
CSIRO PUBLISHING

Australian Journal of Botany

Volume 47, 1999

© CSIRO Australia 1999

An international journal for the publication of
original research in plant science

www.publish.csiro.au/journals/ajb

All enquiries and manuscripts should be directed to

Australian Journal of Botany

CSIRO PUBLISHING

PO Box 1139 (150 Oxford St)

Collingwood

Vic. 3066

Australia

Telephone: 61 3 9662 7624

Facsimile: 61 3 9662 7611

Email: simone.farrer@publish.csiro.au



Published by **CSIRO PUBLISHING**
for CSIRO Australia and
the Australian Academy of Science



***Sphagnum* Peatlands of Kosciuszko National Park in Relation to Altitude, Time and Disturbance**

Peter J. Clarke^{AC} and A. R. H. Martin^B

^ADepartment of Botany, University of New England, Armidale, NSW 2351, Australia.

^B2A Birdwood Street, Ryde, NSW 2112, Australia.

^CCorresponding author; email: pclarke1@metz.une.edu.au

Abstract

Sphagnum peatlands or bogs in the Kosciuszko National Park ranging from montane to alpine in elevation were sampled on two occasions spanning a maximum interval of 32 years. Data analysed for individual samples (305 quadrats) clustered into consistent microhabitat (hummock/hollow) groups and subalpine/alpine subgroups. Quadrat data were aggregated for sites (13 bogs) and analysed for floristic trends over time. Cluster and ordination analyses showed a large change in a single montane bog, but relatively little composition (presence/absence) change for the subalpine and alpine bogs. Analyses of dominant species in alpine (three) and subalpine bogs (three) showed some temporal trends in cover. There appears to be an increase in the cover of *Sphagnum* and a decrease in shrub cover in the subalpine bogs over the 20–32 years. Changes in shrub cover in undisturbed subalpine sites are attributed to shrub senescence and lack of recruitment. Changes at a site with intensive ski field development (Smiggin Holes) were analysed separately and compared with adjacent sites with no such development. *Sphagnum* cover had not increased at this site and shrub decline was pronounced. Bare ground and ruderal species increased in cover whereas 13 native species that were originally recorded in 1959 were not re-recorded in 1991. The detection of vegetation change in bogs through monitoring is important for adaptive management of vegetation under intensive use.

Introduction

‘Peatlands’ or ‘mires’ are general terms referring to a wide range of peat-accumulating ecosystems (Gore 1983). *Sphagnum* vegetation that is found in nutrient-poor acid conditions is, in a broad sense, referred to as bog whereas vegetation found in less acid nutrient-enhanced areas is referred to as fen. Bogs that are mainly influenced by water falling directly on them as snow or rain are described as ombrotrophic, and those that are mainly influenced by nutrient-poor groundwater are termed soligenous bogs (Gore 1983). *Sphagnum* bogs of the Kosciuszko massif are mainly of the latter type and are structurally diverse, ranging from mosslands through to heath.

Sphagnum bogs of the Kosciuszko massif have been described by a number of authors (McLuckie and Petrie 1927; Costin 1954; McVean 1969), and their floristics are reasonably well understood. They have, however, never been subjected to detailed study in respect to their change in floristic composition with altitude and time. Subalpine bogs usually form discrete entities, more or less convex in shape with marginal or central drainage. The majority of these bogs are on sloping ground, are of small area (range 500–2500 m²) and shallow with seldom more than 1 m of peat above the mineral substrate. Above *c.* 1850 m, bogs tend to occur in elongated bands along contours and frequently lack clear margins.

During long-term palynological studies of *Sphagnum* bogs of the Kosciuszko National Park, one of us (A. R. H. M.) made some quantitative observations on the flora of several bogs with a view to comparing their present floristic composition with pollen floras preserved in the peat. More specifically it was hoped that current altitudinal differences in species composition would help in the climatic interpretation of Holocene pollen diagrams. The original observations were made in summer (January–February) between 1959 and 1973, the majority being between 1959 and 1963.

Discussion between the present authors led us to realise the added value of re-examining the same sites to study floristic change over a period of up to 32 years. Change, other than through post-grazing regeneration, might result from various causes (e.g. ski activities, climatic fluctuations, herbivory, competition or fire regime). These sites were revisited and re-recorded in the summer of 1991. The present report examines (1) small-scale variation in composition; (2) among bog compositional change; (3) correlation of bog floristic variation with environmental factors; (4) changes in the cover of dominant species; and (5) specific changes at Smiggin Holes in relation to development.

Materials and Methods

Background and Study Sites

During the 1940s and 1950s, grazing was progressively withdrawn from the Kosciuszko massif and this was accompanied by a reduction in 'burning off' of grassy vegetation (Wimbush and Costin 1979a). By the late 1950s, when some of the original sites were sampled (Table 1), the general vegetation of the Kosciuszko massif still showed signs of disturbance from the effects of grazing, burning and the large regional fire of 1939 (Wimbush and Costin 1979a, 1979b). Analyses of snow gum stands adjacent to the subalpine bogs sampled indicate that these stands recruited after the wildfires of 1939.

When sites were originally selected (1959–73), they were chosen on the basis of having little obvious disturbance and all sites had an intact bog surface with little or no erosion. This contrasted with many subalpine and alpine bogs that, at the time, were often severely degraded (Wimbush and Costin 1979a, Wraggs Creek Transects). Thus, *a priori*, the trends described here probably represent less pronounced examples of vegetation change in Kosciuszko bogs.

The majority of the bogs sampled lay along the main Kosciuszko summit road or within 1 km of it, (Fig. 1) and between 1450 and 1980 m (Table 1). One site (Schlink Pass bog) lay close to the Schlink Pass road within the Kosciuszko National Park. Names applied to each of the bogs are usually from the nearest named geographic feature. The exceptions are Hydrology bog, which is informally named because Dr A. B. Costin conducted hydrology experiments there in the 1950s, and Lake Browne bog, which is informally named after Professor W. R. Browne who believed a Late Pleistocene lake lay in the valley below the site.

Most bogs had no specific history of disturbance when originally sampled, other than Smiggin Holes, which once had a higher than average cattle concentration because of the proximity of cattle licks ('Smiggin' was rock-salt for cattle lick). When resampled in 1991, several sites had some signs of disturbance, but most appeared unmodified by development. Smiggin Holes had been considerably

Table 1. Location of sample sites, Kosciuszko 1 : 50 000 map sheet coordinates, altitude, vegetation zone, year of sampling, number of quadrats sampled and analysis used

#Sample site could not be confidently matched with previous site. a, Quadrat floristic comparisons; b, whole site floristic comparisons; c, alpine, subalpine cover comparisons; d, Smiggin Holes cover comparisons

Sites	Map coord.	Alt. (m)	Vegetation zone	Year	Quadrats	Analysis
Wilson Valley bog	FV373775	1460	Upper montane forest	1960, 1991	30, 30	a, b
Boggy Plains bog	FV331748	1580	Subalpine woodland	1959, 1991	25, 25	a, b, c
Hydrology bog	FV293717	1660	Subalpine woodland	1963, 1991	25, 25	a, b, c, d
Smiggin Holes bog	FV277716	1690	Subalpine woodland	1959, 1991	40, 50	a, b, d
Digger's Creek bog	FV330726	1690	Subalpine woodland	1960, 1991	30, 30	a, b, c, d
Schlink Pass bog	FV243839	1770	Subalpine woodland	1973, 1991	25, 25#	a
Charlotte Pass bog	FV203675	1820	Approx. treeline	1959, 1991	25, 25	a, b, c
Wright's Creek upper	FV195654	1850	Tall alpine herbfield	1963, 1991	25, 25#	a
Wright's Creek lower	FV194956	1850	Tall alpine herbfield	1963, 1991	25, 25#	a
Lake Browne bog	FV174664	1885	Tall alpine herbfield	1973, 1991	30, 30	a, b, c
Mt Stilwell bog	FV189660	1950	Tall alpine herbfield	1960, 1991	25, 25	a, b, c

developed with roading, ski lodges and ski runs in the area. The bog at Boggy Plains had some peripheral disturbance where road drainage had deposited a gravel fan on one edge of the bog and a ditch along its northern margin is probably affecting the local hydrology. The area around Charlotte Pass bog has also been developed to a lesser extent with a T-bar ski run.

Sampling of Vegetation

The data set of 1959–63 consisted of 11 bogs on which 0.1-m² quadrats were thrown (Table 1). An additional bog at Happy Jacks Plains was also recorded in 1970, but was not used in this analysis because it was distant from the other sites. The number of quadrats was varied according to the area of the bog: 25 quadrats for the smaller ones, 50 for the largest, 30 or 40 for intermediates. Approximate randomness was achieved by throwing the quadrat frame haphazardly in any direction. Species presence and abundance were recorded by the Domin scale (Kent and Coker 1992). Small quadrats were used because of the small-scale heterogeneous nature of bog surfaces and the richness of the vegetation at small spatial scales (see Appendix 1).

Each quadrat was also classified as follows: building hummock (BH), consisting of low *Sphagnum* hummocks with *Empodisma minus* as the second most common species, and few shrubs, mostly of low

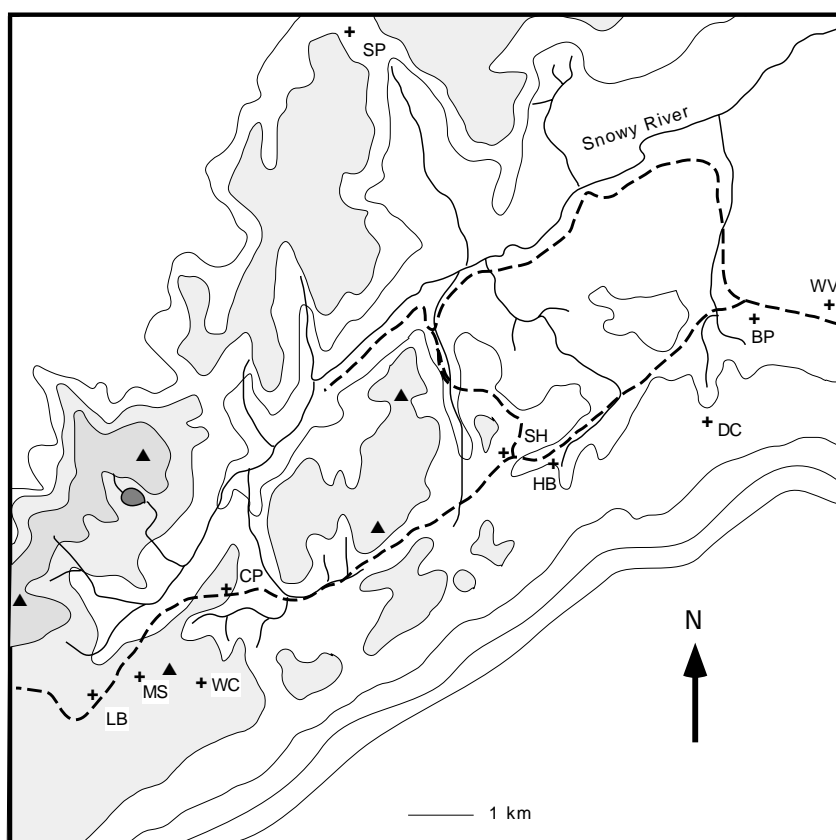


Fig. 1. Location of sample sites along the Kosciuszko massif within Kosciuszko National Park. Approximate level of treeline shown as a shaded contour. Roads shown as a broken line. WV, Wilson Valley; BP, Boggy Plain; DC, Digger's Creek; HB, Hydrology bog; SH, Smiggin Holes; SP, Schlink Pass; CP, Charlotte Pass; WC, Wright's Creek; MS, Mt Stilwell; LB, Lake Brown. Contour intervals approximately 150 m.

cover; mature hummocks (MH), comprising more-developed hummocks with abundant healthy *Sphagnum*, and shrubs invariably present and well-grown; shrubby (S), comprising quadrats dominated by shrubs, *Sphagnum* in low abundance, moribund or absent, hummocky topography reduced or absent, and peaty, not mineral soil; pool/channel (P), which was a hollow with water present irrespective of flora; and margin of bog (M), in which *Sphagnum* was absent, shrubs or *Poa* were present, and soil had a higher mineral content. As the hummock, hollow and pool components were of the order of 1 m in dimensions, the quadrat size was considered adequate. In practice quadrats rarely fell across two units; when this happened they were classified as BH/P or P/BH according to which unit occupied most of the quadrat area. The terminology used to describe bog vegetation follows that which implies cyclic development of bog features. The use of this habitat/successional terminology is discussed later.

Sample sites were revisited in the summer of 1991. However, the precise location of three sites could not be confidently identified at this time. Subsequently, one site at Schlink Pass was confidently identified; but not resampled. A summary of the sites sampled, the number of quadrats used, and the years of sampling are shown in Table 1. Resampling of sites was done from the same quadrat and by the same semiquantitative method as in the previous samples. Note that although bogs were resampled, the actual quadrat locations were re-randomised, thus avoiding the independence problems of fixed sample sites through time.

Multivariate Data Analyses

Cluster analysis was used to classify quadrat data collected between 1959 and 1973 to obtain a general account of the floristic variation at small spatial scales within and between the bogs sampled. This matrix consisted of 305 quadrats (objects) and 98 species (attributes). Species' abundances were entered as Domin scores from 1 to 10 and any species that occurred less than twice in the matrix was excluded from the matrix. The Bray–Curtis coefficient was used to calculate an association matrix using unstandardised data. Sites were clustered by agglomerative classification (UPGMA), with the PATN package. A two-way table was also generated to facilitate the floristic description of quadrat groups. A similar cluster analysis was undertaken for all quadrats sampled in 1991 and comparisons between equivalently sampled sites were made at the seven-group level using the RIND subroutine statistic in the PATN package (Belbin 1993).

Cluster analysis was also used to classify sites at the whole bog spatial scale. In this case, eight bogs studied from 1959 to 1963 were included together with the equivalent eight from 1991. In this analysis, only frequency scores were used to detect any large changes in composition among bogs through time. This matrix consisted of 16 bogs (objects) and 87 species (attributes). Species that either occurred less than twice and or had a summed frequency of less than 0.05 were excluded from the analysis.

Constrained ordination was also used to 'correlate' five environmental variables with the ordination space of species and bogs. Canonical correspondence analysis (CANOCO) was used to produce a direct visualisation of the site/bog relationship through time and the relationship of species to environmental correlates (ter Braak 1987). This approach uses weighted averages and assumes a unimodal response model of species. Five environmental variables were used in the analysis: altitude (continuous variable), disturbance (nominal variable), frequency of hummocks (continuous variable), frequency of pools and drainage lines (continuous variable), and time between sampling (continuous variable). The significance of the relationship was tested using Monte Carlo simulations with 999 permutations. Interpretation of the triplot ordination diagrams follow that of ter Braak and Verdonschot (1995).

Univariate Data Analyses

A univariate model was used to test for changes in species cover in space and time. Domin scores were converted to their cover equivalents and these percentage data were arcsine transformed. Species richness and the amount of bare ground were also analysed. Species used in the analysis were those that had high amounts of variance accounted for by the first axis of the ordination diagram. A three-factor analysis of variance model was used with altitude (three alpine v. three subalpine bogs) and time (1959–1973 v. 1991) as fixed interactive factors. A third nested factor of bogs within altitudinal zones was also included to test for spatial variation within patches. This effect was pooled with the residual when $P > 0.1$. Differences were only reported using conservative probabilities where $P < 0.01$.

A second univariate ANOVA model was used to analyse specific data collected at Smiggin Holes. These data were compared in a before (1960), after (1991), control (Hydrology bog and Digger's Creek bog: no ski slope development), impact (Smiggin Holes bog: ski slope development) model (Green

1979). This model was used to specifically test for relative changes in species cover at Smiggin Holes bog as detected by the interaction term in the model. It is preferable in such analyses to have more than one 'before' time and more than one 'control' site (Green 1993); so although there is one time in this analysis, two controls are used and from each site more than 20 replicates were taken.

Results

Small-scale Classification

Analyses of the 1959–73 quadrat data showed interpretable groupings at the seven-group level (Fig. 2). The groups reflect the floristic variation both within bogs and between bogs as they are based on the 0.1-m² quadrats. A floristic pattern of hummock and hollow was detected in the numeric analysis together with a clear alpine/subalpine pattern within the hummock grouping and within the hollow grouping. Species richness in the hummocks showed no altitudinal trend, although species richness in the hollows was higher in the alpine group. Species composition and group membership are provided in the descriptions of the vegetation groups in Appendix 1. Comparison of the seven-group level for the 1959–73 quadrats corresponds closely with grouping of quadrats sampled in 1991. Floristic classification showed close correspondence with broad habitat classifications used in the field in terms of hummocks and hollows. However, the habitat/successional classifications of BH, MH and S did not correspond closely with the floristic classification shown in Fig. 2.

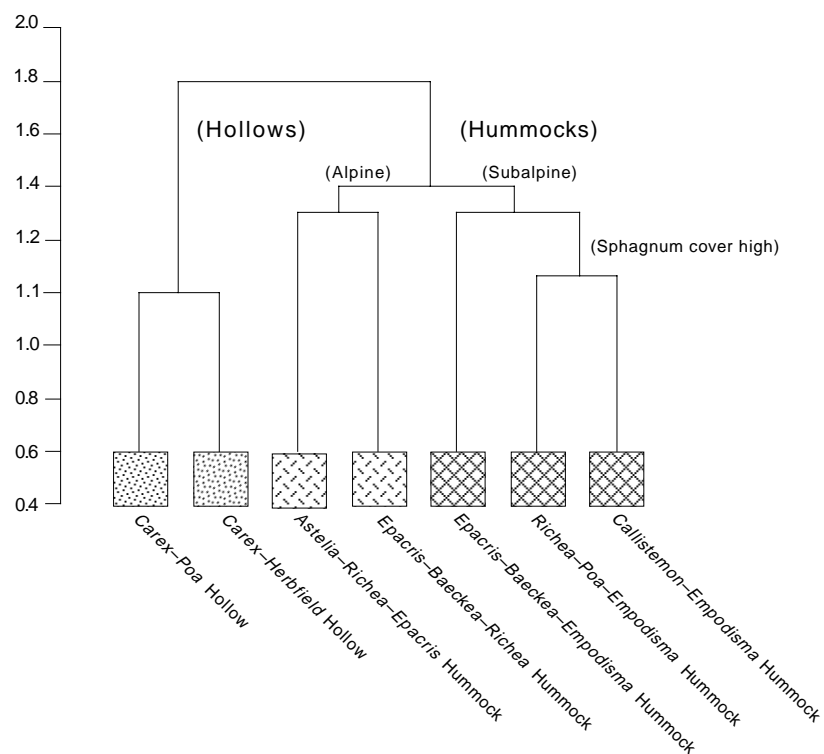


Fig. 2. Classification of quadrat samples from 1959 to 1973 at the seven-group level by an agglomerative clustering algorithm (UPGMA). Main environmental correlates of three- and two-group levels are shown in parentheses. Names that have been applied are based on the more frequent and abundant species. (See Appendix 1 for full descriptions of the groups.)

Among-bog Classification and Ordination

Classification of bogs using sets of data paired in time produced a dendrogram that shows a distinct spatial pattern and some temporal patterns (Fig. 3). A clear separation of subalpine and alpine sites is evident in the dendrogram together with a separation of the montane site at Wilson Valley in 1960. Such was the floristic difference in 1991 that the Wilson Valley site was classified as an outlier in 1991. Within the remaining alpine and subalpine sites no distinct temporal groups could be detected. A clear separation of Smiggin Holes from the rest of the subalpine bogs is evident. Note that in this analysis infrequent species have been excluded and only presence/absence data were used as a basis for similarity.

Ordination scores across space (eight bogs) and time (two times) are shown in Fig. 4a and are hardly distinguishable from an unconstrained ordination by correspondence analysis with the first two eigenvalues being very similar. Whilst the eigenvalues for the first two axes of the ordination diagram are low (0.20 and 0.12) their cumulative percentage variance (32%) is high for vegetation data. A Monte Carlo permutation test of this main axis indicates that it is significant ($P < 0.03$). Clear separation of alpine and subalpine bogs is shown, together with separation of the Smiggin Holes bog in space and time. Although time is not shown to be a

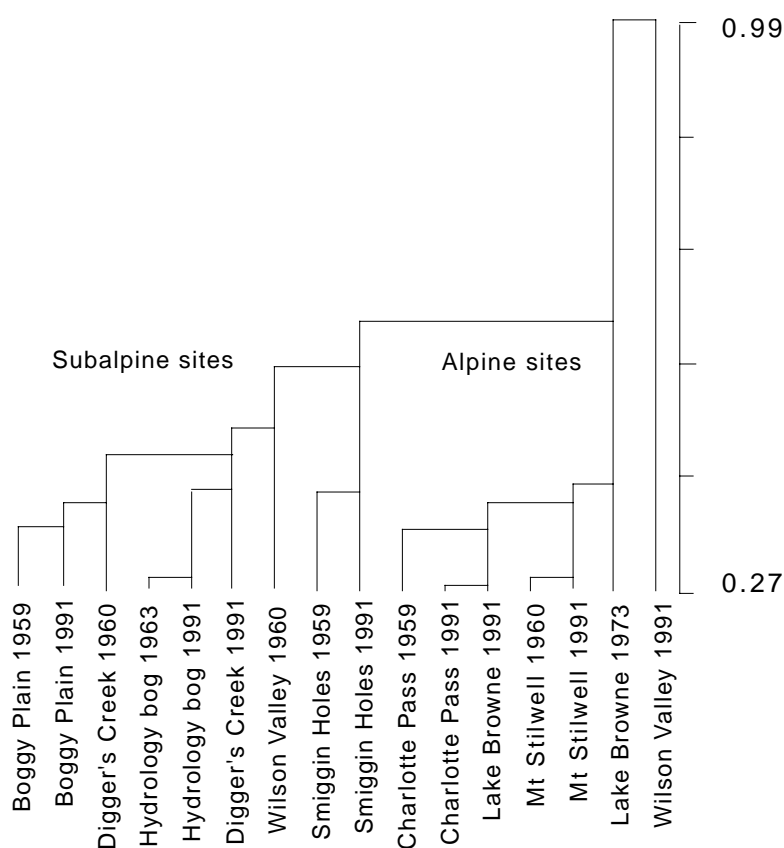


Fig. 3. Classification of sites based on the summed frequencies of species' presences level by an agglomerative clustering algorithm (UPGMA). Only bogs that could confidently be identified for resampling were used in the analysis.

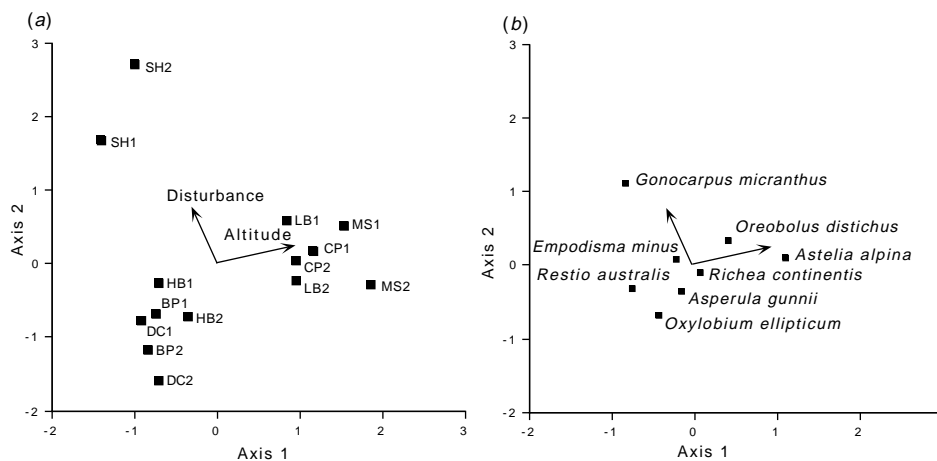


Fig. 4. Constrained ordinations of (a) sites and (b) species that had more than 70% of variance accounted for by the two axes of the ordination. Environmental variables are shown as arrows. Strength of association can be gauged by the length of the vector. Note the clear grouping of alpine and subalpine sites and the lack of separation in time. BP, Boggy Plain bog; HM, Hydrology bog; SH, Smiggin Holes bog; DC, Digger's Creek bog; CP, Charlotte Pass bog; LB, Lake Browne bog; MS, Mt Stilwell bog.

significant external correlate, the distance between scores for the Smiggin Holes site across time is relatively large.

Ordination scores for those species that have > 70% of variance accounted for are shown for the same scaled axes in Fig. 4b. In this figure the species coordinates represent their weighted averages of the axis scores of sites in which they occur. Figure 4b is reasonably faithful in displaying observed abundances and fitted abundance values given the overall inertia is 1.04. In terms of the species environmental correlation, 63% of the variation is accounted for by the first two axes of the ordination. Note that the inferred abundance of species is maximal where site and species points coincide in Fig. 4b. Figure 5 shows in more detail the overall distribution of species in constrained ordination space: species that are close can be expected to be similar in their distribution across sites given the low eigenvalue of the third axis (0.08).

The position of a quantitative environmental variable of altitude is shown as an arrow in each ordination diagram and shows a positive correlation with the first synthetic gradient (interset correlation 0.86). The arrow points in the direction of maximal change and the arrow length from the origin is proportional to the maximum rate of change. The highest correlation with the second synthetic axis is with disturbance (interset correlation of 0.78). Frequency of hummocks was the third most significant environmental variable (interset correlation of 0.69), whereas time was the least significant correlate. Note that each of the three main environmental correlates is negatively correlated with each other as they point in opposite directions. The central group of species in this ordination corresponds closely to those that form hummocks whereas those on the periphery are commonly associated with hollows, pools or edge of bog species. Differentiation of species into those that have a preference for alpine v. subalpine habitats is also evident along the altitude vector. Those associated with alpine sites are located to the right of the centroid in Fig. 5 and species associated with disturbance are scattered to the top left. These apparent preferences associated with site condition were tested more rigorously by cover scores in the following section.

Cover Change Among Bogs

Multivariate analyses of bog sites and species show a clear trend associated with altitude and some weaker trends associated with time. The clear separation of sites into subalpine and alpine groups based on the frequency might also have some basis in terms of species cover, so an analysis of variance model was used to test for difference in space and time. Differences in space between alpine and subalpine zones and the interaction with time were tested along with variation among bogs within altitudinal zones. Of the 87 species used in the multivariate matrix, 53 were suitable for univariate analyses. Differences were conservatively reported by only listing differences at a significance level of $P < 0.01$ (Table 2).

Several species had significant differences in cover for either alpine or subalpine bogs (Table 2). Only a few, however, had an exclusive alpine or subalpine preference and these species are minor components of vegetation cover. Only two species showed gradational trends of cover with increasing altitude: *Astelia alpina* increases in cover as altitude increases (Fig. 6a) whereas *Restio australis* decreases in cover as altitude increases (Fig. 6b). Other species that showed zone effects were often highly patchy in their cover values among bogs within altitudinal zones (Table 2).

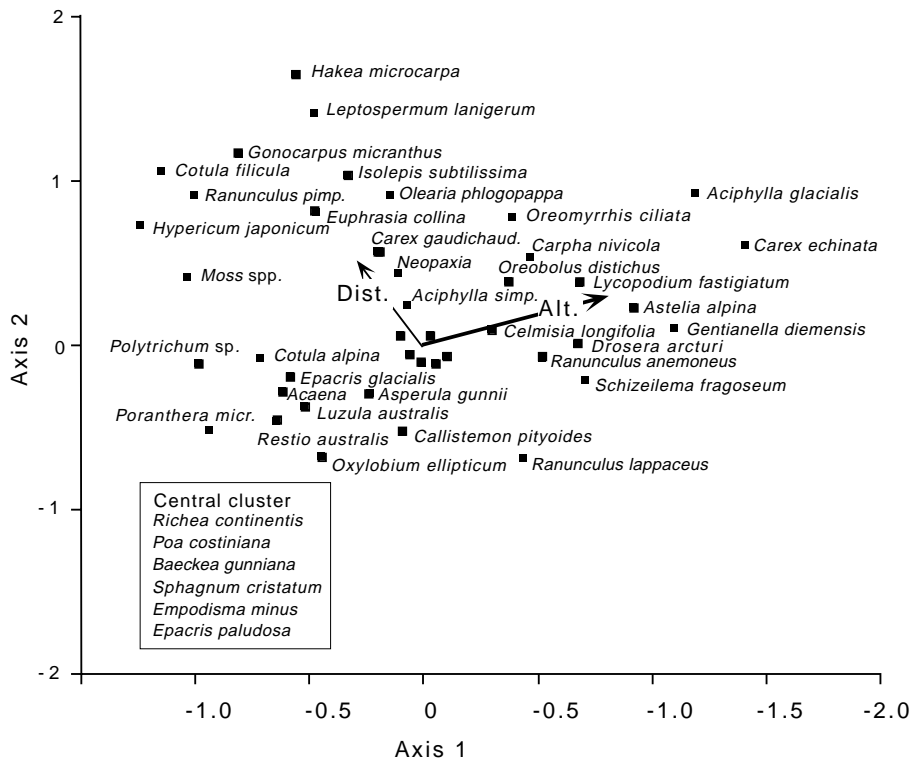


Fig. 5. Constrained ordination of frequent species from alpine and subalpine quadrat data collected at two time sets across seven bogs. The central cluster of species corresponds to the hummocks division of Fig. 2 and the peripheral ring corresponds to the hollows division of Fig. 2. Alpine and subalpine preferences of hummock species are also evident along the altitudinal vector. Environmental variables are indicated as arrows. Alt., altitude; Dist., disturbance.

Table 2. Summary results of ANOVA tests for differences over time, altitude and nested site variation for 53 species of plants across three alpine and three subalpine bogsSignificant effects reported where $P < 0.01$. *Significant nested site effect

Factor	Significant effects	Forbs, mosses and lycopods	Grasses and graminoids	Subshrubs and shrubs
Zone	No cover differences	<i>Sphagnum cristatum</i> * <i>Celmisia longifolia</i> * <i>Euphrasia collina</i> * <i>Oreomyrrhis ciliata</i>	<i>Empodisma minus</i>	<i>Baeckea gunniana</i> * <i>Richea continentis</i>
	Cover higher in the alpine zone	<i>Astelia alpina</i> * <i>Stylidium graminifolium</i> * <i>Lycopodium fastigiatum</i> * <i>Drosera arcturi</i>	<i>Carpha nivicola</i> * <i>Oreobolus distichus</i>	<i>Epacris paludosa</i> * <i>Pimelia alpina</i>
	Cover higher in the subalpine zone	* <i>Asperula gunnii</i> * <i>Epilobium gunnianum</i> * <i>Gonocarpus micranthus</i> * <i>Ranunculus pimpinellifolius</i>	<i>Poa costiniana</i> <i>Luzula australasica</i> * <i>Carex gaudichaudiana</i> * <i>Restio australis</i>	<i>Epacris glacialis</i> * <i>Oxylobium ellipticum</i> * <i>Callistemon pityoides</i> * <i>Hakea microcarpa</i>
Time	Cover unchanged	<i>Astelia alpina</i> <i>Epilobium gunnianum</i> <i>Oreomyrrhis ciliata</i> <i>Drosera arcturi</i> * <i>Gonocarpus micranthus</i>	<i>Carpha nivicola</i> <i>Luzula australasica</i>	<i>Oxylobium ellipticum</i> * <i>Callistemon pityoides</i> * <i>Pimelia alpina</i>
	Cover increase	<i>Sphagnum cristatum</i>		
	Cover decrease in time	<i>Lycopodium fastigiatum</i> * <i>Asperula gunnii</i> * <i>Celmisia longifolia</i> * <i>Stylidium graminifolium</i> * <i>Euphrasia collina</i> * <i>Ranunculus pimpinellifolius</i>	<i>Poa costiniana</i> <i>Oreobolus distichus</i> * <i>Restio australis</i> * <i>Carex gaudichaudiana</i>	<i>Epacris paludosa</i> * <i>Epacris glacialis</i> * <i>Hakea microcarpa</i>
Zone × time	Cover change not consistent across zones	* <i>Empodisma minus</i>	<i>Baeckea gunniana</i>	* <i>Richea continentis</i>

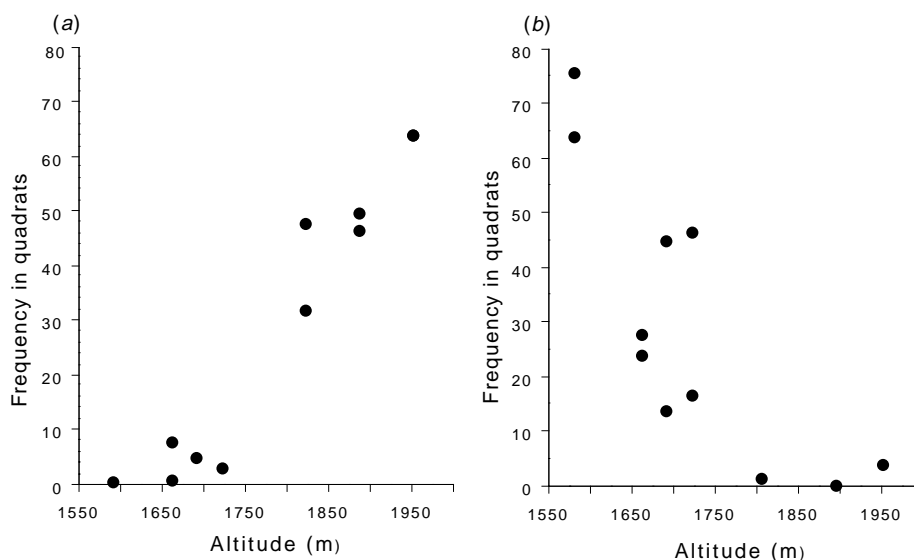


Fig. 6. Relationship of altitude and frequency of (a) *Astelia alpina* and (b) *Restio australis* in quadrats at each of the alpine and subalpine sites.

No detectable cover change in time was found in a range of species from shrubs to herbs; however, most of these species are minor components in terms of total cover (Table 2). Of the major components, *Sphagnum cristatum* had consistent increases in cover in both alpine and subalpine bogs (Fig. 7a). *Empodisma minus* slightly increased in cover in the alpine zone, but conversely decreased in cover in the subalpine zone (Fig. 7b). This trend of decreasing cover, was also mirrored for common subalpine shrub species (*Epacris paludosa*, *Epacris glacialis*, *Baekkea gunniana*) (Fig. 7c, d, f). Many other less-common species also showed a similar trend of decreasing cover in the subalpine zone (Table 2). *Richea continentis* showed an interesting trend with decreasing alpine cover, but conversely increasing subalpine cover (Fig. 7e). The amount of bare ground in the subalpine zone showed no detectable change whereas in the alpine zone it decreased in cover. Bog species richness was higher in the subalpine zone than the alpine zone and did not change through time.

Changes at Smiggin Holes

No detectable cover difference was found in two abundant species, *Sphagnum cristatum* and *Empodisma minus*, at Smiggin Holes bog (Table 3). Nevertheless, *Sphagnum* shows a general increase across all other bogs in both the subalpine and alpine zones (Figs 7a, 8a). Decreases in the cover of common shrub species were detected relative to the control sites (Fig. 8b–d). In particular, an order of magnitude decline in *Richea continentis* is clear at Smiggin Holes bog relative to an increase in cover at Hydrology bog (Fig. 8c). Conversely, two species showed increases in cover at Smiggin Holes bog: *Carex gaudichaudiana* and *Gonocarpus micranthus* (Fig. 8e, f). Bare ground also increased in cover at Smiggin Holes relative to the control sites (Fig. 8g). Two shrub species, one graminoid species and 10 herbaceous species were not re-recorded in 1991 (Table 3). A total of 49 species was recorded in 40 quadrats in 1963 whereas in 1991 a total of 34 species was recorded in 50 quadrats.

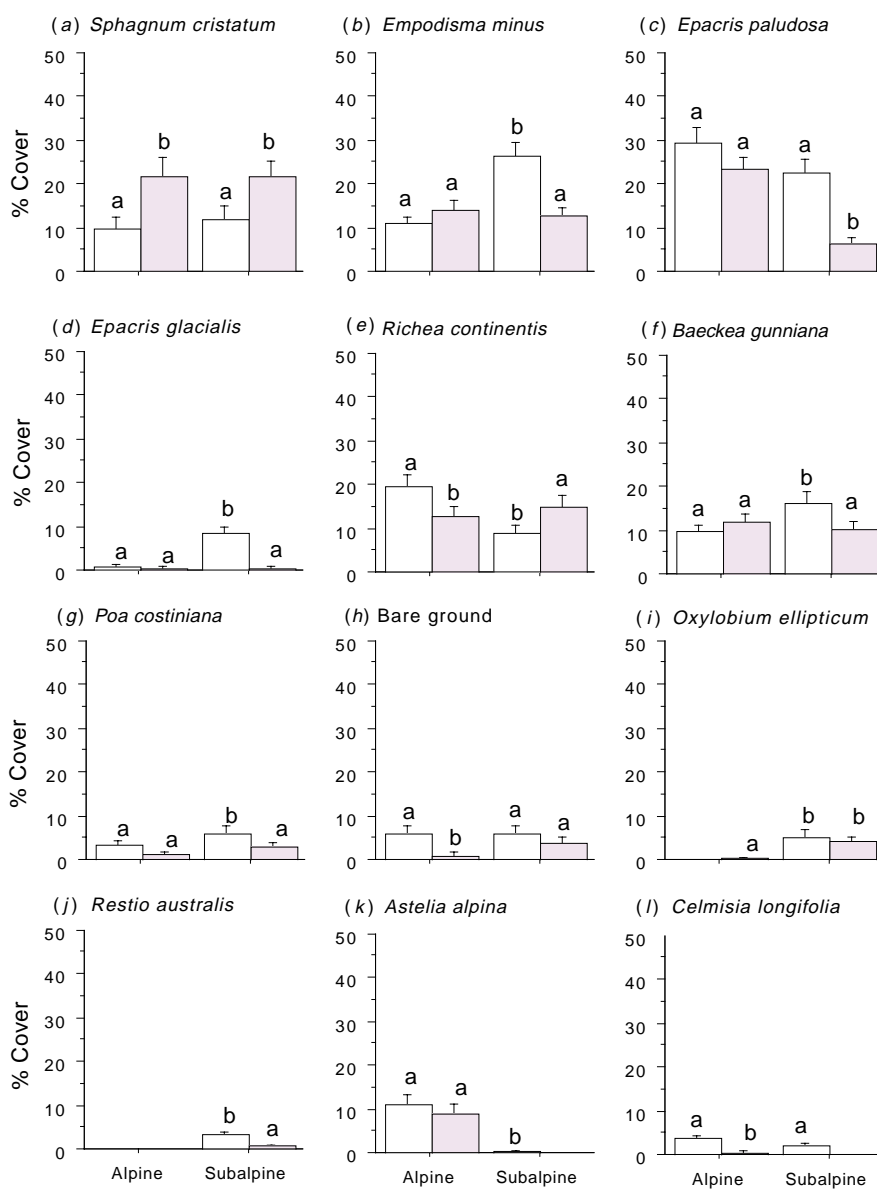


Fig. 7. Mean cover (s.d.) for common bog species and bare ground in alpine and subalpine sites, excluding Smiggin Holes, across time. (□) First set of sampling (1959–73), (■) second sample time (1992).

Discussion

Within-bog Floristic Patterns

A floristic pattern of hummock and hollow was detected in the numerical analysis (Fig. 2). This corresponds to what Costin (1954) has described more broadly as fen and bog communities in the context of floristic alliances and their associations. Our groups, however,

Table 3. Summary results of ANOVA tests for differences in time at Smiggin Holes bogSignificant effects reported where $P < 0.01$. Decreases or increases are reported if the control sites at Hydrology bog and Digger Creek showed no parallel change

Significant effects	Forbs, mosses and lycopods	Grasses and graminoids	Subshrubs and shrubs
No change relative to control site	<i>Sphagnum cristatum</i>	<i>Poa costiniana</i> <i>Carpha nivicola</i>	<i>Epacris glacialis</i> <i>Empodisma minus</i>
Decrease in cover relative to control site	<i>Asperula gummii</i> <i>Ranunculus pimpinellifolius</i>	<i>Restio australis</i> <i>Luzula australasica</i> <i>Oreobolus distichus</i>	<i>Epacris paludosa</i> <i>Baeckea gummiana</i> <i>Richea continentis</i> <i>Oxylobium ellipticum</i>
Increase in cover	Bare ground Dead <i>Sphagnum</i> <i>Gonocarpus micranthus</i> <i>Trifolium repens</i>	<i>Carex gaudichaudiana</i> <i>Carex echinata</i>	
Species previously recorded in 1960 but not recorded in 1991	<i>Celmisia longifolia</i> <i>Asperula gummii</i> <i>Oreomyrrhris ciliata</i> <i>Astelia alpina</i> <i>Aciphylla simplicifolis</i> <i>Prasophyllum alpinum</i> <i>Schizeilema fragoseum</i> <i>Neopaxia australasica</i> <i>Cotula filicula</i>	<i>Juncus antarcticus</i>	<i>Oxylobium ellipticum</i> <i>Olearia phlogopappa</i>

are based on small-scale spatial variation rather than 'community' scale which has generally been applied to the classification of *Sphagnum* peatlands in Australia (Costin 1954; McVean 1969; Kirkpatrick 1989; Whinam *et al.* 1989). In a broad sense, the bogs are most closely related to the Victorian mossland of Walsh *et al.* (1984), and somewhat related to the *Richea-Sphagnum* bogs of Whinam *et al.* (1989) in Tasmania. Our vegetation units often corresponded to those described by McLuckie and Petrie (1927) and Costin (1954) prior to the advent of multivariate numeric analyses.

Small-scale patterns in space in relation to bog topography, pH and floristic correlates have previously been interpreted in terms of temporal processes related to cyclical vegetation change (Costin 1954; Ashton and Hargreaves 1983). This is reflected in the habitat/successional terminology used in the methods to describe hummocks (i.e. 'building' 'mature'). The data demonstrate spatial differentiation between the floristic elements of hummocks and hollows, but show little evidence of finer-scale floristic differentiation between structures interpreted as 'building' 'mature' and 'shrubby'. As we have not directly observed changes in these spatial relationships they offer no proof of cyclic processes within bogs. In an examination of sedimentary profiles at some of the sites that we examined, Martin (1999) found *Sphagnum* growth to be youthful with little evidence of cyclic deposition of *Sphagnum* peat. Whinam and Kirkpatrick (1995) interpreted sequences of macrofossils from Tasmanian *Sphagnum* peatlands as successional sequences that often show Holocene transition from restiad mire to *Sphagnum* mires, and then heath. However, there is little evidence for widespread cyclic changes involving hummock-hollow cycles over the sequence of macrofossils.

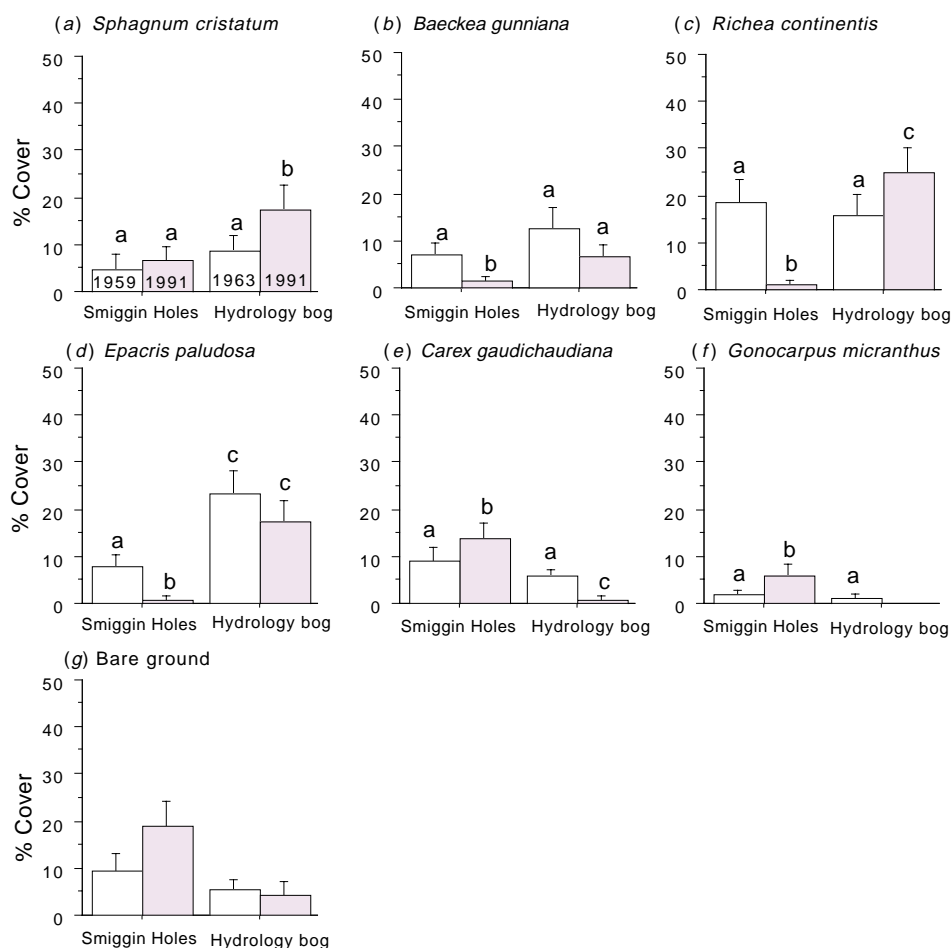


Fig. 8. Mean cover (s.d.) for common bog species and bare ground at Smiggin Holes and Hydrology bog across time. (□) First set of sampling (1959–73), (■) second sample time (1992).

Among-bog Floristic Patterns

In the present study, we have shown a clear alpine/subalpine differentiation within the bog grouping, which has not been previously reported for mainland bogs (Figs 3, 4a). This difference is attributed to the preference of some species for higher or lower altitude (Fig. 5). There are, however, no dominant species that have an obligate requirement for either alpine or subalpine conditions. Species that show clear preference for alpine conditions are those that are more often associated with alpine herbfields and are generally minor components of the bogs. The exception is *Astelia alpina*, which is a common component of the bogs and is more frequent in alpine bogs. This distribution differs from Victorian bogs and those in Tasmania where *Astelia alpina* is also frequently found in the subalpine zone.

The alpine and subalpine vegetation shows little compositional change through time as sites are paired on the classification and ordination diagrams. The montane site at Wilsons Valley shows a major change in composition through time due to the invasion of shrubs (*Baeckea*

gunniana and *Leptospermum lanigerum*). Smiggin Holes bog differed in its relationship to other subalpine bogs in both classification and ordination diagrams. A possible explanation is that the basin was used, as the name implies, for the location of salt licks and attracted large numbers of stock. It had also become by 1959, a place of incipient ski field development. These effects are more apparent in the analysis of cover and richness, which is discussed below.

Among-bog Cover Change

A general increase in the cover of *Sphagnum* and a decrease in bare ground could be due to a number of causes: recovery after fire, recovery after grazing, a response to climate change or interactions of these factors. Because this is a general pattern across all bogs, fire is a less likely explanation, but may be the outcome of recovery from the 1939 fires in individual cases. At least three periods of drought occurred between the initial sampling of the bogs and the sampling in 1991, but the lack of sampling at shorter intervals precludes any climatic interpretation. Trampling by stock is known to cause major effects on peatlands in southern Australia (McDougall 1989). Recovery from trampling could also explain the increase in *Sphagnum* cover, as Ashton and Williams (1989) describe in the recovery of a Victorian bog over 40 years. Wimbush and Costin (1979a, 1979b) also describe the slow recovery of *Sphagnum* near their subalpine and alpine transects after grazing and after the 1967–68 dry period.

Decreases in cover were also often detected for a range of herbaceous species (Table 2). These species generally have a wider distribution in fens or in herbfields and may be displaced by longer-lived hygrophilous shrubs and *Sphagnum*. Long-lived shrub species show inconsistent behaviour in space and time, but generally decrease in the subalpine zone (Fig. 7). In contrast, Wimbush and Costin (1979a, 1979b) have shown increases in shrub cover in their subalpine ground-water transects related to recovery after grazing. Decreases in shrub cover in the bogs sampled may reflect the senescence of populations after post-fire recruitment. A similar trend in the senescence of shrubs has been reported for shrublands in the Victorian Alps (Wahren *et al.* 1994).

Changes at Smiggin Holes

Smiggin Holes was of special interest to us as the bog had been subjected to much use between 1959 and 1991. This bog is one of the largest near the summit road and protects one of the headstreams feeding Piper's Creek, which flows to the Snowy River. It was expected that the effect of slope grooming, since the establishment of a ski slope over the bog, would show up prominently, given the degraded appearance of the bog in 1991. Although no change in the cover of live *Sphagnum* was found, dead *Sphagnum* was present on the groomed part of the bog. In contrast, all other bogs showed increases in *Sphagnum* cover, which suggests that intensive use has suppressed the growth of *Sphagnum*. The increased amount of bare ground has also promoted the growth of *Carex* spp., *Gonocarpus micranthus* and *Trifolium repens*, which have rhizomatous and stoloniferous habits that may be favoured by disturbance. Shrub decline is clear across the whole bog, in particular, *Richea* was absent from the groomed slope and was reduced to small populations on the flanks of the groomed area. Similar patterns were detected for *Baeckea gunniana* and *Epacris paludosa*. Perhaps the most significant change at Smiggin Holes is the absence of 13 native species previously recorded in the samples (Table 3). Relative to the alpine site at Charlotte Pass, which has a T-bar overhead and some ground disturbance but has not been groomed, Smiggin Holes shows major vegetation/habitat decline.

Conclusions

Interpretations of vegetation change in these bogs could be questioned because of the long time interval between observations and the lack of interannual measurements. They are, however, appropriate, given the long-lived nature of the shrub dominants, and the slow trends

detected by Wahren *et al.* (1994), and Wimbush and Costin (1979) using shorter observation intervals. The approach used in the present study differs from other long-term studies in that it used replicate patches (bogs) and randomised the subsampling of each patch. This makes generalisation about change more statistically powerful despite the use of a semi-quantitative measure of abundance. More objective methods for assessing abundance have become available since the original sampling (e.g. Morrison *et al.* 1995), which are less time consuming than cover/transect approaches and more repeatable than the Domin scale.

Analyses of the small-scale quadrat data show clear floristic differences within bogs, but revealed little information about the dynamics of hummocks and hollows. To detect these dynamics photopoints and micro-scale maps need to be collected and monitored at regular intervals. Furthermore, if the cause of small-scale changes is to be understood, field and/or laboratory experiments are required. The dynamics of the bogs as a whole in the alpine and subalpine show relative floristic stability through time. There appears to be some decrease in shrub dominants due to senescence in the subalpine zone. The process by which the hygrophilous shrubs recruit in bogs is not clear, but may be related to fire at long intervals. An overall increase in *Sphagnum* cover is likely to be due to recovery after disturbance from interactions of stock grazing, trampling and perhaps firing.

Changes at Smiggin Holes in terms of the cover of dominant species are unequivocal and relate directly to grooming and intensive use of a ski slope. Grooming of other bogs would similarly result in vegetation decline and is undesirable. Evidence from post-grazing observations (Wimbush and Costin 1979a, 1979b; Ashton and Williams 1989) suggests that bogs recover slowly from grazing disturbance. If slope grooming were to cease at the Smiggin Holes bog then it may recover.

Management of vegetation in Kosciuszko National Park in areas of intensive use will continue to be a major issue in the post-grazing era. To adequately understand the potential impacts of natural and human disturbance on vegetation, a feedback mechanism is required to keep managers informed about the outcomes of their decisions. Well-designed quantitative monitoring of vegetation at the species level provides a mechanism to detect both natural and human-induced change so that extinctions can be avoided.

Acknowledgments

The Director of the National Parks and Wildlife Service is thanked for allowing us to do this work in Kosciuszko National Park under permit No A 129. Daphne Martin is thanked for her invaluable field assistance. This study was aided by funding from The University of Sydney to one of us (A. R. H. M) and from the University of New England (P. J. C).

References

- Ashton, D. H., and Hargreaves, G. R. (1983). Dynamics of subalpine vegetation at Echo Flat, Lake Mountain, Victoria. *Proceedings of the Ecological Society of Australia* **12**, 35–60.
- Ashton, D. H., and Williams, R. J. (1989). Dynamics of the subalpine vegetation in the Victorian region. In 'The Scientific Significance of the Australian Alps'. (Ed. R. Good.) p. 143. (Australian Academy of Science: Canberra.)
- ter Braak, C. J. F. (1987). The analysis of vegetation–environment relationships by canonical correspondence analysis. *Vegetatio* **69**, 69–77.
- ter Braak, C. J. F., and Verdonschot, P. F. M. (1995). Canonical correspondence analysis and related multivariate methods in aquatic ecology. *Aquatic Science* **57**, 153–187.
- Costin, A. B. (1954). 'A Study of the Ecosystems of the Monaro Region of New South Wales.' (Soil Conservation Service of New South Wales: Sydney.)
- Costin, A. B., Gray, M., Totterdell, C. J., and Wimbush, D. J. (1979). 'Kosciuszko Alpine Flora.' (CSIRO–Collins: Melbourne.)
- Gore, A. J. P. (Ed.) (1983). 'Ecosystems of the World, 4A, Mires: Swamp, Bog, Fen and Moor.' (Elsevier: Amsterdam.)

- Green, R. H. (1979). 'Sampling Design and Statistical Methods of Environmental Biologists.' (Wiley: New York.)
- Green, R. H. (1993). Application of repeated measures designs in environmental impact and monitoring studies. *Australian Journal of Ecology* **18**, 81–98.
- Harden, G. J. (Ed.) (1990–1993). 'Flora of New South Wales.' Vols 1–4. (New South Wales University Press: Sydney.)
- Kent, M., and Coker, P. (1992). 'Vegetation Description and Analysis, a Practical Guide.' (Belhaven Press: London.)
- Kirkpatrick, J. B. (1989). The comparative ecology of mainland Australian and Tasmanian vegetation. In 'The Scientific Significance of the Australian Alps'. (Ed. R. Good.) p. 127. (Australian Academy of Science: Canberra.)
- Martin, A. R. H. (1999). Pollen analysis, Ramshead Range: Kosciuszko National Park: vegetation history and tree-line studies. *Australian Journal of Botany* (in press).
- McDougall, K. L. (1989). The effect of excluding cattle from a mossbed on the Bogong High Plains. Arthur Rylah Institute for Environmental Research Technical Report Series, No. 95. Department of Conservation Forestry and Lands, Melbourne.
- McLuckie, J., and Petrie, A. H. K. (1927). The vegetation of the Kosciuszko Plateau. Part 1: the plant communities. *Proceedings of the Linnean Society of New South Wales* **52**, 188–221.
- McVean, D. N. (1969). Alpine vegetation of the central Snowy Mountains of New South Wales. *Journal of Ecology* **57**, 67–86.
- Morrison, D. A., Le Brocque, D., and Clarke, P. J. (1995). Methods for estimating plant abundance: comparison of nested quadrats, frequencies and visual estimates. *Vegetatio* **120**, 131–145.
- Specht, R. L. (1970). Vegetation. In 'The Australian Environment'. (Ed. G. W. Leeper.) pp. 47–67. (CSIRO & Melbourne University Press: Melbourne.)
- Wahren, C.-H., Papst, W. A., and Williams, R. J. (1994). Long-term vegetation change in relation to cattle grazing in subalpine grassland and heathland on the Bogong High Plains: an analysis of vegetation records from 1946 to 1991. *Australian Journal of Botany* **44**, 607–639.
- Walsh, N. G., Barley, R. H., and Gullan, P. K. (1984). The Alpine vegetation of Victoria, excluding Bogong High Plains region. *Muelleria* **6**, 265–292.
- Whinam, J., Eberhard, S., Kirkpatrick, J. B., and Moscal, T. (1989). 'Ecology and Conservation of Tasmanian *Sphagnum* Peatlands.' (Tasmanian Conservation Trust: Hobart.)
- Whinam, J., and Kirkpatrick, J. B. (1995). Successional sequences in two Tasmanian valley *Sphagnum* peatlands. *Journal of Vegetation Science* **6**, 675–682.
- Wimbush, D. J., and Costin, A. B. (1979a). Trends in vegetation at Kosciusko. II. Subalpine range transects, 1959–1978. *Australian Journal of Botany* **27**, 789–831.
- Wimbush, D. J., and Costin, A. B. (1979b). Trends in vegetation at Kosciusko. III. Alpine range transects, 1959–1978. *Australian Journal of Botany* **27**, 833–871.

Appendix 1. Descriptions of small-scale vegetation types based on 0.1-m²-quadrat samples from 1959 to 1973 based on numeric agglomerative classification

Sample numbers arranged in order of similarity. Species nomenclature follows Harden (1990–1993)

Group 1: *Carex*–*Poa* Hollow

Samples: 119, 279, 299, 298, 278, 82, 87, 84, 52, 254, 124, 107, 45.

Localised structure and physiography: Grassy tussock and sedge/moss intertussock matrix in alpine and subalpine pools and edges of drainage lines. Bare ground common.

Species richness: Sum 27, mean 5.2/0.1 m², *n* = 13.

Shrubs: *Epacris glacialis*, *Richea continentis* and *Hakea microcarpa*.

Graminoids: *Carex gaudichaudiana*, *Poa costiniana* and *Empodisma minus*. Less common taxa include *Oreobolus distichus* and *Carpha nivicola*.

Herbs: *Gonocarpus micranthus* is characteristic.

Bryophytes and moss: *Sphagnum cristatum* and *Polytrichum commune*.

Comments: Analogous to the *Poa*–*Hypolaena* and the *Luzula*–*Carex* associates of McLuckie and Petrie (1927) (see Fig. 4) and the *Carex*–*Poa* association in the *Carex* (fen) alliance of Costin (1954).

Group 2: *Carex*–Herbfield Hollow**Samples:** 56, 53, 316, 88, 60, 55, 51, 90, 59, 58, 54, 89, 147, 63, 57, 21, 250, 122.**Localised structure and physiography:** Sedgeland–herbfield matrix in alpine pools, drainage line edges and margins of moss hummocks. Bare ground common.**Species richness:** Sum 44, mean 12.0/0.1 m², *n* = 18.**Shrubs:** *Richea continentis*.**Graminoids:** *Carex gaudichaudiana*, *Empodisma minus*, *Luzula australasica*, *Isolepis subtilissima*, *Juncus falcatus* and *Isolepis crassiuscula*.**Herbs:** *Ranunculus pimpinellifolius*, *Epilobium gunnianum*, *Gonocarpus micranthus*, *Cotula filicula*, *Oreomyrrhis ciliata* and *Hypericum japonicum*.**Bryophytes and moss:** *Breutelia* sp. and *Sphagnum cristatum*.**Comments:** Analogous to the *Luzula*–*Carex* associates of McLuckie and Petrie (1927), the *Carex* associations in the *Carex* alliance of Costin (1954) and the *Carex*–*Drepanocladus* association of McVean (1969).**Group 3:** *Astelia*–*Richea*–*Epacris* Hummock**Samples:** 309, 324, 315, 313, 311, 307, 302, 297, 234, 214, 210, 209, 208, 203, 170, 167, 78, 43, 42, 41, 319, 163, 162, 156, 159, 155, 153, 49, 174, 164, 318, 304, 175, 173, 305, 172, 171, 160, 158, 325, 306, 303, 152, 228.**Localised structure and physiography:** Heathy moss-hummocks in alpine bogs. Occasional bare ground.**Species richness:** Sum 40, mean 8.3/0.1 m², *n* = 44.**Shrubs:** *Richea continentis*, *Epacris paludosa* and *Baeckea gunniana* are characteristic. Other taxa include *Pimelea alpina* and *Epacris glacialis*.**Graminoids:** *Empodisma minus*, *Poa costiniana* and *Carex gaudichaudiana* are characteristic species. Other taxa include *Oreobolus distichus*, *Carpha nivicola*, *Carex echinata*, *Luzula australasica* and *Isolepis subtilissima*.**Herbs:** *Astelia alpina*, *Drosera peltata*, *Asperula gunnii*, *Celmisia longifolia* and *Diplaspis hydrocotyle*. Other taxa include *Stylidium graminifolium*, *Craspedia lamicola*, *Ranunculus gunnianus*, *Oreomyrrhis ciliata*, *Viola betonicifolia* and *Euphrasia collina*.**Bryophytes and moss:** *Sphagnum cristatum* and *Lycopodium fastigiatum*. Other species include *Bryum* sp. and *Hypnum cupressiforme*.**Comments:** Analogous to *Astelia* association in Costin (1954).**Group 4:** *Epacris*–*Baeckea*–*Richea* Hummock**Samples:** 328, 274, 273, 263, 261, 260, 259, 258, 253, 251, 233, 230, 223, 206, 192, 161, 86, 62, 44, 27, 11, 3, 2, 322, 310, 271, 264, 190, 187, 183, 105, 85, 83, 33, 4, 326, 317, 329, 323, 301, 232, 330, 312, 308, 293, 287, 284, 267, 249, 240, 225, 215, 212, 202, 200, 198, 197, 195, 193, 191, 186, 188, 185, 182, 181, 180, 179, 178, 177, 176, 157, 145, 135, 72, 71, 70, 48, 47, 38, 37, 34, 31, 30, 29, 26, 320, 236, 224, 222, 221, 220, 219, 217, 216, 213, 211, 207, 205, 204, 199, 196, 194, 189, 169, 154, 74, 40, 39, 35, 184, 46, 28, 36, 23.**Localised structure and physiography:** Heathy moss-hummocks and grass tussocks in alpine and bogs. Bare ground present.**Species richness:** Sum 54, mean 6.7/0.1 m², *n* = 114.**Shrubs:** *Epacris paludosa*, *Baeckea gunniana* and *Richea continentis*. Less common taxa include *Oxylobium ellipticum* and *Olearia phlogopappa* ssp. *subrepanda*.**Graminoids:** *Empodisma minus* and *Poa costiniana*. Less common taxa include *Carex gaudichaudiana*, *Restio australis*, *Oreobolus distichus* and *Carpha nivicola*.**Herbs:** *Celmisia longifolia*. Less common taxa include *Stylidium graminifolium*, *Astelia alpinum*, *Asperula gunnii*, *Erigeron pappocromus* and *Aciphylla simplicifolia*.**Bryophytes and moss:** *Sphagnum cristatum* and *Lycopodium fastigiatum*.**Comments:** Analogous in part to the *Richea* and *Epacris* associates of McLuckie and Petrie (1927) and the *Richea*–*Sphagnum* association of Costin (1954).

Group 5: *Epacris*–*Baeckea*–*Empodisma* Hummock

Samples: 150, 149, 142, 138, 137, 134, 132, 126, 276, 144, 140, 136, 133, 128, 108, 80, 24, 32, 20, 19, 18, 17, 16, 15, 14, 12, 9, 7, 6, 321, 275, 272, 270, 268, 266, 265, 262, 257, 256, 255, 252, 218, 201, 166, 127, 123, 50, 5, 1, 139, 125, 22, 327, 314, 300, 269, 243, 129, 81, 77, 69, 68, 67, 66, 65, 64, 61, 10, 294, 285, 227, 280, 246, 242, 241, 238, 237, 235, 231, 229, 121, 76.

Localised structure and physiography: Heathy moss-hummock in alpine and subalpine bogs. Bare ground usually absent.

Species richness: Sum 44, mean 8.2/0.1 m², $n = 82$.

Structure: Low heath.

Shrubs: *Epacris paludosa*, *Baeckea gunniana*, *Epacris glacialis* and *Richea continentis*. Less common shrubs include *Oxylobium ellipticum*, *Hakea microcarpa* and *Callistemon ptyoides*.

Graminoids: *Empodisma minus*, *Restio australis*, *Poa costiniana* and *Carex gaudichaudiana*. Less common taxa include *Luzula australasica*.

Herbs: *Asperula gunnii* and *Celmisia longifolia*. Less common taxa include *Thelymitra venosa*, *Chiloglottis gunnii*, *Stylidium graminifolium*, *Epilobium gunnianum*, *Aciphylla simplicifolia*, *Ranunculus muelleri* and *Oreobolus distichus*.

Bryophytes and moss: *Sphagnum cristatum*. Less common taxa include *Polytrichum commune*.

Comments: Analogous to the *Epacris* associates of McLuckie and Petrie (1927) (see Fig. 7) and the *Epacris serpyllifolia*, *Epacris paludosa*–*Sphagnum* associations of Costin (1954).

Group 6: *Richea*–*Poa*–*Empodisma* Hummock

Samples: 292, 291, 288, 286, 283, 282, 281, 289, 248, 141, 247, 245, 244, 239, 226, 111, 103, 98, 97, 96, 94, 91, 75, 296, 295, 290, 277, 168, 151, 165, 116, 115, 110, 100, 92, 79, 73, 25, 13, 8.

Localised structure and physiography: Heathy moss-hummocks and grassy tussocks in subalpine bogs. Bare ground absent.

Species richness: Sum 45, mean 7.5/0.1 m², $n = 40$.

Shrubs: *Richea continentis* and *Epacris paludosa*. Less common shrubs include *Baeckea gunniana*, *Epacris glacialis*, *Hakea microcarpa* and *Oxylobium ellipticum*.

Graminoids: *Empodisma minus*, *Poa costiniana*, *Carex gaudichaudiana* and *Luzula australasica*.

Herbs: *Asperula gunnii* and *Pterostylis alpina*. Less common herbs include *Acaena* spp., *Aciphylla simplicifolia* and *Epilobium gunnianum*.

Ferns: *Blechnum penna-marina* is not common.

Bryophytes and moss: *Sphagnum cristatum* and *Polytrichum commune*. Less common species include *Lycopodium fastigiatum*.

Comments: Analogous to the *Richea* associates of McLuckie and Petrie (1927) and the *Richea*–*Sphagnum* association of Costin (1954).

Group 7: *Callistemon*–*Empodisma* Hummock

Samples: 148, 143, 131, 130, 112, 146, 109, 95, 118, 117, 106, 104, 102, 99, 114, 113, 101, 93, 120.

Localised structure and physiography: Shrubby moss-hummocks in subalpine and montane bogs. No bare ground present.

Species richness: Sum 38, mean 8.5/0.1 m², $n = 19$.

Shrubs: *Callistemon ptyoides*, *Leptospermum lanigerum*, *Richea continentis* and *Epacris paludosa*. Less common species include *Olearia algida* and *Baeckea gunniana*.

Graminoids: *Empodisma minus*, *Poa costiniana*, *Luzula australasica* and *Restio australis*. Less common species include *Carex gaudichaudiana*, *Isolepis subtilissima* and *Carex jackiana*.

Herbs: *Asperula gunnii*, *Acaena* spp. and *Ranunculus muelleri*. Less common species include *Epilobium gunnianum*, *Pterostylis alpina*, *Poranthera microphylla* and *Chiloglottis gunnii*.

Ferns: *Blechnum penna-marina*.

Bryophytes and moss: *Sphagnum cristatum*.

Comments: Analogous to the *Baeckea*–*Callistemon* association of McLuckie and Petrie (1927) and the *Callistemon* association of Costin (1954).