

Floristic variation in *Sphagnum*-dominated peatland communities of the Central Highlands, Victoria

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Abstract: The floristic composition of *Sphagnum*-dominated peatlands in the Central Highlands region of Victoria was surveyed (37° 25' S; 145° 50' E). NMDS ordination and cluster analysis divided the peatland sites into two broad groups with altitude being the most important factor separating these groups. Other important factors were aspect, slope and the amount of shade. Group 1 included subalpine sites that are similar to those found at higher altitudes further east in Victoria. Important species included *Empodisma minus*, *Epacris paludosa*, *Richea continentis* and *Baeckea gunniana*. The two species of *Sphagnum* present were *Sphagnum cristatum* and the more inundation-tolerant *Sphagnum novozelandicum*. Group 2 included montane peatlands with abundant *Sphagnum cristatum*. These sites range from broad wet heaths dominated by *Richea victoriana* and *Carex appressa*, to narrower cool temperate rainforest and riparian systems. The 'rainforest' peatlands are characterised by *Leptospermum grandifolium*, *Nothofagus cunninghamii*, *Carex appressa* and *Blechnum penna-marina*, and are in varying stages of post-fire succession regulated by site-specific microclimate. The conservation status and catchment function of these peatlands are briefly discussed.

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Introduction

Sphagnum mires and peatlands are most prominent at higher latitudes and altitudes. Watertables constantly at, or near the soil surface, are required for peatlands to develop and persist. The resultant anoxic, low nutrient, acidic soil conditions can only be tolerated by bryophytes and specially adapted vascular plants. These soil conditions impede decomposition and nutrient cycling, allowing organic matter accumulation to exceed decay and the excess to be deposited as peat. The vegetation in *Sphagnum*-dominated peatlands is typically a mix of sedges, rushes and low xeromorphic shrubs protruding from an almost continuous, undulating mat of *Sphagnum* moss. Herbs, lilies and other geophytes are also common (Gore 1983a, Charman 2002, Joosten & Clarke 2002). In Australia, these ecosystems are understandably restricted in distribution, accounting for less than 0.02% of the continent (Joosten & Clarke 2002) and are most extensive in western Tasmania and elevated areas of the south-eastern states (Gore 1983b). There have been numerous studies of peatlands throughout their range in Australia, with most of the scientific research focussed on the alpine areas of Tasmania, southern New South Wales and north-east Victoria. These have described floristic composition, system dynamics, anthropogenic impacts and hydrological importance (Costin 1954, Wimbush & Costin 1979, McDougall 1982, Kirkpatrick 1983, Clarke & Martin 1999, Wahren et al. 1999; Wahren et al. 2001, Whinam et al. 2001).

Sphagnum peatland systems occurring in subalpine and

montane areas elsewhere have received less scrutiny. In Victoria, *Sphagnum* systems have been incorporated in studies of subalpine vegetation at the Bennison Plains (Farrell & Ashton 1973), Lake Mountain (Ashton & Hargreaves 1983), Mount Buffalo (Wahren & Walsh 2000), the Snowy Range (Wahren & Papst 1999) and on the Baw Baw plateau (Walsh et al. 1986).

Montane and subalpine peatland systems near Lake Mountain in the Central Highlands of Victoria (37° 25' S; 145° 50' E) were included in a recent state-wide survey by Whinam et al. (2003), but there are other montane peatlands similar to these elsewhere in the region, including largely undocumented subalpine *Sphagnum* mires at Mount Bullfight and Mount Torbreck on the nearby Federation Range (Willis 1948). In this paper, the floristic character of *Sphagnum*-dominated plant communities in the Central Highlands region is examined and possible factors responsible for observed differences amongst sites investigated. The broad aims were to:

- 1) Document and characterise the floristic composition and structure of *Sphagnum* peatlands and associated communities in the Central Highlands and compare them with similar communities elsewhere in Victoria and southern New South Wales.
- 2) Determine the degree of variability apparent amongst the peatland communities in terms of floristic composition, structure and landscape setting, and investigate possible environmental factors responsible for observed differences.

Methods

Study region

The study area is an elevated plateau (>900 m) and associated ranges extending north from the Great Dividing Range near Marysville, 120 km north-east of Melbourne (Fig.1). The area (approximately 400 km²) is bounded in the north by the Goulburn River valley, in the west by the Acheron valley, and on the eastern side by the Big River basin. The western part of this land system is sometimes referred to as the Blue Range or Cerberean Ranges, the eastern as the Federation Range. Highest elevations are along the eastern flank, and range from 1514 m in the north-east at Mount Torbreck, to approximately 1450 m further south at Lake Mountain. All the streams and rivers that drain the study area ultimately feed into the Goulburn River system; the eastern streams via Big River and Lake Eildon, and the western streams via the Acheron and Rubicon Rivers. Wet heathlands and closed riparian scrubs containing *Sphagnum* associated plant communities and mires are located in the headwater streams of these rivers (LCC 1973, Rundle 1977).

The geology of the Central Highlands is relatively uniform, with an upper Devonian dacite-rhyodacite igneous complex extending from Mount Torbreck in the north-east to Mount Donna Buang at the south-western end (Rundle 1977, Ashton & Hargreaves 1983, McKenzie 1997). There are smaller areas of granite outcrop of similar age. The topography is moderate to gently sloping and the major stream systems are generally parallel and follow joint systems and fractures in the igneous bedrock (LCC 1973).

The broader scale vegetation patterns of the region reflect a steep rainfall gradient with movement from the lowlands of the Acheron and Goulburn valleys to the crest of the Cerberean plateau (LCC 1973, Rundle 1977). The northern and western fringes below 600 m carry a dry foothill forest, which becomes damp sclerophyll forest on steeper more elevated ridges. Wet sclerophyll forests dominate most of the plateau with stands of Alpine ash (*Eucalyptus delegatensis*), Shining gum (*Eucalyptus nitens*) and Mountain ash (*Eucalyptus regnans*). Cool temperate rainforest consisting of *Nothofagus cunninghamii* and *Atherosperma moschatum* can be found along stream-lines and gullies, above approximately 600 m. Woodlands of *Eucalyptus pauciflora* occur at altitudes above 1340 m (LCC 1973).

Climate

There is a southern or maritime influence on the climate and precipitation occurs mostly from April to October, peaking in July and August. The mean annual rainfall for Rubicon, in the north of the study area (37° 19' 35" S; 145° 51' 40" E; 380 m.), is 1698 mm (Bureau of Meteorology, Melbourne). BIOCLIM precipitation estimations for several locations on the plateau proper suggest annual averages in excess of 1600

mm are likely over most of the area (McKenzie 1997). Even in the driest period of the year (Jan–Mar), mean monthly precipitation totals on the plateau are likely to be little below 100 mm.

Snowfalls are frequent from May to September, although below 1200 m, snow rarely accumulates to a depth of more than 30 cm. During this period, the mean duration of snow cover above 1200 m is one month, increasing to 10–12 weeks at 1400 m, especially in more sheltered pockets and aspects. Frosts are common in the cold-air drainage hollows of the plateau and largely responsible for inverted tree-lines similar to those present in montane and subalpine areas throughout south-east Australia (Williams 1987, Williams and Costin, 1994). BIOCLIM estimations of mean annual temperatures for several locations (900–1400 m) range between 6.5°C and 10.4°C (McKenzie 1997)

Land use history and current tenure

There has been forestry activity in the area since the late 19th century, and more intensive since the late 1960s. A small hydro-electricity scheme was constructed by the SEC in the Rubicon area during the 1920s and is still in operation (AHC & CNR 1994b). The Lake Mountain-Echo Flat area was subject to livestock grazing until the mid-1960s, although stock numbers were reputedly never large (Ashton & Hargreaves 1983). Low intensity forest grazing also occurred until the 1930s. In recent decades, parts of the study area have become important for recreation purposes, particularly cross-country skiing, bushwalking, deer-stalking and four-wheel drive touring.

The southern parts of the study area are included in the Yarra Ranges National Park, but most is State Forest (Rubicon or Marysville). The Mount Bullfight and Mount Torbreck peatlands are in scenic features or nature conservation reserves (AHC & CNR 1994a).

Floristic sampling

A total of 20 sites were sampled across the region (Fig. 1) using the information obtained from previous studies as a starting point (Ashton & Hargreaves 1983, Walsh et al. 1986, McKenzie 1997). By coupling a knowledge of the landscape setting of known sites with an examination of the relevant 1:100 000 and 1:25 000 topographic map sheets, it was possible to determine a series of other likely *Sphagnum* peatland locations. These were verified during February and March 2003. Some proved to be *Sphagnum* peatlands, others not, but in the process of ground exploration, other sites, less obvious from map examination, were located.

The 20 *Sphagnum* sites surveyed were given a nominal classification according to altitude, landscape position and surrounding forest vegetation type (Table 1). The seven higher altitude subalpine sites (>1300 m) were typically bounded by *Eucalyptus pauciflora* open forest with an

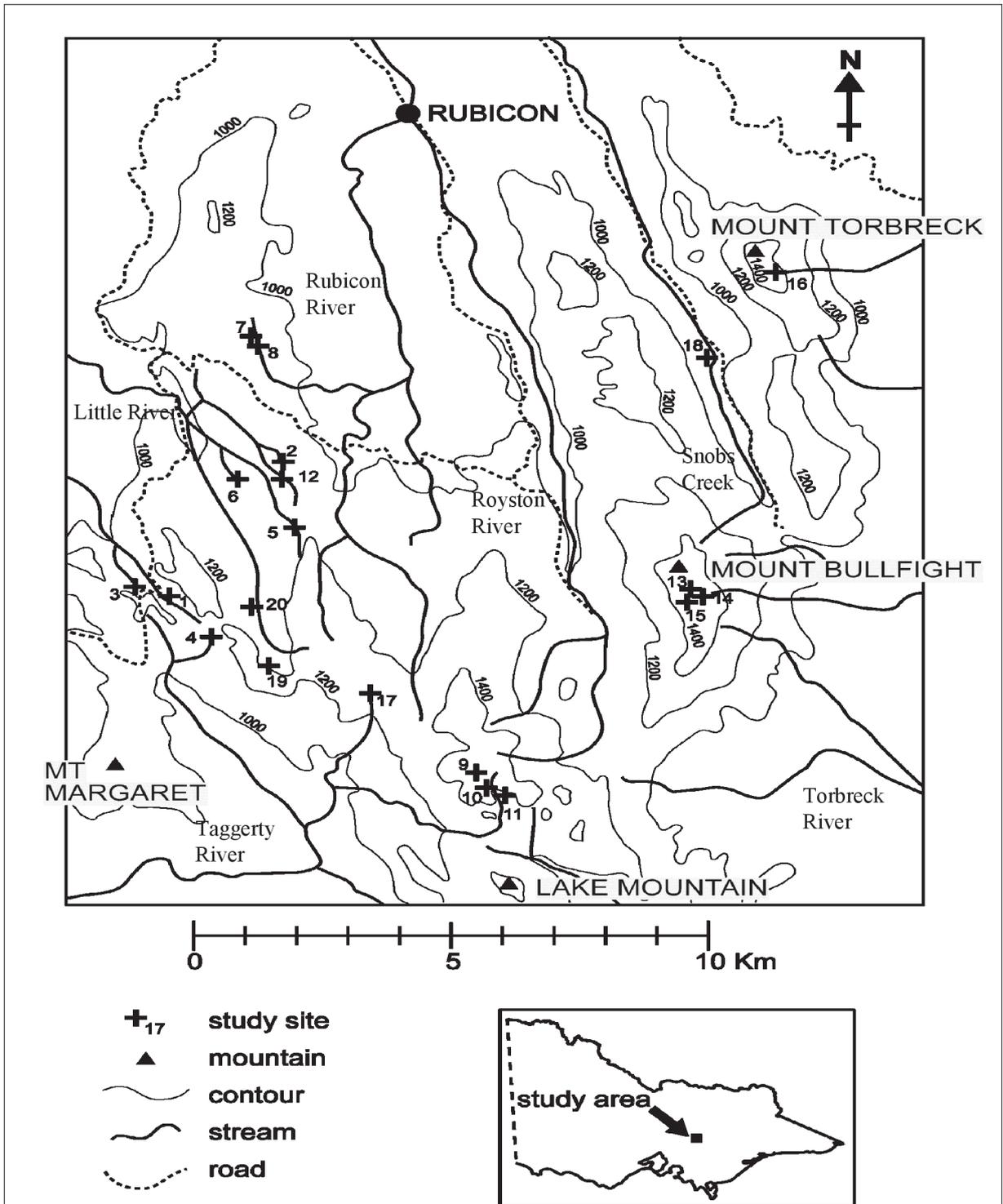


Fig. 1. The Central Highlands region of Victoria showing the location of the 20 *Sphagnum* peatland study sites. (See Table 1 for site names)

understorey of heathy shrubs, whereas the 13 nominally montane sites (900–1300 m) were surrounded by tall open forest (wet sclerophyll) and cool temperate rainforest containing *Nothofagus cunninghamii*.

At each site, floristic composition and abundance were recorded in a 10 x 10 m quadrat. Site selection criteria required a minimum 30% *Sphagnum* cover, as used by Whinam et al. (2003). All vascular plant taxa were identified and their percent cover was recorded using the Braun-Blanquet cover abundance scale. *Sphagnum* species and *Polytrichum commune* (> 5% cover at some sites) were the only bryophytes identified, although other bryophytes were present in very low abundances. Species nomenclature follows Ross and Walsh (2003).

Environmental factors

In each quadrat, peat and substratum depth were recorded using a 1.2 m stainless steel probe. Ten randomly located measurements were recorded across the quadrat and an average calculated. Where peat depths exceeded the probe length, depth was recorded as >1.2 m. Three peat or soil samples were collected from each plot and later tested in the laboratory for pH using the 1:5 distilled water solution method (Rayment & Higginson 1992). The proportion of bare ground and litter were also estimated using the Braun-Blanquet scale, as was the amount of free-water cover within the quadrat. The available light or amount of shade at ground

level was ranked from full light (class 0) to full shade and 100% canopy cover (class 5). The average height of the canopy strata was estimated in each quadrat. Where shrubs represented the upper layer, estimation was to the nearest 0.3 m. When tall shrubs or small trees comprised the canopy layer, estimations were to the nearest metre. The combined percent cover of all *Sphagnum* species within each quadrat was also used as a variable.

Aspect was determined using a hand held 'Suunto' bushwalking compass and later assigned to one of five categories: (1) north-west aspect, (2) north or west aspect, (3) north-east or south-west, (4) south or east, (5) south-east. This system of classification reflects the gradient in moisture loss due to evaporation in the mid-latitudes of the southern hemisphere, from high (1) to low (5) (Kirkpatrick & Bridle 1998). Slope was estimated subjectively and allocated to one of three categories: (0) flat or barely perceptible, (1) slight but definite slope (<5%), (2) more pronounced slope (<10%). In all cases the slope was less than 10%.

Data analyses

The data consisted of 20 sites in which 85 plant species were recorded. Single species occurrences, of which there were 24, were deleted for the purposes of analysis. The amount of *Sphagnum* cover was examined as a factor influencing composition; thus, it was appropriate to remove the two *Sphagnum* species recorded from the analysis data matrix.

Table 1. Locality details of the 20 *Sphagnum* peatlands surveyed in the Central Highlands region.

Site No.	Site Name	Altitude (m)	Surrounding Forest Type	Land Tenure	Size (ha)
1	Storm Creek	1175	Montane	State forest	4.0
2	'Carex Bog'	1090	Montane	State forest	1.2
3	Storm Creek West	1180	Montane	State forest	0.4
4	Whitehouse Creek	1180	Montane	State forest	0.2
5	McFadyens Track No.1	1135	Montane	State forest	1.0
6	McFadyens Track No.2	1085	Montane	State forest	1.0
7	Tom Burns Creek No.1	1090	Montane	State forest	3.0
8	Tom Burns Creek No.2	1090	Montane	State forest	3.0
9	Triangle Junction	1430	Subalpine	National Park	2.0
10	Long Flat	1400	Subalpine	National Park	4.0
11	'The Camp'	1390	Subalpine	National Park	0.6
12	McFadyens Track No.3	1100	Montane	State forest	0.2
13	Bullfight No.1	1420	Subalpine	Conservation Reserve	0.5
14	Bullfight No.2	1405	Subalpine	Conservation Reserve	1.2
15	Bullfight No.3	1420	Subalpine	Conservation Reserve	0.4
16	Torbreck	1430	Subalpine	Scenic Reserve	0.6
17	Keppel Hut	1290	Montane	State forest	0.2
18	Snobs Creek	910	Montane	State forest	0.2
19	Boundary Trail	1190	Montane	State forest	0.8
20	Little River	1115	Montane	State forest	0.8

This left a final count of 59 species. Cover-abundance classes were converted to their mid-point percent values. Separate analyses were run using both percent cover data and species presence-absence data. The former of these methods emphasises dominant species, whereas the latter, similarity in overall composition. Presence-absence data may exaggerate the importance of infrequently occurring species.

The data were analysed using non-metric multi-dimensional scaling (NMDS) techniques (Minchin 1987). Classification and cluster analysis (Group-average-linkage) were used subsequently to confirm apparent groupings in the ordination and identify possible sub-groupings. Ordinations were performed in two and three dimensions on both cover-abundance and presence /absence data, using 30 random starting configurations with 1000 iterations for each. The Bray-Curtis coefficient was used to measure dissimilarity for both ordinations and cluster analysis (Faith et al. 1987). Minimum stress configurations were compared using procrustean analysis. Stress is a measure of the goodness of fit and levels below 0.2 are acceptable and biologically meaningful (Clarke 1993). The two dimensional solutions are easier to interpret and were preferred for analysis, unless stress values were greater than 0.2.

Vectors of maximum correlation with the ordinations were fitted for all the variables outlined in the environmental factors section. The significance level of these was tested using Monte-Carlo procedures which compares the observed maximum correlation with the distribution of values using 1000 permutations ($P = 0.001$). Only the trend directions of those significantly correlated with the sample ordination and responsible for greater than 50% of the variability ($R^2 > 0.5$) were superimposed on the resultant configuration to assist interpretation (Minchin 1987). The presentation of ordinations and vector diagrams follow a format similar to that used in Wahren (1997).

Key discriminating species

The species characteristic of groups within the vegetation samples and those distinguishing groups were determined

using the SIMPER procedure (Clarke 1993), which uses similarity and dissimilarity measures to determine the species that best define vegetation units and those that most effectively discriminate between them. The contribution of each species to the similarity (S_i) or dissimilarity (D_i) can then be assessed and there are two indicators that measure the consistency of this contribution. These are the standard deviation of the mean similarity ($SD(S_i)$), and the ratio of the mean to the standard deviation ($S_i/SD(S_i)$). The most useful indicator species will have a low standard deviation value and hence, a high ratio value. Important species in one floristic group are not necessarily useful discriminators between units.

Software

Ordination and vector fitting procedures in this study employed the Database for Ecological Data Analysis (DECODA) program (Minchin 1989). Resulting configuration coordinates and vector line angles were plotted using SYSTAT (version 10.0). Cluster analysis and SIMPER procedures were performed using the Plymouth Routines in Multivariate Ecological Research software package (PRIMER, version 4.0, 1997).

Results

Summary of the flora

Of the 85 species recorded, 79 (93%) were native and six exotic. Several Victorian endemics were recorded: *Carex alsophila*, *Epacris microphylla* var. *rhombifolia*, *Wittsteinia vacciniacea* and *Richea victoriana*. These last two are locally abundant but elsewhere only occur in the vicinity of the Baw Baw plateau. *Coprosma moorei* and *Brachyscome obovata* are listed as rare in Victoria and, in this study, were recorded at Mount Bullfight and Lake Mountain respectively. *Sphagnum cristatum* was present at all sites surveyed. Several of the higher altitude sites also contained *Sphagnum novozelandicum*, which is more inundation-tolerant and typically occurs in shallow hollows and pools.

Table 2. Environmental variables showing high correlation with NMDS ordination configurations. P-values are: * = significant at 0.05 level; ** = 0.01 ; * = 0.001.**

Environmental Variable	Cover (%) Data		Presence- Absence Data	
	Maximum correlation (R ² -value)	Significance (P-value)	Maximum correlation (R ² -value)	Significance (P-value)
Altitude	0.848	0.001**	0.867	0.000***
Canopy	0.710	0.003**	0.820	0.000***
Shade	0.578	0.024*	0.725	0.000***
Aspect	0.594	0.026*	0.540	0.054
Slope	0.830	0.001**	0.614	0.003**
Water	<0.5	NS	0.529	0.075

Of the 82 vascular taxa identified, there were 32 forbs or creepers, 21 grasses or sedges, 16 small or medium shrubs, 3 tall shrub or small tree species, 6 lilies and orchids, and 4 ferns. Only 6% of species occurred at more than 12 sites, while 85% were present at eight sites or less. Five of the six exotic species recorded were only found at two sites or less, the exception being the cosmopolitan *Hypochoeris radicata* which was recorded at four sites. Two other introduced species were observed in the wet heathlands surveyed but were not recorded within the 100 m² plots. Several mature individuals of *Salix cinerea* were located at three of the montane sites, while the two small patches of *Lotus corniculata* were both observed at Storm Creek.

NMDS ordinations and fitted environmental vectors of significant correlation.

Minimum stress configurations in two dimensions for the NMDS ordinations based on percent cover data clearly separate the twenty sites into two groups (Fig. 2). The seven subalpine sites and one of the nominally montane sites (Storm Creek) form a cluster on the right of the ordination space. This group is henceforth referred to in the text as the 'subalpine' group for ease of description. The remaining montane sites form a less tightly clustered group on the left. Greater separation amongst the montane sites suggests more floristic variation across this group.

Five of the 10 environmental variables tested for correlation with the percent cover ordination configuration were significant ($P < 0.05$, Table 2). These were altitude, slope, aspect, shade and canopy height. The fitted vector for altitude is unsurprisingly orientated towards the cluster of subalpine sites (Fig. 2). The other four fitted vectors are somewhat diagonal to the two axes although more aligned with the vertical axis. The vectors for slope and aspect are correlated slightly with the subalpine cluster, but more importantly, are directed in the opposite direction to shade and canopy height. The latter factors all increase in value towards montane sites.

The minimum stress ordination configuration based on the presence /absence data, while again clearly separating subalpine and montane groups, suggests a looser association amongst the subalpine group than was apparent in the ordination derived from the percent cover data (Fig. 3). There is considerable spread in both groups along the vertical axis. Only four of the 10 tested environmental variables were significant (Table 2): altitude, canopy height, slope and shade. Aspect and water cover were marginally significant and still recorded 'R²' correlation values of greater than 0.5 (50% of the variation attributable to the variable in question). Their vector lines are arguably of some interpretative value and have been plotted.

Canopy height and shade are correlated, to a certain extent, with the vertical axis and no doubt explain much of the variation amongst the montane group. They are slightly

orientated towards these sites. The vector for water cover points in the opposite direction to shade and canopy height, while the vector for aspect runs diagonal to the main axes, but is directed more towards the subalpine group.

Key species representing the two groups.

Vascular plant species identified by SIMPER analysis as being significant indicator species and important contributors to similarity amongst subalpine *Sphagnum* peatlands were *Empodisma minus* and the shrubs *Baeckea gunniana*, *Epacris paludosa* and *Richea continentis* (Table 3b). These species also feature at the higher end of the altitude vector divide (Table 5a). Conversely, species that were more abundant at the lower end of the altitude vector divide were important contributors to the similarity amongst montane sites (Tables 3a & 5a). Amongst these were *Leptospermum grandifolium*, *Carex appressa*, *Richea victoriana* and *Blechnum penna-marina*. Many of the species comprising these two sets were also identified as useful discriminators of the montane and subalpine sites (Table 4). Most notable amongst these was *Empodisma minus* which had an average cover of 32% in the subalpine peatlands, but was entirely absent from sites in the montane group. *Baeckea gunniana* was also restricted to the subalpine group. On the other hand, *Leptospermum grandifolium* averaged 24% cover in montane sites, but was a very minor component in subalpine peatlands (0.06% cover). The two heath species from the genus *Richea* are of interest in this regard; *Richea victoriana* being mostly confined to montane sites and *Richea continentis* to subalpine. In montane areas, the only recording of *Richea continentis* was at the Boundary Trail site (1190 m), which is less than five kilometres from the extensive Lake Mountain subalpine wet heathlands.

Taxa more prevalent in shaded sites were those typical of montane cool temperate rainforest and riparian vegetation. These included the canopy species *Nothofagus cunninghamii* and *Leptospermum grandifolium* as well as ground stratum plants such as *Blechnum penna-marina*, *Libertia pulchella* and *Wittsteinia vacciniacea*. Subalpine species such as *Baeckea gunniana*, *Epacris paludosa*, *Empodisma minus*, *Juncus sandwithii* and *Oreobolis oxycarpus* feature in high light conditions at the opposite end of the shade vector (Table 5b), reflecting the generally more open nature of the subalpine systems.

Subgroups within montane and subalpine Sphagnum peatlands

Cluster analysis of the presence /absence data using group-average-linkage and the Bray-Curtis similarity coefficient separates the peatland sites into montane and subalpine clusters at the 20% similarity level (Fig. 4). The montane group can be generally separated into two subgroups using the presence /absence ordination configuration and associated vectors (Fig. 3). Sites 2, 5, 6 and 20 form a cluster at 60%

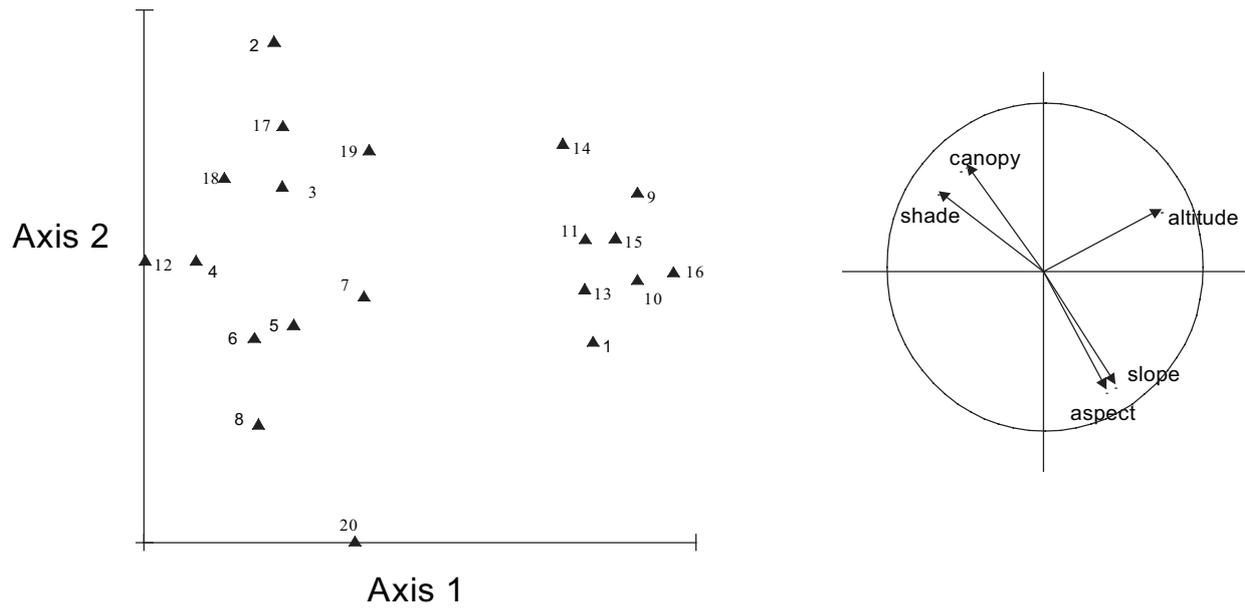


Fig. 2. NMDS ordination of the Central Highlands *Sphagnum* peatland sites. Two dimensional configuration based on (%) cover data, with the vector diagram for factors significantly correlated with the configuration (Minimum stress = 0.11).

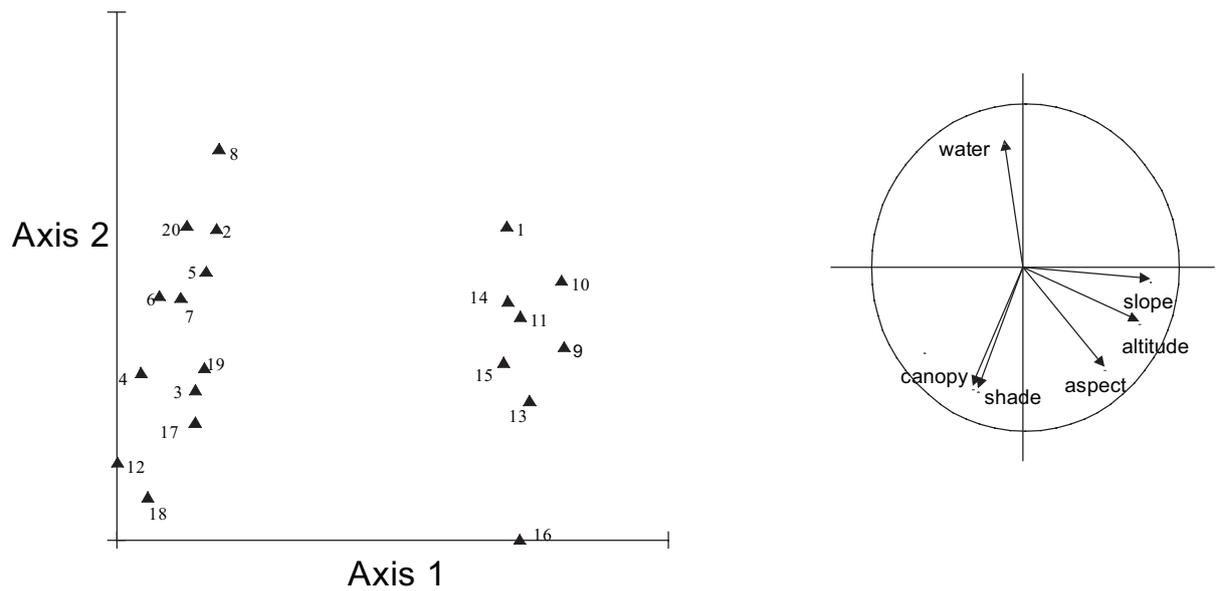


Fig. 3. NMDS ordination of the central highlands *Sphagnum* peatland sites. Two dimensional configuration based on presence /absence data, with the vector diagram for environmental factors significantly correlated with the configuration (Minimum stress = 0.10).

Table 3. Mean cover (%) of important species in the Central Highlands *Sphagnum* peatlands. a) Montane sites b) Subalpine sites. Species are listed in order of their contribution to the mean similarity amongst the sites in each group, up to a cumulative contribution of 90% in the case of montane sites and 95% for subalpine sites. 'Si' stands for similarity and represents the contribution of that species to the average similarity of the group. The neighbouring column gives the ratio of that species similarity contribution to the standard deviation of its contribution.

(a) Montane sites. Average similarity = 35.82

Species	Mean Cover(%)	Si	Si/SD(Si)	Cumulative (%)
<i>Leptospermum grandifolium</i>	23.54	21.2	1.66	59.30
<i>Carex appressa</i>	7.88	3.9	0.64	70.19
<i>Richea victoriana</i>	5.25	2.9	0.35	78.32
<i>Blechnum penna-marina</i>	1.00	0.9	1.76	80.97
<i>Nothofagus cunninghamii</i>	3.00	0.8	0.23	83.30
<i>Wittsteinia vacciniacea</i>	1.96	0.7	0.92	85.16
<i>Tasmania xerophila</i>	0.88	0.6	0.70	86.80
<i>Deyeuxia brachyathera</i>	0.42	0.6	1.36	88.36
<i>Polytrichum commune</i>	0.71	0.5	0.82	89.90

(b) Subalpine sites. Average similarity = 65.52

Species	Mean Cover(%)	Si	Si/SD(Si)	Cumulative(%)
<i>Empodisma minus</i>	31.88	41.0	2.86	62.57
<i>Epacris paludosa</i>	17.50	14.7	1.38	84.94
<i>Richea continentis</i>	5.06	3.1	0.74	89.63
<i>Baeckea gunniana</i>	3.31	1.9	1.18	92.56
<i>Erigeron paludicola</i>	0.69	0.6	1.59	93.54
<i>Astelia alpina</i>	0.88	0.6	0.69	94.42

Table 4. Mean cover (%) of important species discriminating between the montane and subalpine peatland sites.

Species are listed in order of their contribution to the mean dissimilarity of the groups, up to a cumulative contribution of 90%. 'Di' stands for dissimilarity and represents that species contribution to the average dissimilarity between the groups. The neighbouring column gives the ratio of that species dissimilarity contribution to the standard deviation of its contribution.

Average dissimilarity = 94.42%

Species	Montane Cover(%)	Subalpine Cover(%)	Di	Di/SD (Di)	Cumulative (%)
<i>Empodisma minus</i>	0.00	31.88	25.20	3.28	26.69
<i>Leptospermum grandifolium</i>	23.54	0.06	17.86	1.32	45.61
<i>Epacris paludosa</i>	1.58	17.50	12.23	1.49	58.56
<i>Richea continentis</i>	3.13	5.06	5.94	0.76	64.85
<i>Carex appressa</i>	7.88	0.25	5.84	0.74	71.03
<i>Richea victoriana</i>	5.25	0.31	4.63	0.74	75.93
<i>Gleichenia dicarpa</i>	3.17	0.00	2.62	0.30	78.70
<i>Nothofagus cunninghamii</i>	3.00	0.00	2.59	0.52	81.44
<i>Baeckea gunniana</i>	0.00	3.31	2.44	0.83	84.03
<i>Astelia alpina</i>	1.25	0.88	1.59	0.53	85.71
<i>Wittsteinia vacciniacea</i>	1.96	0.06	1.55	0.45	87.36
<i>Coprosma granadensis</i>	1.79	0.38	1.34	0.47	88.78
<i>Blechnum penna-marina</i>	1.00	0.00	0.77	1.24	89.60

composition similarity and are positioned in the ordination space at the lower value end of the shade and canopy height vectors. One of the Tom Burns Creek plots (site 8) is the out-group in the montane branch of the dendrogram, but it has been included in this group because of its position along the shade vector. These are the montane 'treeless' peatlands.

The remainder of the montane sites (3, 4, 7, 12 & 17–19) form a cluster at approximately 55% similarity. In the ordination space, they are positioned at the high value end of the shade /canopy height vectors and have therefore been classified as the montane 'rainforest' peatlands.

The same method was used to divide subalpine sites into subgroups, although the distinction is not as clear due to the greater overall similarity of subalpine sites (Table 3b & Figure 4). The Lake Mountain plots (sites 9–11) and one of the Mount Bullfight plots (site 14) form a cluster at 70% similarity and are positioned in ordination space at the higher end of the water cover vector (Figure 3). The Storm Creek plot is an out-group in the dendrogram, but is positioned at the high end of the water cover vector and thus has been included. These sites comprise the subalpine 'valley-floor' peatlands. The remaining Mount Bullfight sites (13 & 15) form a separate cluster and the Mount Torbreck site (16) is an out-group. All three fall at the opposite end of the water cover vector and are referred to as the subalpine 'hillslope' peatlands.

Subgroup descriptions, characteristics and important species

1) Montane 'Treeless' Peatlands:-

These are characterised by stunted *Leptospermum grandifolium* (< 2 m), *Richea victoriana*, *Carex appressa*, *Coprosma granadensis* and *Blechnum penna-marina*. A total of 43 species were recorded, including three exotics (Table 6). The sites in this group were typically wetter. In the absence of a tree canopy they are also subjected to cold-air drainage and consequent 'frost' effects. Included in this group is the Tom Burns Creek *Gleichenia dicarpa* dominated peatland (site 8), which contained abundant juvenile and stunted *Leptospermum grandifolium* shrubs and occasional *Gahnia sieberiana* (Table 7).

2) Montane 'Rainforest' Peatlands:-

This peatland type generally contained a canopy of tall *Leptospermum grandifolium*. Some also had *Nothofagus cunninghamii* as a canopy species. Understorey composition in these sites was variable but consistently included *Carex appressa* and *Blechnum penna-marina*. Other important species were *Wittsteinia vacciniacea*, *Deyeuxia brachyathera* and *Libertia pulchella*. This was the most species rich group on arguably the shallowest peats. Mean species richness per site was 20 and a total of 52 taxa were recorded at the seven sites. Five of these were introduced species.

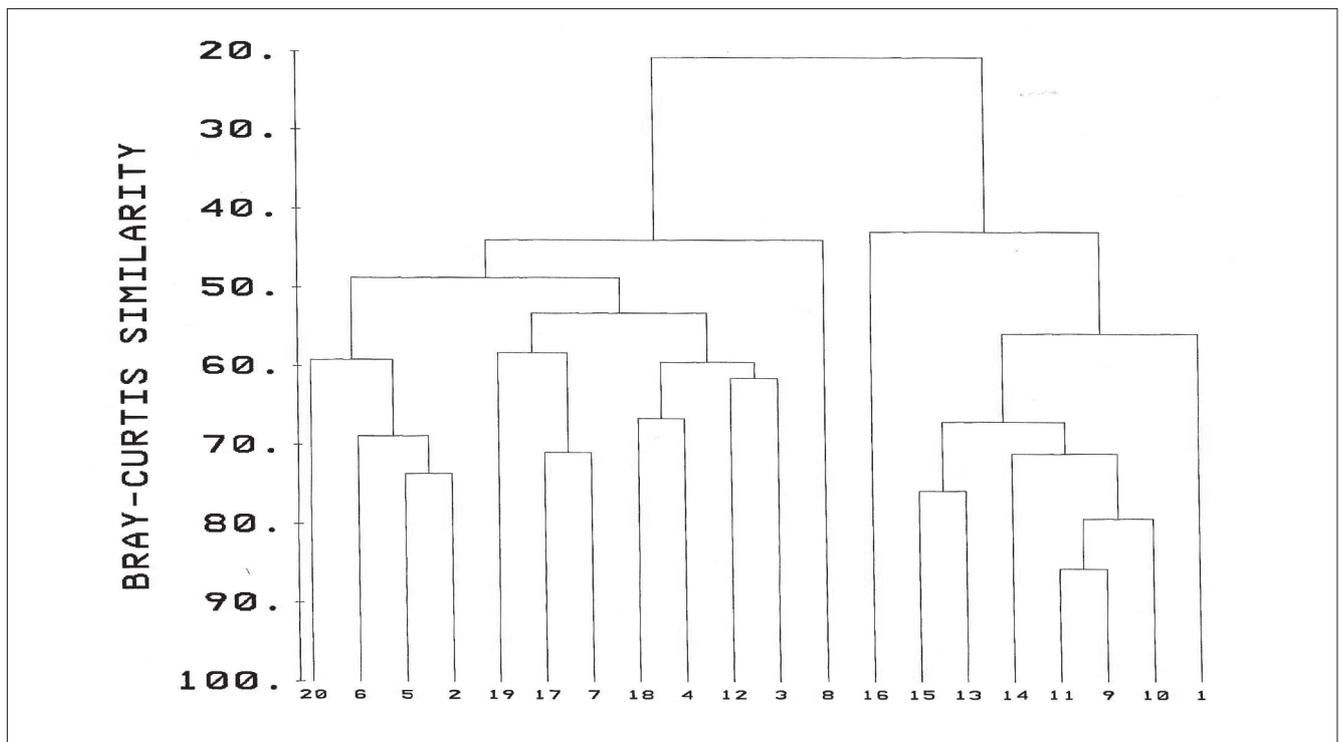


Fig. 4. Dendrogram (group average linkage, using Bray/Curtis) of the Central Highlands *Sphagnum* peatlands based on species presence /absence data. The sites separate into two groups at approximately 20% similarity. In general the subalpine sites (right-hand branch) cluster at higher similarity levels.

Table 6. Summary of environmental variables recorded for each peatland subgroup, giving ranges, (averages in bold).

Peatland community type	Total no. of sites	<i>Sphagnum</i> cover (%)	Altitude (m)	pH	Peat depth (m)	Shade cover (%)	Species richness
Montane 'treeless'	5	25–75 52	1085–1135 1103	4.8–5.5 5.3	0.83–1.2+ >0.93	0–2.5 1.3	13–23 18
Montane 'rainforest'	7	25–100 54	910–1290 1134	4.2–5.5 4.8	0.71–1.18 0.98	2.5–62.5 24.6	13–25 20
Subalpine 'hill-slope'	3	25–75 46	1420–1430 1423	4.7–5.5 5.1	0.95–1.2+ >1.15	0.5–15 6.0	11–16 14
Subalpine 'valley-floor'	5	25–75 52	1175–1430 1360	4.4–5.5 4.8	0.89–1.2+ >1.07	0.5–2.5 0.9	14–20 17

Table 7. Mean cover (%) of important species discriminating between the 'rainforest' and 'treeless' montane peatland sites.

Species are listed in order of their contribution to the mean dissimilarity amongst sites, up to a cumulative contribution of 85%. 'Di' stands for dissimilarity and represents that species contribution to the average dissimilarity between the groups. The neighbouring column gives the ratio of that species dissimilarity contribution to the standard deviation of its contribution. Average dissimilarity = 67.03

Species	'rainforest' sites cover (%)	'treeless' sites cover (%)	Di	Di/SD(Di)	Cumulative(%)
<i>Leptospermum grandifolium</i>	28.57	16.5	14.99	0.91	22.37
<i>Carex appressa</i>	7.29	8.70	8.68	1.03	35.31
<i>Richea victoriana</i>	2.21	9.50	7.86	1.18	47.03
<i>Gleichenia dicarpa</i>	0.00	7.60	6.17	0.50	56.24
<i>Nothofagus cunninghamii</i>	5.14	0.00	4.74	0.74	63.30
<i>Richea continentis</i>	5.36	0.00	4.47	0.40	69.97
<i>Coprosma granadensis</i>	0.43	3.70	2.71	0.69	74.01
<i>Wittsteinia vacciniacea</i>	3.14	0.30	2.44	0.54	77.65
<i>Epacris paludosa</i>	2.64	0.10	2.14	0.51	80.85
<i>Astelia alpina</i>	2.14	0.00	1.76	0.40	83.47
<i>Erigeron paludicola</i>	0.14	1.30	0.92	1.16	84.84

Table 8. Mean cover (%) of important species discriminating between subalpine hill-slope and valley-floor peatland sites.

Species are listed in order of their contribution to the mean dissimilarity amongst sites, up to a cumulative contribution of 90%. 'Di' stands for dissimilarity and represents that species contribution to the average dissimilarity between the groups. The neighbouring column gives the ratio of that species dissimilarity contribution to the standard deviation of its contribution. Average dissimilarity = 37.87

Species	Valley-floor sites cover %	Hill-slope sites cover %	Di	Di/SD (Di)	Cumulative(%)
<i>Epacris paludosa</i>	8.75	30.00	15.18	1.77	40.08
<i>Empodisma minus</i>	31.88	30.00	8.30	0.79	62.01
<i>Richea continentis</i>	5.63	6.00	4.43	0.86	73.72
<i>Baeckeke gunniana</i>	1.50	6.67	3.55	0.86	83.11
<i>Astelia alpina</i>	1.50	0.33	0.88	1.05	85.42
<i>Poa costiniana</i>	0.88	0.50	0.50	0.69	86.73
<i>Erigeron paludicola</i>	1.00	0.33	0.47	0.70	87.98
<i>Juncus sandwithii</i>	0.50	0.00	0.39	3.87	89.02
<i>Celmisia pugioniformis</i>	0.38	0.00	0.30	1.48	89.82

Both subalpine valley floor peatlands and treeless montane communities were positioned at the high value end of the water vector. This is likely to be related to landscape position, these communities being situated in lower topographic positions, in larger open cold-air drainage hollows and on deeper peats. Peat depths in excess of 1.2 m were recorded at many sites. Mean depths were similar amongst the four subgroups and was not a significant differentiating variable in ordination analysis. However, the actual depth range was less in montane rainforest peatlands than in the other three subgroups (Table 6).

The pH measurements were variable in all four peatland types. There was no clear trend and mean figures ranged from 4.8 in montane rainforest and subalpine valley-floor systems to 5.3 in treeless montane peatlands.

Species richness was significantly greater in montane as opposed to subalpine systems ($t = -2.149$; $p = 0.045$; $df = 18$). Amongst the montane site group, rainforest systems displayed higher species richness than treeless, and valley-floor peatlands were richer in the subalpine group.

Discussion

Variation within the Central Highlands region

Floristic composition of *Sphagnum*-dominated plant communities varies considerably within the Central Highlands of Victoria. The key factors appear to be altitude-related. Altitude is a surrogate in the analysis for climate factors such as temperature, frost intensity, and duration of snow cover. The variables shade, canopy height, aspect and slope were also important in explaining vegetation patterns.

Shade and canopy height are indirectly tied to climate, by facilitating the existence of a humid micro-climate, reducing evapotranspiration and *Sphagnum* dessication, and, by moderating temperature variation and reducing frost exposure. The montane 'treeless' peatland communities all occurred in broad natural forest gaps. Distances from forest fringe to forest fringe were between 40 and 150 m. Frost and anoxic water-logged peats are thought to act in unison to determine plant composition, by excluding trees and limiting shrub growth (Farrell and Ashton 1973, Ashton and Hargreaves 1983). However, the palaeoecological evidence suggests that the substratum has been wet enough to prevent tree establishment for thousands of years (McKenzie 1997) and the absence of trees has been reinforced by temperature limitations due to cold air pooling. Where present in montane treeless peatlands, the shrub *Leptospermum grandifolium* was typically stunted, bushier in growth habit, and associated with other shrubs like *Richea victoriana* and *Tasmannia xerophila*. At the peatland fringe, *Leptospermum* achieved its more familiar form (6–7 m), probably partly in response to access to richer mineral soils. In narrower gullies and depressions, *Leptospermum* and *Nothofagus cunninghamii*

form a low open forest of between 3 and 7 m, assisted by the associated milder microclimate. The ground layer in this context consists of abundant *Sphagnum cristatum* and *Carex appressa*, with a reduced shrub presence.

Aspect and slope were important factors in subalpine peatlands. The 'hill-slope' *Sphagnum* communities observed at Mount Torbreck and Mount Bullfight occur on gentle to moderate southerly to easterly slopes where they are protected from desiccation by the surrounding *Eucalyptus pauciflora* heathy forest. They are also assisted by seepage from the ridges above and therefore remain moist even through drier months. Similar hill-slope, seepage, or 'raised bogs' occur throughout the alpine and subalpine areas of Victoria and New South Wales, although composition varies slightly (McDougall 1982, Wahren et al. 1999, Costin et al. 2000). Subalpine valley floor peatlands are associated with less slope, more surface water, and display greater variation in microtopography.

Successional Development

Vegetation patterns across the entire region appear to have been shaped by the large landscape-scale fires of the late 19th and early 20th century, particularly those in 1926 and 1939 (LCC 1973, Rundle 1977, Ashton & Hargreaves 1983, Ashton 2000). Most peatland sites examined contained large stumps or 'stags' at their perimeter, probably formerly *Eucalyptus delegatensis*. Many burnt trunks have collapsed into and across the peatlands as a result of decay or the salvage logging operations that followed the 1939 fires. In some cases this has further impeded drainage, possibly facilitated *Sphagnum* growth, and provided substrate for shrub establishment (Agnew et al. 1993).

Perhaps of greater significance is the presence of narrower stumps and stags within many treeless montane sites. These are likely to be the remains of trees which would have been at least 7 or 8 m high (Fig. 5). Evidence suggests that these were *Leptospermum grandifolium* and *Nothofagus cunninghamii* (some *Nothofagus* coppicing observed), and that these sites may have once resembled the Keppel Hut site (Fig. 6), an example of the climax of this succession. In the present study, the range of montane sites from 'treeless' to 'rainforest', may relate to seral stages. Narrower sites have quickly reverted to low open forest communities, albeit with a high understorey cover of *Sphagnum*. Some of the slightly broader peatland gullies may also revert to *Leptospermum*-*Nothofagus* low open forest, given at least 60 years without major disturbance. However, this disturbance-free period seems unlikely given current forestry activity and projected future fire frequencies under climate change (Overpeck et al. 1990).

The severity of the 1939 fires, the scale of post-fire salvage logging and more recent forestry activities, have probably contributed to some montane 'treeless' sites being in the relatively early stages of post-fire succession, even more

than 60 years after the event (Fig. 5). These appear to exist as a type of disclimax community, or in an alternative state, and may never acquire their former structure (Beisner et al. 2003, Suding et al. 2005). *Leptospermum grandifolium* swamps on shallow slopes in the upper head-water streams north and east of Mount Disappointment, on the Hume Range 50 km further west, are considered to have formerly been *Nothofagus cunninghamii*-*Atherosperma moschatum* cool temperate rainforest prior to a succession of fires between 1898 and 1926 (Ashton 2000). The absence of epacridaceous shrub species such as *Richea victoriana* and *Epacris paludosa* at some of the montane sites may also be due to the high fire frequency in the 80 or 90 years prior to 1939. Species of *Richea* in particular, appear to be very fire-sensitive (Wahren & Walsh 2000).

The landscape position of the Keppel Hut site, in a southern aspect amphitheatre-like gully at 1290 m, surrounded by forested ridges reaching elevations of 1360 m or more, has protected it from recent large fire events. The *Sphagnum* community at this site is situated in a gap of senescent *Nothofagus cunninghamii* of considerable age, and is surrounded by large moss and epiphytic fern encrusted 'stags' (Fig. 6). *Leptospermum grandifolium* was less prevalent at this site, but some individuals present were also of large girth (30 cm diameter). The understorey contained the highest cover of *Astelia alpina* recorded in this study, a species more generally associated with hummocks in higher altitude 'bogs' but occurring as an understorey species in montane communities in Tasmania (Martin 1999).



Fig. 5. Peatland site 2 looking north from near the south-west margin. Burnt stumps, formerly *Nothofagus cunninghamii* or *Leptospermum grandifolium*, are clearly visible in the foreground and middle distance. *Carex appressa* dominates the ground layer and there is a high continuous cover of *Sphagnum*. *Leptospermum grandifolium* shrubs approximately 2.5 m high are visible in the right and centre distance. These mark the main drainage line. Evidence suggests that the peatland had a *Nothofagus cunninghamii*-*Leptospermum grandifolium* low open forest canopy prior to the fires in 1939.

The Keppel Hut community may be associated with gap formation in an over-mature *Nothofagus cunninghamii* canopy, a process thought to occur after 400–600 years (Howard 1973), but is perhaps more likely to be naturally open, due to the effects of water-logging and peatland dynamics (Van Breeman 1995, Malmer et al. 2003). At the Snobs Creek site, the *Sphagnum* is etiolated due to diminishing light and may therefore be 'migrating' along the forest floor as small gaps open in the riparian rainforest canopy. In this context, *Sphagnum* mosses represent an earlier seral stage or are present as a community component only, rather than constituting the climax vegetation type and system 'driver', as is the case in open subalpine wet heath (Costin 1954, Van Breeman 1995). The optimum canopy cover for *Sphagnum* growth is 20–40%, a higher cover than this and the lack of light will limit its abundance (Whinam & Buxton 1997).

The large 'treeless' montane sites which experience cold air drainage and contain deeper peats (Storm Creek, Tom Burns and Little River), are not part of this dynamic.

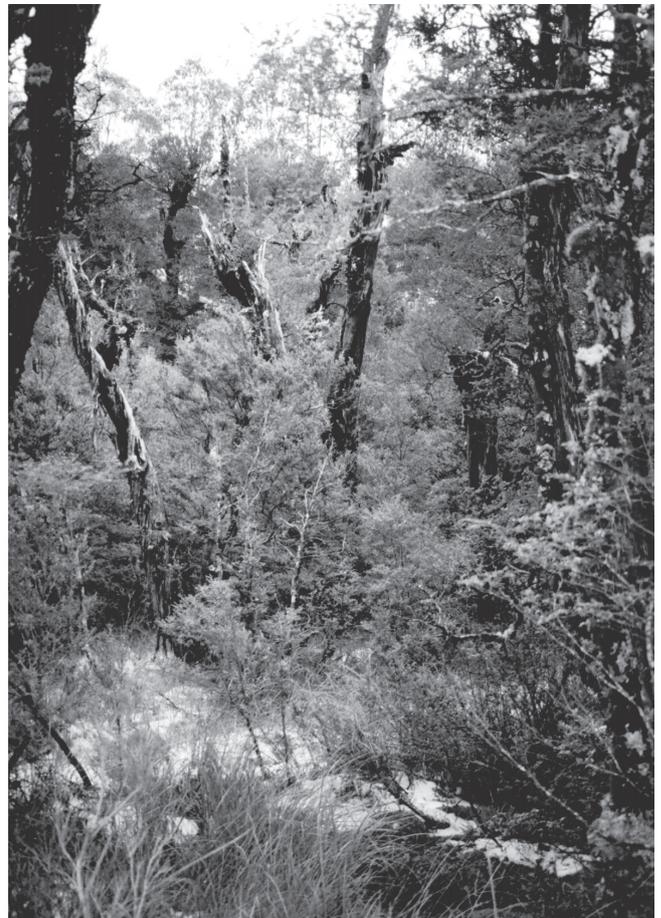


Fig. 6. The montane rainforest peatland at Keppel hut (site 17) is surrounded by large senescent *Nothofagus cunninghamii* and is representative of the subgroup. It is likely that site no. 2 (Fig.5) may have resembled this site before the fires of 1926 and 1939. Light snow is lying on the hummocks of *Sphagnum cristatum* (June, 2003).

Hence, subalpine species exist both within and at the fringe of these peatlands. This is particularly true of the Storm Creek peatland, which was more floristically similar to the subalpine sites than to other sites at similar altitudes. These species are possibly remnants from earlier in the Holocene when temperatures were cooler and subalpine vegetation extended to lower elevations (McKenzie 1997). While many of these larger montane peatland sites also have large *Eucalyptus delegatensis* stumps at their perimeter on mineral soils, they do not show evidence of a former 'within peatland' *Nothofagus* occupation.

Amongst the 'treeless' montane *Sphagnum* peatlands, the Little River site is particularly interesting, partially due to its landscape position, and because it demonstrates the influence of cold-air drainage on vegetation patterns (Fig. 7). It is located in a broad valley at approximately 1100 m and is surrounded on three sides by ridge-tops that rise to well over 1200 m, reaching 1380 m on the eastern side. The *Sphagnum* peatlands are along the valley floor, surrounded by the relatively cold-tolerant *Eucalyptus perriniana* which forms a low open forest with an understorey of heath shrubs such as *Leionema phyllicifolium* and *Pultenaea muelleri*. There is no *Nothofagus cunninghamii* in the vicinity of these peatlands, and only limited stunted *Leptospermum grandifolium*.

Species richness patterns within peatlands

Sphagnum peatland plant communities are not species-rich by nature (Joosten & Clarke 2002). The higher species richness in montane, compared to subalpine systems in the Central Highlands, is perhaps to be expected given higher mean temperatures, a longer growing season, and conditions generally less demanding for plants. Plant exposure to frost may actually be greater in montane 'cold-air' drainage hollows than subalpine ones because they are not protected by an insulating layer of snow for several months over winter (Williams 1987). This, however, does not seem to be manifest in reduced diversity and is perhaps more likely to enhance species richness by limiting shrub dominance. Within the montane sites group, 'rainforest' peatland communities appeared to be richer in species. The narrower nature of these, and their proximity to the wet sclerophyll forest ecotone may partly explain this. Many non-wetland species were recorded at these sites. There was more evidence of disturbance in and around montane sites (forestry, deer, rabbits) and this may be a factor contributing to higher species richness.

The montane 'rainforest' peatlands with large mature *Nothofagus* and *Leptospermum* individuals, contained sub-communities on raised roots and around tree bases including species such as *Wittsteinia vacciniacea*, *Libertia pulchella*



Fig. 7. Treeless montane peatland in the upper reaches of the Little River (site 20) looking south-east from the head of the system. *Eucalyptus perriniana* forest surrounds the peatland on higher ground either side, *Richea victoriana* is visible at the fringe. The centre of the peatland is dominated by *Carex appressa*, *Carex gaudichaudiana* and *Sphagnum cristatum*. Stunted *Leptospermum grandifolium* is just visible at the far end.

and *Carex breviculmis*. Epacridaceous species were rare and sparse at these sites. Bare peat patches contain *Isolepis aucklandica* and *Epilobium gunnianum*, while *Coprosma granadensis* and *Erigeron paludicola* occur in *Sphagnum* cushions. Hence, niche diversity and variability in resource availability probably contributes to the higher species richness.

Subalpine valley-floor peatlands (Fig. 8) displayed a high species richness relative to hill-slope communities, probably as a result of a similar micro-habitat diversity to the above mentioned montane 'rainforest' systems. Shallow rooted species like *Asperula gunnii*, *Erigeron paludicola*, *Luzula modesta* and the lily *Astelia alpina*, were often present in hummocks of *Sphagnum cristatum*. Hollows contained *Sphagnum novo-zelandicum*, *Carex gaudichaudiana* and *Juncus sandwithii*, with *Oreobolus* species often found at the edge of hollows adjacent to *Empodisma minus*. Peatland site no. 14, at Mount Bullfight, contained far less *Sphagnum novo-zelandicum*. In its place, hollows contained *Oreobolus oxycarpus* cushions and *Ranunculus collinus*, *Epilobium gunnianum* and *Hypericum japonicum*. These sub-communities containing *Oreobolus* and rhizomatous herbs are reminiscent of peat and gravel pavements that occur in similar landscape settings on the Bogong High Plains in north-east Victoria and at Kosciusko in New South Wales (Costin 1954, Wimbush & Costin 1979, McDougall 1982, Wahren et al. 1999). Where they occur in these regions, they are thought to be associated with earlier seral stages, and a precursor to *Sphagnum* colonisation. *Caltha introloba* is a component of this community elsewhere in subalpine and alpine areas of Victoria and southern New South Wales (Wimbush & Costin 1979, McDougall 1982, Walsh et al. 1986), but seems to be absent from the Central Highlands.

Hill-slope subalpine peatlands tended to be dominated by the shrubs *Richea continentis*, *Epacris paludosa* and *Baeckea gunniana*, perhaps a response to more humified peats (Malmer et al. 2003). Greater shrub growth in these communities is characteristic of soligenous peatlands or 'sloping' mires, where greater peat water flow, in response to slope, enhances nutrient availability in the rhizosphere (Gore 1983a, Charman 2000, Joosten & Clarke 2002). These communities are less species-rich but still maintain a high *Sphagnum* cover.

Comparison with other highland regions in Victoria and southern New South Wales

Sphagnum-dominated peatlands in the Central Highlands appear to display mixed floristic affinities. Subalpine communities are similar to those occurring at Mount Baw Baw, and to a lesser extent, on the Bogong High Plains and in the Kosciuszko region. Subalpine systems, while containing many of the same species (*Richea*, *Baeckea*, *Empodisma*, *Astelia*), also contain a second *Sphagnum* species (*Sphagnum novo-zelandicum*), which is abundant in hollows and shallow pools, but which is much less conspicuous in the peatlands of

north-eastern Victoria. This hummock /hollow partitioning of *Sphagnum* species, common in the northern hemisphere, seems to be rare in Australia (Whinam & Hope 2005).

The montane systems in this study are quite different from subalpine peatlands both within this region and further to the north-east, but appear to be similar to those systems in the upper Thompson River and Yarra headwaters region, to the west of the Baw Baw plateau (Willis 1945, Walsh et al. 1986). They also differ in composition from montane systems found in southern New South Wales (Costin 1954, Whinam & Hope 2005), and further east in Victoria (Ladd 1979, Whinam & Chilcott 2002, Shannon & Morgan unpublished data).

The general floristic affinities of the Central Highlands region with Tasmania (Busby & Brown 1994) apply equally to wet heathlands and *Sphagnum* peatlands (Costin 1957, 1962). *Nothofagus cunninghamii* is a component of montane 'rainforest' peatlands and is also present in vegetation fringing treeless peatlands in montane and subalpine areas. Many species with Tasmanian associations are also either community members or present in surrounding vegetation. The prostrate, scrambling epacrid species *Trochocarpa clarkei* is a local endemic and frequently found at peatland margins in both montane and subalpine areas. It is the only Victorian representative of the genus, other members being prevalent in Tasmania. There are several species of *Richea* associated with peatlands in Tasmania (Whinam et al. 2001) and two of these occur in the Central Highlands, though only one occurs in peatlands further to the north-east (McDougall 1982, Walsh et al. 1986).

The Tasmanian floristic affinities have been attributed to the more maritime climate of the southern end of the mainland highland regions (Costin 1957, 1962, Williams & Costin 1994, Kirkpatrick & Bridle 1998, 1999). The Kosciusko and Bogong High Plains regions are subject to a more continental climate with greater precipitation variability and colder winter temperatures. Summer precipitation totals are higher and less variable in southern areas, whereas snow cover duration is greater in the more continental areas further north (Kirkpatrick & Bridle 1998).

Four of the sites in this study were the subject of earlier palaeoecological analysis (Ashton & Hargreaves 1983, McKenzie 1997). The basal layers of peat cores taken from Tom Burns Creek were estimated to be 32 000 years old, and those at Storm Creek 17 000 years (McKenzie 1997), suggesting that they have functioned as peatlands for longer than the higher altitude systems in the Kosciusko and Bogong regions, which are generally believed to have developed over the 11 000 years since the end of the last glacial period (Kershaw & Strickland 1989, Martin 1999).

Overall condition

In relative terms, the peatland ecosystems of the Central Highlands region are in a good condition. Limited livestock

grazing occurred across the area but is not thought to have been as intensive as in the eastern highlands (Lawrence 1999, Wahren et al. 1999). This activity decreased in the forests in the 1930s, and had ceased altogether in subalpine areas by the middle of the 1960s (Ashton & Hargreaves 1983). 'Pugging', exposed bare peat, and the common introduced 'pasture' species associated with livestock grazing and degraded systems elsewhere are absent, except for some small isolated patches linked to introduced deer (authors pers. obs.). The dense forests that surround the Central Highlands peatlands have, in this sense, protected them.

Fires burnt nearly 3 million hectares of vegetation across highland areas of southern New South Wales, Australian Capital Territory and eastern Victoria in January 2003 (Esplin 2003). Large areas of peatland were also burnt in these fires (Hope & Whinam 2005, Tolsma et al. 2005) and are thus now in the fragile, early stages of post-fire regeneration. At the time of writing (December 2006), extensive fires were burning in sections of the Alpine National Park north of Gippsland. It is likely that these have burnt areas of peatland. In contrast, the peatlands of the Central Highlands and Baw Baw Plateau have not experienced fire since 1939.

The impact of past and current forestry activities in montane areas on peatland hydrology, processes and composition is hard to determine. In some cases fallen logs have impeded drainage, favourably altering hydrology and enhancing mire activity. However, the scale and intensity of current activities is still of concern. Several of the peatlands surveyed were adjacent to recently cleared logging coupes, or regrowth forest less than 30 years old, and this has implications for the supply of seepage water to these systems (Vertessy et al. 2001), not to mention shorter-term alterations to microclimate. In palaeoecological studies, an increased charcoal presence is sometimes linked to a combination of climate fluctuation and anthropogenic activity. Furthermore, it often coincides with a subsequent increase in *Sphagnum* derived peat in the profile above. However, in most of these examples the surrounding catchment slopes were permanently cleared of trees (Martin 1999, McGlone et al. 1997, McGlone & Wilmshurst 1999).

Anthropogenic activity (timber extraction, frequent fire) has been focussed in the surrounding forests and the impacts appear to have been greater there, and perhaps less within actual peatland systems. The presence of exotic plant species within those systems surveyed is relatively low, although they are quite well represented in logging regrowth forest. There is some evidence of illegal *Sphagnum* moss harvesting on small scales at one or two sites (Whinam et al. 2003). Introduced herbivores such as rabbits and hares are perhaps of concern. Damage caused by them is evident in some grassy clearings at peatland /forest margins and sometimes within peatlands on *Empodisma minus* mats (droppings).

Conclusion

McKenzie (1997) highlighted the palaeoecological significance of several of the peatlands within the region. They have a long history, which began before the last glacial maximum. Much important information on past vegetation patterns and climates is stored in the peat layers of these sites.

There are several significant areas. Storm Creek and Tom Burns Creek have already been identified as significant Victorian wetlands (ANCA 1996). The mature *Nothofagus cunninghamii* 'rainforest' peatland at Keppel Hut seems to have escaped recent major fires (1939). Sites observed in the upper reaches of the Little River are of interest as much for their landscape setting and associated surrounding vegetation. Several key species have interesting distributions across the region; *Sphagnum novo-zelandicum* is noticeably more prevalent at the southern end of the study area (Lake Mountain and Storm Creek sites). *Richea continentis*, a key species in alpine and subalpine systems in north-east Victoria, is present at the subalpine sites examined, but is replaced by *Richea victoriana* in montane sites and at Storm Creek. It is interesting to note that the Mount Bullfight valley-floor site was the only one in which both species were present.

Sphagnum 'bog' communities are listed as threatened under the Victorian Flora and Fauna Guarantee Act (1988). Many in the Central Highlands area are outside existing reserves and deserve more formal protection, particularly those at Keppel Hut and Little River (Table 1). Mire systems in south-eastern Australia face an uncertain future given their already marginal status (Whinam et al. 2001) and the unfavourable climate change outlook for south-east Australia (Whetton et al. 1996). However, the palaeoecological evidence from some of these peatlands suggests that they are resilient to large climate fluctuations and changes in the vegetation of the surrounding landscape (McKenzie 1997, 2002). Provided anthropogenic interference is minimised through appropriate management, they will continue to exist and function as peatlands. Efforts should be made to ensure the protection of these previously undescribed peatlands.

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Fig. 8. A good example of a subalpine valley-floor peatland at Mt Bullfight (site 14), showing a well developed 'bog' pool surrounded by *Sphagnum cristatum*, *Empodisma minus*, *Richea continentis*, *Epacris paludosa*, *Poa costiniana* and *Carex appressa*.

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