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Multivariate Relationships between Floristic Composition and Stand Structure in Vegetation of Ku-ring-gai Chase National Park, New South Wales

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Abstract

The relationships between stand structure and floristic composition were examined from data collected from 100 quadrats on two soil types: Hawkesbury sandstone and Narrabeen group soils, occurring within Ku-ring-gai Chase National Park, New South Wales. Floristic composition was determined using the frequency of species occurring within nine concentric sub-quadrats of total area 500 m². Stand structure was determined by a multivariate classification scheme utilising the foliage projective cover of eight strata within each quadrat. The patterns in floristic composition and stand structure were examined through multivariate analyses. Procrustes analysis of non-metric multidimensional scaling ordinations of both the stand structure and composition data showed floristic composition gradients to be well recovered by the structure data. Similar gradients were evident in both vegetation attributes, between and within the two soil types, with the rank order of community types across the ordinations being the same. However, some important differences were evident between the ordinations of floristic composition and stand structure between and within soil types. A number of floristically dissimilar communities exhibited very similar multivariate structural characteristics. In particular, two floristically distinct communities on different soil types were indistinguishable in terms of their structural characteristics. The multivariate analyses suggest a possible convergence of some compositionally distinct communities towards a common structural formation.

Introduction

The description of the structural characteristics of vegetation (stand structure) has provided a useful adjunct to classifications based on floristic compositional attributes (e.g. presence, abundance, frequency, density) in eastern Australia (e.g. Outhred *et al.* 1985). Structural and compositional descriptions of plant communities have often been regarded as highly complementary (e.g. Mueller-Dombois and Ellenburg 1974); however, few studies have examined the relationships between these two community attributes in any detail (although see Webb *et al.* 1970; Fox and Fox 1981; Rice and Westoby 1985; Rotenberry 1985). Although some attempts have been made to combine both composition and physiognomy in the classification of vegetation (e.g. Barkman 1979), vertical structure in vegetation stands has primarily been seen as a useful tool in the naming and simple description of plant communities rather than an integral component of communities. In plant community studies the structural classification systems employed often include floristic attributes (e.g. Webb 1959; Carnahan 1981; Outhred *et al.* 1985), and as such are not independent of floristic composition, making comparisons of structural and compositional characteristics of the communities difficult. Furthermore, differences between the patterns in floristic composition and structure or physiognomy have been regarded as a failure of either of these attributes to adequately reflect patterns in the other (e.g. Rice and Westoby 1985; Wilson and Fensham 1994), rather than the possibility that very different ecological processes may be operating. The possibility that stand structure and floristic composition

provide different information on plant communities has been largely overlooked. Part of the reason for this may be the general failure to recognise plant community structural characteristics as intrinsically multivariate. Rotenberry (1985), in particular, notes that many patterns are obscured by the loss of information that results from summarising stand structure with only one or a few simple indices.

Specht (1970) described a simple classification of the major structural forms of vegetation in Australia based on height and/or life-form and foliage projective cover (FPC) classes of vegetation in the tallest stratum of plant communities. This scheme is widely recognised among Australian ecologists and provides a useful starting point from which to develop a multivariate classification of stand structure. The system includes only structural information (height and/or life-form and FPC) and thus enables comparison to patterns observed in floristic composition or any other vegetation attribute.

Webb *et al.* (1970) compared multivariate composition and structural–physiognomic classifications of rainforest vegetation of north-eastern Australia. They found the two classifications to strongly concur at the broad-scale level, although differences were apparent at finer scales. Similarly, Outhred *et al.* (1985), in comparing composition and structure of vegetation in Ku-ring-gai Chase National Park, found that although there was a correlation between the two community attributes, some differences were apparent. They found that a number of floristically distinct communities shared similar structural attributes based on foliage projective cover of three growth-form classes.

In this paper some of the relationships are examined between stand structure and floristic composition in vegetation of Ku-ring-gai Chase National Park, New South Wales. Height and life-form categories and foliage projective cover of Specht (1970, 1981) are used here to provide a multivariate structural data matrix amenable to numerical ordination. Developments in techniques for comparing multivariate data matrices in the last 25 years (e.g. Gower 1971) have made such a comparison between floristic composition and stand structure possible. Further, the comparison of the floristic composition and the structural characteristics of vegetation stands may provide some insight into underlying ecological processes.

Materials and Methods

Ku-ring-gai Chase National Park (146 km²) is situated approximately 24 km north of Sydney on the Hornsby Plateau. Fifty sites were located within the Park to sample the range of vegetation types occurring on soils derived from Hawkesbury sandstone and Narrabeen shale and sandstone parent materials. Site selection was based on a number of criteria: to avoid the confounding effects of fire on vegetation, only sites that had not experienced fire for at least 10 years were sampled; and sites had to show no obvious signs of anthropogenic disturbance and be at least 50 m and, where possible, upslope from any roads or fire trails to avoid any possible effects of these structures. Site locations are shown in Fig. 1, and each was sampled on a single occasion between September 1991 and March 1993. Duplicate 500 m² quadrats from the 50 sites were sampled for compositional, environmental and structural characteristics. Compositional and environmental characteristics of the plant communities and their relationships are described by Le Brocque and Buckney (1995).

Vegetation Attributes

Methods for the collection of floristic composition data have been reported previously (Le Brocque and Buckney 1995). These data consisted of measures of the frequencies of all tracheophyte species within nine nested concentric sub-quadrats within the 500 m² quadrats. Eleven distinct vegetation types were identified by Le Brocque and Buckney (1995) through indicator species analysis (ISA; TWINSpan program, Hill 1979) of floristic composition data. Nomenclature for the communities identified is based on the projective foliage cover of the tallest stratum as per Specht's (1981) structural classification scheme (see Table 1).

For the structural data, eight strata were pre-defined according to the structural classification of Specht (1970, 1981), modified to include the predominant life-forms of the vegetation of the study area: trees > 30 m height, trees 10–30 m, trees < 10 m, shrubs > 2 m, shrubs < 2 m, graminoids (including

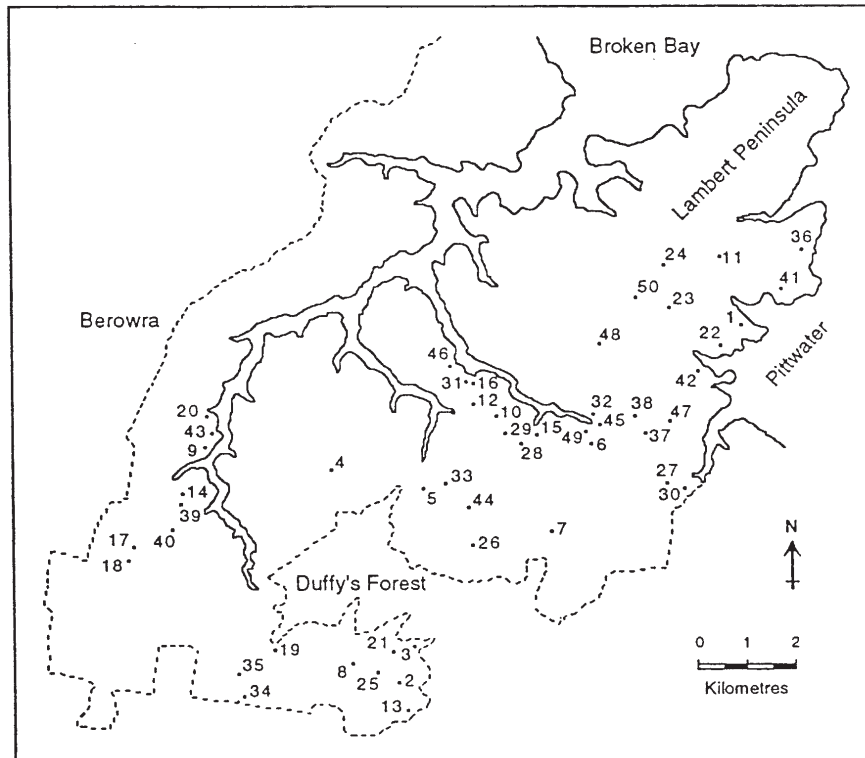


Fig. 1. Map of the study area showing location of sample sites within Ku-ring-gai Chase National Park, New South Wales.

grasses, rushes and sedges), herbs and ferns. Trees are defined as single or multiple-stemmed plants greater than 3 m in height, shrubs are defined as multiple-stemmed plants less than 3 m in height. Within each 500 m² quadrat, FPC of each stratum was estimated at four points located 3.2 m, 5.0 m, 7.1 m and 10 m along each of four transects oriented at right angles to each other and originating from the point that defined the centre of the quadrat. These points were used as they coincided with markers that determined nested concentric sub-quadrats for composition data (Le Brocque and Buckney 1995). Foliage projective cover of vegetation less than 1.5 m was estimated by the point intercept (point quadrat) method of Levy and Madden (1933). A narrow-diameter (15 mm) stainless steel pole was inserted into the ground and the stratum of plants touching the pole recorded. Foliage projective cover of strata greater than 1.5 m high was estimated using a cross-wire periscope apparatus (Winkworth and Goodall 1962; Specht 1981). The presence of foliage on either the pole or in the cross-wire sighting tube for each of the strata for the quadrat was used to express FPC as the number of sampling points where foliage was present as a proportion of the total number of sampling points. While the accuracy of this technique as an estimation of plant above-ground cover is very much dependent on the relative diameter of the sampling pole having a finite size (see Goodall 1952; Winkworth 1955) and the number of sampling points utilised (see Goodall 1952, 1953), for comparative purposes this technique does provide a simple and quick approximation of foliage projective cover.

Numerical Analyses

Foliage projective cover data were transformed by arc-sine transformations prior to numerical analyses in an attempt to stabilise variances (following Goodall 1952). Essentially this data consisted of a sample-by-strata matrix (100 samples × eight strata) of transformed FPC values. Composition data

Table 1. Means and ranges (in parentheses) of foliage projective cover (%) for eight strata from 11 vegetation types

Nomenclature for communities follows that of Specht (1981). Communities 1–6 were located on Hawkesbury sandstone; communities 7–11 were located on Narrabeen shales and sandstones; *n* refers to the number of samples within each community

Community	<i>n</i>	Trees > 30 m	Trees 10–30 m	Trees < 10 m	Shrubs > 2 m	Shrubs < 2 m	Graminoids	Herbs	Ferns
1. Open scrub–closed heathland	12	0 (–)	0 (–)	7.8 (0–19)	19.3 (0–44)	62.0 (31–81)	54.7 (44–63)	52.1 (38–63)	0 (–)
2. Low woodland–open heathland	8	0 (–)	0 (–)	16.4 (0–32)	27.4 (6–50)	50.0 (38–56)	63.3 (50–75)	51.6 (44–69)	0 (–)
3. Woodland 1	5	0 (–)	23.8 (19–25)	30.0 (25–31)	35.0 (31–44)	33.8 (25–38)	41.3 (31–50)	40.0 (38–44)	1.3 (0–6)
4. Woodland–open forest	9	0 (–)	29.2 (19–38)	27.8 (19–31)	31.3 (25–38)	32.7 (25–44)	41.0 (38–50)	34.8 (31–44)	5.6 (0–13)
5. Woodland 2	10	0 (–)	20.6 (13–25)	23.1 (19–25)	28.8 (25–44)	28.8 (19–38)	37.5 (31–44)	32.5 (31–38)	0 (–)
6. Open forest 1	12	2.1 (0–13)	36.5 (31–44)	25.5 (19–38)	35.4 (25–44)	30.8 (25–38)	39.1 (31–50)	36.5 (31–44)	13.6 (6–19)
7. Open forest 2	8	3.2 (0–6)	42.2 (38–50)	37.5 (31–44)	34.4 (25–38)	32.1 (31–38)	46.1 (38–50)	35.2 (31–44)	18.0 (13–25)
8. Tall woodland	12	21.4 (13–31)	48.5 (44–63)	19.2 (0–44)	28.7 (25–38)	24.5 (18–31)	37.5 (31–44)	36.5 (25–44)	51.6 (38–63)
9. Open forest 3	8	3.9 (0–13)	49.3 (44–63)	38.3 (25–50)	37.5 (25–44)	31.3 (19–44)	40.7 (31–63)	26.6 (19–38)	68.8 (63–81)
10. Forest	6	0 (–)	52.1 (50–56)	31.3 (19–44)	17.7 (13–25)	24.0 (19–31)	32.3 (25–44)	27.1 (19–38)	56.3 (50–63)
11. Closed forest	10	8.1 (0–19)	78.2 (69–81)	24.4 (18–31)	18.1 (13–25)	4.4 (0–13)	20.0 (13–25)	27.5 (18–38)	30.0 (25–38)

consisted of a corresponding sample-by-species matrix (305 species). Non-metric multidimensional scaling (NMDS) ordinations of both the structure data and composition data (using Bray–Curtis similarity) were used to compare the patterns of the two data matrices. The ordinations were compared using Procrustes analysis (PATN program, Belbin 1989). Procrustes analysis (Gower 1971) provides a quantification of the match between two ordinations, where one ordination (test) is rotated, translated (reflected) and scaled to fit another ordination (target) in such a way as to minimise the sum of squared distances between the points in the two ordinations. As the objective of this study was to determine the closeness of the structural patterns to those observed in the composition data, the ordination of the composition data was used as the target plot in this analysis. This ordination also provided the initial configuration of points for the NMDS of the structure data (see Belbin 1989). The final NMDS ordination of the composition data was obtained from 10 random starting configurations in one through to four dimensions. In all ordinations, the first two dimensions provided the best solution (i.e. lowest stress). Three sets of analyses were performed, one using all the data, and a separate one each for the samples from Hawkesbury sandstone and Narrabeen group soils.

Results

Considerable variability in the foliage projective cover of the eight strata was evident (Table 1), although differences in stand structure between communities cannot be attributed to any single stratum. Tall trees (trees > 30 m) were notably absent from woodland and heathland communities on Hawkesbury sandstone (Communities 1–5) and the forest community (Community 10) on Narrabeen group soils, while trees 10–30 m and ferns were absent from both heathland communities (Communities 1 and 2). A fern stratum was also absent from woodland 2 (Community 5) on Hawkesbury Sandstone. The mean foliage projective cover was highest (78%) for trees 10–30 m in the closed forest (Community 11) on Narrabeen group soils.

Figure 2a shows the ordination of results from the NMDS of the complete composition data matrix. The results of the NMDS of the structure data, subjected to Procrustes rotation, translation and scaling to provide the best fit to the composition ordination, is shown in Fig. 2b. Centroids of the community types for both ordinations are presented in the biplot shown in Fig. 2c. A degree of contraction of the samples in the two-dimensional space of the structural ordination indicates that the samples are more similar structurally than in terms of floristic composition. This is shown by the fact that for many of the sample pairs the structure sample is closer to the centre of the ordination (Fig. 2c).

Open forest 3 and forest communities (Communities 9 and 10, respectively) showed little difference in position in the ordinations, and were indistinguishable, as indicated by the centroids of these communities (Fig. 2c). Greater variability between quadrats within the tall woodland and closed forest communities (Communities 8 and 11) was indicated by the structure data (Fig. 2b) rather than the composition data. Open scrub–closed heathland and low woodland–open heathland communities (Communities 1 and 2) also exhibited greater variability in the ordination of the structure data than in the ordination of the composition data. The greater variability within the open scrub–closed heathland community is largely the result of four quadrats of this community having closer similarity, in terms of stand structure, to low woodland–open heathland (Fig. 2b). Less variability was exhibited by woodland 1, woodland–open forest, woodland 2 and open forest 1 (Communities 3, 4, 5 and 6, respectively) in the ordination of the structure data than exhibited by the composition data, although these communities also showed the greatest deviation from the ordination of samples by composition data, as indicated by the large residuals shown by the lines between centroids (Fig. 2c). Open forest 2 (Community 7) was indistinguishable from open forest 1 in terms of structure (Fig. 2b). The woodland 1, woodland–open forest and woodland 2 communities, although reasonably well separated in the ordination of the composition data, also formed a single cluster in the ordination of the structure data (Fig. 2b). However, the rank order of samples across the gradients in the two vegetation attributes were essentially the same (Table 2).

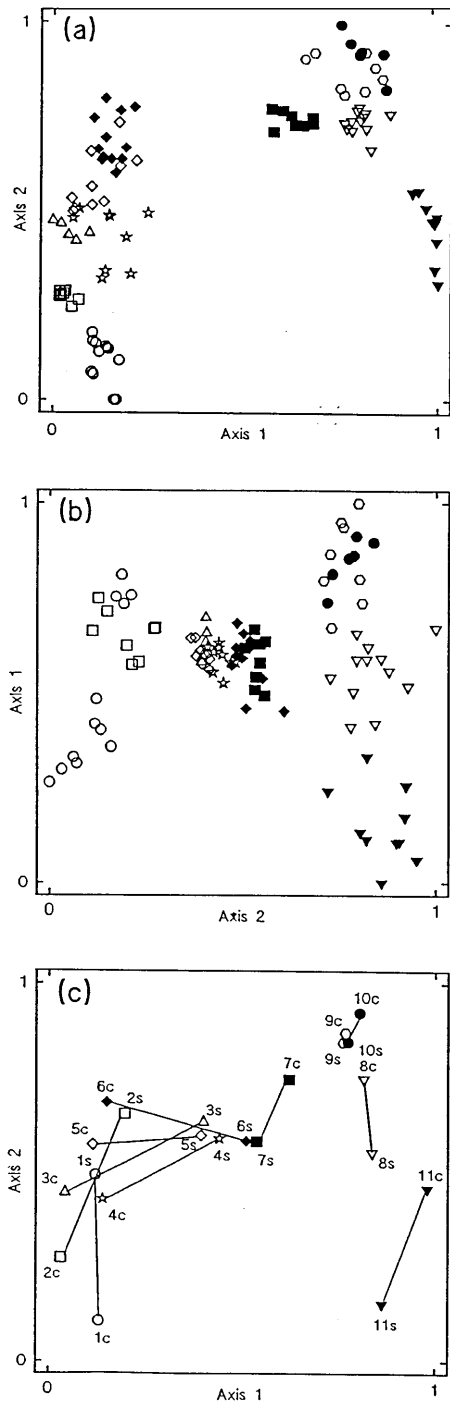


Fig. 2. Ordination of axes 1 and 2 from NMDS of the composition data (a) and procrustes NMDS of the structure data (b) for the complete data set.

(c) Centroids biplot of the composition data (c) and structure data (s). Community types were identified by indicator species analysis of composition data (Le Brocque and Buckney 1995).

Hawkesbury sandstone communities:

1. open scrub–closed heathland (○);
2. low woodland–open heathland (◻);
3. woodland 1 (△);
4. woodland–open forest (☆);
5. woodland 2 (◇);
6. open forest 1 (◆);

Narrabeen group communities:

7. open forest 2 (■);
8. tall woodland (▼);
9. open forest 3 (○);
10. forest (●);
11. closed forest (▼).

Table 2. Spearman rank correlation coefficients (r_s) between axis scores from NMDS ordinations of the composition and structure data matrices
All coefficients are significant at $P < 0.001$

	n	Axis 1	Axis 2
Complete data set	100	0.85	0.36
Hawkesbury sandstone communities	56	0.75	0.76
Narrabeen group communities	44	0.85	0.86

Considerably less variability was shown in the structure data (Fig. 3*b*) than in the composition data (Fig. 3*a*) for most of the Hawkesbury sandstone communities. Again, some degree of contraction of samples in the ordination of the structure data was indicated in the centroids biplot for the Hawkesbury sandstone communities (Fig. 3*c*), particularly in the case of woodland 1, woodland–open forest, woodland 2 and open forest 1 communities contracting towards the lower right corner of the ordination of the structure data (Fig. 3*b*). These communities were largely indistinguishable in the NMDS of the structure data. These communities also exhibited the greatest difference between the two ordinations as shown by the large residuals in the centroids biplot (Fig. 3*c*).

Generally greater variability within the tall woodland and closed forest communities in terms of the structure data than the composition data was evident in the ordinations of the Narrabeen group communities; however, open forest 2 and forest exhibited less variability in the structure data (Fig. 4*a, b*). The centroids biplot (Fig. 4*c*) shows that the forest community exhibits the greatest deviation from the ordination of samples by the composition data. Open forest 2 was less similar to the other Narrabeen group communities in terms of structure (Fig. 4*c*).

Discussion

Comparison of the patterns in floristic composition and multivariate structural characteristics of the vegetation communities of Ku-ring-gai Chase National Park examined by NMDS and Procrustes analyses shows a strong correspondence between these two community attributes. The major floristic composition gradient across the two soil types from open scrub–closed heathland through woodland and open forest on Hawkesbury sandstone, open forest and tall woodland communities on Narrabeen group soils to forest and closed forest (Fig. 2*a*) was evident in the ordination of the structure data (Fig. 2*b*). The similarity of gradients in these two vegetation attributes was also evident in the correlations between the axis scores (Table 1) with all coefficients highly significant ($P < 0.001$). Comparison of the NMDS composition and structural ordinations shows that the gradients in these two vegetation attributes are essentially the same. However, the distinction between the two soil types was less clear in the ordination of the structure data, primarily as a result of the close similarity of the Narrabeen group community, open forest 2 (Community 7), to the Hawkesbury sandstone communities in terms of the multivariate structural characteristics. Other differences between the two ordinations, such as the close structural similarity of the woodland and open forest communities, are sufficient to suggest that stand structural characteristics exhibit distinct spatial patterns and are not necessarily the artefact of an autocorrelation with species composition.

Outhred *et al.* (1985) recognised a gradient from heathland and scrub on Hawkesbury sandstone to closed forest on Wianamatta Shale soils in Ku-ring-gai Chase National Park.

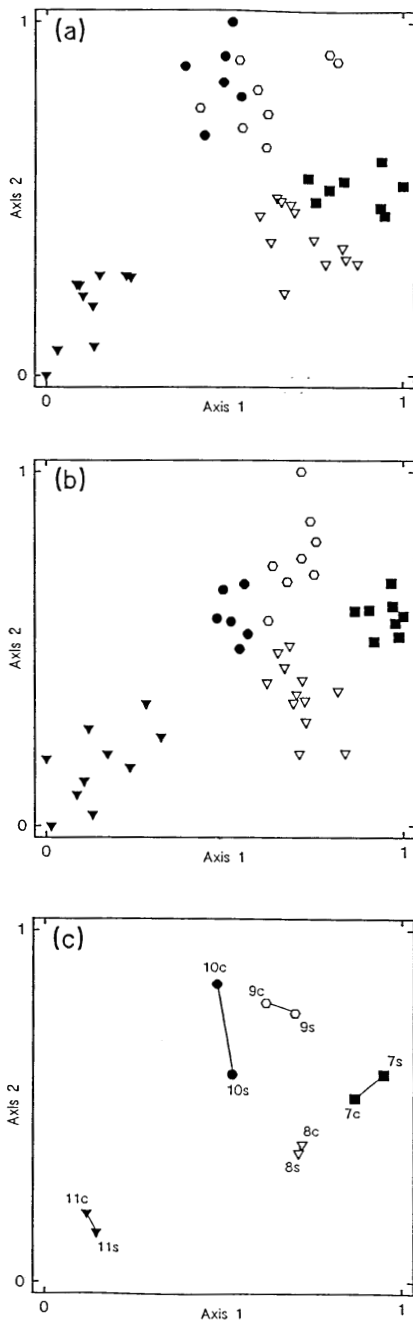


Fig. 3. Ordination of axes 1 and 2 from NMDS of the composition data (a) and procrustes NMDS of the structure data (b) for the Hawkesbury sandstone communities. (c) Centroids biplot of the composition data (c) and structure data (s). Symbols for community types are shown in Fig. 2.

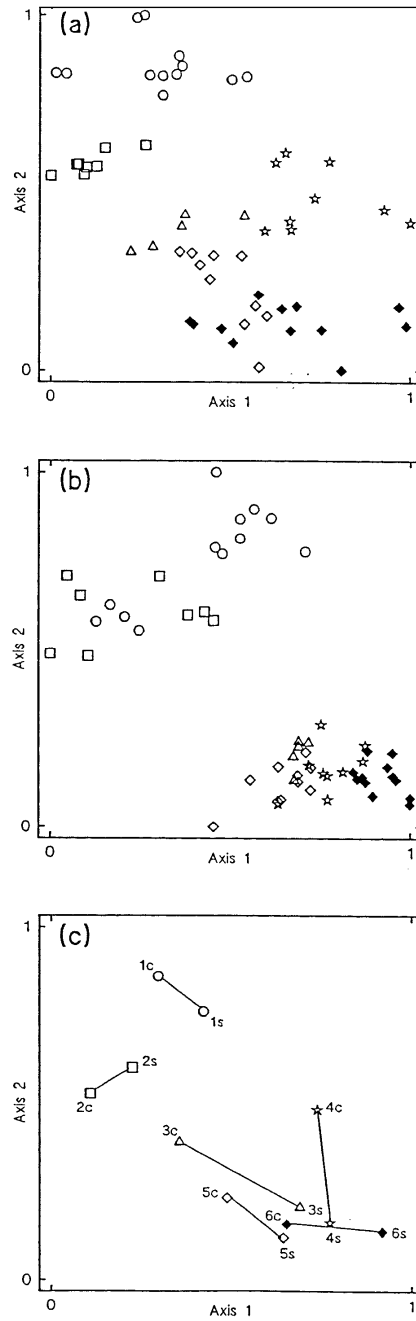


Fig. 4. Ordination of axes 1 and 2 from NMDS of the composition data (a) and procrustes NMDS of the structure data (b) for the Narrabeen group communities. (c) Centroids biplot of the composition data (c) and structure data (s). Symbols for community types are shown in Fig. 2.

However, their data suggested a relatively simple structural trend from scrub–heathland through low woodland–open forest, moderately low open forest, medium–tall open forest to closed forest (‘marginal rainforest’). In the present study, woodland and open forest communities (Communities 3–7) are largely indistinguishable in terms of their multivariate structural characteristics (Fig. 2*b*). This suggests that a floristic composition gradient, largely independent of stand structure, may be operating.

The floristic composition gradients within the two soil types were also shown to be well recovered by the multivariate structure data. Within the Hawkesbury sandstone communities the major floristic gradient from heathland, through woodland to open forest type communities, was evident in the structure data (r_s axis 1 = 0.75, axis 2 = 0.76; Table 2) although the distinction between woodland and open forest communities was less clear (Fig. 3*b*). The complex floristic gradient within the Narrabeen group soils was also shown in the ordination of the structure data (Fig. 4; Table 2).

The similarity between open forest 2 (Community 7) on Narrabeen group soils and the Hawkesbury sandstone communities is stronger on the basis of stand structure. This is particularly the case for the strong structural similarity between open forest 1 (Community 6) on Hawkesbury sandstone and open forest 2 on Narrabeen group soils as shown by the very similar FPC of all strata. Both these floristically distinct communities possess an emergent tall tree layer (trees > 30 m), mid-dense (*sensu* Specht 1981) tree, shrub, graminoid and herb layers, and a sparse fern layer (Table 1). The floristic difference between these two communities is evidenced by the dominant species in the upper strata. Dominant tree species within the upper strata of open forest 1 on Hawkesbury sandstone were *Eucalyptus gummifera* (Sol. ex Gaertner) Hochr., *Eucalyptus haemastoma* Smith and *Angophora costata* (Gaertner) Britten (Le Brocque and Buckney 1995). Dominant tree species within open forest 2 on Narrabeen group soils were *Ceratopetalum gummiferum* Smith and *Allocasuarina torulosa* (Aiton) L. Johnson (Le Brocque and Buckney 1995). However, both communities exhibited similar FPC of the tree strata. Woodland 1, woodland–open forest and woodland 2 (Communities 3, 4 and 5, respectively) on Hawkesbury sandstone also have similar FPC to the open forest communities, particularly in lower strata, although an emergent tree layer (trees > 30 m) is absent from these communities (Table 1). Although these communities shared dominant species in the upper strata (Le Brocque and Buckney 1995) differences in overall floristic composition were evident. These observations suggest a convergence of compositionally distinct plant communities towards a common stand structure.

This convergence of stand structural characteristics is also indicated by the overall closer similarity of other Narrabeen group communities to the sandstone communities (‘contraction’ of centroids towards centre of biplot shown in Fig. 2*c*) in terms of structure. Open forest 3 and forest (Communities 9 and 10) on Narrabeen group soils are generally more similar in terms of structure to the woodland and open forest communities on Hawkesbury sandstone in that they contain sparse to mid-dense tree, shrub, graminoid and herb layers, although other differences, such as a high FPC of the fern layer in open forest 3 and forest communities (Table 1), were also apparent.

The considerably less variability shown by the woodland and open forest communities on the Hawkesbury sandstone soils (Communities 3, 4, 5 and 6) in the structure data than in the composition data may be a response to a reduced efficiency of the structural classification scheme to distinguish between these communities. However, for other communities (1, 2, 8 and 11) there was considerably more variability between the quadrats in the ordination of the structure data (Fig. 2*b*). In particular, four quadrats of the open scrub–closed heathland community, identified floristically as similar, were different structurally. These quadrats were more similar to the low woodland–open heathland community in terms of structure in that they exhibited relatively high FPC of trees < 10 m (c. 13%) and graminoids (c. 63%) and low FPC of shrubs < 2 m (c. 38%). These differences between composition and structure data

were also shown within the two soil types. This suggests that the 'contraction' of samples in terms of stand structure in ordination space has an ecological basis and is not a function of the efficiency of the structural classification scheme used.

Evolutionary convergence of stand structural characteristics has been observed in broad-scale studies examining structure and composition attributes of vegetation communities. Webb *et al.* (1970), while examining the composition and physiognomic-structural relationships of rainforest vegetation in eastern Australia, found that one site had a structural form similar to other geographically and compositionally distinct sites. They further concluded that 'it is obvious that, as a survey becomes increasingly wide-ranging, this must occur'. Other studies have also observed convergence of structural characteristics at the broad scale (e.g. Parsons and Moldenke 1975; Parsons 1976; Cowling and Campbell 1980; Box 1981).

In the present study, a possible convergence (in the broad sense) of stand structure within a single biogeographic region was observed. Floristically distinct communities (Communities 6 and 7) were shown to exhibit similar structural characteristics. The data also suggest that woodland communities (Communities 3, 4 and 5) on Hawkesbury sandstone soils may be approaching this structural type. This convergence in stand structure may represent a possible successional gradient towards an ecologically stable structure or 'equilibrium point'. Why an open forest-type structural formation may represent a possible endpoint of a successional gradient is very much open to speculation. It is possible that, within the vegetation of the study area, such a structural formation allows for maximum occupation of each of the strata. Clearly, further work is required to determine the generality of these findings.

While the evolutionary convergence discussed above and the local spatial convergence in community structural attributes within Ku-ring-gai Chase National Park observed here may represent two very distinct processes, the possible mechanisms involved may be similar. Various mechanisms have been proposed for convergence of community attributes in inter-continental comparisons (i.e. convergent evolution). Parsons and Moldenke (1975) and Parsons (1976) observed considerable convergence in stand structure between floristically distinct communities in California and Chile sharing common (Mediterranean-type) climatic conditions. They suggested that under similar climatic conditions similar forms will evolve independently of the genetic (floristic) history of the floras. Similarly, Box (1981) found convergence of life forms at the global scale, and attributed this primarily to the general levels and mean seasonal patterns of temperature and water balance. Cowling and Campbell (1980) examined convergence of vegetation structure in Mediterranean-type communities of California, Chile and South Africa, and found major differences between the fynbos vegetation of South Africa and the vegetation of the other two continents. They attributed this divergence in community structure to the nutrient-poor substrate of the South African communities. Cowling and Witkowski (1994) found evidence for strong convergence between Australian and South African shrublands in a wide range of plant traits, including life-form characteristics. They suggested that examples of divergence may be related to regional and historical processes, including microclimate and fire effects.

The possible role of environment in the convergence of stand structure in the vegetation communities of Ku-ring-gai Chase National Park is currently being investigated. However, preliminary observations (Le Brocque 1995) would suggest that, at least in the absence of fire, the present-day environmental characteristics show strong correlations with the patterns in stand structure observed. We conclude that the plant communities of Ku-ring-gai Chase National Park exhibit similar patterns in floristic composition and stand structure: the gradients in these two vegetation attributes, both between and within the two soil types examined, are essentially the same. However, there is also evidence to suggest a convergence of some compositionally distinct communities towards a common structural formation.

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