmena ingens				C4		
Austromyrtus bidwillii				C4	C5	
Austromyrtus hillii					C5	
Backhousia sciadophora					C5	
Callistemon salignus	C1	C2	C3			
Corymbia citriodora subsp. *variegata*	C1		C3			
Corymbia gummifera	C1					
Eucalyptus acmenoides	C1	C2	C3			
Eucalyptus brunnea	C1					
Eucalyptus fibrosa	C1	C2	C3		C5	
Eucalyptus microcorys	C1	C2	C3			
Eucalyptus moluccana	C1		C3			
Eucalyptus propinqua	C1		C3			
Eucalyptus saligna	C1	C2		C4		
Eucalyptus siderophloia						O
Eucalyptus umbra	C1					
Lophostemon confertus	C1	C2	C3	C4		
Rhodamnia rubescens		C2	C3			
Syzygium francisii						O

Taxon	C1	C2	C3	C4	C5	Opportunistic
Oleaceae						
Notelaea longifolia		C2				
Olea paniculata						O
Onagraceae						
Epilobium billardierianum subsp. *cinereum*						
Ophioglossaceae						
Ophioglossum reticulatum						O
Orchidaceae						
Bulbophyllum elisae					C5	
Calanthe triplicata						O
Dendrobium bowmanii					C5	
Dendrobium fairfaxii					C5	
Dendrobium gracilicaule					C5	
Dendrobium monophyllum					C5	
Dendrobium schoeninum					C5	
Dendrobium speciosum				C4	C5	
Dendrobium tarberi					C5	
Dendrobium teretifolium					C5	
Eriochilus cucullatus				C4		
Plectorrhiza tridentate						O
Rhinerrhiza divitiflora					C5	
Sarcochilus falcatus						O
Sarcochilus weinthalii					C5	
Oxalidaceae						
Oxalis chnoodes						O
Oxalis perennans		C2	C3			
Passifloraceae						
Passiflora subpeltata						O
Phormiaceae						
Dianella caerulea var. *assera*	C1	C2	C3	C4	C5	
Dianella caerulea var. *caerulea*	C1		C3			
Dianella revoluta						O
Pittosporaceae						
Bursaria spinosa						O
Citriobatus pauciflorus		C2	C3	C4	C5	
Rhytidosporum procumbens			C3			
Plantaginaceae						
Plantago debilis						O
Plantago varia	C1					
Poaceae						
Agrostis avenacea						O
Cenchrus caliculatus			C3			

Taxon	C1	C2	C3	C4	C5	Opportunistic
Poaceae cont.						
Dichelachne sieberiana	C1					
Digitaria ramularis	C1					
Entolasia marginata					C5	
Imperata cylindrica var. *major*	C1	C2	C3			
Oplismenus imbecillis	C1	C2	C3		C5	
Oplismenus undulatifolius						O
Paspalidium distans					C5	
Poa sieberiana	C1	C2	C3			
Sorghum leiocladum	C1		C3			
Themeda triandra	C1		C3			
Polygalaceae						
Polygala japonica	C1					
Polygonaceae						
Rumex brownii						O
Polypodiaceae						
Platycerium superbum	C1	C2		C4	C5	
Pyrrosia confluens var. *dielsii*					C5	
Pyrrosia rupestris	C1				C5	
Primulaceae						
**Anagallis arvensis*						O
Proteaceae						
Grevillea robusta				C4	C5	
Persoonia cornifolia						O
Pteridaceae						
Pteris umbrosa						O
Ranunculaceae						
Clematis glycinoides	C1	C2				
Ranunculus lappaceus	C1					
Rhamnaceae						
Alphitona excelsa						O
Ripogonaceae						
Ripogonium album						O
Rosaceae						
Acaena novae-zealandiae						O
Rubus moluccanus var. *moluccanus*	C1					
Rubus parvifolius	C1					
Rubus rosifolius	C1	C2				

Taxon	C1	C2	C3	C4	C5	Opportunistic
Rubiaceae						
Asperula conferta						O
Canthium vacciniifolium				C4	C5	
Galium migrans		C2	C3			
Ixora beckleri						O
Morinda jasminoides		C2			C5	
Pomax umbellata						O
Psychotria daphnoides			C3		C5	
Psychotria loniceroides		C2	C3	C4	C5	
Rutaceae						
Acronychia oblongifolia			C3			
Correa reflexa var. *reflexa*						O
Flindersia australis (S)				C4	C5	
Flindersia collina	C1					
Flindersia schottiana		C2				
Flindersia xanthoxyla (S)				C4	C5	
Geijera latifolia						O
Geijera salicifolia				C4		
Melicope elleryana (S)						O
Melicope erythrococca		C2		C4		
Melicope micrococca			C3	C4		
Sarcomelicope simplicifolia subsp. *simplicifolia*						O
Zanthoxylum brachyacanthum (S)		C2	C3	C4	C5	
Santalaceae						
Exocarpus cupressiformis						O
Sapindaceae						
Alectryon subcinereus				C4	C5	
Alectryon subdentatus						O
Arytera divaricata						O
Atalaya hemiglauca (S)						O
Atalaya salicifolia					C5	
Cupaniopsis parvifolia					C5	
Diploglottis australis						O
Dodonaea viscosa	C1					
Elatostachys nervosa						O
Elatostachys xylocarpa						O
Guioa semiglauca		C2				
Jagera pseudorhus var. *pseudorhus*	C1		C3	C4		
Rhysotoechia bifoliata						O
Sarcopteryx stipitata						O
Sapotaceae						
Planchonella australis						O
Scrophulariaceae						
Veronica calycina	C1		C3			

Taxon	C1	C2	C3	C4	C5	Opportunistic
Simaroubaceae						
Ailanthus triphysa						O
Sinopteridaceae						
Cheilanthes sieberi						O
Smilaceae						
Smilax australis	C1	C2	C3	C4	C5	
Solanaceae						
Nicotiana debneyi subsp. *debneyi*						O
Solanum campanulatum	C1		C3		C5	
Solanum densevestitum	C1	C2	C3			
Solanum opacum			C3			
Solanum pungetium					C5	
Solanum stelligerum	C1	C2	C3			
Stackhousiaceae						
Stackhousia viminea						O
Sterculiaceae						
Brachychiton discolor						O
Brachychiton populneus						O
Commersonia fraseri						O
Stylidiaceae						
Stylidium graminifolium						O
Thymelaeaceae						
Pimelea latifolia subsp. *hirsuta*		C2				
Pimelea neo-anglica	C1		C3			
Pimelea strigosa		C2	C3			
Ulmaceae						
Aphananthe philippinensis					C5	
Urticaceae						
Dendrocnide excelsa		C2		C4		
Dendrocnide photinophylla		C2				
Elatostemma reticulatum						O
Urtica incisa			C3			
Verbenaceae						
Gmelina leichhardtii					C5	
**Lantana camara*	C1	C2	C3	C4	C5	
**Verbena officonalis*		C2	C3			
Violaceae						
Hybanthus monopetalus	C1					
Hybanthus stellarioides	C1		C3			

Taxon	C1	C2	C3	C4	C5	Opportunistic
Violaceae cont.						
Viola betonicifolia	C1					
Viola hederacea	C1	C2		C4		
Vitaceae						
Cayratia clematidea	C1	C2			C5	
Cissus antarctica	C1	C2	C3	C4	C5	
Cissus hypoglauca						O
Cissus opaca	C1					
Tetrastigma nitens						
Xanthorrhoeaceae						
Xanthorrhoea glauca	C1		C3			
Zamiaceae						
Macrozamia fawcettii	C1	C2	C3			
Zingiberaceae						
Alpinia caerulea	C1	C2		C4		

The spread of the introduced *Euphorbia paralias* (Euphorbiaceae) along the mainland coast of south-eastern Australia.

Petrus C. Heyligers

Heyligers, P.C. (CSIRO Sustainable Ecosystems, Long Pocket Laboratories, 120 Meiers Road, Indooroopilly Qld 4068) 2002. The spread of the introduced Euphorbia paralias *(Euphorbiaceae) along the mainland coast of south-eastern Australia.* Cunninghamia 7(3): 563–578.

Euphorbia paralias, Sea Spurge (Euphorbiaceae), indigenous to the sandy shores of southern Europe and northern Africa, was first collected in Australia near harbours: at Albany, Western Australia in 1927 and at Port Victoria, South Australia in 1934. *E. paralias* seeds are buoyant and dispersed by ocean currents. By 1974 *E. paralias* had reached Wilsons Promontory, but was not recorded from southern New South Wales until 1987, while in East Gippsland it was first recorded in 1993. Since then it has spread to other beaches in this region and has also turned up on Lord Howe Island.

Surveys have been carried out to ascertain the status of *Euphorbia paralias* in East Gippsland and southern New South Wales during the last decade. The results together with other observations have been correlated with the published results of drifter experiments. The latter relied on reporting back of stranded bottles, cards or envelopes released at certain distances offshore. The establishment of *E. paralias* in southern New South Wales, before doing so in East Gippsland, is in agreement with the stranding pattern of bottles released west of Wilsons Promontory. Another bottle and two cards released in eastern Bass Strait washed up on Lord Howe Island, thus underpinning the assumption that the colonising *E. paralias* seed was carried there on ocean currents. *E. paralias* is still expanding its range in New South Wales. Modelling based on climatic parameters has shown that extension to the lower North Coast of New South Wales can be expected. However, the spread of the introduced sea-rocket *Cakile edentula* beyond its known climatic range into the Great Barrier Reef area could provide a precedent for what may also happen in the case of *E. paralias*.

Introduction

Euphorbia paralias L., Sea Spurge (family Euphorbiaceae), is a coastal dune plant native to sandy shores of the Atlantic Ocean from Mauritania to southern Ireland and England, the Mediterranean Sea and the Black Sea (Heyligers 1993). In Australia the first herbarium collections of this species were made at Albany in 1927 and at Port Victoria in 1934. This strongly suggests that seeds were accidentally introduced through shipping, possibly in ballast carried by grain ketches. As *E. paralias* seeds are buoyant in sea water and spread by ocean currents, the species progressed west as well as eastward, along the coasts of southern Australia (Heyligers 1989a, 1989b, 1993, Wilcock 1997). By 1974 it had reached Norman Bay on the west coast of Wilsons

Promontory and in 1982 I spotted plants on the east side at Five Mile Beach. The earliest collection in Tasmania was made in 1980 along Waterhouse Beach in the north-east. In 1982 *E. paralias* was also collected on Flinders Island and in 1984 on King Island.

During his coastal survey of New South Wales in 1987 Clarke (1989) found *Euphorbia paralias* plants on Loader Beach, about 10 km south of Narooma (Fig. 1). In the 1980s I regularly visited several beaches along the South Coast of New South Wales and in East Gippsland to research the influence of plant species on dune development. After intensifying reconnaissance of beaches in the Narooma area, I found a large population of *E. paralias* on the small alcove beach of Scuff Bay, not far north from where the first plants were seen. This beach was likely to be the spot first colonised by *E. paralias* on the east coast, thus forming a focus for further spread. New occurrences were documented through my observations as well as by members of the Eurobodalla Natural History Society with the result that by 1995 Sea Spurge was found to be widespread along beaches stretching about 20 km north and south from Narooma, while scattered occurrences were reported between Broulee and Pambula (Heyligers 1989b, 1991, 1995).

In 1993 the Eastern Victorian Coastal Trek (Heislers 1994) provided an opportunity to investigate the distribution of *Euphorbia paralias* in Gippsland. The participants walked along all beaches from the entrance of Port Phillip Bay to Cape Howe. They came across only one occurrence of *E. paralias* west of Wilsons Promontory, at Cape Conran (Fig. 1). Some years later, Parks Victoria (G. McLeod, pers. comm.) reported several new occurrences in East Gippsland, while in New South Wales *E. paralias* had been found on beaches a few kilometres south of Jervis Bay (Mills & Associates 1998). The present paper reviews the dispersal and establishment of *E. paralias* in recent years and investigates to what degree dispersal by ocean currents has influenced the colonisation process in coastal south-eastern mainland Australia.

Morphology and ecology

Euphorbia paralias is a perennial with a long taproot. The 30–55 cm long stems die after flowering and are replaced by new shoots from the root crown (Fig. 2). Stem number is influenced by growing conditions; a vigorous three or four year old plant can produce up to 100 stems in a season, but under unfavourable conditions this figure can be less than ten. Side-branches may develop anywhere along the stems, giving *E. paralias* the capacity to grow through accumulating sand. A plant on a lower lee slope which received sand blown over the dune crest, had at least twice coped with a 30 cm deep sand deposit by producing new shoots at the latest surface level. I did not succeed in digging out the root crown, but there had been at least one earlier deposition event. Elsewhere I have seen shoots breaking through the surface of a dune crest on which *E. paralias* plants had been buried by recent heavy sand accumulation. On the other hand, the taproot anchors the plant during erosion. Immediately below the crown the root has a diameter of 2.5–3 cm and tapers over a length of 30–40 cm to a mere millimetre. Blown-out plants show that this thin root penetrates for a metre or more into the sand. From the tapered section of the root a few lateral roots, about 1 cm thick, grow out horizontally.

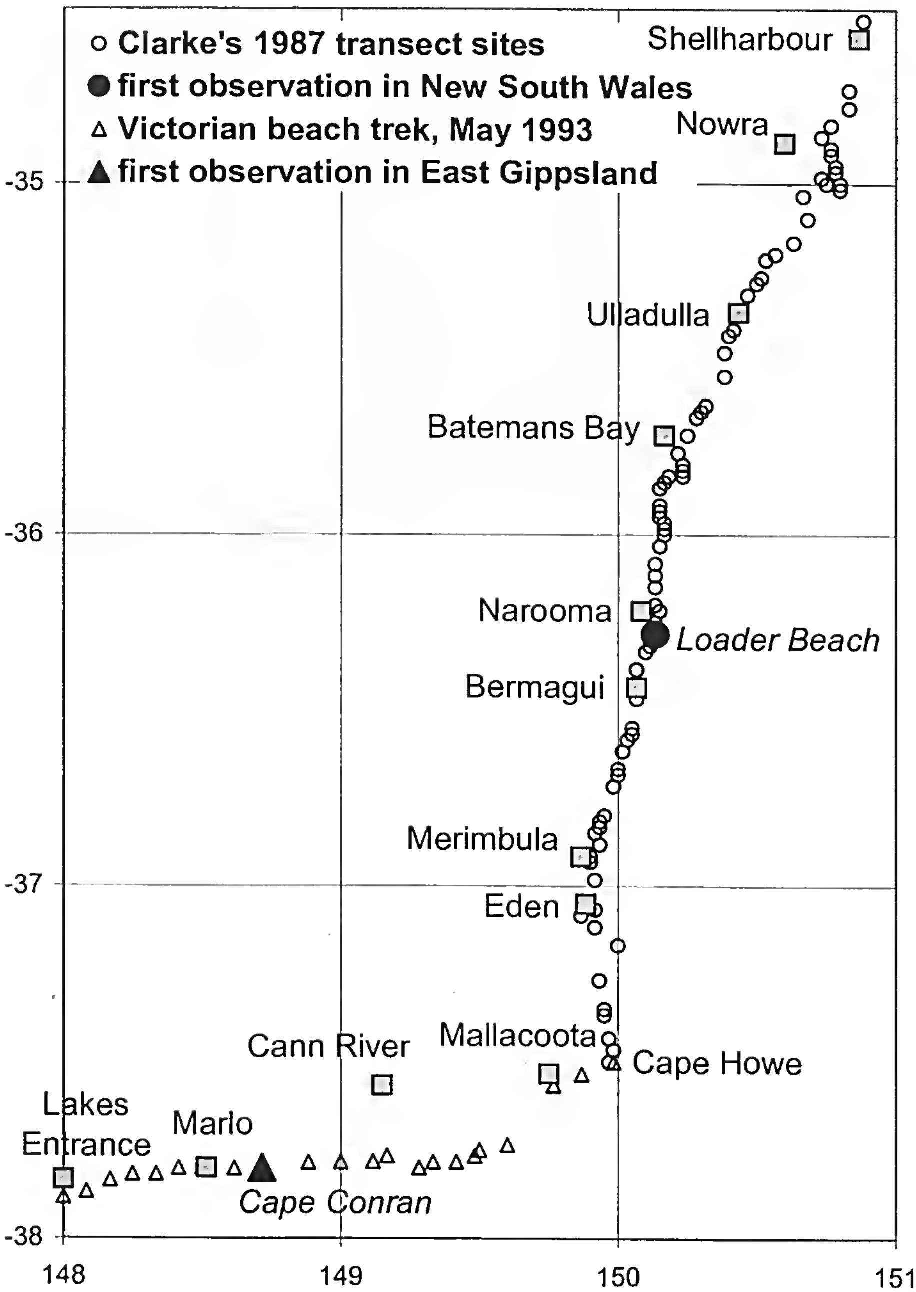

Fig. 1. Systematic coastal surveys during which the first observations of *Euphorbia paralias* in New South Wales and East Gippsland were made. Open circles indicate the position of the transects surveyed in 1987 (Clarke 1989), open triangles the route followed by the participants of the 1993 beach trek (Heislers 1994). The first observation sites for *E. paralias* are indicated with black symbols.

Figure 2. A single *Euphorbia paraljas* plant on the sandspit at Potato Point, c. 20 km north of Narooma, photographed in March 1992, showing three generations of stems: old, browned-off flowering stems, stems presently flowering, and a few younger shoots.

Flowering appears to be more dependent on growing conditions than on time of year. Each shoot has the potential to develop a terminal, branched, leafy inflorescence. Vigorous plants can produce 25 to 80 fruits per stem. With three seeds per fruit, this means the annual production may be over 20 000 seeds per plant. However, seed production is variable with severely stressed plants producing virtually no seeds. *E. paralias* has two modes of dispersal: the three-valved fruits open explosively and the globular seeds, about 3 mm in diameter, are buoyant. Seedlings around single plants show that the effective 'firing range' does not extend much beyond 2 m. If a seed lands in open vegetation or on the beach, slope and wind may increase this distance. By keeping seeds in jars with seawater I found that most seeds float for at least one and a half years and that some stay afloat for more than eight years. No data are available on effective buoyancy periods at sea. After two years about half the floating seeds had lost their viability, while none germinated after six years. Seeds that sank were not viable. Dry-stored seeds remain viable for at least seven years (Heyligers 1993).

Methods

Distribution surveys

A survey of *Euphorbia paralias* occurrences along the New South Wales South Coast between Batemans Bay and Merimbula was organised in cooperation with the Eurobodalla Natural History Society and the Far South Coast Birdwatchers for November 2000. I followed up this survey in February 2001 and inspected 32 beaches between Batemans Bay and Shellharbour (Heyligers 2002). In East Gippsland Westhead (1996) and Gormley (1997) had surveyed beaches from Marlo to Mallacoota for Parks Victoria. In addition, P.J. Wilcock provided data obtained through an Australia-wide questionnaire (Wilcock 1997), K. Mills from a weed survey of Cudmirrah and Conjola National Parks (Mills & Associates 1998) and L. Evans, New South Wales National Parks and Wildlife Service Far South Coast Region, from counts at Nadgee Nature Reserve. The most recent extension of the range of *E. paralias* to Lord Howe Island was reported by K. Mills (pers. comm.).

Drifter experiments

To assess the role of sea currents in dispersal of *Euphorbia paralias* seeds, results obtained with drift bottles (Anon. 1968), drift cards (Marshallsay & Radok 1972) and drift envelopes (Wood 1996) were used. The earlier experiments were carried out before satellite tracking of drogued buoys dramatically changed oceanographic research. However, for the study of plant dispersal, data obtained by the drifter method provide more relevant information, as drifters are subject to the same wind and current forces as propagules afloat on the ocean surface. However, in contrast to drifters dropped from ships or offshore oil and gas platforms, propagules need to reach the sea by other means, for instance through beach erosion or offshore winds.

Anon. (1968) lists the results from experiments carried out by the CSIRO Division of Oceanography between September 1958 and May 1962. Each month 50 weighted bottles were released at four different positions at the western entrance to Bass Strait. Two release positions were close to the mainland, namely about 15 km south of Cape Northumberland and 55 km southwest of Cape Otway. Bottles were ballasted with blue-metal chips to float with only 2 cm of the neck exposed. Retrieval information was received for nearly one third of the 8050 bottles released. In addition, at the Cape Otway site, between January 1960 and January 1961, 600 bottles without ballast were used to compare with the performance of weighted bottles. Of these 55% were recovered. For the purposes of this paper only data from recoveries along the mainland coast east of Wilsons Promontory have been used.

On 19 December 1969 Marshallsay and Radok (1972) released driftcards in five batches of 500 from oil and gas platforms in eastern Bass Strait. These cards were made from high-density PVC. About one-quarter of the cards released from Barracouta, the platform closest to the shore, were later found, whereas the proportion of retrieved cards from other platforms was not as high.

Wood (1996) used floats made from clear plastic envelopes. On 25 occasions, from June 1985 to October 1987, batches of five floats were released at 9 km, 35–45 km and 50–90 km east of Wollongong. Recovery rates were close to 30% for the near-shore and mid-distance batches and 10% for the batches dropped further out to sea.

Nomenclature

Nomenclature follows Harden (1990–1993). The spelling of *Tetragonia tetragonioides* is adopted from Gray (1997).

Results

The distribution of *Euphorbia paralias*

Since its appearance in southern New South Wales in the mid-1980s and in East Gippsland in the early 1990s, *Euphorbia paralias* has spread to many other beaches. Early in 2001 its range stretched from Jervis Bay in the north to Marlo in the south, a total distance of about 550 km, with an outpost on Lord Howe Island, about 850 km to the east-north-east of Jervis Bay.

To show the history of this spread, observations along the Australian mainland coast have been summarized over four periods (Fig. 3a–d). The first period (1987–1992) spans the time from the first record of *Euphorbia paralias* at Loader Beach up to the first find in East Gippsland. The second (1993–1995) covers this event and ends with the first survey of the New South Wales South Coast. The third period (1996–1999) incorporates detailed surveys in East Gippsland, while the fourth (2000–February 2001) includes results of the second South Coast survey. Maps also show the location of beaches where *E. paralias* was not seen, to give some measure of reliability. Fig. 4 summarises the data presented in Fig. 3.

At many sites *Euphorbia paralias* occurs in small numbers. This is demonstrated by the detailed surveys between Marlo and Mallacoota (Westhead 1996, Gormley 1997; Fig. 5). Considerations of scale made it necessary to base the mapped number of plants on the number of individuals, including seedlings and immature plants, present per one minute longitude (or c. 1.5 km). Hence, in quite a few cases where the map shows a modest number of plants, these do not necessarily grow together, but usually comprise several single plants, some groups of a few mature plants and surrounding seedlings. It is evident from comparison with Fig. 3 that the greatest concentrations of plants occur at and near the sites where *E. paralias* was found in 1993 and 1994.

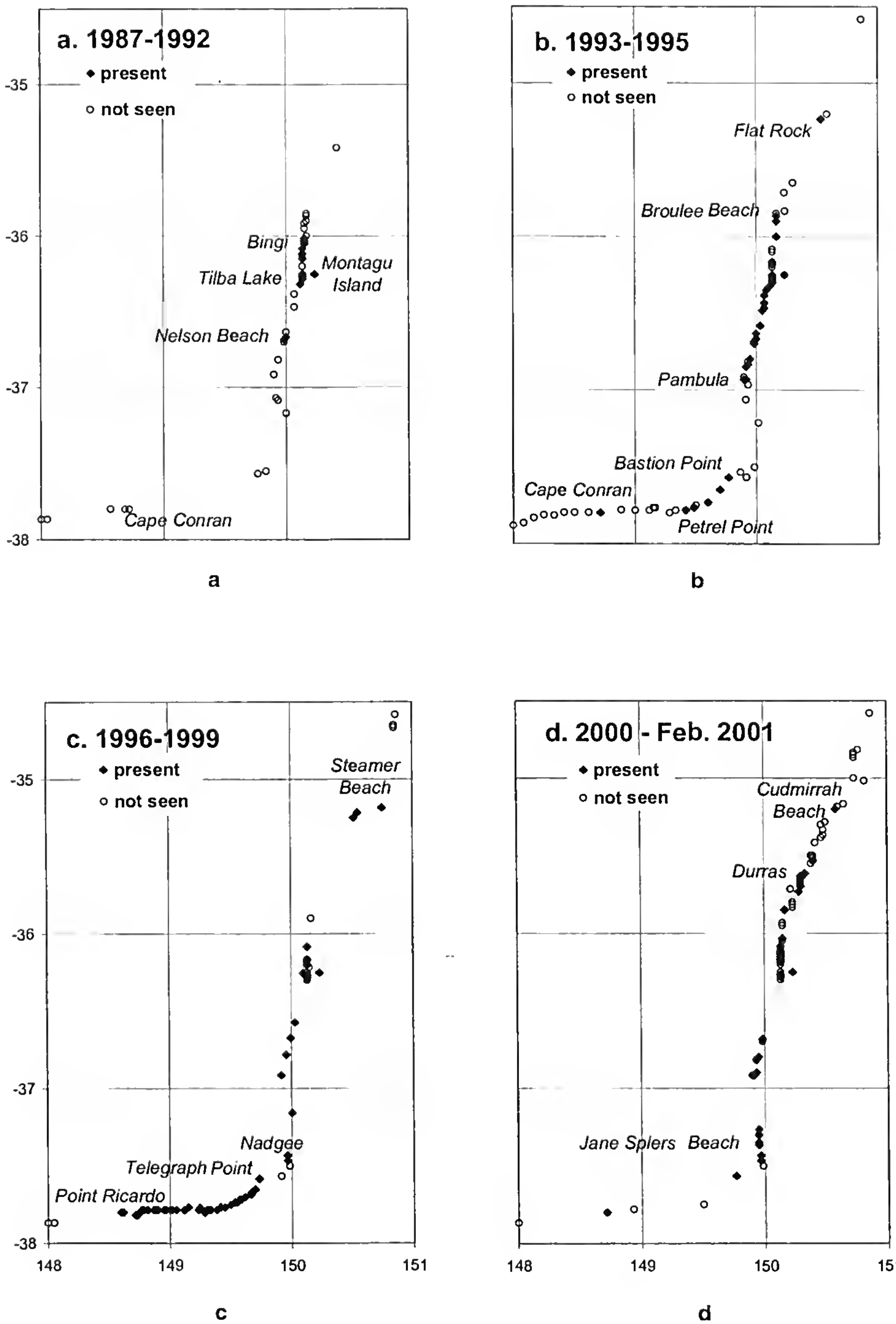

Fig. 3. Observations of *Euphorbia paralias* between 1987 and 2001. Map a summarises the years between the discovery in New South Wales and the Victorian beach trek; b, the time from the trek up to and including the 1995 South Coast survey, c, the period in which the East Gippsland surveys were done, and d, the results of the second South Coast survey. The coastline has been not been indicated to make the observations stand out more clearly.

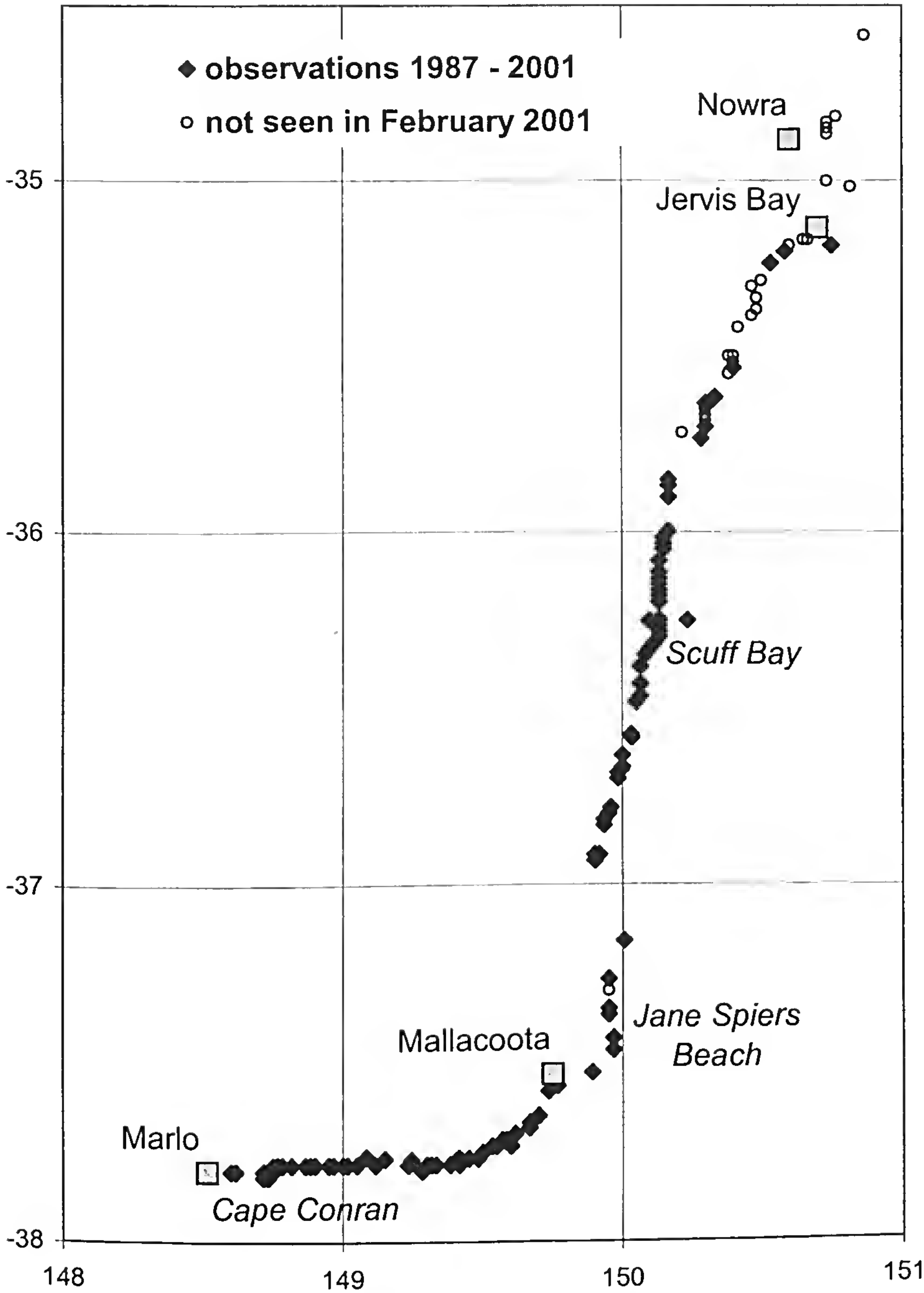

Fig. 4. An overview of *Euphorbia paralias* occurrences in south-eastern coastal mainland Australia.

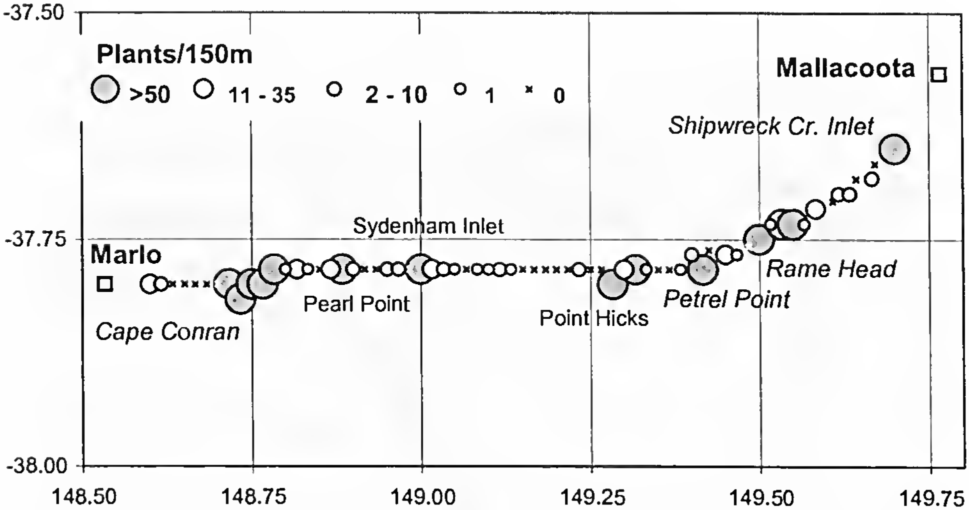

Fig. 5. Distribution of *Euphorbia paralias* along the coast between Marlo and Mallacoota, based on data from Gormley (1997) and Westhead (1996). Geographic names in italics refer to sites where *E. paralias* was originally seen in 1993 or 1994; those in regular case to additional sites with > 50 plants/150 m found during the 1996 and 1997 surveys.

Sea currents

Many weighted drift bottles released off Cape Northumberland and Cape Otway drifted around Wilsons Promontory and washed up along the Gippsland coast (Fig. 6). The first recoveries were 23 and 24 days after release, when four bottles were picked up on the southwestern end of Ninety Mile Beach. Subsequent retrievals along this beach were made 48, 67 and 100 days after release. Only a few bottles drifted past Cape Howe and stranded on the New South Wales coast. The first of these was found near Green Cape after 67 days at sea, the next one, near Sydney, after 118 days. The fate of unweighted bottles was very different. No bottles were reported from Gippsland, but strandings were widespread along the east coast of New South Wales and Queensland. Their journeys took more time than the weighted bottles, with the first recoveries coming from southern New South Wales after 116, 145 and 148 days. One bottle was found on Lord Howe Island 564 days after release.

From the 500 cards released from Barracouta, 130 were recovered from East Gippsland beaches (Fig. 7). The retrievals were concentrated along the eastern section, where 110 cards were found within nine months after release (Marshallsay & Radok 1972). Of these, 23 were picked up in the first week at Point Hicks and most of the remainder were found within three weeks. No cards of this batch were found along the east coast.

In contrast, the 2000 cards released from the other platforms, located further out in Bass Strait, bypassed this stretch of coast (Fig. 6). Over the next year and a half 22 of them washed up along the east coast as far north as Cape Tribulation in northern Queensland. The first two recoveries came from the Port Kembla area after 80 days. In addition, two cards were found on Lord Howe Island 198 days after release.

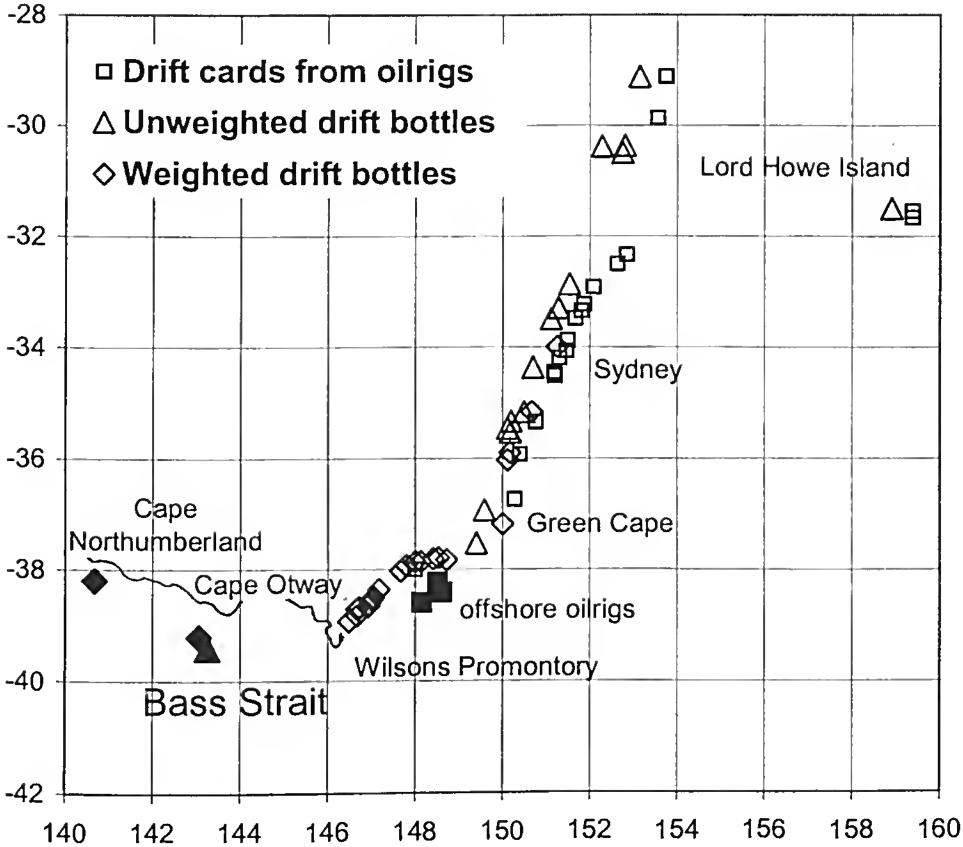

Fig. 6. Schematic map of Bass Strait release locations of drift cards and drift bottles (solid symbols) and recovery sites east of Wilsons Promontory and along the coast of New South Wales (open symbols). Data extracted from Anon. (1968) and Marshallsay and Radok (1972).

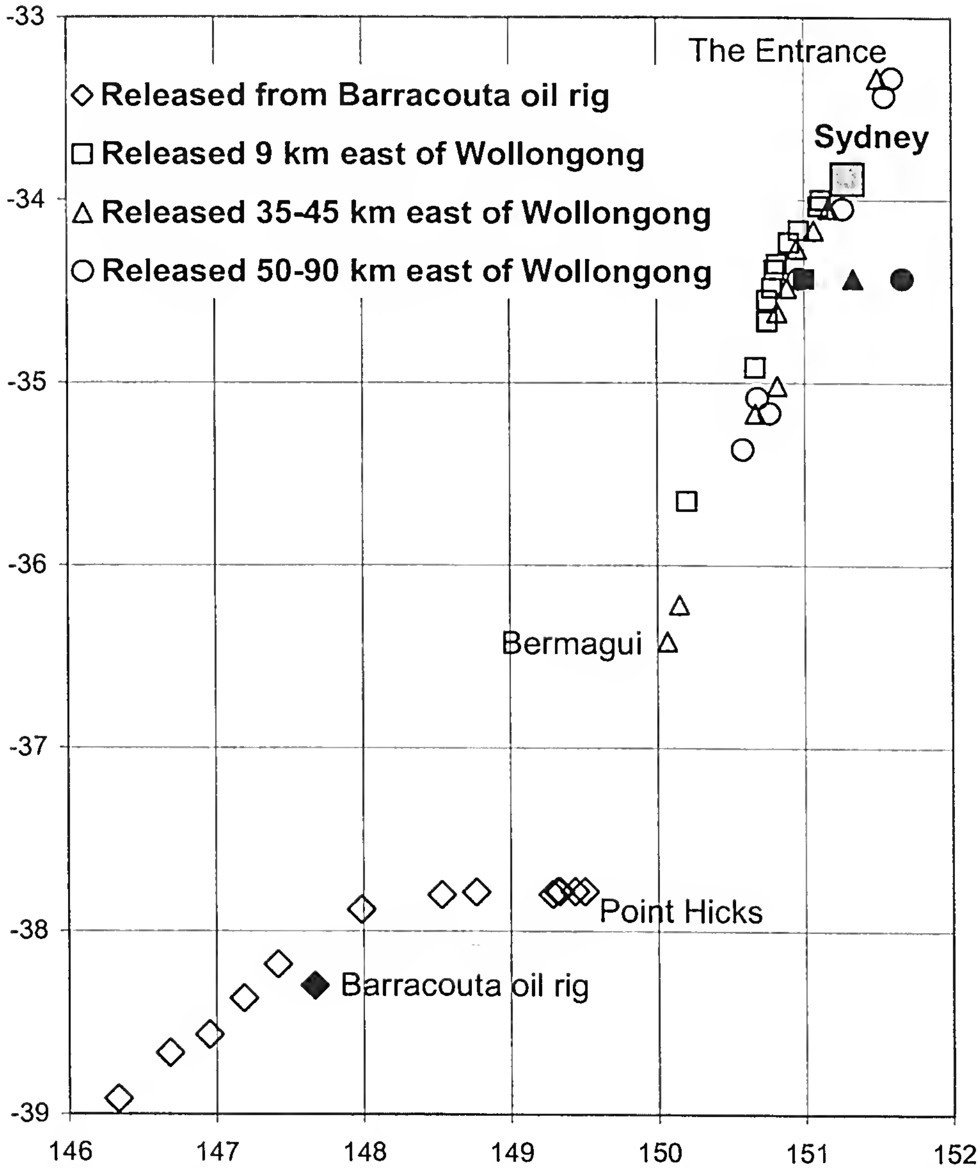

Fig. 7. Schematic map of retrieval locations (open symbols) for floats released at short distances offshore (solid symbols): cards from the Barracouta oil rig and envelopes thrown overboard at incremental distances from Wollongong. Data extracted from Marshallsay and Radok (1972) and Wood (1996).

Recoveries of floats released at various distances out from Wollongong were limited to the 310 km stretch of coast between Entrance Point and Bermagui (Fig. 7; Wood 1996). Recovery times for floats released 9 km offshore could be as short as one day; those for floats released about 40 km offshore two days and for the ones released further out three days. The float that was picked up at Bermagui was released at the 40 km site 28 days earlier. From six groups of floats, released in late autumn or winter months, no recoveries were reported at all.

Discussion

Evidence of dispersal by sea

Effectiveness of propagule dispersal by sea is demonstrated by plant assemblages that germinate and subsequently flourish in flotsam lines on the upper beach. A good example was seen at Myrtle Beach, south of Durras, where vigorous young plants of *Euphorbia paralias*, *Atriplex cinerea* Poir. (Chenopodiaceae), *Cakile maritima* Scop. (Brassicaceae) and *Tetragonia tetragonioides* (Pallas) Kuntze (Aizoaceae) were found growing together in flotsam along the margin of the low dune terrace with *Zoysia macrantha* Desv. (Poaceae) vegetation. Like the seeds of *E. paralias*, fruits of the other three species are buoyant in seawater (Heyligers 1989b, 2001). Also, it is not unusual to find flotsam remnants around older *E. paralias* plants in swales on the inland side of foredunes. Such flotsam was deposited there during storm high tides, either directly through wave overwash or via low areas in the foredune.

Where do drifting seeds come from?

Retrievals of drift cards and drift envelopes show that recovery rates for releases close to the coast can be quite high. From this one may assume that local dispersal of *Euphorbia paralias* seeds by inshore currents generated by wind or tides is a relatively efficient way of establishing pioneer plants in the vicinity of existing populations. In contrast, retrieval rates for releases further out at sea are much lower. The corollary of this is that, if seeds were pushed further out to sea, for instance by persistent offshore winds, and became entrained in major current systems, the chances of stranding are greatly diminished. To counteract this effect a large and enduring seed source is needed. Which poses the question: where is this source to be found?

Because *Euphorbia paralias* plants are very uniform, variation in habit cannot be used to make an informed guess about the origin of a seed that initiated a particular population. *E. paralias* is widespread and, in places, very common along the southern coastline west of Wilsons Promontory (Wilcock 1997). This large section of continental coastline must function as a steady seed supplier. Given the easterly direction of the prevailing current systems, the majority of the seeds, like the unweighted drift bottles released near Cape Otway, would bypass East Gippsland due to the barrier formed by Wilsons Promontory. Eventually, some of them would have stranded at Scuff Bay, Jane Spiers Beach, Flat Rock or Lord Howe Island.

Where did *Euphorbia paralias* arrive in southern New South Wales?

Until recently, I had assumed that Scuff Bay was the spot first colonized by *E. paralias* on the east coast of mainland Australia. However, in 1997 National Parks and Wildlife Service personnel discovered a population of *Euphorbia paralias* numbering more than 10 000 mature plants on the rather inaccessible Jane Spiers Beach in Nadgee Nature Reserve (L. Evans, pers. comm.). In view of that large number, colonization could have been more than a decade ago and contemporaneous with the appearance of *E. paralias* at Scuff Bay, if not earlier. An unweighted drift bottle released off Cape Otway was reported from Mallacoota Inlet 138 days after release and another one from Merimbula seven days later. This demonstrates that stranding of a seed from a source west of Wilsons Promontory in the Cape Howe area is a feasible proposition and that such a journey to the New South Wales South Coast could be achieved in less than half a year. In any case, it appears that we are dealing with two independent colonisation events.

Favourable habitat conditions

Although *Euphorbia paralias* is now widespread in southeastern coastal mainland Australia, it is not necessarily common over this area. There are still a number of beaches where it is absent, and at many others plant number are low. Only under favourable growing conditions do pioneer plants give rise to large populations: 100 or more individuals are not uncommon in such situations, with a population of well over 10 000 plants at Jane Spiers Beach the largest that has been reported. From my observations it would seem that favourable conditions occur where a fresh supply of sand or flotsam enriches the nutrient status of the foredunes, while a reliable source of fresh water appears to be a contributing factor.

Pioneering plants growing further inland from the beach, for instance in a dry swale behind the foredune, may develop into sizable individuals, but many of the surrounding plants of the new generation often remain small. In such circumstances colonisation of the local beach progresses only at a slow pace or, alternatively, plants may die and disappear. Even large populations such as the one at Scuff Bay may seriously decline after a number of years (Van der Heul, pers. comm.). This could be due to a decrease in nutrient status of the site. There is some evidence that plants grow better in association with *Acacia sophorae* (Labill.) R.Br. However, as shrubs increase in height, the *E. paralias* stems become elongated and eventually plants die from lack of light. Dune erosion can be another cause of disappearance, but at the same time this process provides an opportunity for seed dispersal.

The likelihood of future spread

Euphorbia paralias has established a firm foothold in East Gippsland and southern New South Wales. Various agencies, such as National Parks services and Dune Care groups, have attempted to eradicate *Euphorbia paralias* from some beaches (Gormley & Britton 1997, Heyligers 2002, L. Evans pers. comm.). Given the fecundity of this species, such effort will need to be sustained to have a long-lasting effect (Wilcock 1997). Moreover, nearby areas will remain a seed source for local dispersal and range extension. As drifter experiments have shown, many of the cards and envelopes released at relatively short distances from the shore wash up on beaches in the general vicinity of release points. In East Gippsland drift cards were found over a distance of 220 km; along the southern coast of New South Wales drift envelopes were found over 310 km. Weather conditions influence local wave and current regimes and are the predominant agency in determining the fate of drifting objects including seeds. As is evident from Fig. 7, the resulting movement can be in either direction along the coast. In the case of *E. paralias* seeds, these may strand along beaches with an existing or recently eradicated population, or wash up at new locations. It is the latter process that leads to a gradual range extension.

In addition to local populations, many occurrences of *Euphorbia paralias* west of Wilsons Promontory will provide an ongoing seed supply. As discussed earlier, these seeds could strand at locations well beyond the present range of the species. This raises the question: how far beyond? Wilcock (1997) used the computer software program 'Climate' to predict the potential range of *E. paralias* in Australia based on its native distribution. His map shows that, climate-wise, most of the East Gippsland coast and the New South Wales coast south of Port Macquarie has a 50–60% suitability rating for growth of *E. paralias*. Predictions using the 'Bioclim' program and based on the mid 1990s Australian distribution gave similar results. However, climate factors are not necessarily the overriding determinants of distribution limits. In the case of seashore plants a striking example is provided by the sea-rocket *Cakile edentula* (Bigelow) Hook., a strandline species from the Atlantic and Great Lakes shores of temperate North America. It was introduced to Australia around 1850 and became established along the shores of Bass Strait. From there it spread west to South Australia and north to New South Wales and southern Queensland (Rodman 1986). In 1958 it had reached Heron Island and since then has been collected on several other Great Barrier Reef islands as far north as Bushy Island, at c. 21°S well inside the tropics (Heyligers 1996). On the mainland it has also been collected near Mackay at a similar latitude. The southernmost occurrences in its native range are on the Outer Banks of North Carolina at c. 36°N, roughly at the transition between the cool-temperate climate zone to the north and the warm-temperate, subtropical zone to the south (Rodman 1974, Müller 1982). If *E. paralias* were equally 'insensitive' to climatic conditions, it would be impossible to predict how far north this species could spread. Unweighted drift bottles released in western Bass Strait and drift cards from outlying oilrigs have been reported back from as far north as Cape Tribulation at c. 16°S. Their time at sea varied from one year to 21 months, short enough for many floating *E. paralias* seeds to remain viable.

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I sincerely thank the members of the Eurobodalla Natural History Society and the Far South Coast Birdwatchers who participated in the 1995 and 2000 surveys. I am much indebted to Brooke Connor (Parks Victoria), Lyn Evans (New South Wales National Parks and Wildlife Service), Kevin Mills (Kevin Mills & Associates Pty Ltd), Rebecca Pirzl (Booderee National Park), Teresa and John van der Heul, and Peter Wilcock (Environment Australia) for data they provided. I thank Mike Hilton (Department of

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References

Anon. (1968) Drift bottle releases and recoveries in Bass Strait and adjacent waters, 1958–1962. CSIRO Australia Oceanographical Station List Vol. 78, Melbourne.

Clarke, P.J. (1989) Coastal dune vegetation of New South Wales. University of Sydney Coastal Studies Unit Technical Report No. 89/1 and Soil Conservation Service of New South Wales Technical Report No. 21. 105 pp.

Gormley, L. (1997) A survey of Sea Spurge (*Euphorbia paralias*) occurrences from Sydenham Inlet to Marlo, East Gippsland, Victoria 1997. 13 pp., 3 Appendices (Report to the Department of Natural Resources and Environment, Victoria.)

Gormley, L. & Britton, A. (1997) A report on Sea Spurge (*Euphorbia paralias*) along the coastline of East Gippsland from Marlo to Wingan Inlet, 1996/97. 6 pp., 6 Appendices (Report to the Department of Natural Resources and Environment, Victoria.)

Gray, M. (1997) A new species of *Tetragonia* (Aizoaceae) from arid Australia. *Telopea* 7: 119–127.

Harden, G. J. Ed. (1990–1993) *Flora of New South Wales*. Volumes 1–4 (New South Wales University Press: Kensington).

Heislers, D. (1994) Eastern Victorian coastal trek: an environmental snapshot. iv + 61 pp., 7 Appendices. Victorian Coastal Trekkers Inc.

Heyligers, P.C. (1989a) Sea Spurge (*Euphorbia paralias*), a strandline pioneer new to the Perth region. *Western Australian Naturalist* 18: 1–6.

Heyligers, P.C. (1989b) Strandline plants: history in the making. *Nature in Eurobodalla* 3: 30–36.

Heyligers, P.C. (1991) Strandplant report — June 1991. *Nature in Eurobodalla* 5: 71–74.

Heyligers, P.C. (1993) An investigation into the dispersal of Sea Spurge in southern Australia. Ecological Society of Australia, 1993 Open Forum and Symposium Conference, Canberra, List of Abstracts (not paginated).

Heyligers, P.C. (1995) A survey of Sea Spurge occurrences in southern New South Wales. *Nature in Eurobodalla* 9: 70–74.

Heyligers, P.C. (1996) Rockets down under: what's going on? Ecological Society of Australia, 1996 Open Forum and Symposium Conference, Abstracts: 47.

Heyligers, P.C. (2001) Dispersal and monoecy in *Atriplex cinerea* Poir. (Chenopodiaceae). *Australian Journal of Botany* 49: 501–508.

Heyligers, P.C (2002) Sea Spurge *Euphorbia paralias* in southern New South Wales at the start of the 21st century. *Nature in Eurobodalla* 15: 75–81.

Marshallsay P.G. & Radok, R. (1972) Drift cards in the Southern and adjacent oceans. Research Paper No. 52. The Horace Lamb Centre for Oceanographic Research, Flinders University, Bedford Park, South Australia.

Mills, K. & Associates Pty Ltd (1998) Weed survey. Cudmirrah and Conjola National Parks. Nowra District (National Parks and Wildlife Service of New South Wales).

Müller, M.J. (1982) Selected climatic data for a global set of standard stations for vegetation science. *Tasks for Vegetation Science* 5, Leith, H., Series Ed. (Junk: The Hague.)

Rodman, J.E. (1974) Systematics and evolution of the Genus *Cakile* (Cruciferae). *Contributions from the Gray Herbarium* 205: 3–146.

Rodman, J.E. (1986) Introduction, establishment and replacement of sea-rockets (*Cakile*, Cruciferae) in Australia. *Journal of Biogeography* 13: 159–171.

Westhead, B.D. (1996) Sea Spurge survey in the Croajingolong Nat. Park. 8 pp., 3 Appendices. Advanced Certificate in Resource Management, Bendigo Regional Institute of TAFE.

Wilcock, P.J. (1997) Aspects of the ecology of *Euphorbia paralias* L. (Sea Spurge) in Australia. ix + 120 pp. BAppliedSc (Hons) thesis, University of Ballarat.

Wood, K.A. (1996) Experiments to determine the fate of dead seabirds off Wollongong, New South Wales. *Corella* 20: 35–41.

Effects of time since fire, topography and resprouting eucalypts on ephemeral understorey species composition, in semi-arid mallee communities in NSW.

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In 1985 and 1989, two studies examined the effects of time since fire, topography and resprouting eucalypts on the composition of understorey species in mallee vegetation at Yathong Nature Reserve, in semi-arid New South Wales. Emphasis was on ephemerals. Species richness was significantly higher at 2.5 years after fire. Species present five years after fire were a subset of those occurring earlier. Two-dimensional ordination based on ranked similarity measures of species and analysis of similarities indicated discrete time since fire groups. Short-lived species dominated early groups (≤ 2.5 years) i.e. *Haloragis odontocarpa, Convolvulus erubescens, Sclerolaena parviflora* and *Solanum coactiliferum*. All these species had disappeared at ≥ 5 years. The perennials *Triodia scariosa, Amphipogon caricinus* and *Halgania cyanea*, dominated at ≥ 5 years post-fire. Species composition was significantly affected by topographic position (upper, mid, lower dune) but not by mallee eucalypts (under canopy, in gap). Two-dimensional ordination based on ranked similarity measures of species and ANOSIM indicated that upper and lower topographic positions were significantly different. Most common species in upper topographic positions were *Haloragis odontocarpa, Bracteantha viscosa* and *Sclerolaena parviflora* and in the lower *Stipa scabra, Haloragis odontocarpa* and *Chenopodium* sp. Species richness was not significantly affected by topography or eucalypts (17.45/10m^2 +/- 0.16). The number of ephemeral species (10 m^{-2}) was higher in the lower topographic positions (7.87 +/- 0.66) than the upper (4.88 +/- 0.44). There was no significant effect of eucalypts on the number of ephemeral or perennial species.

Introduction

Although studies have examined the effects of factors such as time since fire and topography on perennial plant species in Australian semi-arid mallee communities (Cheal 1981, Hodgkinson & Griffin 1982, Maconochie 1982, Bradstock 1989, Hill 1989, Noble 1989a, 1989b, Wellington 1989, Bradstock & Cohn 2002, Noble & Grice 2002), comparatively little is known about the ephemeral grass and herb species with which they coexist. These species are difficult to study because they appear sporadically, which in part reflects their dependence on seasonal rainfall for germination, growth and reproduction (Holland 1968, Noble 1989b, Fox 1990).

A number of studies examining the effect of time since fire on ephemeral herb and grass species composition have either compared recently burnt and unburnt mallee stands (Zimmer 1940, Cheal 1981, Van der Moezel & Bell 1984), or, if a range of times since fire has been examined, then emphasis has been on biomass changes in the most dominant species (Noble 1989b). Whilst both types of studies agree on a decline in species richness with time since fire, resulting from the disappearance of short-lived herb and grass species, neither has provided detailed information on the changes in frequency of individual or suites of species over time.

In the semi-arid zone subtle changes in soil texture, water balance and nutritional status are known to determine the distribution of perennial species, resulting in a mosaic of mallee communities (Beadle 1981, Parsons 1981, Specht 1981, Bradstock & Cohn 2002). Within mallee dunefields of New South Wales, different vegetation patterns in swales and on dunes have been attributed to an interaction between topography, soil type and fire (Noble 1984). Although the broad distribution of mallee species in relation to topography and soil types is well documented (Bradstock 1989, Morcom & Westbrook 1990, Fox 1991, Scott 1992, Cohn 1995, Sivertsen & Metcalfe 1995, Porteners et al. 1997, Westbrooke et al. 1998), no study has concentrated on the small scale distribution of understorey ephemeral species in relation to those two factors. Work by Noble (1981, 1984) however suggests that the heavier soils of swales have a greater capacity to carry ephemeral species than the sandier soils of adjacent dunes.

Microhabitat diversity may also influence the distribution of herb and grass species. Mallee eucalypts develop pronounced soil hummocks at their bases, mostly from soil accretion (Noble 1989a). Since there is evidence that wind and water probably play a role in distributing seeds (Hodgkinson et al. 1980), the composition of herb and grass species may be different below eucalypts than in the gaps between them. A number of studies have found a relationship between species composition and distance from eucalypts (Story 1967, Hodgkinson et al. 1980, Harrington et al. 1981, Noble 1989b, Lunt 1990, Scanlan & Burrows 1990, Magcale-Macandog & Whalley 1991, Kirkpatrick 1997). Such trends, however, could be attributed to the influence of the overstorey in relation to radiation, temperature and competition for soil-moisture and nutrients (Kirkpatrick 1997). Such effects could be minimised directly after a fire when a reduction in competition from *Eucalyptus* spp. results from live tissue removal from the aerial growing parts and resprouting is in its infancy.

Our studies examine species richness and composition in the understorey; firstly in relation to a range of times since fire (up to 15 years), and secondly in relation to topographic position (lower slope, mid-slope, upper slope), the position of species in relation to resprouting eucalypts (in gap, under canopy), and their interactions.

Methods

The studies were undertaken in Yathong Nature Reserve, in central western New South Wales, approximately 130 km south of Cobar (32°35′ S, 145°35′ E). Sites were located in mallee on low east-west oriented dunes of deep red siliceous sands and in the swales on deep calcareous red earths and red texture-contrast soils (Lawrie &

Stanley 1980, Mabbutt et al. 1982, Soil Conservation Service 1984). The mallee was dominated in the overstorey by *Eucalyptus dumosa* and *Eucalyptus socialis* with an understorey of *Acacia rigens, Acacia wilhelmiana* and the hummock grass *Triodia scariosa* subsp. *scariosa*.

Most of the Nature Reserve lies between the 325 mm and 350 mm isohyets. Rainfall is characteristically non-seasonal, and variable annually (Leigh et al. 1989). At Cobar the mean minimum daily temperature in July is 4.1°C and the mean maximum daily temperature in January is 34.6°C. Evaporation is high, especially in non-winter months (Anon. 1968).

Taxonomy follows Harden (1990–1993). At the time of the survey the taxonomy of *Stipa variabilis* complex was in disarray. The complex has now been identified as four separate species namely *Austrostipa nitida, Austrostipa nodosa, Austrostipa drummondii* and *Austrostipa trichophylla*, which are considered annuals (Surrey Jacobs, pers. comm). Since our specimens were not available for a second examination, we have referred to this complex as *Austrostipa* spp.

Effects of time since fire

This study was undertaken in November 1989. We examined the frequency of occurrence of all species of grasses, herbs and seedlings of woody species at different times since fire. The chronosequence approach involved selecting sites with a range of times since last fire with uniform site characteristics. The five sampled sites were previously burnt in the summers of, respectively, 1974/75 and 1984/85, April of 1987, March of 1988 and 1989. The wildfires in 1974/75 and 1984/85 burnt extensive areas (> 10 000 ha) and the former burnt all study sites. The fires after 1985 were small-scale experimental burns varying in size from 50 ha in 1987, 20 ha in 1988 and 6 ha in 1989 (Bradstock et al. 1992, Cohn & Bradstock 2000). Within homogeneously burnt areas in each time since fire, 20 transects were selected within an area of approximately 1 km^2. Data were collected in 1 m^2 quadrats located along the transects, measuring 20 m in length. There were five quadrats per transect and within each, the presence of all plant species was recorded.

The chronosequence approach depended on uniformity of site characteristics. Departures from this included variation in the year/season of the last burn and previous fire intervals. Since the survival of post-fire seedlings are dependent on post-fire conditions, trends in our data may have been, in part, influenced by variations in rainfall and vertebrate grazing (Noble 1989a, 1989b, Cohn & Bradstock 2000). Former fire intervals ranged from 10 to 14 years, except for the 1974/75 fire, for which the previous interval was 'unknown'. Given that the known range of fire intervals was not large and that the decline in species richness for 1974/75 site were consistent with other similar studies in semi-arid mallee communities (Cheal 1981), concerns for this departure were considered minimal.

Effects of topography and eucalypts

This study was undertaken in December 1985 in an area previously burnt in the summer of 1984/85. It examined the effects of topography, eucalypt presence and their interactions on the composition of understorey species, especially ephemerals during ideal conditions i.e. in the first growing season after fire, following above average spring rainfall. On a transect placed from one swale to the next (i.e. bisecting a prominent dune; approx. 200 m long), plant species were recorded in 1 m^2 quadrats at specified topographic positions: swale, lower slope, mid-slope, dune crest and upper slope. At each topographic position, which occurred twice along the transect, 10 quadrats sampled under resprouting *Eucalyptus* spp. and a further 10 sampled in the gaps. A total of 200 quadrats were sampled. Data from the swale and lower slope were pooled and referred to as 'lower'; pooled data from the dune crest and upper slope were called 'upper'; mid-slope data was called 'mid'.

Statistical Analyses

Analyses of variance (ANOVA) used Tukey tests for post-hoc pairwise comparisons. To satisfy Cochran's test of homogeneity of variances, data were square root transformed. Where heterogeneity of variance could not be overcome through transformation, a more conservative level of significance ($P < 0.01$) was applied (Underwood 1981).

Effects of time since fire

The null hypothesis that the number of species (per transect i.e. 5 m^2) did not vary with time since fire (0.75, 1.75, 2.5, 5, 15 years) was tested using a one-factor ANOVA. Pearson's correlation coefficient tested for a correlation between time since fire and the number of species.

The null hypothesis of no difference in the composition of plant species in different times since fire was tested. Presence/absence scores were modified to the frequency of each species (0 to 5) along each transect. The Bray Curtis association measure was used on the untransformed data to produce a similarity matrix. Ordination of the samples used non-metric, multi-dimension scaling (MDS) to graphically illustrate the ranked similarity matrix in two-dimensional space. One-way analyses of the ranked similarity of ordinated groups (ANOSIM: Analysis of similarities) used the statistic $R = (r_B - r_W)/(M/2)$, where r_W was the average rank of similarities within sites and r_B was the average rank of similarities from all pairs of replicates between sites; and $M = n(n-1)/2$, where n was the total number of samples (Clarke & Warwick 1994). The characterisation of sample groupings by species was computed using the average dissimilarity between all pairs of inter-group samples, reduced to contributions from each species.

Differences in the frequency of individual species (5 m^{-2}) were tested using ANOVA. One-factor ANOVAs examined the effect of time since fire on species which occurred in greater than 20% of the quadrats. Seedlings of perennial woody *Acacia* spp. were excluded, since emphasis was on grasses, herbs and sub-shrubs for which there was little information on their dynamics.

Effects of topography and eucalypts

The null hypotheses of no difference in species composition with respect to eucalypt position (in gap, under canopy) and topographic position (lower, mid, upper) were tested. Presence/absence scores were modified to frequency scores for each topographic position along each transect (10 m^{-2}), so each species had a score of between 0 and 10 (0 = not present in any quadrat, 1 = present in one quadrat etc). A similarity matrix based on the untransformed data and the Bray Curtis association measure formed the basis of analyses. Ordination of the samples used MDS. A two-way crossed (eucalypt position, topographic position) analysis of the ranked similarities tested the similarity of ordinated groups. Characterisation of the resultant group by species was computed using dissimilarity scores (see above).

Differences in the frequency of the 11 most common species (i.e. occurred in 50% of quadrats), species richness and the number of ephemeral and perennial taxa (10 m^{-2}) were tested. Orthogonal two-factor ANOVAs examined the effect of eucalypt (in gap, under canopy) and topographic positions (lower, mid, upper) on each. The lifecycles of eight taxa identified to genus were unknown, so they were excluded from analyses.

Results

Effects of time since fire

A total of 45 species were identified among all the transects sampled (total area of 500 m^2). The number of species was inversely proportional to time since fire, i.e. 32, 24, 27, 16 and 8 species were found at respectively 0.75, 1.75, 2.5, 5 and 15 years post-fire, each within an area of 100 m^2 (Appendix 1). The mean number of species per transect (5 m^{-2}) was significantly affected by time since fire ($F = 76.7$, d.f. = 4,95, $P < 0.001$; $r = -0.835$, $P < 0.001$). The number was lower at 5 and 15 years after fire than from 0.75 to 2.5 years after fire (Fig. 1). Whilst there were no significant differences between 0.75, 1.75 and 2.5 years, the number of species was significantly higher at 5 years than 15 years after fire.

A two-dimensional ordination based on the ranked similarity measures (stress = 0.17) indicated discrete groups (Fig. 2). A global analysis based on species composition, showed significantly higher similarity along transects within the same time since fire than between different times since fire groups ($R = 0.776$, $P < 0.001$). Analyses of pairs of sample groups, which appeared close in the ordination, namely 5 (1985) and 15 (1974) years post-fire ($R = 0.489$, $P < 0.001$), 1.75 (1988) and 2.5 (1987) years post-fire ($R = 0.602$, $P< 0.001$), also showed significantly higher similarity within rather than between different times since fire.

The average within group similarity was lowest for 15 years post-fire, followed in order by 2.5, 5, 0.75 and 1.75 years (Table 1). Up to nine species characterised 90% of the average within group similarity for each time since fire. Up to seven plant species characterised 50% of the average dissimilarity between time since fire groups (Table 2). There was no gradual trend in the average dissimilarity between pairs of time since

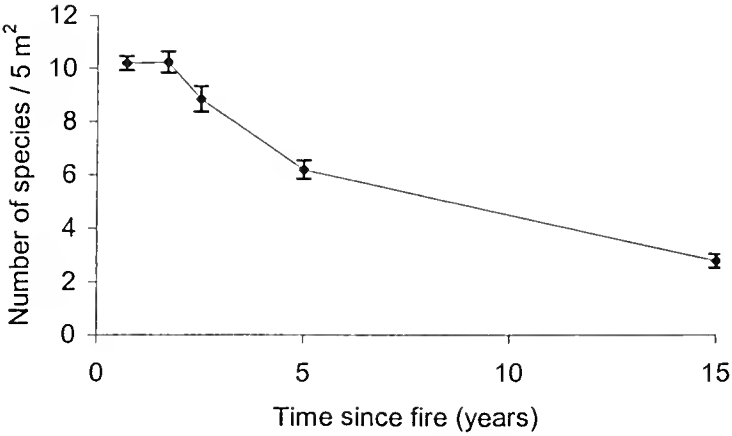

Fig. 1. Species richness (per transect: 5 m²) in different time since fire groups. Data are mean and standard error.

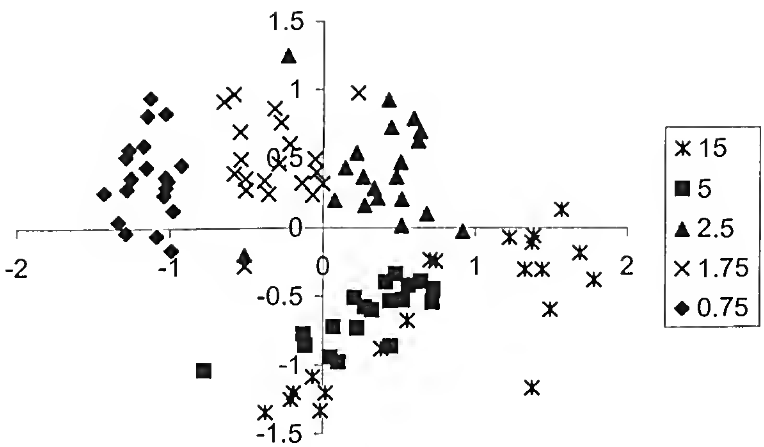

Fig. 2. Ordination plot (stress = 0.17) showing groups defined by cluster analysis. Each point represents a transect of 5 quadrats (5 m²) in time since last burnt (years).

Table 1. Species (ranked in order of importance) contributing to 90% of the similarities within each time since fire group.

Species	Average frequency (5 m^{-2})	Cumulative contribution to similarity (%)
0.75 years since fire	average similarity 58.20	
Convolvulus erubescens	4.80	37.63
Haloragis odontocarpa	3.55	61.15
Triodia scariosa	1.80	69.70
Podolepis jaceoides	1.05	75.11
Psoralea eriantha	1.10	80.26
Goodenia willisiana	1.25	84.71
Poranthera microphylla	1.15	89.05
1.75 years since fire	average similarity 55.81	
Sclerolaena parviflora	3.45	22.34
Haloragis odontocarpa	2.80	40.79
Convolvulus erubescens	2.20	51.86
Solanum coactiliferum	2.00	61.54
Triodia scariosa	1.85	69.95
Amphipogon caricinus	1.75	77.63
Lomandra collina	1.20	82.92
Schoenus subaphyllus	1.25	87.64
Acacia wilhelmiana	0.90	90.82
2.5 years since fire	average similarity 50.69	
Amphipogon caricinus	3.70	34.93
Solanum coactiliferum	2.50	52.84
Haloragis odontocarpa	1.60	64.88
Triodia scariosa	1.45	73.46
Sclerolaena parviflora	1.45	80.40
Chenopodium desertorum	1.00	86.18
Vittadinia cuneata	0.70	89.91
5 years since fire	average similarity 59.43	
Halgania cyanea	3.55	36.01
Triodia scariosa	2.95	63.40
Amphipogon caricinus	2.80	83.28
Solanum coactiliferum	1.00	90.21
15 years since fire	average similarity 40.26	
Amphipogon caricinus	2.35	63.08
Triodia scariosa	1.85	86.33

Table 2. Species (ranked in order of importance) contributing to 50% of the dissimilarities (dissim.) between pairs of time since fire (tsf) groups (5 m^{-2}).

Species	Tsf groups (years) 1	Tsf groups (years) 2	Age diff. (years)	Mean dissim.	Meanfreq. tsf groups 1	Meanfreq. tsf groups 2	Cum. contrib. to dissim. (%)
Convolvulus erubescens	0.75	1.75	1.00	61.95	4.80	2.20	10.19
Sclerolaena parviflora					0.95	3.45	20.11
Amphipogon caricinus					0.00	1.75	26.43
Solanum coactiliferum					0.65	2.00	32.74
Triodia scariosa					1.80	1.85	38.22
Haloragis odontocarpa					3.55	2.80	43.68
Goodenia willisiana					1.25	0.00	48.37
Convolvulus erubescens	0.75	2.5	1.75	78.66	4.80	0.10	16.07
Amphipogon caricinus					0.00	3.70	28.59
Haloragis odontocarpa					3.55	1.60	35.88
Solanum coactiliferum					0.65	2.50	42.94
Sclerolaena parviflora					0.95	1.45	47.71
Convolvulus erubescens	0.75	5	4.25	85.24	4.80	0.00	16.39
Halgania cyanea					0.00	3.55	28.41
Haloragis odontocarpa					3.55	0.05	40.20
Amphipogon caricinus					0.00	2.80	49.46
Convolvulus erubescens	0.75	15	14.25	92.94	4.80	0.00	19.52
Haloragis odontocarpa					3.55	0.00	33.71
Amphipogon caricinus					0.00	2.35	43.19
Triodia scariosa					1.80	1.85	50.96
Amphipogon caricinus	1.75	2.5	0.75	60.79	1.75	3.70	10.40
Sclerolaena parviflora					3.45	1.45	20.75
Convolvulus erubescens					2.20	0.10	29.86
Solanum coactiliferum					2.00	2.50	37.23
Haloragis odontocarpa					2.80	1.60	43.74
Triodia scariosa					1.85	1.45	49.96
Sclerolaena parviflora	1.75	5	3.25	74.36	3.45	0.00	13.05
Halgania cyanea					0.20	3.55	25.94
Haloragis odontocarpa					2.80	0.05	36.43
Convolvulus erubescens					2.20	0.00	44.74
Sclerolaena parviflora	1.75	15	13.25	82.12	3.45	0.00	15.24
Haloragis odontocarpa					2.80	0.00	27.74
Convolvulus erubescens					2.20	0.00	37.42
Triodia scariosa					1.85	1.85	46.25
Halgania cyanea	2.5	5	2.50	67.40	0.05	3.55	17.30
Amphipogon caricinus					3.70	2.80	27.11
Triodia scariosa					1.45	2.95	36.44
Solanum coactiliferum					2.50	1.00	45.58
Solanum coactiliferum	2.5	15	12.50	75.02	2.50	0.00	14.49
Amphipogon caricinus					3.70	2.35	26.87
Triodia scariosa					1.45	1.85	38.11
Haloragis odontocarpa					1.60	0.00	47.43
Halgania cyanea	5	15	12	67.21	3.55	0.20	25.44
Triodia scariosa					2.95	1.85	43.16

fire groups, based on their age differences. Dissimilarity was, however, highest between extremes in time since fire (0.75 and 15 years) and lowest between the closest (1.75 and 2.5, 0.75 and 1.75 years).

Ten of the most frequently occurring species (excluding seedlings of *Acacia* spp.) were tested for the effect of time since fire on their frequency of occurrence (Table 3). All species except *Triodia scariosa* and *Lomandra leucocephala* were significantly affected by time since fire. In seven significant cases, frequency was highest within five years of fire, dwindling to zero or near zero by 15 years after fire (Fig. 3). The frequencies of *Haloragis odontocarpa* and *Convolvulus erubescens* peaked quickly within 0.75 years of fire and had declined to near zero by five and 2.5 years respectively. *Sclerolaena parviflora* and *Solanum coactiliferum* peaked in frequency at respectively 1.75 and 2.5 years after fire and had declined to near zero by respectively five and 15 years after fire. *Halgania cyanea* peaked at five years after fire and was at low frequency 10 years later. *Podolepis jaceoides, Schoenus subaphyllus* and *Lomandra leucocephala* maintained relatively low frequencies throughout. Only *Triodia scariosa* and *Amphipogon caricinus* still had high frequencies at 15 years after fire. Whilst *Amphipogon caricinus* peaked at five years after fire, *Triodia scariosa* maintained a relatively high frequency throughout.

Effects of topography and eucalypts

A two-dimensional ordination based on the ranked similarity measures (stress = 0.08) indicated discrete plant species groups in relation to topographic position, confirmed by a two-way crossed ANOSIM ($R = 0.45$, $P < 0.001$; Fig. 4). Lower topographic sites differed significantly from upper topographic sites, but there were no significant differences between these sites and mid-slope sites. There was no significant effect of eucalypt canopy ($R = 0.22$, $P < 0.08$).

The average within group similarity was higher for the upper (61.67%) than the lower topographic positions (43.88%; Table 4). Ninety percent of the average within group similarity was characterised by nine in the upper and 13 species in the lower topographic positions. The percentage representation of ephemeral taxa was higher in the lower than the upper topographic positions.

The average dissimilarity between the upper and lower topographic groups was 69.41%. Thirteen plant species characterised 60% of this dissimilarity (Table 5): those more frequent in upper topographic positions included *Bracteantha viscosa, Amphipogon caricinus, Sclerolaena parviflora, Haloragis odontocarpa, Triodia scariosa* and an unknown species; those more frequent in lower topographic positions included *Hyalosperma semisterile, Rhyncharrhena linearis, Austrostipa scabra, Chenopodium* sp., *Sclerolaena diacantha, Austrostipa* spp. and *Harmsiodoxa blennodioides*.

Of the 11 most frequently occurring species (≥ 50% of quadrats), nine were significantly affected by topographic position. Of these, two were also significantly affected by the position in relation to mallee eucalypts. Two species were not significantly affected by either factor (Table 6). Species more frequent in upper topographic positions concur with dissimilarity results, with the addition of *Halgania cyanea* (see above). *Austrostipa scabra* and *Harmsiodoxa blennodioides* were more frequent

Table 3. The effects of time since fire on species which occurred in greater than 20% of quadrats (excluding seedlings of perennial Acacia shrub spp.). Results are derived from one-way analyses of variance of the frequency of species (5 m^{-2}). Time since fire included 0.75, 1.75, 2.5, 5 and 15 years. Means are arranged in ascending order; underlining indicates no significant difference. Transformations of data include square root[1] and heteroscedastic data assessed at P< 0.01 were either untransformed[2] or square root transformed[3] (P < 0.05 *, P < 0.01 **, P < 0.001*, not significant ns).**

Species	Means					$F_{(4,95)}$	P
Amphipogon caricinus	0.75	1.75	15	5	2.5	19.6	***
Convolvulus erubescens[2]	15	5	2.5	1.75	0.75	183	***
Halgania cyanea[1]	0.75	2.5	1.75	15	5	121	***
Haloragis odontocarpa[2]	15	5	2.5	1.75	0.75	71.4	***
Lomandra leucocephala	15	1.75	0.75	2.5	5	1.0	ns
Podolepis jaceoides[3]	15	2.5	5	1.75	0.75	12.7	***
Schoenus subaphyllus[1]	0.75	2.5	15	5	1.75	7.3	***
Sclerolaena parviflora[2]	15	5	0.75	2.5	1.75	38.7	***
Solanum coactiliferum[1]	15	0.75	5	1.75	2.5	19.0	***
Triodia scariosa[2]	2.5	0.75	1.75	15	5	3.0	ns

Table 4. Taxa (ranked in order of appearance) contributing to 90% similarities within the data set in lower and upper topographic positions (Lifecycle type taken from Harden (1990–3), S. Jacobs (pers. comm.): p = perennial, a = annual, slp = short lived perennial, ? =unknown).

Taxa	Mean freq. (10 m-2)	Cumulative contribution to similarity (%)	Family	Lifecycle type
1/ Lower (average similarity 43.88)				
Austrostipa scabra	8.38	27.47	Poaceae	p
Haloragis odontocarpa	5.38	39.65	Haloragaceae	a
Chenopodium sp.	4.13	49.41	Chenopodiaceae	?
Rhyncharrhena linearis	4.00	56.48	Asclepidaceae	p
Harmsiodoxa blennodioides	3.50	63.08	Brassicaceae	a
Hyalosperma semisterile	4.00	68.86	Asteraceae	a
Austrostipa spp.	3.50	74.03	Poaceae	a
Sclerolaena parviflora	2.50	78.14	Chenopodiaceae	slp
Sclerolaena diacantha	3.25	82.19	Chenopodiaceae	p
Rhodanthe floribunda	2.12	84.80	Asteraceae	a
Bracteantha viscosa	2.00	86.77	Asteraceae	a
Nicotiana velutina	2.13	88.65	Solanaceae	a
Vittadinia dissecta var. *hirta*	1.50	90.40	Asteraceae	a/slp
2/ Upper (average similarity 61.67)				
Haloragis odontocarpa	9.50	22.86	Haloragaceae	a
Bracteantha viscosa	8.38	41.68	Asteraceae	a
Sclerolaena parviflora	7.38	56.34	Chenopodiaceae	slp
Amphipogon caricinus	6.00	66.13	Poaceae	p
Austrostipa scabra	5.25	74.21	Poaceae	p
Unknown sp. 9	4.00	80.07	Unknown	?
Triodia scariosa	3.38	85.10	Poaceae	p
Halgania cyanea	*1.88*	*88.16*	*Boraginaceae*	*p*
Poranthera microphylla	1.88	90.34	Euphorbiaceae	a

Table 5. Species (ranked in order of importance) contributing to 60% of the dissimilarities between lower and upper topographic groups.

Average dissimilarity between groups 69.41

Species	Mean frequency /10m2		Cumulative contribution to dissimilarity (%)
	lower	upper	
Bracteantha viscosa	2.00	8.38	7.47
Amphipogon caricinus	1.00	6.00	13.58
Sclerolaena parviflora	2.50	7.38	19.46
Haloragis odontocarpa	5.38	9.50	24.36
Hyalosperma semisterile	4.00	0.13	28.98
Rhyncharrhena linearis	4.00	0.00	33.37
Austrostipa scabra	8.38	5.25	37.65
Chenopodium sp.	4.13	1.75	41.58
Sclerolaena diacantha	3.25	0.00	45.40
Unknown sp. 9	1.38	4.00	49.10
Austrostipa spp.	3.50	0.13	52.79
Harmsiodoxa blennodioides	3.50	0.25	56.45
Triodia scariosa	0.13	3.38	60.09

Table 6. Significant effects of topography (lower (l), mid (m), upper (u)) and position in relation to eucalypts (in gaps (g), under canopy (c)) on species which occurred in at least 50 % of quadrats. Results are derived from fully factorial two-way analyses of variance of the frequency of each species /10 m^2. Means are arranged in ascending order. Transformations of data include square root[1] and heteroscedastic data assessed at P < 0.01 were either untransformed[2] or square root transformed[3] (P < 0.05*, P < 0.01, P < 0.001***, not significant ns).**

Species	Topography mean	$F_{(2,14)}$	P	Eucalypt mean	$F_{(1,14)}$	P
Amphipogon caricinus	l m u	9.0	**	-	-	ns
Halgania cyanea	l m u	4.4	*	-	-	ns
Haloragis odontocarpa	l m u	4.8	*	-	-	ns
Harmsiodoxa blennodioides[3]	u l m	10.8	***	-	-	ns
Bracteantha viscosa	l m u	8.5	**	-	-	ns
Sclerolaena parviflora	l m u	9.3	**	c g	5.7	*
Austrostipa scabra	u l m	5.1	*	-	-	ns
Triodia scariosa[1]	l m u	9.1	**	-	-	ns
Pseudognaphalium luteoalbum	-	-	ns	-	-	ns
Chenopodium sp.	-	-	ns	-	-	ns
Unknown sp. 9	l m u	4.3	*	c g	7.9	*

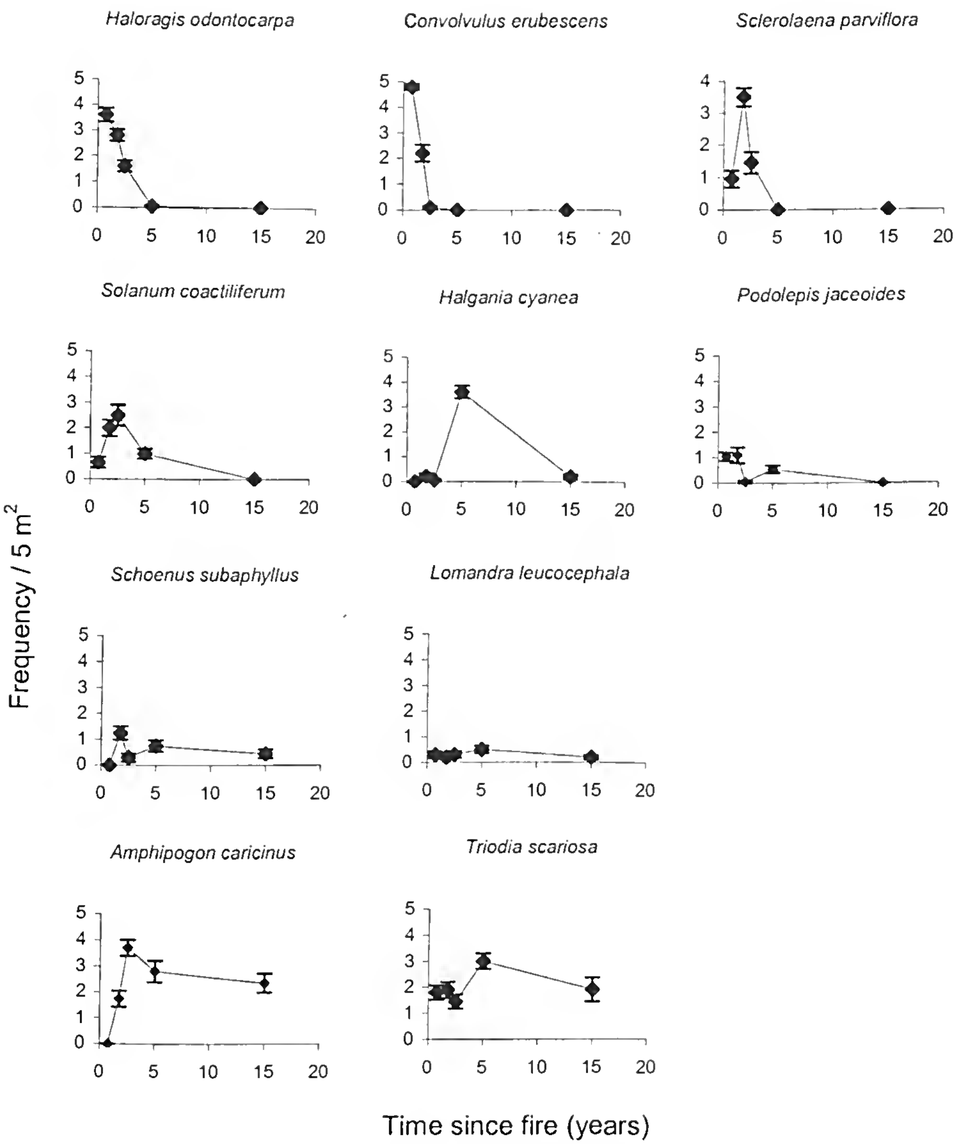

Fig. 3. Frequency of species (per transect: 5 m^2) that occurred in greater than 20% of quadrats in response to time since fire. Data are mean and standard error.

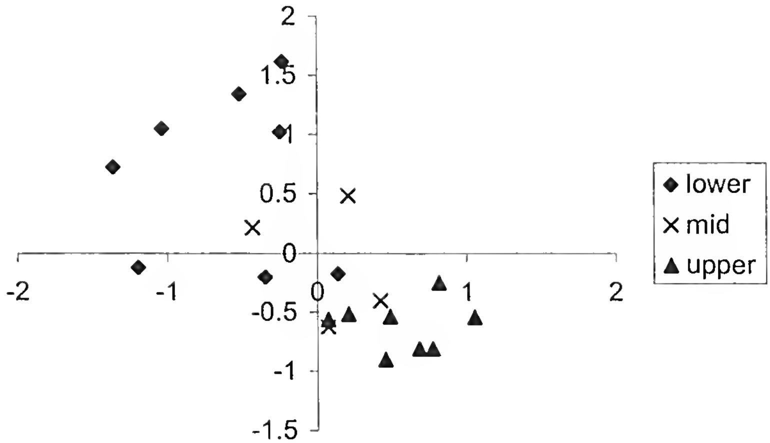

Fig. 4. Ordination plot (stress = 0.08) showing groups defined by cluster analysis. Each point represents 10 quadrats (10 m^2) in the different topographic positions (lower slope, mid-slope, upper slope).

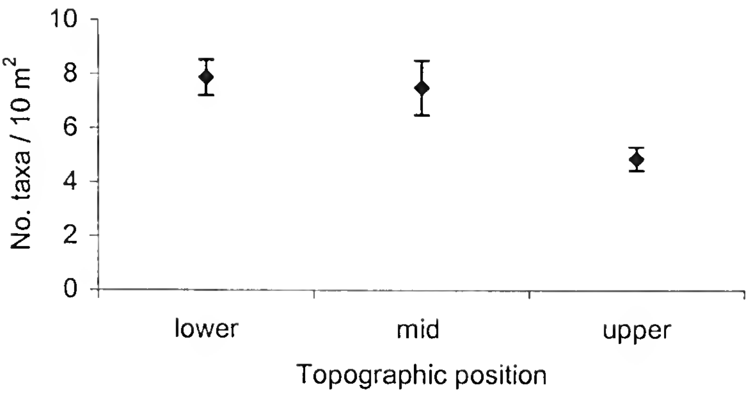

Fig. 5. Number of ephemeral taxa (10 m^{-2}) in different topographic positions (lower slope, mid-slope, upper slope). Data are mean and standard error.

in lower than upper topographic positions. *Sclerolaena parviflora* and an unidentified species occurred more frequently in the gaps than under the canopies of eucalypts. *Gnaphalium luteo-album* and *Chenopodium* sp. were not significantly affected by either factor or their interaction.

There were no significant effects of topography or eucalypt position on species richness per 10 m^2 ($P > 0.05$). The mean number of species for all the data pooled was 17.45 / 10 m^2 (+/- 0.16 s.e.). A total of 58 species were identified in the 200 quadrats sampled (200 m^2).

There was a significant effect of topography on the number of ephemeral ($F = 6.6$, d.f. = 2, $P < 0.01$), but not perennial taxa ($P > 0.05$). The mean number of ephemeral taxa was higher in the lower than the upper topographic positions. Neither were significantly different from the mid-slope (Fig. 5). There was no significant effect of eucalypt position on the number of ephemeral or perennial taxa ($P > 0.05$).

Discussion

Effects of time since fire

The results from this study indicate a decline in the above ground richness of all understorey species with increasing time since fire. A flush of short-lived species up until 2.5 years after fire resulted in higher richness than five and more years after fire, which was dominated by perennials. The results confirm Bradstock's (1990) original observations that few ephemeral grasses and herbs existed five to seven years after fire. Trends in other mallee studies, which examined both total species (Zimmer 1940, Cheal 1981) and herbaceous species richness (Noble 1989b) with time since fire, are also comparable. Cheal (1981) found that total species richness in Victorian mallee dominated by *Eucalyptus foecunda* remained high up to four years after fire. A study by Holland (1968) in mallee near our study site also found that the life expectancy of field layer plants was between six months and five years.

Distinct suites of species defined different times after fire (Table 1). The most common short-lived species up to 2.5 years post-fire included *Haloragis odontocarpa* and *Convolulus erubescens* which peaked in the first spring, followed by *Sclerolaena parviflora* in the second spring. All three species had either disappeared or were in very low numbers within five years of fire. *Solanum coactiliferum* peaked in the second/third springs and had disappeared 15 years after fire; in South Australian mallee it produces seeds within 2.4 years of fire (Morelli & Forward 1996). Other studies in semi-arid mallee in NSW have similarly observed the rapid growth and decline of *Haloragis odontocarpa* (Bradstock 1989), and *Sclerolaena parviflora* following fires, irrespective of the season of the burn (Noble 1989b). Noble (1989b) believed that the quick response of *Haloragis odontocarpa* to fire indicated an effect of scarification or charred wood, although his field observations also suggested its germination was stimulated by mechanical scarification.

In their respective studies, Noble (1989b) and Bradstock (1989) note the proliferation of the short-lived grasses *Stipa* spp. in the first year following fire. Since their presence is reliant on adequate rainfall (Noble 1989b, Noble & Vines 1993), their relative absence in our study may relate to the very low rainfall experienced in the spring at the start the survey (1989), which received a monthly average of 7 mm. This was well below the long term spring monthly average of 27 mm (Cohn & Bradstock 2000).

Other relatively common species typifying early time since fire groups ($\leq$ 2.5 years) included *Podolepis jaceoides, Psoralea eriantha, Goodenia willisiana, Poranthera microphylla, Lomandra collina* and *Vittadinia cuneata* (Table 1). All of these species had either disappeared or were rare five or more years after fire. A study by Cheal and Parkes 1989, found *Poranthera microphylla* as scattered individuals in the 'decades old mallee' dominated by *Callitris verrucosa*, suggesting that its seeds are not necessarily dependent on fire for germination.

Whilst the perennial grasses *Triodia scariosa* and *Amphipogon caricinus* were relatively common throughout most time since fire groups, they dominated along with *Halgania cyanea*, at 5five or more years after fire (Table 1). Their dominance coincided with a significant decline in species richness. Other studies have found that as the original dominants regain their post-fire structure and composition, a decline in richness and diversity occurs (Zimmer 1940, Noble et al. 1980, Cheal 1981). In hummock grasslands and woodlands, competition between *Triodia* spp. and other herbaceous species occurs as the former matures, leading to a decline in the initial number of species (Burbidge 1943, Allan & Griffin 1986, Noble 1989b, Allan & Baker 1990). Indeed, Noble (1989b) found a strong negative correlation between total herbage cover over time, with the combined cover of *Triodia* and mallee eucalypts.

The average similarity measure within each time since fire group was noticeably lowest at 15 years (40.26) than all other time since fire groups (50.69 to 59.43; Table 1). As the ephemerals 'died off' with increasing time since fire, one may have expected increasing homogeneity. It is possible that varying and subtle site factors or the hardiness of individual plants within a species to the same set of environmental conditions may have resulted in differential mortality for each species.

The highest mean dissimilarity measure between pairs of time since fire groups was between the most and the least recently burnt sites (Table 2). The species largely responsible were short-lived species *Convolvulus erubescens, Haloragis odontocarpa* and perennial grasses *Amphipogon caricinus* and *Triodia scariosa*. Whilst a study in *Triodia* spp. communities in central Australia found a similar trend in the dissimilarity measures between extremes in times since fire, it also found high variation in the dissimilarity measures between pairs of more recently burnt sites (Allan & Baker 1990). Allan and Baker (1990) believed this reflected the importance of rainfall in the early stages of post-fire recovery. Although our results do not show a high variation in dissimilarity between pairs of recently burnt sites, other studies in semi-arid mallee communities have recognised the influence of seasonal rainfall on the composition of ephemeral (Fox 1990) and perennial species, especially in the first growing season following fire (Noble 1989b, Cohn & Bradstock 2000).

For herbaceous 'fire species', which appear mainly after fire, reproduce and disappear until the next fire (e.g. *Haloragis odontocarpa*), the abundance and viability of the soil-stored seed is important (Van der Moezel & Bell 1984, Noble et al. 1986, Noble 1989a, 1989b). These species are described as obligate seed regenerators by McMahon (1984). It is believed that the abundance of these species is dependent on soil seed banks being 'topped up' by periodic fire (Noble et al. 1986, Noble 1989). Our results indicate a minimum fire interval of at least five years is needed to allow all herb and grass species recognised in this study, to grow and reproduce. Since the maximum number of above ground species was experienced within 2.5 years of fire, following a previous interval of 14 years, a maximum fire interval is estimated at 14 years. Similarly, in Victorian mallee dominated by *Eucalyptus incrassata*, Cheal (1981) found that fire ephemerals generally absent from vegetation 15 years or more post-fire, rapidly established from soil-stored seed. In mallee in NSW, Noble (1989a) found that *Haloragis odontocarpa* comprised of a proportionally higher biomass after a fire interval of 13 years (54% of biomass) rather than at least 50 years (4% of biomass).

Little is known about the lifecycles of the grasses and herbs in this study. While the appearances of seedlings of *Acacia* spp., *Haloragis odontocarpa* and possibly *Triodia scariosa* (Noble 1989b) were stimulated directly by the effects of fire, it is not known whether other species, which peaked in frequency soon after the fire, were similarly stimulated, or simply responded to a reduction in competition from perennial species. This was beyond the scope of this study.

Effects of topography and eucalypts

Given a well-defined dune system with corresponding soil texture differences, sandy soils on dune crests and heavier textured soils in swales, it was not surprising that this was reflected in species composition, with the mid-slope acting as a transition zone. Ephemeral species were more common in the lower than the upper topographic positions. At the microhabitat scale, species composition was not affected by eucalypt position.

A mixture of ephemeral, and perennial taxa from principally Asteraceae, Poaceae and Chenopodiaceae characterised the upper and lower topographic positions. Similarly, Fox's (1990) surveys of plant species, including ephemerals, in mallee in New South Wales, found that these families and Fabaceae predominated. In the lower topographic positions characteristic species included ephemerals *Harmsiodoxa blennodioides, Hyalosperma semisterile, Austrostipa* spp., and perennials *Austrostipa scabra, Rhyncharrhena linearis, Sclerolaena diacantha* and *Chenopodium* sp. In the upper slope and crest positions, ephemerals included *Haloragis odontocarpa, Bracteantha viscosa*, and perennials *Sclerolaena parviflora, Amphipogon caricinus* and *Triodia scariosa* (Table 5). Most of these species did not occur exclusively in one topographic position, but were simply more common in one.

A number of surveys and studies in mallee in southeastern Australia have found similar occurrences of some of these species i.e. *Sclerolaena diacantha* (Cheal & Parkes 1989, Porteners et al. 1997), *Triodia scariosa* (Bradstock 1989, Cheal & Parkes 1989, Morcom & Westbrooke 1990, Fox 1991, Scott 1992, Porteners et al. 1997), *Stipa scabra* complex (Cheal & Parkes 1989) and *Stipa variabilis* (= *Austrostipa* spp., Noble 1981, 1984). In mallee in South Australia and New South Wales, however, *Sclerolaena diacantha* has been found to occur in a variety of topographies and soil types (Forward 1996, Porteners et al. 1997). In their survey of mallee communities in north-western Victoria, Cheal and Parkes (1989) emphasised the dangers of extrapolating trends in the occurrence of species between sites which differ geographically and climatically.

The number of ephemeral species was significantly higher in the lower (7.87/10m^2 +/- 0.66 s.e.) than the upper topographic positions (4.88/10m^2 +/- 0.44 s.e.; Fig. 5). The preponderance of ephemerals in the soils of the lower topographic positions suggests that conditions are more favourable for their survival than the sandier soils of the upper topographic positions. Characteristics of the heavier soils, such as their lower porosity, proximity to the water table, and higher fertility would no doubt be an advantage to ephemerals which are characteristically shallow rooted and quick growing (Casson et al. 1984). Higher 'run-on' to the lower topographic positions would also assist survival. Cheal and Parkes (1989) similarly found that the distribution of mallee communities in Victoria was related to environmental features such as topography, elevation in relation to water table or depth to the under-lying sandstone.

Although our study found no effect of topography on species richness, a survey of mallee communities in south western New South Wales found species richness to be negatively correlated with topography, that is, higher in the swales (Fox 1984). In mallee in Western Australia, Van der Moezel and Bell (1989) found that soils with the lowest nutrient content i.e. sandy soils, had the highest species richness. The absence of a topographic effect in our study, may reflect its localised nature compared with the regional nature of these other studies. Greater variation in factors, such as, topography and soil type is more likely over larger areas and hence there is a higher potential for the distribution of species to influence species richness.

The presence of resprouting *Eucalyptus* spp. was found to have no significant effect on either the understorey species composition or richness. Common species, such as, ephemeral herbs/forbs *Bracteantha viscosa, Haloragis odontocarpa, Pseudognaphalium luteoalbum, Harmsiodoxa blennodioides,* perennial subshrub *Halgania cyanea,* perennial grasses *Amphipogon caricinus, Austrostipa scabra, Triodia scariosa* and *Chenopodium* sp., were just as likely to grow under eucalypts as in the gaps between them. An exception was *Sclerolaena parviflora,* which was found to be more common in the gaps. These results are contrary to observations by Noble (1989a) who found that after fire in the mallee, herbs rarely colonised eucalypt and *Triodia* mounds because of their hydrophobic properties. Most grew between the hummocks until eucalypt and triodia cover returned. It is possible, that the higher than average spring monthly rainfall prior to our study in 1985 (77 mm vs 27 mm long term spring monthly average; Cohn & Bradstock 2000), reduced any hydrophobic effect of the hummocks.

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References

Allan, G.E. & Baker, L. (1990) Uluru (Ayers Rock-Mt Olga) National Park: an assessment of a fire management programme. *Proceedings of the Ecological Society of Australia* 16: 215–220.

Allan, G.E. & Griffin, G.F. (1986) Fire ecology of the hummock grasslands of Central Australia. pp.126–129. Australian Rangeland Society Working Papers. 4th Biennial Conference, Armidale.

Anon. (1968) *Review of Australia's water resources-monthly rainfall and evaporation* (Commonwealth Bureau of Meteorology: Melbourne).

Beadle, N.C.W. (1981) *The vegetation of Australia* (Cambridge University Press: Sydney).

Bradstock, R.A. (1989) Dynamics of the perennial understorey. Pp. 141–154 in Noble, J. C. & Bradstock, R.A. (Eds): *Mediterranean landscapes in Australia — mallee ecosystems and their management* (CSIRO: Melbourne).

Bradstock, R.A. (1990) Relationships between fire regimes, plant species and fuels in mallee communities. Pp. 218–225 in Noble, J.C., Joss, P.J. & Jones, G. K. (Eds): *The mallee lands — a conservation perspective* (CSIRO: Melbourne).

Bradstock R.A. & Cohn, J.S. (2002) Fire regimes and biodiversity in semi-arid mallee ecosystems. Pp. 238–258 in Bradstock, R.A., Williams, J.E., Gill, A.M. (Eds): *Flammable Australia: the fire regimes and biodiversity of a continent* (Cambridge University Press: Cambridge).

Bradstock, R.A., Auld, T.D., Ellis, M.E. & Cohn, J.S. (1992) Soil temperatures during bushfires in semi-arid mallee shrublands. *Australian Journal of Ecology* 17: 433–440.

Burbidge, N.T. (1943) Ecological succession observed during regeneration of *Triodia pungens* R.Br. after burning. *Proceedings of the Royal Society of Western Australia* 28: 149–156.

Casson, N.E., Pate, J.S., Rullo, J.C. & Kuo, J. (1984) Biology of fire ephemerals of the south western Australian Sandplain. Pp. 24–25. in Bell, B. (Ed.): *Medecos IV, proceedings of the 4th international conference on Mediterranean ecosystems* (University of Western Australia: Nedlands).

Cheal, D.C. & Parkes, D.M. (1989) Mallee vegetation in Victoria. Pp.125–140 in Noble, J.C. & Bradstock, R.A. (Eds): *Mediterranean landscapes in Australia - mallee ecosystems and their management* (CSIRO: Melbourne).

Cheal, P.D.C. (1981) Ecological effects of fire, north-west Victoria. Pp.1–13 in Heislers, A., Lynch, P. & Walters, B. (Eds): *Fire ecology in semi-arid lands* (CSIRO: Division of Land Resources Management Committee Group).

Clarke, K.R. & Warwick, R.M. (1994) *Change in marine communities: an approach to statistical analysis and interpretation* (Natural Press Limited: Bournemouth).

Cohn, J.S. (1995) The vegetation of Nombinnie and Round Hill Nature Reserves, central-western New South Wales. *Cunninghamia* 4: 81–101.

Cohn, J.S. & Bradstock, R.A. (2000) Factors affecting post-fire seedling establishment of selected mallee understorey species. *Australian Journal of Botany* 48: 59–70.

Forward, L.R. (1996) Vegetation. Pp. 51–164 in Forward, L.R. & Robinson, A.C. (Eds): *A biological survey of the South Olary Plains South Australia* (Department of Environment and Natural Resources: South Australia).

Fox, M.D. (1984) Mapping the natural vegetation of south-western NSW. Pp. 74–86 in Myers, K., Margules, C. & Musto, I. (Eds): *Proceedings from a workshop on survey methods for nature conservation*. Volume 1 (CSIRO: Canberra).

Fox, M.D. (1990) Composition and richness of New South Wales mallee. Pp. 8–11. in Noble, J.C., Joss, P.J. & Jones, G.K. (Eds): *The mallee lands — a conservation perspective* (CSIRO: Melbourne).

Fox, M.D. (1991) The natural vegetation of the Ana Branch-Mildura 1: 250 000 map sheet (New South Wales). *Cunninghamia* 2(3): 443–493.

Harden, G.J. (1990–93) (Ed.): *Flora of New South Wales*: Volumes 1–4 (New South Wales University Press: Kensington).

Harrington, G.N., Dawes, G.T. & Ludwig, J.A. (1981) An analysis of the vegetation pattern in semi-arid *Eucalyptus populnea* woodland in north-west New South Wales. *Australian Journal of Ecology* 6: 279–287.

Hill, K.D. (1989) Mallee eucalypt communities: their classification and biogeography. Pp.93–108 in Noble, J.C. & Bradstock, R.A. (Eds): *Mediterranean landscapes in Australia-mallee ecosystems and their management* (CSIRO: Melbourne).

Hodgkinson, K.C. & Griffin, G.F. (1982) Adaptation of shrub species to fires. Pp.145–152 in Barker, W.R. & Greenslade, P.J.M. (Eds): *Evolution of the flora and fauna of arid Australia* (Peacock Publications: Adelaide).

Hodgkinson, K.C, Harrington, G.N. & Miles, G.E. (1980) Composition, spatial and temporal variability of the soil seed pool of *Eucalyptus populnea* shrub woodland in central New South Wales. *Australian Journal of Ecology* 5: 23–29.

Holland, P.G. (1968) Seasonal growth of field layer plants in two stands of mallee vegetation. *Australian Journal of Botany* 16: 615–22.

Kirkpatrick, J.B. (1997) Vascular plant-eucalypt interactions. Pp. 227–245 in Williams, J.E. & Woinarski, J.C.Z. (Eds): *Eucalypt ecology, individuals to ecosystems* (Cambridge University Press: Melbourne).

Lawrie, J.S. & Stanley, R.J. (1980) Representative land systems of mallee lands in the western division of NSW. Pp. 85–100 in Storrier, R.R. & Stannard, M.E. (Eds): *Aeolian landscapes in the semi-arid zone of south eastern Australia* (Australian Society for Soil Science, Riverina Branch: Wagga Wagga).

Leigh, J.H., Wood, D.H., Holgate, A. & Stanger, M.G. (1989) Effects of rabbit and kangaroo grazing on two semi-arid grassland communities, in central-western New South Wales. *Australian Journal of Botany* 37: 375–396.

Lunt, I.D. (1990). Species-area curves and growth-form spectra for some herb-rich woodlands in western Victoria, Australia. *Australian Journal of Ecology* 15: 155–161.

Mabbutt, J.A., Chartres, C.J., Fitzpatrick, E.,A. & Melville, M.D. (1982) Physical bases of mallee landscapes. Pp.17–33 in Mabbutt, J. (Ed.): *Threats to mallee in New South Wales* (NSW Department of Planning: Sydney).

McMahon, A. (1984) The effects of time since fire on heathlands in the Little Desert, N.W. Victoria, Australia. Pp. 99–100 in Bell, B. (Ed.): *Medecos IV, proceedings of the 4th international conference on Mediterranean ecosystems* (University of Western Australia: Nedlands).

Maconochie, J.R. (1982) Regeneration of arid zone plants: a floristic survey. Pp. 141–144 in Barker, W.R. & Greenslade, P.J.M. (Eds): *Evolution of the flora and fauna of arid Australia* (Peacock Publications: Adelaide).

Magcale-Macandog, D.B. & Whalley, R.D.B. (1991) Distribution of *Microlaena stipoides* and its association with introduced perennial grasses in a permanent pasture on the Northern Tablelands of New South Wales. *Australian Journal of Botany* 39: 295–303.

Morcom, L., & Westbrooke, M. (1990) The vegetation of Mallee Cliffs National Park. *Cunninghamia* 2: 147–166.

Morelli, J. & Forward, L.R. (1996) Fire Ecology. Pp. 263–272 in Forward, L.R. & Robinson, A.C. (Eds): *A biological survey of the South Olary Plains South Australia* (Department of Environment and Natural Resources, South Australia).

Noble, J.C. (1981) Use of fire for ecological purposes: vegetation management. Pp. 1–8 in Heislers, A., Lynch, P. & Walters, B. (Eds): *Fire ecology in semi-arid lands*. Proceedings of a workshop held in Mildura, Victoria. CSIRO Division of Land Resources Management Communications Group.

Noble, J.C. (1984) Mallee. Pp. 223–240 in Harrington, G.N., Wilson, A.D. & Young, M.D. (Eds): *Management of Australia's rangelands* (CSIRO: Melbourne).

Noble, J.C. (1989a) Fire regimes and their influence on herbage and mallee coppice dynamics. Pp.168–180 in Noble, J.C. & Bradstock, R.A. (Eds): *Mediterranean landscapes in Australia — mallee ecosystems and their management* (CSIRO: Melbourne).

Noble, J.C. (1989b) Fire studies in mallee (*Eucalyptus* spp.) communities of western New South Wales: the effects of fires applied in different seasons on herbage productivity and their implications for management. *Australian Journal Ecology* 14: 169–187.

Noble, J.C. & Grice, A.C. (2002) Fire regimes in semi-arid and tropical pasture lands: managing biological diversity and ecosystem function. Pp. 373–400 in Bradstock, R.A., Williams, J.E., Gill, A.M. (Eds): *Flammable Australia: the fire regimes and biodiversity of a continent* (Cambridge University Press: Cambridge).

Noble, J.C. & Vines, R.G. (1993) Fire studies in mallee (*Eucalyptus* spp.) communities of western NSW: grass fuel dynamics and associated weather patterns. *Rangeland Journal* 15: 223–240.

Noble, J.C., Harrington, G.N. & Hodgkinson, K.C. (1986) The ecological significance of irregular fire in Australian rangelands. Pp. 577–580. in Joss, P.J., Lynch, P.W. & Williams, O.B. (Eds): *Rangelands: a resource under siege. Proceedings of the 2nd International Rangeland Congress* (Australian Academy of Science: Canberra).

Noble, J.C., Smith, A.W. & Leslie, H.W. (1980) Fire in the mallee shrublands of western NSW. *Australian Rangeland Journal* 2:104–114.

Parsons, R.F. (1981) Eucalyptus scrubs and shrublands. Pp. 227–253 in Groves, R.H. (Ed.): *Australian vegetation* (Cambridge University Press: Cambridge).

Porteners, M.F., Ashby, E.M. & Benson, J.S. (1997) The natural vegetation of the Pooncarie 1: 250 000 map. *Cunninghamia* 5: 139–231.

Scalan, J.C. & Burrows, W.H. (1990) Woody overstorey impact on herbaceous understorey in *Eucalyptus* spp. communities in central Queensland. *Australian Journal of Ecology* 15: 191–197.

Scott, J.A. (1992) The natural vegetation of the Balranald-Swan Hill area. *Cunninghamia* 2: 597–652.

Sivertsen, D. & Metcalfe, L. (1995) Natural vegetation of the southern wheat-belt (Forbes and Cargelligo 1: 250 000 map sheets). *Cunninghamia* 4: 103–128.

Soil Conservation Service (1984) 1: 250 000 Land Systems Series Sheet S1 55–2: Nymagee (Soil Conservation Service of New South Wales).

Specht, R.L. (1981) Responses to fires in heathlands and related shrublands. Pp. 395–415 in Gill, A.M., Groves, R.H. & Noble, I.R. (Eds): *Fire and the Australian biota* (Australian Academy of Sciences: Canberra).

Story, R. (1967) Pasture patterns and associated soil water in partially cleared woodland. *Australian Journal of Botany* 15: 175–87.

Underwood, A.J. (1981) Techniques of analysis of variance in experimental marine biology and ecology. *Annual Reviews of Oceanography and Marine Biology* 19, 513–605.

Van der Moezel, P.G. & Bell, D.T. (1984) Fire in the Western Australian Mallee. Pp. 151–152 in Dell, B. (Ed.): *Medecos IV, Proceedings 4th international conference on Mediterranean ecosystems* (University of Western Australia: Nedlands).

Van der Moezel, P.G. & Bell, D.T. (1989) Plant species richness in the mallee region of Western Australia. *Australian Journal of Ecology* 14: 221–226.

Wellington, A.B. (1989) Seedling regeneration and population dynamics of eucalypts. Pp.155–167 in Noble J.C. & Bradstock, R.A. (Eds): *Mediterranean landscapes in Australia — mallee ecosystems and their management* (CSIRO Publications: Melbourne).

Westbrooke, M.E., Miller, J.D. & Kerr, M.K.C. (1998) The vegetation of the Scotia 1: 100 000 map sheet, western New South Wales. *Cunninghamia* 5: 665–684.

Zimmer, W.J. (1940) Plant invasions in the mallee. *The Victorian Naturalist* 56: 143–7.

Appendix 1. Average abundance of each species (5 m^{-2}) with time since fire. Data are taken from analyses of similarity (ANOSIM). Those species which occurred only once in a time since fire group are marked with an X and were not included in ANOSIM.

Species	Average abundance (5 m^{-2}) at time since fire (years)				
	0.75	1.75	2.5	5	15
ASTERACEAE					
Calotis cuneifolia	-	-	0.6	0.5	-
Chrysocephalum apiculatum	-	-	0.3	-	-
Rhodanthe floribunda	-	X	0.3	-	-
Olearia pimelioides	-	X	0.1	-	-
Podolepis arachnoidea	-	0.7	X	-	-
P. jaceoides	1.1	1.1	0.7	0.6	-
Vittadinia cuneata	X	X	0.7	X	-
BORAGINACEAE					
Halgania cyanea	-	0.2	X	3.6	0.2
BRUNONIACEAE					
Brunonia australis	X	-	-	-	-
CAMPANULACEAE					
Wahlenbergia sp. 1	0.2	-	-	-	-
CARYOPHYLLACEAE					
Spergularia rubra	-	0.4	-	X	-
CHENOPODIACEAE					
Chenopodium desertorum	X	-	-	-	-
Sclerolaena parviflora	1.0	3.5	1.5	-	-
CONVOLVULACEAE					
Convolvulus erubescens	4.8	2.2	0.1	-	-
CYPERACEAE					
Schoenus subaphyllus	-	1.3	0.3	0.8	0.5
EUPHORBIACEAE					
Poranthera microphylla	1.2	-	X	-	-
FABACEAE					
Acacia brachybotrya	-	-	3.7	-	0.3
A. rigens	0.4	0.7	-	-	0.6
A. wihelmiana	0.6	0.9	0.8	0.4	X
Eutaxia microphylla	-	X	-	-	-
Psoralea eriantha	1.1	-	X	-	-
Templetonia aculeata	X	-	-	-	-
GOODENIACEAE					
Goodenia cycloptera	0.2	-	-	0.1	-
G. willisiana	1.3	-	-	-	-
G. sp. 1	0.3	-	X	-	-
G. sp. 2	X	-	-	-	-
Scaevola aemula	0.7	-	X	-	-
S. depauperata	0.2	-	0.3	X	-
Velleia connata	0.5	0.5	X	-	-

Species	Average abundance (5 m^{-2}) at time since fire (years) 0.75	1.75	2.5	5	15
HALORAGACEAE					
Haloragis odontocarpa	3.6	2.8	1.6	X	-
LILIACEAE					
Dianella revoluta	X	X	-	-	-
LOMANDRACEAE					
Lomandra effusa	0.1	0.2	0.2	-	-
L. collina	-	1.2	-	-	-
L. leucocephala	0.3	0.2	0.3	0.5	0.2
MYRTACEAE					
Eucalyptus sp.	X	-	-	-	-
POACEAE					
Amphipogon caricinus	-	1.8	3.7	2.8	2.4
Austrostipa nodosa	-	-	0.3	0.1	-
Triodia scariosa	1.8	1.9	1.5	3.0	1.9
PROTEACEAE					
Grevillea sp.	X	-	-	-	-
SOLANACEAE					
Nicotiana velutina	0.1	-	-	-	-
Solanum coactiliferum	0.7	2.0	2.5	1.0	-
STACKHOUSIACEAE					
Stackhousia monogyna	0.3	X	-	-	-
THYMELACEAE					
Pimelea simplex	0.5	-	0.2	0.3	-
Unknown sp.1	0.1	-	-	-	-
Unknown sp.2	X	-	-	-	-
Number species with score	23	18	20	12	7
Number species with X	9	6	7	4	1
Total number	32	24	27	16	8

The flora of Nungar Plain, a treeless sub-alpine frost hollow in Kosciuszko National Park

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Nungar Plain is a large, naturally treeless area in the northern part of Kosciuszko National Park. A brief survey of the flora of Nungar Plain (December 2001–January 2002) recorded 206 taxa, 18 of which were introduced. Seven taxa appear to be of especial significance. The great floral diversity of Nungar Plain suggests that the botanical significance of sub-alpine plains in Kosciuszko National Park has been under-estimated. The flora and vegetation of Nungar Plain are threatened by pigs, which have scoured large areas of grassland vegetation. In six pairs of quadrats across disturbance boundaries, damage by pigs was found to have greatly reduced the cover and diversity of vegetation. Control of pigs is urgently required.

Introduction

Whilst the composition and significance of the alpine flora of New South Wales has received considerable attention (e.g. McVean 1969, Barlow 1989, Costin et al. 2000), little has been published about the flora of sub-alpine plains in New South Wales (an exception being Benson 1994). This is in contrast to the ACT and Victoria, where the flora and vegetation of sub-alpine plains has been well studied (e.g. McDougall 1982, Walsh et al. 1984, Helman & Gilmour 1985). In addition, the vegetation of sub-alpine plains in New South Wales has not been accorded especial significance. Whilst several alpine plant communities are listed in the Kosciuszko Plan of Management's Schedule of Significant Natural Features (NPWS 2000), of the sub-alpine communities, only wetlands are listed. Benson (1994) considered the montane grassy plains of Kosciuszko National Park to be well conserved and did not identify threats to their survival and integrity.

While searching for populations of threatened plant species in the Kiandra area between 1999 and 2001, we noticed considerable damage to sub-alpine treeless vegetation by pigs. Most damage was recorded in dry grassland communities and was evidenced by denuded circles up to 20 m in diameter. Some of these bare circles appeared to have been scoured more than once, judging by the varying amount of regeneration within them. Permanent quadrats to measure degradation and regeneration are currently being set up. This paper presents some data from quadrats in one sub-alpine plain affected by pigs and includes a checklist of the flora recorded there. We re-appraise the significance of sub-alpine treeless vegetation and threats to its survival.

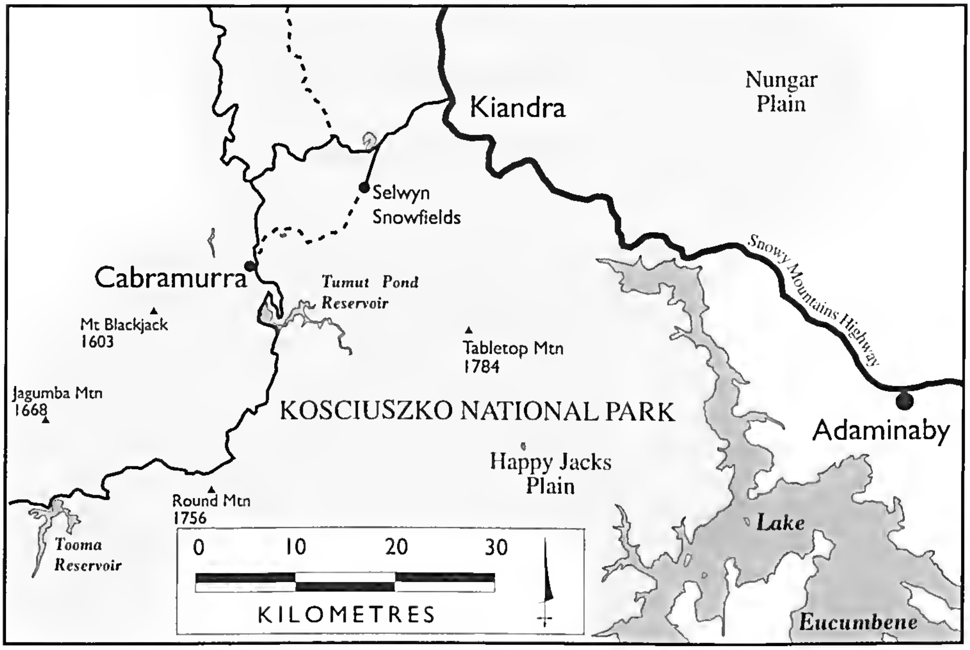

Fig. 1. Location of Nungar Plain, Kosciuszko National Park.

Fig. 2. View across Nungar Plain from a heathy knoll dominated by *Eucalyptus lacrimans*.

Methods

Nungar Plain

Nungar Plain is on the eastern edge of Kosciuszko National Park, to the south of Tantangara Dam and about 15 km east of Kiandra (Fig. 1). The treeless portion of the plain is about 7 × 2 km, ranging in elevation from 1340 to 1380 m asl. Soils are of the alpine humus type developed on a parent material of Silurian siltstone and shale of the Tantangara Formation.

The plain is surrounded by woodland dominated by *Eucalyptus pauciflora*. Structurally, the treeless portion is largely grassland, although shrubland dominated by *Hovea montana* occurs on slopes with shallow soils, and one knoll in the centre of the plain is dominated by sparse, low *Eucalyptus lacrimans* trees (Fig. 2). The grasslands are of two broad types: 1) herb-rich and dominated by *Poa petrophila, Poa hookeri* or *Poa phillipsiana,* occurring on dry slopes and 2) species-poor and dominated by *Poa labillardierei* and/or *Austrofestuca hookeriana,* occurring on damp flats. Wetland vegetation (dominated by *Carex gaudichaudiana*) is confined mostly to cut-off meanders in the main drainage channel of Nungar Creek, although there are very small patches of *Sphagnum* bog on some tributaries. One or more aquatic species (*Myriophyllum variifolium, Nymphoides montana, Potamogeton cheesemanii*) grow along much of the creek, the latter two species being largely confined to slow-moving sections of the watercourse.

Nungar Plain has had a long history of stock grazing. Grazing pressure may have been considerably greater at Nungar Plain than on the higher parts of Kosciuszko National Park because of its much shorter duration of snow cover. Grazing by domestic stock ceased in the 1970s.

Survey

A checklist of the flora of Nungar Plain was made in about one and a half days of random meander in December 2001 and January 2002.

Six pairs of permanently marked quadrats (2.5 × 2.5 m) were set up across the boundary of areas affected by pigs. All species within each quadrat were recorded and an estimate of their cover was made using the cover rating system of McDougall et al. (2002). The percentage cover of bare ground was also estimated.

Results and Discussion

Flora and Vegetation

The survey located 206 taxa (from 44 families), 18 taxa of which are introduced (Appendix 1). The families Poaceae and Asteraceae account for 38% of the flora of Nungar Plain.

The grassland vegetation of Nungar Plain and similar treeless plains nearby was found by Benson (1994) to be distinct from grassland communities at lower elevations in the Monaro region. The grassland vegetation is also floristically dissimilar to alpine grassland communities described by McVean (1969), which are dominated by other species of *Poa*, and appears to be floristically distinct from sub-alpine grasslands at higher elevation in Kosciuszko National Park (eg. Happy Jacks Plain). The grassland communities of the Nungar area are likely to be localised.

Conservation Significance

Considering that the Kosciuszko alpine flora comprises about 200 species from a great diversity of habitats (Costin et al. 2000), the flora of Nungar Plain is notable. Several species are of particular conservation and/or taxonomic significance:

Bulbine glauca: This species is quite common within the grassland/herbfield communities on Nungar Plain where plants are robust, with leaf dimensions exceeding those normally given for the species (e.g. Watson 1987, Godden 1993, Conran 1994). The non-rocky habitat is also very unusual for the species. Plants of *Bulbine glauca* of similar form and habitat have not been observed by either of us in other sub-alpine treeless communities in either New South Wales or Victoria. Research into its taxonomic status is warranted.

Calotis cuneata var. *pubescens*: This mat-forming daisy is apparently restricted to Nungar Plain. The sites of collections from Victoria by Ferdinand von Mueller in 1854 and from Snowy Plain in NSW by Max Mueller in 1956 have not been relocated. The taxon is believed to be extinct in Victoria (Ross in prep.). Nineteen populations of *Calotus cuneata* var. *pubescens* were located in grassland in Nungar Plain. A brief search of nearby plains (Gulf, Long and Boggy Plains) failed to locate further populations. We regard this taxon to be specifically distinct from *Calotis cuneata* (Walsh & McDougall in press).

Calotis glandulosa: This species is listed as vulnerable in New South Wales under the *Threatened Species Conservation Act 1995* (TSC Act). It is locally common in Nungar Plain and surrounding areas in grassland and on bare ground of roadside batters.

Hovea sp. aff. *heterophylla*: This is an undescribed species of *Hovea* mentioned under *Hovea heterophylla* in a revision of eastern Australian members of the genus by Thompson (2001) and since confirmed by him as such (I. Thompson, National Herbarium of Victoria, pers. comm.). At the time of writing, Thompson knew of only one specimen from the Kiandra area. This is clearly a very localised species, the precise geographic and morphological parameters of which are still not fully known.

Prasophyllum retroflexum: This species, which was previously known as *P. morganii* (now regarded as a Victorian endemic), is listed as vulnerable in New South Wales under the TSC Act. It is a localised orchid known with certainty only from grasslands in the Tantangara – Kiandra – Yarrangobilly areas (Jones 2000) but may also occur in Victoria near the Cobberas Mountains (J. Jeanes, National Herbarium of Victoria, pers. comm.). Only one plant was found in Nungar Plain during the survey but many *Prasophyllum* plants were not in flower at the time so its abundance could not be assessed. *Prasophyllum retroflexum* was also observed on Long Plain.

Senecio sp. nov. Sect. Erechthites: An ongoing revision of the genus *Senecio* has identified this as an undescribed species collected recently only from Long and Nungar Plains (I. Thompson, National Herbarium of Victoria, pers. comm.). Pre-1950 specimens are known from other sub-alpine sites in south-eastern Australia, and perhaps paradoxically, from south-western Western Australia.

Taraxacum aristum: Although known from pre-1900 specimens from both lowland and upland areas as far north as the Walcha area and Barrington Tops, this species now appears to be confined to sub-alpine areas of south-eastern Australia (ACT, NSW, Victoria and Tasmania) south of the Bimberi Range (N. Scarlett, La Trobe University, pers. comm.). It was not listed in the *Flora of NSW* treatment of *Taraxacum* (Murray 1992). It is probably very rare in NSW, however, and may be eligible for listing as threatened under the NSW *TSC* Act, considering the disturbance to its habitat by pigs. Only a few plants were seen on Nungar Plain but the species seems to be more common on Long Plain.

The Effect of Pigs

A group of 15 pigs and piglets was observed in Nungar Plain during the survey. Damage to vegetation by pigs is obvious and extensive. Herb-rich grassland communities are the worst-affected. Rooting is localised but very thorough. Total plant cover (including plant litter) in the six quadrat pairs sampled was 35% in pig-affected vegetation compared with 99% in unaffected vegetation (Fig. 3). There were 27.3 ± 2.1 species/quadrat in unaffected vegetation and 16.8 ± 3.3 species/quadrat in pig-damaged vegetation. Nineteen species recorded in quadrats in unaffected vegetation were not recorded at all in pig-affected quadrats. Of the species that were recorded in four or more quadrats in unaffected vegetation, the frequency and/or cover of the following species was more than 75% less in pig-affected quadrats: *Asperula scoparia, Brachyscome decipiens, Carex breviculmis, Epilobium billardierianum subsp. cinereum,* **Hypochaeris radicata, Luzula flaccida, Microseris* sp. aff. *lanceolata, Poa hookeri, Poa petrophila, Poa phillipsiana, Pultenaea polifolia* and *Scleranthus biflorus.* The following species occurred equally frequently in unaffected and pig-affected quadrats but all had a greater cover (by at least 50%) in pig-affected quadrats: **Acetosella vulgaris, Geranium antrorsum, Senecio pinnatifolius* subsp. *pleiocephalus* and *Tristeum spicatum.* Three species (*Drabastrum alpestre, Neopaxia australasica,* and *Stellaria multiflora*), which were rarely recorded in the quadrats, appeared to benefit from pig rooting.

Changes in species composition and a large reduction in vegetation cover following pig rooting have also been reported for sub-alpine plant communities in the ACT (Alexiou 1983). Recovery in vegetation cover was found to be slow and species composition was still markedly different more than three years after disturbance. Bloomfield and Parsonson (1977) reported that pig disturbance in the ACT was associated with areas containing *Arthropodium milleflorum* and Parsonson (1979) found that this species was commonly detected in stomach contents analysis of pigs. Although *A. milleflorum* was located in the current study, it was not especially common or widespread. Despite this, there are many species in Nungar Plain that have fleshy underground organs, including several of the significant species listed above.

* exotic species.

Fig. 3. An abrupt boundary between rooted and undisturbed vegetation at Happy Jacks Plain. Many rooted areas are remarkably circular in outline.

That Benson (1994) did not report pig damage to vegetation on Nungar Plain, where it is now exceptionally obvious, suggests that pig rooting is a recent phenomenon there, or at least that the magnitude of the problem has grown greatly in recent times. There are also no obvious patches of damaged vegetation that are in an advanced stage of recovery, suggesting either that pigs continually turn over the same ground or that the pig damage is recent. If pigs are a recent threat to the vegetation of Nungar Plain, control measures are urgently required to prevent catastrophic degradation of this significant area.

Conclusions

The flora and vegetation of Nungar Plain are of considerable conservation importance. Pigs pose a significant threat to the natural values of Nungar Plain and several other treeless sub-alpine plains in Kosciuszko National Park. Further work is proposed by NPWS to investigate the effects of pig damage a .: the rate of recovery. A better understanding of the vegetation and flora of sub-alpine plains in the Kosciuszko should be a by-product of such studies.

References

Alexiou, P.N. (1983) Effect of feral pigs (*Sus scrofa*) on subalpine vegetation at Smokers Gap, ACT. *Proceedings of the Ecological Society of Australia* 12: 135–142.

Barlow, B. (1989) The alpine flora: autochthones and peregrines. Pp. 69–78. In: Good, R. (Ed.) *The scientific significance of the Australian Alps* (Australian Alps National Parks Liaison Committee — Australian Academy of Science: Canberra).

Benson, J.S. (1993) The native grasslands of the Monaro region: Southern Tablelands of NSW. *Cunninghamia* 3: 609–650.

Bloomfield, W. & Parsonson, D. (1977) Feral pigs in the Cotter River catchment. Survey No. 4 — Jan. 1977. Unpublished report, Department of the Capital Territory, Forests Branch, Canberra (Reported in Alexiou 1983).

Conran, J.G. (1994) *Bulbine* Pp. 667–670. In: Walsh, N.G. & Entwisle, T.J. (Eds) *Flora of Victoria Volume 2* (Inkata Press: Melbourne).

Costin, A.B., Gray, M., Totterdell, C. & Wimbush, D. (2000) *Kosciuszko alpine flora* (CSIRO Publishing: Collingwood).

Godden, D C. (1993) *Bulbine* Pp. 83, 84. In Harden, G. (Ed.) *Flora of New South Wales*. Volume 4 (University of New South Wales Press: Kensington).

Helman, C.E. & Gilmour, P. M. (1985) *Treeless vegetation above 1000 metres altitude in the A.C.T.* Unpublished report to the Conservation Council of the Southeast Region and Canberra.

Jones, D.L. (2000) 10 new species of *Prasophyllum* (Orchidaceae) from south-eastern Australia. *The Orchadian* 13: 149–173.

McDougall, K.L. (1982) The alpine vegetation of the Bogong High Plains. *Environmental Studies Publication No. 357* (Ministry for Conservation, Victoria: East Melbourne).

McDougall, K.L., Hobbs, R.J. & Hardy, G.E. St.J. (2002) Floristic and structural differences between *Phytophthora* infested and adjoining uninfested vegetation in the northern jarrah (*Eucalyptus marginata*) forest of Western Australia. *Australian Journal of Botany* 50: 277–288.

McVean, D.N. (1969) Alpine vegetation of the central Snowy Mountains of New South Wales. *Journal of Ecology* 57: 67–86.

Murray, L. (1992) *Taraxacum*. Pp. 337. In: Harden, G. (Ed.) *Flora of New South Wales Volume 3* (University of New South Wales Press: Kensington).

NPWS (2000) *Revision of the Schedule of Significant Natural Features. Supplement to the 1988 Kosciusko Plan of Management*. Second edn (New South Wales National Parks and Wildlife Service, Hurstville).

Parsonson, D. (1979) *Feral pig survey of the Cotter River catchment, Dec. 1978 – Feb. 1979*. Unpublished report, Department of the Capital Territory, Forests Branch, Canberra (Reported in Alexiou 1983).

Ross, J.H. (in prep.) A census of the vascular plants in Victoria. 7th edn (Royal Botanic Gardens Melbourne).

Thompson, I.R. (2001) Morphometric analysis and revision of eastern Australian *Hovea* (Brogniartieae-Fabaceae). *Australian Systematic Botany* 14: 1–99.

Walsh, N.G. (1999) *Senecio*. Pp. 941–965. In: Walsh, N.G. & Entwisle, T.J. (Eds) *Flora of Victoria. Volume 4. Dicotyledons. Cornaceae to Asteraceae* (Inkata Press: Melbourne).

Walsh, N. G. & McDougall, K.L. (in press) *Calotis pubescens* (Asteraceae), change in rank and notes on its distribution and ecology. *Muelleria*.

Walsh, N.G., Barley, R.H. & Gullan, P.K. (1984) The alpine vegetation of Victoria (excluding the Bogong High Plains region). *Environmental Studies Publication No. 376* (Department of Conservation, Forests and Lands, Victoria: East Melbourne).

Watson, E.N. (1987) *Bulbine* Pp. 236–241. In: George, A.S. (Ed.) *Flora of Australia Volume 45* (Australian Government Printing Service: Canberra).

Appendix 1. Plant Species of Nungar Plain. * indicates an exotic species

FERNS AND FERN ALLIES

ASPLENIACEAE
Asplenium flabellifolium

BLECHNACEAE
Blechnum penna-marina

CONIFERS

PODOCARPACEAE
Podocarpus lawrencei

MONOCOTYLEDONS

CYPERACEAE
Carex blakei
Carex breviculmis
Carex capillacea
Carex chlorantha
Carex gaudichaudiana
Carex hebes
Carex incomitata
Carex tereticaulis
Isolepis fluitans
Isolepis producta
Lepidosperma curtisiae
Oreobolus distichus
Schoenus calyptratus

JUNCACEAE
Juncus brevibracteus
Juncus falcatus
Luzula flaccida
Luzula modesta
Luzula novae-cambriae

LILIACEAE sens. lat.
Arthropodium milleflorum
Bulbine bulbosa
Bulbine glauca
Caesia alpina
Dianella tasmanica

ORCHIDACEAE
Diuris monticola
Prasophyllum retroflexum
Prasophyllum sphacelatum
Pterostylis cycnocephala
Thelymitra cyanea
Thelymitra megcalyptra

POACEAE
Agrostis aemula
Agrostis meionectes
Agrostis venusta
**Aira elegantissima*
**Aira praecox*
**Anthoxanthum odoratum*
Austrofestuca hookeriana
Australopyron velutinum
Austrodanthonia eriantha
Austrostipa nivicola
Austrodanthonia pilosa
Deyeuxia monticola
Dichelachne crinita
Dichelachne rara
Festuca asperula
**Holcus lanatus*
Joycea pallida
Microlaena stipoides
Poa clivicola
Poa costiniana
Poa fawcettiae
Poa hiemata
Poa hookeri
Poa labillardierei
Poa petrophila
Poa phillipsiana
**Poa pratensis*
Poa saxicola
Poa sieberiana var. *cyanophylla*
Themeda triandra
Trisetum spicatum
**Vulpia bromoides*

POTAMOGETONACEAE
Potamogeton cheesemanii

RESTIONACEAE
Baloskion australe
Empodisma minus

XANTHORRHOEACEAE
Lomandra longifolia var. *exilis*

DICOTYLEDONS

APIACEAE
Aciphylla simplicifolia
Gingidia harveyana
Hydrocotyle algida
Oreomyrrhis argentea
Oreomyrrhis ciliata
Oreomyrrhis eriopoda

ASTERACEAE
Brachyscome aculeata
Brachyscome decipiens
Brachyscome obovata
Brachyscome rigidula
Brachyscome scapigera
Brachyscome spathulata
Brachyscome tadgellii
Bracteantha subundulata
Calotis cuneata var. *pubescens*
Calotis glandulosa
Cassinia sp. aff. *uncata*

ASTERACEAE cont.
Celmisia pugioniformis
Celmisia tomentella
**Cirsium vulgare*
Cotula alpina
Craspedia coolaminica
Craspedia crocata
Craspedia jamesii
**Crepis capillaris*
Cymbonotus preissianus
Erigeron bellidioides
Euchiton argentifolius
Euchiton collinus
Euchiton fordianus
Euchiton poliochlorus
Helichrysum rutidolepis
**Hypochaeris radicata*
Leptorhynchos elongatus
Leptorhynchos squamatus
Microseris sp. aff. *lanceolata*
Olearia myrsinoides
Ozothamnus secundiflorus
Ozothamnus sp. aff. *hookeri*
Picris angustifolia subsp. *merxmuelleri*
Podolepis jaceoides
Podolepis robusta
Podolepis sp. aff. *robusta*
Rhodanthe anthemoides
Senecio gunnii
Senecio pinnatifolius var. *pleiocephalus*
Senecio sp. 1 (sensu Walsh 1999)
Senecio sp. 2 (sensu Walsh 1999)
Senecio sp. nov. Sect. Erechthites
Solenogyne gunnii
Taraxacum aristum
**Taraxacum officinale sens. lat.*
**Tragopogon dubius*

BORAGINACEAE
Myosotis australis

BRASSICACEAE
Cardamine astoniae
Cardamine papillata
Drabastrum alpestre
**Erophila verna* ssp. *verna*

CAMPANULACEAE
Pratia pedunculata
Pratia surrepens
Wahlenbergia ceracea
Wahlenbergia densifolia
Wahlenbergia multicaulis

CARYOPHYLLACEAE
**Cerastium vulgare*
Scleranthus biflorus
Scleranthus fasciculatus
Stellaria multiflora
Stellaria palustris
Stellaria pungens

CLUSIACEAE
Hypericum japonicum

CONVOLVULACEAE
Dichondra repens

DROSERACEAE
Drosera peltata subsp. *peltata*

EPACRIDACEAE
Epacris breviflora
Epacris gunnii
Epacris paludosa
Leucopogon hookeri
Leucopogon montanus

EUPHORBIACEAE
Poranthera microphylla

FABACEAE
Daviesia ulicifolia
Dillwynia prostrata
Hovea montana
Hovea sp. aff. *heterophylla*
Podolobium alpestre
Pultenaea fasciculata
Pultenaea polifolia
Pultenaea subspicata
**Trifolium arvense*
**Trifolium repens*

GERANIACEAE
Geranium antrorsum

GOODENIACEAE
Goodenia hederacea subsp. *alpestris*
Velleia montana

HALORAGACEAE
Gonocarpus micranthus
Gonocarpus montanus
Myriophyllum pedunculatum
Myriophyllum variifolium

LAMIACEAE
Ajuga australis

LINACEAE
Linum marginale

MENYANTHACEAE
Nymphoides montana

MYRTACEAE
Baeckea gunniana
Eucalyptus lacrimans
Eucalyptus pauciflora
Eucalyptus rubida
Kunzea muelleri
Leptospermum myrtifolium

ONAGRACEAE
Epilobium billardierianum subsp. *cinereum*
Epilobium gunnianum

OXALIDACEAE
Oxalis exilis

PITTOSPORACEAE
Rhytidosporum alpinum

PLANTAGINACEAE
Plantago alpestris
Plantago antarctica
Plantago euryphylla

POLYGALACEAE
Comesperma retusa

POLYGONACEAE
**Acetosella vulgaris*

PORTULACACEAE
Neopaxia australasica

PROTEACEAE
Grevillea australis
Hakea microcarpa

RANUNCULACEAE
Ranunculus collinus
Ranunculus graniticola
Ranunculus lappaceus
Ranunculus millanii
Ranunculus pimpinellifolius

ROSACEAE
Acaena echinata
Acaena novae-zelandiae
**Aphanes microcarpa*
Geum urbanum
Rubus parvifolius

RUBIACEAE
Asperula gunnii
Asperula scoparia
Coprosma nivalis
Galium gaudichaudii

SCROPHULARIACEAE
Derwentia perfoliata
Euphrasia collina subsp. *paludosa*
**Verbascum thapsus*
Veronica gracilis

STYLIDIACEAE
Stylidium montanum

THYMELAEACEAE
Pimelea biflora
Pimelea linifolia subsp. *caesia*

VIOLACEAE
Hymenanthera dentata
Viola betonicifolia
Viola fuscoviolacea

Corrigendum – Cunninghamia 7(2) p.193

Deborah A Perry. The distribution, relative abundance and conservation status of *Doryanthes palmeri* (Doryanthaceae) in New South Wales

Page 193 The following references and footnotes were inadvertently deleted.

Patil, D.A. & Pai, R.M. (1981) The floral anatomy of Doryanthes excelsa Corr. (Agavaceae). Indian Journal of Botany 4: 5–9

Perry, D.A. (1998) Aspects of the autecology and life history of Doryanthes palmeri W. Hill ex Benth. (Doryanthaceae). Bachelor of Applied Science (Honours) Thesis. Southern Cross University, Lismore, North-east NSW.

Rymer, J. (1983) Doryanthes excelsa. In: Growing native plants, No. 12 National Botanic Gardens (Australian Government Publishing Service: Canberra).

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