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

J. Whinam and N. Chilcott

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 (ºC): 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 (ºC): The highest temperature of any weekly maximum temperature.	39	0.8919	9.4–21.9
MeTCo	Mean temperature of the coldest period (ºC).	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 *Chinogentias 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*, *Chinogentias muelleriana*, and *Celmisia tomentella*).

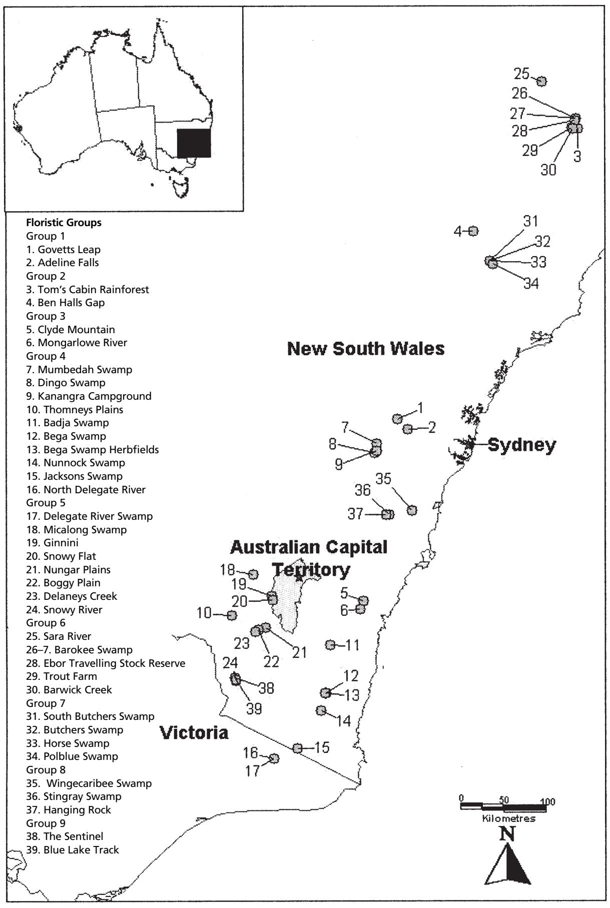

Fig. 1. Distribution of *Sphagnum* peatlands in NSW and ACT See text for descriptions of floristic groups.

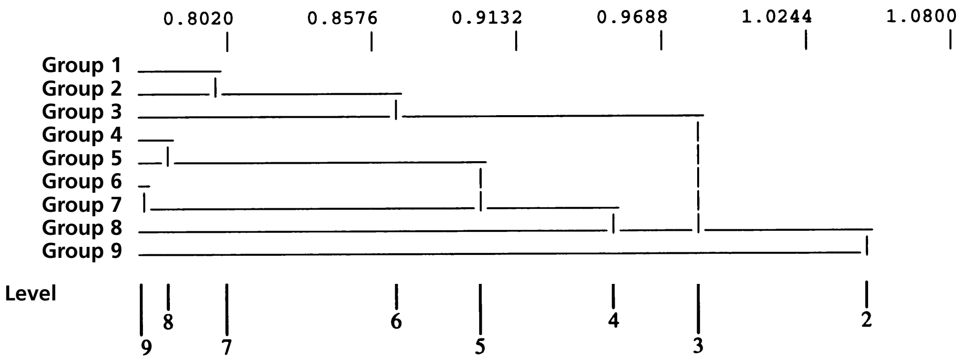

Fig. 2. Dendrogram from the WPGMA clustering of *Sphagnum* plots in NSW and ACT The dissimilarity is displayed on the top edge of the dendrogram, while 'Level' (displayed) along the bottom edge of the dendrogram denotes the fusions for reference to the two-way table of indicator species displayed in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

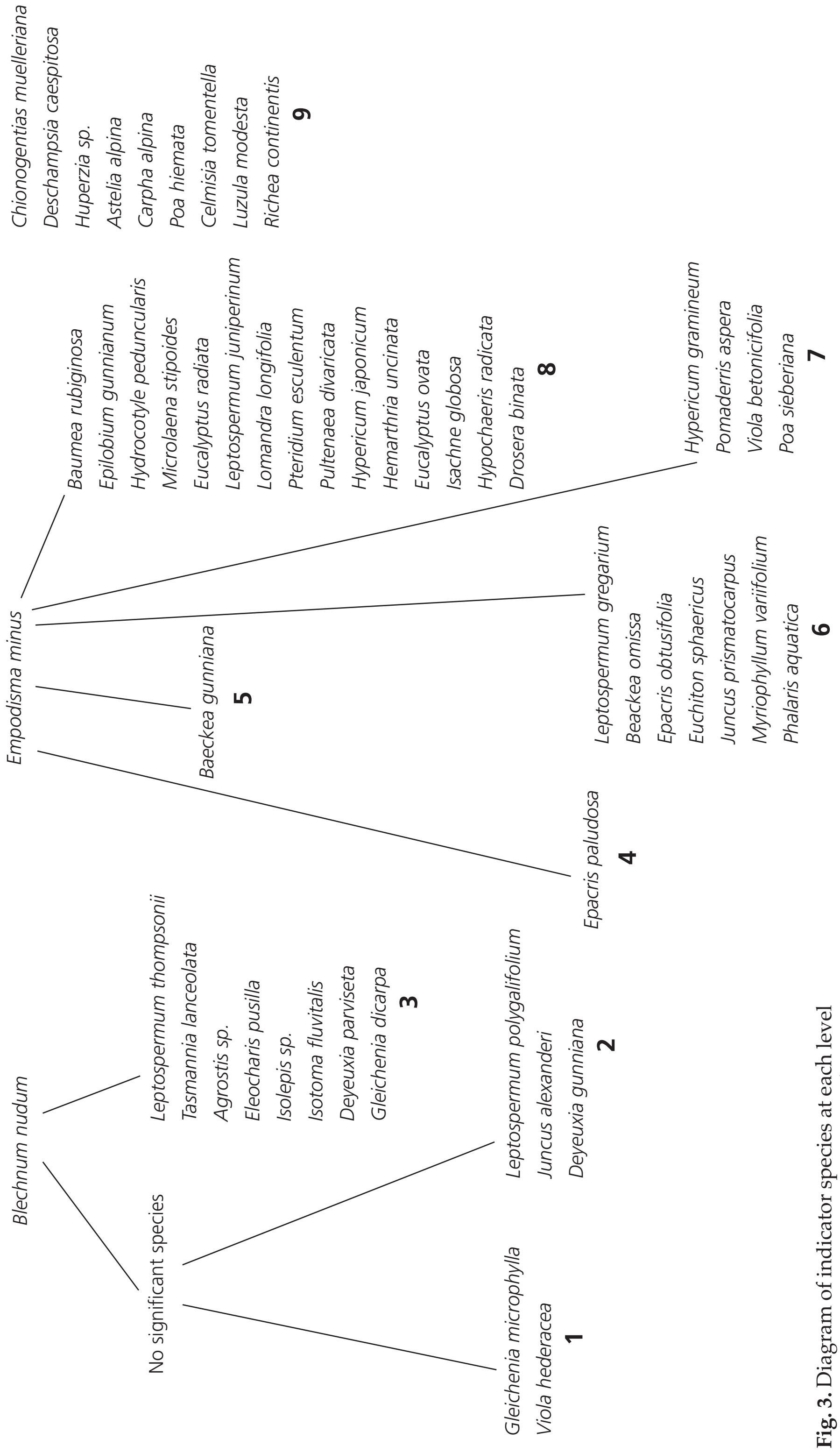

Fig. 3. Diagram of indicator species at each level of split in PATN. Bold text denotes the nine floristic groups (see text for group definitions).

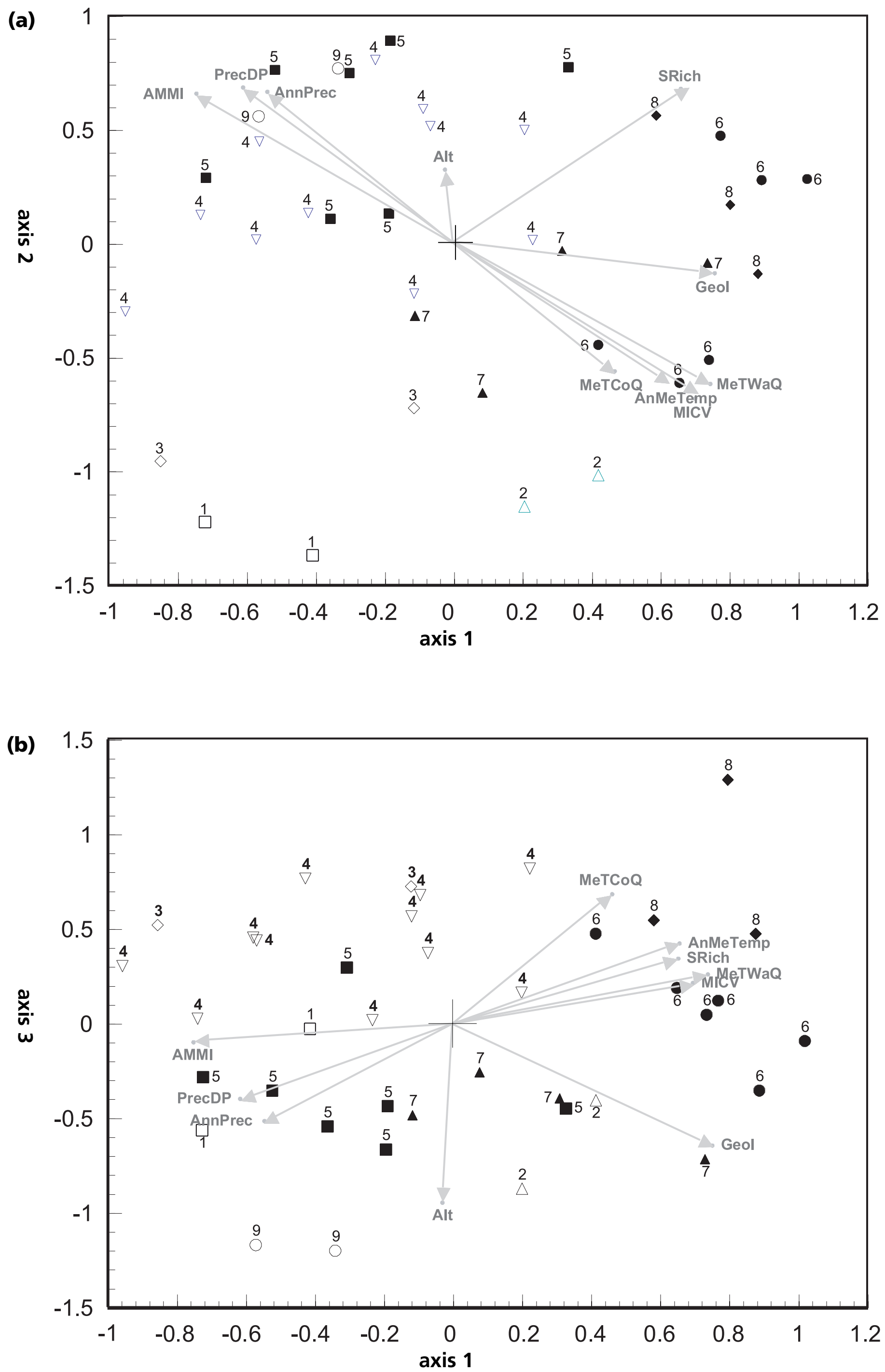

Fig. 4. HMDS in three dimensions, showing sites and significant ($p < 0.05$) fitted vectors for environmental variables and species richness with respect to (a) axis 1 v 2, and (b) axis 1 v 3. Abbreviations for environmental variables are: Alt = altitude, Geol = Geology, SRich = species richness, AnMeTemp = 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., *Eleochaeris 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 ºC (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*, *Euchiton 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 oleraceus*.

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 *Chinogentias 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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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	Wingecarribee
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	Wingecarribee
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								

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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																				

	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
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															

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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															

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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																															

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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																				