

CHAPTER 6 RESULTS: SURVEY DESIGN AND EFFICIENCY

6.1 Comparative Analyses

This chapter presents comparative results of the different data types collected and of analyses designed to examine survey efficiency. Information on time spent at each field activity is presented. The purpose of the chapter is to examine the comparative efficiency or suitability of different methods used. These include the stratification, patch or plot sampling, qualitative or quantitative data, and tree species data as opposed to other synusiae or bryophytes. On the basis of these results Chapter 7 will assess justification of decisions made on methods in Chapter 4.

6.1.1 Qualitative versus quantitative data

A simplified classification of binary data for the 231 sites is presented in Fig. 12. Fig. 13 shows the correlations of site occurrences between groups in the quantitative and binary classifications. The site numbers for each group are listed in Appendix 8. The overall structure of the dendrogram is very similar to the quantitative one, with the major division separating high and low altitude sites.

The largest difference between the two classifications is that the intermediate altitude subgroup of community-types 3 and 4, which in the quantitative classification was part of the high altitude group, has fused in the binary one with the low altitude sites. This fusion is however at a fairly high level as

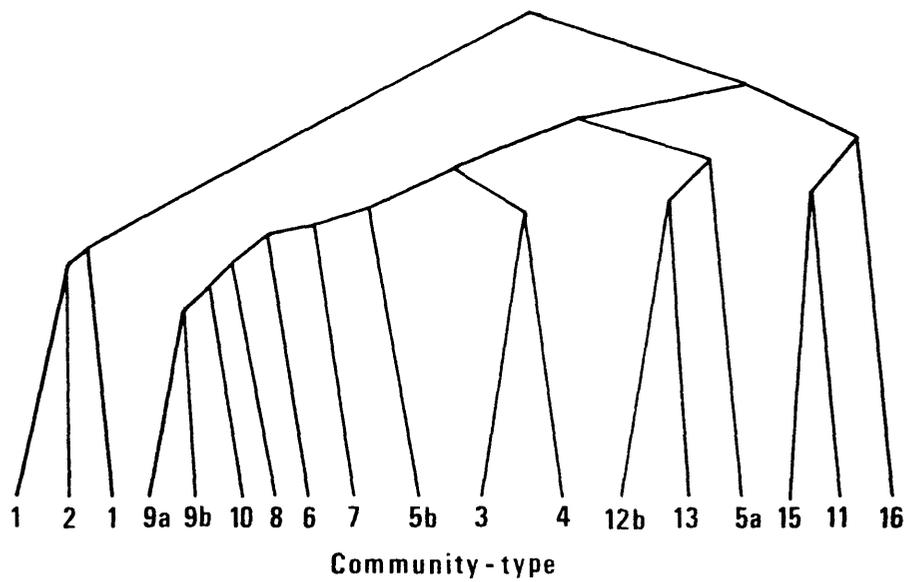


Fig. 12. Binary classification of 231 sites. This dendrogram is simplified for presentation and comparison, by being truncated at the community-type level. Each community-type number is located where the site grouping most closely matches that community-type in the quantitative classification. (Most types match closely, but a few are split.)

was the quantitative one, indicating that major differences still exist. Sites in community-types 3 and 4 are low to intermediate diversity sites, mostly in the southern gradsect, which occur between 200 and 650 m altitude. In altitudinal range this subgroup overlaps both the high (400 to 1050 m) and low (0 to 450 m) groups. The rearrangement has the effect of restricting the new smaller left-hand group to high altitude sites, while forming a much larger low to medium altitude group on the right. In this large group the intermediate altitude sites form a third (simple warm temperate) subgroup between the original two subgroups (warm temperate/subtropical and dry/successional). Thus the abundance of some high altitude species in quantitative groups 3 and 4 suggest high altitude affinity, while the binary data is influenced by the many lower altitude species.

Another difference between the two dendrograms, though involving only a small number of sites, is the return of the highest altitude site 124 (in the left-hand group) to join its neighbour 123 and other high altitude sites dominated by Eucryphia moorei. In the quantitative classification it had been separated very early from site 123 and became an outlier at the right-hand end of the dendrogram as described in Section 5.3.2. However, whereas site 123 together with site 73 (but not 124) are located within the high altitude group in the quantitative dendrogram, these three sites are now located as a separate very high altitude subgroup on the right-hand side of the high altitude group. Species presences make site 123 fuse with 124 in the binary classification, while in the quantitative data

abundances over-ride this and make 123 more similar to site 73, even though 73 has six extra species and is missing two of those in site 123 (Table 21). All three sites have eight species in common, 123 and 124 have ten in common and 73 and 123 have 11. Sites 123 and 124 have six double zeros, Callicoma serratifolia, Smilax australis, Doryphora sassafras, Microsorium scandens, Blechnum pattersonii and Asplenium bulbiferum, which are all conspicuous by their absence.

Whereas in the quantitative classification community-type 7 (littoral) fused with the Ceratopetalum apetalum-dominated subgroup (community-types 8, 9 and 10) before community-type 6 did (Citronella moorei and Dendrocnide excelsa), in the binary classification community-type 6 fused before type 7. The bond between community-types 6 and 5b is less strong in this classification, as community-type 7 fuses between them and some of the original 5b sites have fused with the warm temperate medium altitude community-type 3.

The small successional outlier community-type 11 has moved from the warm temperate/subtropical group to fuse at a high level with the other small successional outliers, community-types 15, then 16. This community-type is not considered a robust one in the sense that it comprises only three sites.

Within the right-hand group of the dendrogram the dry rainforest and successional sites form a subgroup at a high level. The lower subdivisions of this group (not presented in Fig. 12) produce subgroups with more internal chaining than is found in the equivalent subgroups of the quantitative

classification. Communities 12a and 12c, which had weakly grouped in the quantitative analysis as a result of different abundances of Acmena smithii and Backhousia myrtifolia, have now disappeared, with sites spread throughout the dry and successional subgroup, but community 12b remains. This suggests that these groups which had been subjectively recognized in the field on the basis of tree dominance are more heterogeneous when the total flora is considered as presence/absence data. Community-type 14, of only two sites, is absorbed into type 13, supporting the decision that this type is too small to be considered robust. Community 5a now fuses with the dry and successional group before the latter fuse with the warm temperate/subtropical group.

Thus, apart from these minor differences between the two classifications, qualitative data would appear to be sufficient. The main overall difference is that the binary classification has separated many of the neighbouring sites within patches, which are grouped together as patches in the quantitative classification. All these differences may be considered minor. We may conclude that the main features of the interpretation are robust to changes in measurement of the floristics.

6.1.2 Tree species, non-tree species versus total vascular species

Tree data

Using only quantitative tree data the major groups of both the quantitative and binary classifications are again

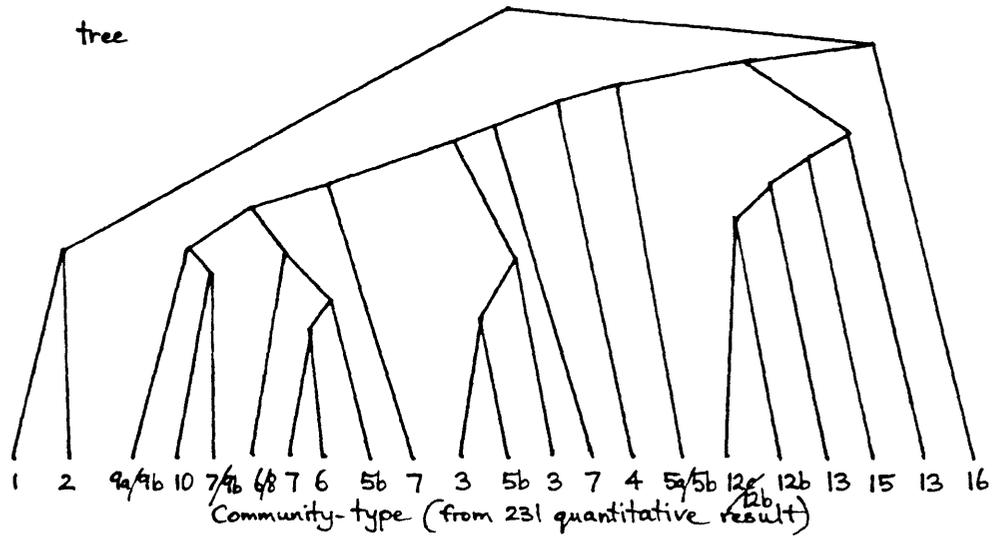
apparent with a high altitude group and, at low altitudes, a warm temperate/subtropical mixture and a dry/successional group (Fig. 14a). The community-types within the two low altitude groups are not as clearly defined by the tree species classification, with community-types 3, 5b, 6, 7, 12b and 13 all fragmented. This classification resembles the binary more than it does the quantitative classification because the intermediate altitude community-types 3 and 4 are part of the large low altitude group rather than the high altitude group. In this case, however, this intermediate altitude group is less discrete as it is highly fragmented. The littoral community-type loses its integrity and the presence of cool/warm temperate sites is due to four sites containing Eucryphia moorei, but from the lower end of the high altitude range (between 400 and 800 m).

An interesting characteristic belonging solely to the tree dendrogram is the removal of the small outlier (5a) of successional Dromedary sites, containing Dendrocnide excelsa, from the right side of the dry rainforest subgroup to now fuse to the intermediate altitude subgroup before the dry and successional one. In the quantitative classification this outlier was manually rotated to the left of the total warm temperate/subtropical group to form community 5a, as described in Section 5.3.1.

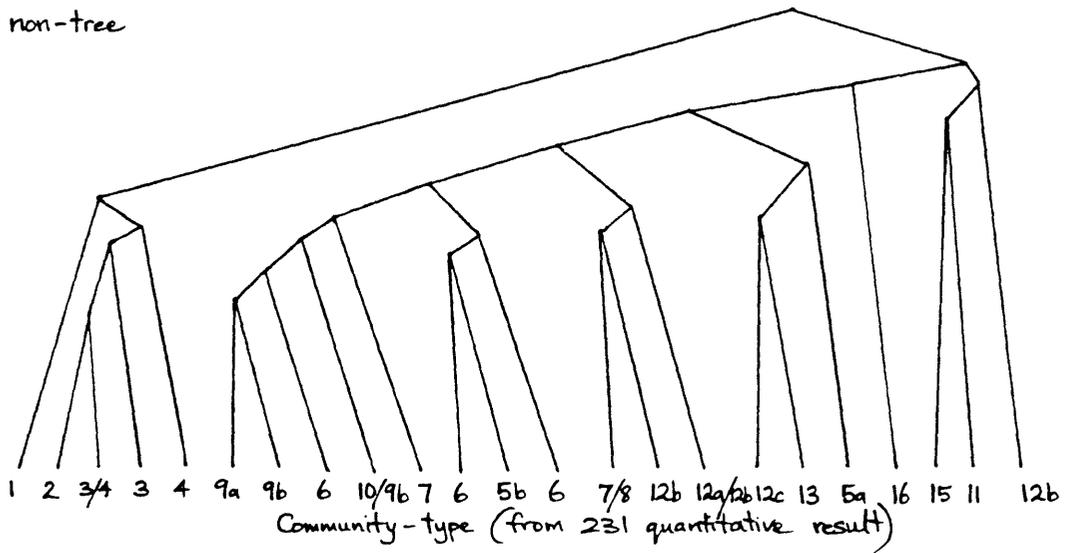
In the tree classification the high altitude community-types 1 and 2 remain discrete, and sites 123 and 124 fuse in the highest altitude section.

Fig. 14a Classification of tree and non-tree data

tree



non-tree



Backhousia myrtifolia-dominated sites (12a, b and c) form a distinct subgroup, (though not as discrete as in the quantitative classification), but within this group considerable chaining gives poor structure. There is some overlap between types 12 and 13, and type 14, as in the binary result, no longer exists.

The three sites forming outlier type 11 in previous classifications are now dispersed amongst the warm temperate/subtropical and dry/successional groups indicating lack of robustness of this type. Community-types 15 and 16 remain distinct outliers, but part of type 13 has joined 15.

Community 5b has lost its integrity in this classification by splitting three ways to join types 6 and 7 (as in earlier classifications), and also type 3 (warm temperate Acmena smithii, Doryphora sassafras-dominated) and 5a. On the basis of field recognition, which was strongly influenced by dominant tree species, community 5a had been placed with 5b and community-type 6 in the original dendrogram manipulation.

Thus tree species alone are only sufficient to distinguish the major groups. In particular the results are not informative about the intermediate altitude community-types 3 and 4, the littoral type 7, community 5b, and less informative than the total quantitative classification as to the dry rainforest communities. In contrast it is more informative about the relationship between site 123 and 124, and about the relationship of community 5a to the warm temperate/subtropical group.

Non-tree data

The non-tree classification (of all species other than trees) bears some resemblance both to the quantitative and binary classifications. Here the intermediate altitude sites rejoin the high altitude sites as in the quantitative classification to form a high to medium altitude left-hand group.

The left-hand side of the dendrogram is less clearly structured than in the quantitative classification because the Eucryphia moorei, Doryphora sassafras-dominated sites are located in a large E. moorei, D. sassafras, Acmena smithii-dominated subgroup.

Another similarity between the non-tree and quantitative classifications is the intactness of a moderately rich Clyde subgroup of community-type 6 containing sites 38, 39, 47-50. In the binary dendrogram and more so in the tree dendrogram this subgroup is dispersed. However whereas in the quantitative classification it is located in the middle of the floristically rich Clyde community-type 6, the non-tree classification fuses it with 5b, a group of moderately rich Dromedary sites, with the effect of forming a more moderate end of the rich group comprising community-types 5 and 6. Thus the rich and moderately rich Clyde sites become distinct from each other.

Another subgroup of community-type 6 containing no Ceratopetalum apetalum-dominated sites, joins the C. apetalum-dominated types 9a and b in this classification. Community-type 8, which had been fairly distinct in the other classifications,

here joins part of the littoral type 7 and they are together moved away from the warm temperate/subtropical group to the dry/successional end of the dendrogram. Community-type 14 has again been absorbed into other types.

Dry rainforest does not form such a clear group here as in other classifications. Many of these Backhousia myrtifolia-dominated sites join with the moderately rich Clyde sites, by fusing with community-types 7 and 8 as described above, to leave a reduced right-hand dry rainforest group.

The outlier component at the right side is strongly developed in this classification, and community-type 11 is reformed here (as in the binary dendrogram) and joins Backhousia myrtifolia-dominated sites of the Clyde gradsect (type 15) and some of the Dromedary gradsect (community 12b).

The non-tree result thus supplies some information similar to both quantitative and binary classifications, but is less informative about the differences between the higher altitude types 1 to 4, and the differentiation between warm temperate/subtropical and dry/successional groups. In contrast it forms a new distinction between moderately rich Clyde/Dromedary sites and rich Clyde/Dromedary sites. It differs from the tree classification in having community-types 1 to 4 completely separated from the lower altitude groups, but in contrast has less segregated dry/successional and warm temperate/subtropical groups.

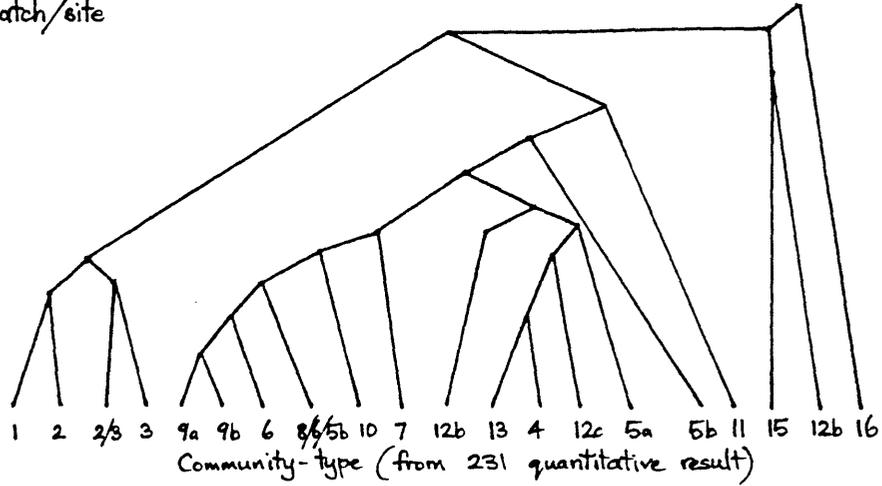
6.1.3 Patch versus site (combined to make patches) data

The overall dendrogram structure of the four site classifications previously described is repeated in classifications of patches based on a 'walk-around' species list as well as patches based on their combined plots (Fig. 14b). Both were based on binary data. Three major groups are produced in both cases to give a high altitude group and two low altitude groups, one of warm temperate/subtropical rainforest and one of dry/successional forest.

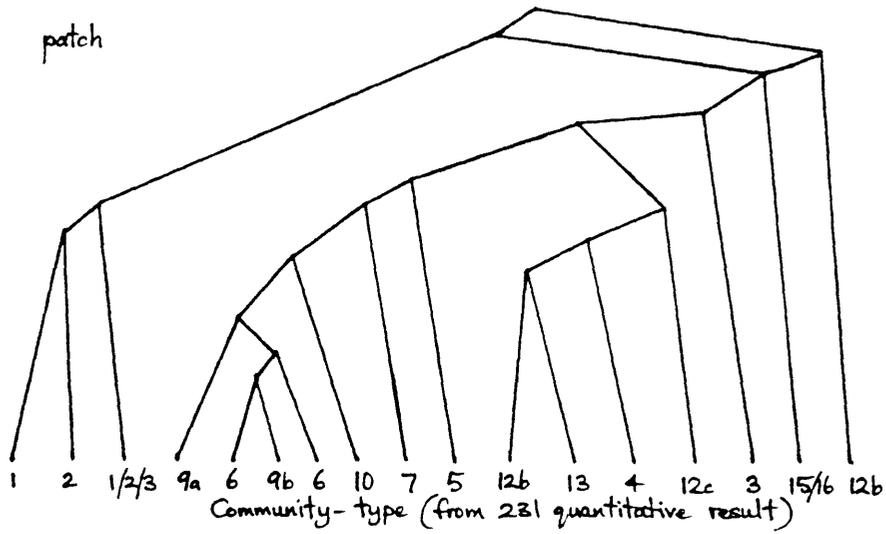
In the patch analysis two cool temperate Eucryphia moorei-dominated patches are located at the right side of the high altitude group, separated from other E. moorei-dominated ones by the E. moorei, Doryphora sassafras, Acmena smithii-dominated group. These two patches in contrast move left in the patch-site analysis to join other cool temperate patches, thus producing a cool temperate-warm temperate gradient of associations from E. moorei, through E. moorei, D. sassafras, A. smithii to D. sassafras, A. smithii, which correlates clearly with reducing altitude. The latter group (D. sassafras, A. smithii) is also enlarged in the patch-site classification by the addition of patches 112, 95, 115. These patches had been located near the right-hand end of the dry/successional group in the patch analysis.

The removal of these intermediate altitude patches back to the left of the dendrogram in the patch-site analysis indicates that the influence of high altitude species was recovered less by patch data. This reflects the omission of

Fig. 14 b Classification of patch and site/patch data
patch/site



patch



small and inconspicuous species such as filmy ferns and other small epiphytes from the intermediate altitude group where they are uncommon. Examination of the data showed this to be true for Polyphlebium venosum, Tmesipterus parva and Fieldia australis, which were present in patch-site 95 but absent in patch 95, and for F. australis in patch-site 112. A similar cause of the high altitude patch separations can be found. Close examination of data for patch 92 again reveals omission of small high altitude indicators from the patch list, with P. venosum, Microsorium diversifolium, Parsonsia brownii and F. australis present only in the patch-site list. Collection of a wider generalist species list by walking the patches, perhaps through inclusion of more edge species, may be another contributing factor in both of these cases.

As in the non-tree analysis community-type 6 is divided in the patch analysis and fuses within the Ceratopetalum apetalum-dominated community-type 9. Communities 9a and 9b fuse at a lower level in the patch-site analysis. An explanation for these differences is that the more wide-ranging species list of the patch collected more non-tree species, and particularly more transitional species, reducing the influence of the dominant tree species.

The most obvious difference between the patch analysis and all others is the removal of community 5a from amongst dry and successional sites, to join the warm temperate/subtropical group. This suggests that the broader patch species list recovered a broader sample of the floristic affinities of the

patch, whereas the four sites in this community may have emphasized successional influences. An interesting characteristic of both patch and patch-site results is that the communities 5a and 5b join, a confirmation of the validity of their subjective association in the original community-type interpretation (Section 5.3.3).

It is concluded that patch walk-around lists without specific plots could be used to give a broad outline of rainforest types, but that some inadequacies occurred. For example this method recovered less clear information on altitudinal gradation in high to medium altitude forests and on distinctions between some of the warm temperate and warm temperate/subtropical forest types. It produced a different picture of the affinities of the low altitude patches on Mount Dromedary.

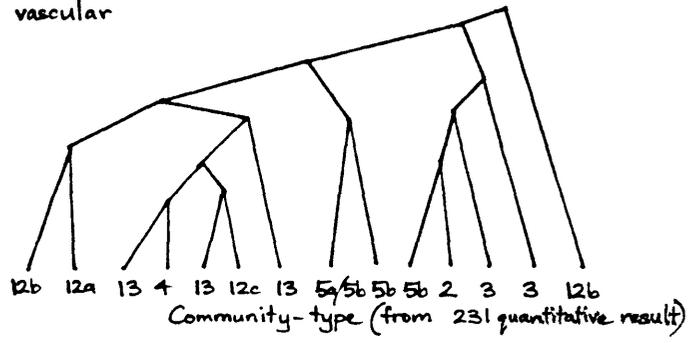
6.1.4 Vascular species, bryophytes versus combined vascular/bryophyte data

As described in Section 4.3.3 bryophyte data were collected in the southern gradsect, and could therefore only be analyzed in the context of that gradsect. The data were recorded for patches rather than plots, so a separate classification of Dromedary patches using combined vascular/bryophyte presence and absence data was carried out.

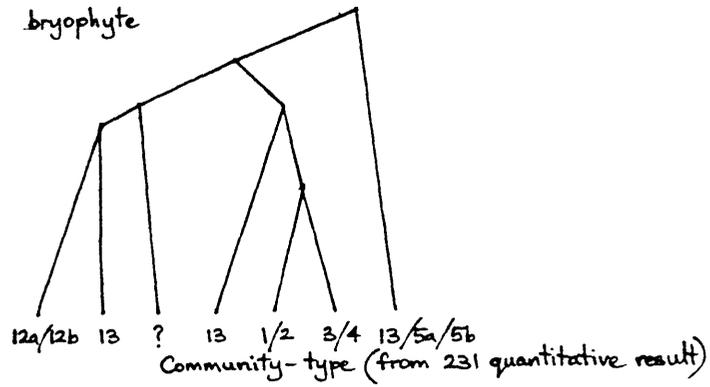
The simplified dendrogram is presented in Fig. 14c. The overall structure is similar to the analyses of combined gradsects, but the high altitude sites form a group on the right

Fig. 14c Classification of Dromedary gradsect patch data.

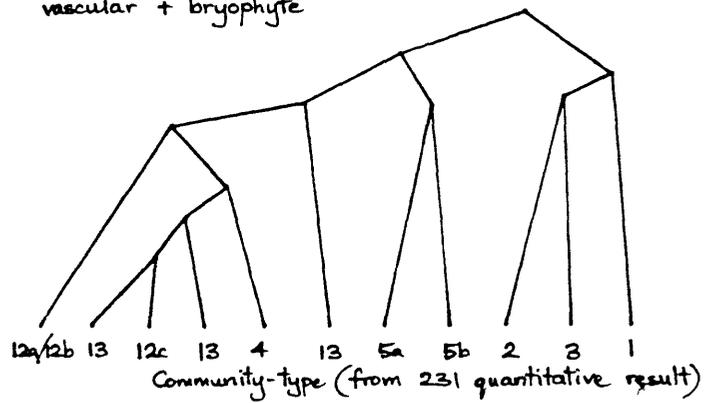
vascular



bryophyte



vascular + bryophyte



in this case, which is uninformative because of the one dimensional limitation of the dendrogram. On the left is a dry rainforest group, followed by two successional groups then a small warm temperate/subtropical one. The main difference between these and other analyses is the reduction of warm temperate/subtropical groups and the prominence of dry and successional groups which is a function of the single gradsect sample involved.

Separate classifications of these patches were done using only vascular species, then only bryophytes (Fig. 14c). The vascular result broadly resembles the combined vascular/bryophyte one. However, two Backhousia myrtifolia-dominated patches form a small dry rainforest outlier on the right, separating early from other dry rainforest patches. The latter form two clear (12b and 12a) groups in the vascular classification. Community-type 4 fuses at a low level into the successional group (community-type 13), whereas in the combined classification it had only fused to the top of this group. Community-type 1, dominated by Eucryphia moorei, does not form a clear group in this classification, and communities 5a and 5b are less clearly differentiated, though together still forming a clear warm temperate/subtropical group.

Structure in the bryophyte dendrogram is not as clear as in the other two, although the three major groups (dry/successional, cool/warm temperate and warm temperate/subtropical) are repeated. In this case the warm temperate/subtropical group is located at the right side of the dendrogram with the cool temperate/warm temperate group fusing

between it and the dry and successional group. A large 'ragbag' group containing sites from community-types 2, 3, 5a, 5b, 12b and 13 fuses with the main dry/successional one. This results from the fragmentation of the dry and successional community-types 12 and 13 defined within the quantitative result, which also have sites spread through the three main groups. Part of community-type 13 fuses with the major cool/warm temperate group (types 1 to 4). The high altitude group (community-type 1) is reformed as in the combined analysis but does not stand as an independent subgroup because it fuses at a low level with type 2. It is interesting that although community-type 1 is not separate it is at least fused with type 2, whereas in the combined vascular/bryophyte classification types 2 and 3 combined, and type 1 fused with this group.

It can be concluded that bryophyte data is useful in complementing vascular data, but has limited use on its own. Similarly vascular data alone is limited as the coherence of higher altitude forest groups and also dry rainforest is greater when vascular and bryophyte data are combined.

6.2 Survey Efficiency

6.2.1 Travelling and sampling time

It can be seen from Table 22 that travelling by both car and foot took a large proportion of the field time, with driving, walking and the general patch species lists taking three times as much time as the plot activities. Mean number of hours per site was higher for the Dromedary gradsect than for the Clyde gradsect.

TABLE 22. Field time analysis*

a. Recorded field time

Activity	CLYDE GRADSECT 125 plots in 64 segments		DROMEDARY GRADSECT 106 plots in 56 segments		Total hours
	Hours	% of total for gradsect	Hours	% of total for gradsect	
Driving	65.1	20%	91.7	30%	156.8
Walking to patch	102.0	32%	94.7	31%	196.7
Walk species list	61.5	20%	51.7	17%	113.2
Plot data - floristic	55.3	18%	44.3	15%	99.6
- proforma	28.8	9%	20.0	7%	48.8
Total hours	312.7		302.4		615.1
+ Total weeks	7.8		7.6		15.4
Mean hours per plot	2.5		2.8		

Legend

* Not including travel to/from Canberra, equipment maintenance, specimen processing and identification, talks with locals to gain information etc.

+ Calculated on an 8 hour day and 5 day week basis.

b. Potential for reduction of field time

		Clyde	Dromedary	Total
Purely walk-around species list	hours	228.6	238.1	466.7
(i.e. no plot floristics or proforma)	weeks	5.7	5.9	
o Reduced to 90 plots (including patch and plot measurements)				252
o Reduced to 40 plots (patch and plot measurements)				112

Legend

o The higher plot time of the Dromedary gradsect has been used for this calculation on the assumption that sampling fewer, widely dispersed plots would clock up more travel time.

If sampling had been reduced by doing only a walk-around species list (i.e. not plot floristics or proforma) it would have taken 229 hours or 5.7 weeks for the Clyde and 238 hours or 5.9 weeks for the Dromedary gradsect. If smaller samples of 90 sites had been taken (with both patch and plot measurements) field work would have taken 252 hours (6.3 weeks). More marked reduction to 40 sites would have taken 112 hours (2.8 weeks). These figures have been calculated using the higher plot time (2.8 hours) of the Dromedary gradsect on the assumption that sampling fewer widely dispersed plots would involve proportionally more travel time than did the total 231 sites.

6.2.2 Reduced sample size

Section 4.5 explains the reason for and method of devising reduced sample analyses for testing survey efficiency. The reduced data sets of 91 and 41 sites were classified and ordinated, and results compared with the 231 site quantitative result. The dendrograms (which are not presented) repeated the general structure of the quantitative classification, with high and low altitude groups. Differences, which were suggested (though not clear) in the classifications, were displayed more clearly by ordinations, which nonetheless repeated the correlation of altitude with vector 1. Table 23 presents percentage variance accounted for by the first three axes in different analyses, as well as the environmental correlates of the axes. It can be seen that, as is typical in ecological studies, the axes do not account for a large proportion of the

TABLE 23. Percentage of variance accounted for on first three vectors of different ordinations

Sample	Vector					
	1		2		3	
Stratified						
231 site quantitative	13.0	A	8.0	D	5.0	F
91 site	16.0	A	8.0	D	6.4	F
41 site	16.2	A	8.5	F	*	7.4 D
Semi-Random (within stratified sample)						
91 site	14.0	A	10.2	D	5.5	F
41 site	13.2	A	10.0	D	6.4	F
Random (within stratified sample, but area- proportional)						
41 site	1	15.8	A	9.8	D	8.0 +B
	2	13.9	A	10.7	D	7.5 F
	3	12.2	D	*	11.9	A 8.7 F
	4	12.2	A	9.9	D	7.4 F
	5	14.0	A	10.4	D	8.1 F

Correlations

- A altitude
D disturbance/soil moisture
F soil fertility
B separation of Backhousia myrtifolia-dominated sites from other disturbed sites
* correlations of vectors have reversed (in relation to 231 and majority of results)
+ new correlation introduced.

available information. However, except in one case, the largest proportion is consistently accounted for by altitude on the first vector.

The 91 site sample most closely followed the 231 result, with only minor differences. In contrast, in the 41 site sample, environmental correlations of axes 2 and 3 were reversed compared with the 231 result axes, so that axis 2 correlates with fertility and axis 3 with disturbance. Correlations between the first vector scores for sites in these reduced samples are plotted against the first vector scores for the same sites in the 231 analysis, showing strong linear relationships (Figs 15a and 15b). A strong correlation with altitude is thus recovered by the first vector in both cases. These results indicate that the basic rainforest distribution pattern of the 231 analysis is repeated by reduced samples, with differences only in detail, the implications of which will be discussed in Section 7.3.4.

Fig. 6 presents graphs showing increasing species numbers with increasing plot numbers in major community groups. This test was utilized in order to determine the impact of reduction in sample number on adequacy of sampling different community-types (Section 4.5). Minor deviations from the curve may result from sampling order, e.g. a move to a different region, or conversely a series of sites in one patch. It can be seen that community-types 7/8 and 9/10 are still increasing steeply at the close of the sample, in contrast with types 3/4 and 12/13/14, which appear over-sampled. Between these extremes community-types 1 and 6 are still increasing, though not steeply,

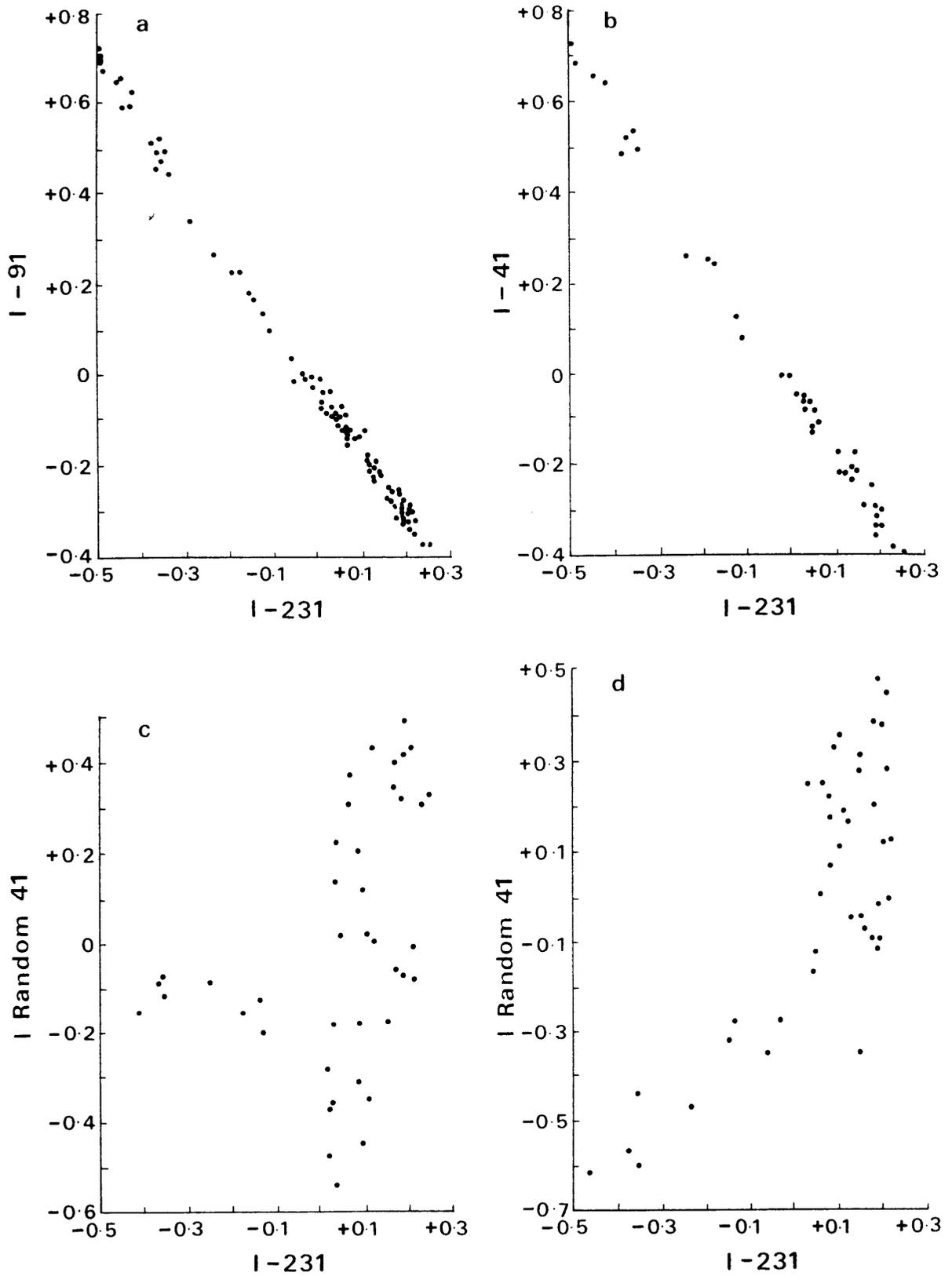


Fig. 15. First vector scores for sites in reduced samples plotted against the scores of the same sites in the total 231 analysis. (a) stratified 91 sites, (b) stratified 41 sites, (c) third area-proportional random 41 sites, (d) 5th area proportional random 41 sites.

and type 2 is approaching an asymptote. It appears that as a general rule approximately 30 sites in any rainforest type recover the majority of species. As each plot is 0.1 ha this gives an area of three ha for adequate sampling. The gradual increase in species above this may be accounted for by occasional occurrences of rare species and 'weedy' species as heterogeneity increases with increased plot number. The implications of these results in terms of sampling efficiency will be discussed in Section 7.3.4.

6.2.3 The affect of stratification on reduced sampling

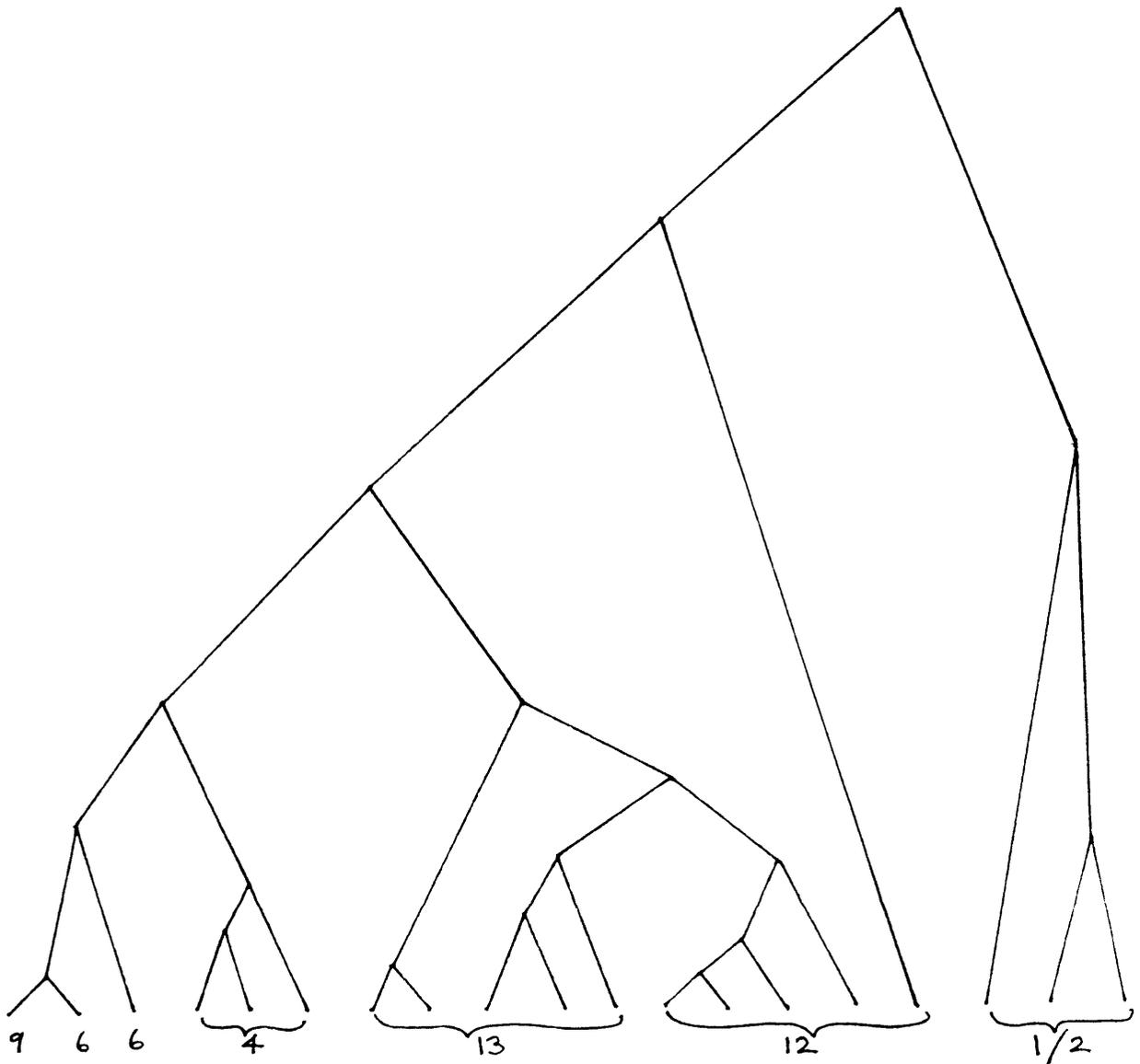
The influence of the stratification on ensuring recovery of the major rainforest environments identified was tested by random subsets of the 231 data set as outlined in Section 4.5. If there is a strong environmental correlation random samples should recover it, unless extreme distributions result from environmental heterogeneity. The dendrograms generally follow the broad structure of the 231 site result, but with more discrepancies than in the initial reduced samples. Ordinations were used to interpret differences. Correlations between site scores on vector 1 for the 231 and semi-random (Section 4.5.3) 91 and 41 site subsamples (not illustrated) were not as tight as those of the reduced (but stratified) 91 and 41 samples (Figs 15a and 15b), although the basic linear relationship is repeated. Thus in both reduced and semi-random subsets of the purposive stratified sample the influence of altitude dominates the ordination. In contrast, in area

proportional random samples the lower relationship broke down in varying degrees, as illustrated in Figs 15c and 15d. The most extreme divergence is in the third random subset (15c) in which the first ordination axis no longer represents altitude, but represents the original second axis (disturbance), while altitude is reflected on axis 2 and fertility again on axis 3.

Although there is a general trend towards reduced correlation with the 231 result (from the 91 and 41 results, through semi-random to random results), some exceptions occur. Notably, the first semi-random 41 subset produced similar correlation on axes 2 and 3 to 231 axes, whereas those of the stratified 41 sample were reversed. The implications of such a discrepancy, and the inconsistency within the five random subset results will be discussed in Section 7.3.4. In the first random subset, although axis 1 correlates with altitude and 2 with disturbance, as in the majority of samples, the third axis does not correlate with fertility, which is the third major correlate in other results. This axis approximates the fourth axis (which was not examined in detail) of the 231 site result, separating dry from successional rainforest.

Results of the field random sample (Section 4.4.3) were available at a late stage in the preparation of this thesis and are therefore only briefly presented here (Fig. 16). The altitudinal gradient is clearly reduced with extreme under-sampling of higher altitude areas, so community-types 1 and 2 are virtually absent. Community-types 5 and 10 are omitted because the Durras Mountain and Mount Dromedary areas were not sampled.

Fig. 16 Dendrogram from analysis of 40 site field random sample



Community-type (from 231 quantitative result)

Missing community-types - 3, 5, 7, 8, 10 (considering only major types from 231 analysis)
 Under-represented types - 1, 2

Community-types 3 and 7 are also missing. Community-types 6 and 9 are emphasized by the inclusion of the Mares Hill area, which was not included in the original sample. Community-type 4 is clear because of the many sites in the inland southern region, and community-types 12 and 13 are recovered. The implication of this result will be discussed in Section 7.3.4.

6.2.4 Adequacy of base data set

Results from Chapters 5 and 6, which contribute to assessment of adequacy of the base data set (as explained in Section 4.4.1), will be discussed in Section 7.3.5.

CHAPTER 7 DISCUSSION

7.1 Introduction

This chapter reviews the study in the context of the objectives listed in Chapter 1. This includes interpretation of inventory results as well as examination of problems in survey design. Limitations arise because of shortcomings in mapping, survey design and measurement. Interpretation of inventory results comprises the first part of the Chapter, and the examination of methods which follows it discusses deficiencies in the inventory.

7.2 Factors Influencing Rainforest Distribution and Variation in Southern New South Wales

7.2.1 Environment

As described in Section 5.2 rainforest in southern New South Wales exists as scattered patches through the coastal strip, in sites of high topographic shelter. Larger patches tend to occur in the north and inland, with many small patches dominating the southern and coastal areas (Appendices 1 and 2). This trend in the present data is generally confirmed by the geographically wider-ranging mapping of rainforest by the New South Wales Forestry Commission (anon. 1981).

It is clear from the results (Section 5.6) that latitude, altitude and disturbance mainly in the form of fire are the dominant influences on rainforest species and type distributions in southern New South Wales. The first two factors

function indirectly through climate in conjunction with topography, supporting gradients of rainforest from subtropical in the north and coastal areas to cool temperate in the south and inland. Austin and Cunningham (1981) examine the concept of indirect environmental gradients.

Rainfall, temperature, terrain (which influences shelter) and fire regime (which is dependent on other variables) interact to create these rainforest gradients. Latitude compensates for altitude, giving a latitudinal-altitudinal shift (described by Baur 1964) so that at increasing latitudes species which normally occur only at high altitudes can be found much lower. For example the author observed Eucryphia moorei in the Nadgee Nature Reserve on the far south of New South Wales at 130 m altitude and close to the coast, while it normally only occurs higher than 500 or 600 m in the study area. Here the higher temperatures associated with the lower altitude would be compensated for by reduced temperature with higher latitude (Table 3).

Other controlling factors include soil fertility and moisture, aspect and historical factors. The interaction of climate and fire would contribute to the reduction of large patches with increasing latitude, because of increasing fire frequency at high latitudes. The reduction in number and size of patches in the coastal strip can be explained by limited topographic shelter. Latitudinal influence is evident at a high level in the classification and ordination in two main ways. The high altitude groups comprise predominantly Clyde gradsect sites,

which will be discussed in the Section on terrain. Of the low altitude groups the dry/successional types predominate in the southern gradsect and the more complex and less disturbed types in the north. The discussion of fire history, topography, soil and subtropical floristic influence which follows, will expand on the reasons for this.

Rainfall

Rainfall is correlated with both latitude and altitude through differences in precipitation, evaporation and seasonality (Fig. 2a). In the study area rainfall decreases and declines in seasonality with increasing latitude (Fig. 2). Rainfall influences altitudinal distribution of rainforest types through its relationship with degree of elevation, distance from sea and terrain. The very high precipitation (both rain and cloud) and low evapotranspiration in the escarpment area of the northern gradsect (partly evidenced in Monga rainfall figures, Table 3) fosters the extensive development of high altitude cool and cool/warm temperate rainforest (community-types 1 and 2) in that region. Similarly, the often cloud-capped mountainous massifs of Mount Dromedary and Mount Peak Alone harbour well-developed cool/warm temperate forest despite their locations nearer the coast.

Temperature

Temperature correlates with both latitude and altitude and is a controlling factor, for some rainforest types at least (Fig. 2b). The warm maritime climate of the Durras Mountain area

at the coast north of Batemans Bay supports the development of the rich subtropical/warm temperate community-type 10 and the littoral type 7 containing some species which do not occur any further inland or south. Some of the type 10 sites are in gullies which have a northwesterly aspect and would be therefore subject to higher temperatures than any other community-types. It is suggested that the contribution of subtropical species to these community-types results from the high mean annual temperature north of Batemans Bay being accentuated by northerly aspects, creating an environment with a marked hot summer period with frosts only rarely occurring.

A patch with unusually high species number was that at Spring Mountain in the inland section of the Dromedary gradsect. This will be discussed in the Section on soils, but is noted here also because the gully faces northeast, so would be warmer than most of the rainforest gullies in the area. It is presumed that temperature is more important than rainfall in determining the subtropical influence on this rainforest type.

Topographic shelter

Further complication results from consideration of terrain along with rainfall and temperature. The increased ruggedness of terrain in escarpment areas, whilst ensuring greater precipitation and reduced maximum temperatures also ensures greater protection from fire and reduction of evaporation (the latter being influenced by northwest winds and insolation) as was described in Section 2.1.2 in relation to Fraser and

Vickery's work. Similarly the presence of mountains in the coastal area compensates for other factors. Radiation index interacts with precipitation and soil moisture storage, to control waterbalance. Thus the presence of warm temperate/subtropical species such as Sarcomelicope simplicifolia and Piper novae-hollandiae on the lower slopes of Mount Dromedary is a function of the sheltered environment and the warm maritime location. High on the same mountain, elevation provides shelter, together with the cool temperatures and increased precipitation which enable development of Eucryphia moorei-dominated forests. Because of the abrupt nature of the escarpment in the northern gradsect, E. moorei/Doryphora sassafras-dominated forests are more prominent there than in the southern one.

Fire

The fire history of southern New South Wales is documented as severe, "with running-crown fires of the conflagration (mass-ignition) type with extensive spotting fires during the dry late summer and early autumn" (Webb 1968). The area is subject to dry summer thunderstorms which contribute to fire risk. Fire has a significant effect in modifying the climatic potential for development of rainforest. This has been discussed in Chapter 3. The influence of terrain on fire regime should not be ignored. It appeared in the study area that the dry rainforest community-type 12 occurred in areas of less marked relief and lower soil moisture than most other types. Backhousia myrtifolia dominates this community-type, which separated out on

ordination axis 2, and this species with thick fibrous bark is considered to be comparatively fire resistant (Floyd 1982). During the survey it was observed to coppice as a response to fire and other disturbance, and the open mossy floor of these forests would be resistant to burning. The interaction between soil moisture (and fertility) and fire regime is thus responsible for the separation of the low altitude sites on vector 2 into a dry/successional group and a less-disturbed and moister group. This must be reflected not in how many species are present but in which ones, as the dry rainforest sites are floristically poor, while the successional ones are more like the less disturbed sites in richness. The richness of the successional sites can be accounted for by both more fertile soils and more recent fire influence promoting establishment of successional species. The dry rainforest sites on the other hand, which show little canopy disturbance by fire in the short-term as well as being located on poorer, often rocky and shallow, soils do not support such a wide range of species. Fires had recently burnt the edges of some of the dry rainforest patches killing saplings in expansion zones around the rainforest, but not destroying the rainforest proper.

Many of the species in the warm temperate rainforests, e.g. Acmena smithii, Doryphora sassafras, Pittosporum undulatum and Rapanea howittiana are also relatively fire tolerant, and were observed during the study to coppice from burnt trunks. Ashton and Frankenberg (1976) described this ability in A. smithii. Eucryphia moorei with its enormous ability to coppice (Section 5.5.1) can also survive fire (Floyd 1982). No evidence

was found to suggest that the species restricted to well-developed subtropical forest have this ability.

The forests of community-type 10 at Durras Mountain are in protected gullies. They contain some of the most mature rainforests (with very uneven tree diameters and structurally and floristically complex), which seem to have been undisturbed (including by fire) for a long period. The mountainous inland gullies of the northern gradsect supporting much of the high altitude rainforest show marked fire protection. In Nadgee Nature Reserve however, where Eucryphia moorei grows at lower altitudes and in areas of less marked relief fires, were observed to have caused extreme devastation to these forests in recent years. A patch at Yowrie in the southern gradsect, which will be discussed in the soil section, may also contain subtropical elements because of the extreme protection created by its very deep, narrow gully refuge situation.

Murrah and Mumbulla State Forests together include an unusually high number of rainforest patches close to the coast. This may be accounted for by interaction between terrain and disturbance factors (logging and fire). A curious gap in extent of rainforest appears between Batemans Bay and Moruya, with little rainforest in Mogo, Wandera and Mungerarie State Forests or the northern part of Deua National Park, between two of the most densely rainforested areas (Buckenbowra and Dampier State Forests). A large proportion of the coastal lowlands in this area is freehold land, so any rainforest which was present on granite there is likely to have been cleared for agriculture.

The absence of rainforest from the State Forests and National Park further inland can be accounted for partly by fire history and low rainfall. The narrow strip of freehold properties along the Deua River below Araluen is sandwiched between Deua National Park and Wandera State Forest. Here residents, presumably feeling vulnerable to fire from forested areas in all directions, and believing they should burn-off to reduce fuel loads, are responsible for the exceptionally intensive fire history of that area (Floyd pers. comm.). Fires lit at inappropriate times and without adequate back-up equipment result in wildfires. Floyd (1982) found the few rainforests in the area are extremely fire damaged, with vine tangles over low canopies, and suggests these patches are in a process of demise under the present fire regime. The area is also low in rainfall which contributes to lack of rainforest, both directly, through lack of moisture, and indirectly through greater flammability. These personal observations are consistent with the distribution of rainforest observed along the gradsects.

It is concluded that fire is very important in determining distribution of the rainforest types and that if the rainforest is to be preserved special fire management practices will be required.

Soil

Although soil is a controlling factor independent of altitude it must be considered in conjunction with other factors, because its influence may be complemented and/or masked by them.

For example the Mesozoic monzonite and banatite parent material on Mount Dromedary produces fertile soil which supports rich warm temperate/subtropical rainforest. This community-type (5), which was described earlier as being a function of topographic shelter and its maritime location, is therefore also on richer soil. It mainly occurs on the northeast slopes of the mountain, so is also subject to warmer temperatures. Its neighbour in the classification and ordination, and equivalent in the northern gradsect, is community-type 6, which is found inland in the lower escarpment gullies in both northerly and southerly aspects. This community-type is supported by the relatively fertile soils on parent material of upper Devonian sediments and volcanics.

A patch at Yowrie in the inland zone of the southern gradsect is also located on Devonian sediments, but at intermediate altitude in a high rainfall area (Fig. 2a). It fell in community-type 4, presumably on the basis of altitude, but the sites are located at the fertile end of this community-type on axis 3. This patch is unusual in comprising more subtropical elements than most of the inland patches in the southern gradsect, with large specimens of Dendrocide excelsa and Asplenium australasicum. Although the soil analyses did not show high available phosphorus for these soils, they are high in calcium, so high fertility in conjunction with fire protection may be the reason for development of subtropical elements. D. excelsa is rare in the medium altitude community-types 3 and 4, occurring only in five sites - two in the northern gradsect, one on Mount Dromedary at the coast and two of the Yowrie sites. A

similar pattern is found for A. australasicum, which for community-type 3 occurs only in four sites on Mount Dromedary, and for type 4 in one site in the intermediate zone (Fern Creek) and two at Yowrie.

The Spring Mountain patch mentioned in regard to temperature has soil derived from granite which should be more fertile than many of the soils sampled. The two sites involved fell at the high fertility ends of community-types 12 and 13 on axis 3, being high in calcium. A surprising occurrence here was a sapling of Sarcomelicope simplicifolia. This species is a northern one which is generally restricted to the subtropical rainforests. Its southern limit was thought to have been at the Shoalhaven River, some 120 km north, but was extended in this study to Mount Dromedary. In the southern gradsect, apart from this one specimen at Spring Mountain, it was found only at Mount Dromedary. The Spring Mountain gully contains a number of other subtropical species, such as Dendrocnide excelsa and Ficus rubiginosa, which are unusual so far inland at this latitude, and also Asplenium australasicum (Plate 18). The subtropical elements may therefore result from a combination of high soil fertility and the warm northeasterly aspect described in the temperature section.

The correlation with soil fertility on axis 3 was described in Section 5.6.3. It is most obvious in the Clyde gradsect because more rock types occur there. (In the Dromedary gradsect the main inherently fertile parent material is the monzonite of Mount Dromedary, where it can not easily be isolated

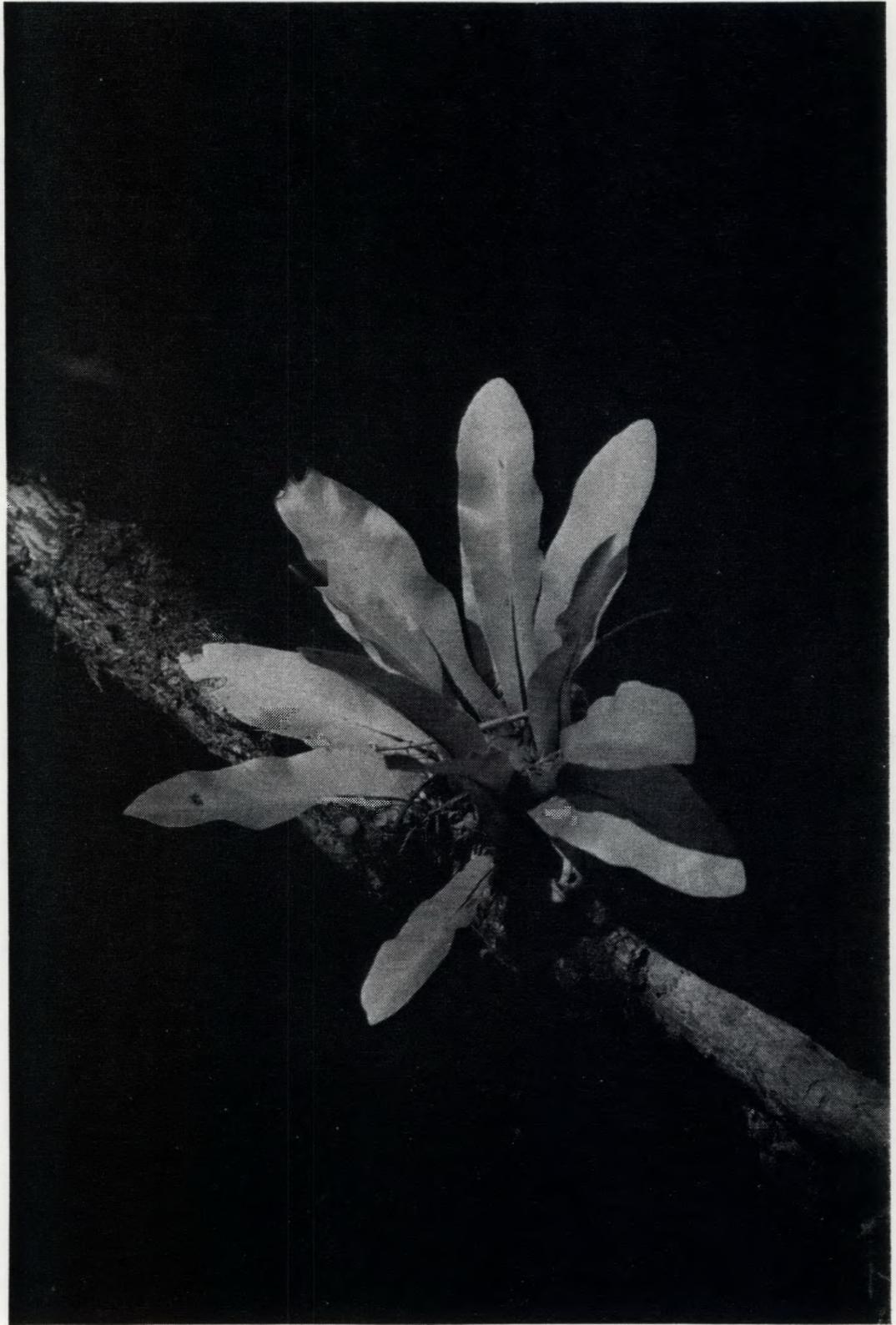


Plate 18. Young individual of Asplenium australasicum in community-type 4 at Wadbilliga National Park.

from other contributing factors which have already been discussed.) Another factor is that many of the subtropical species through which the fertility difference is expressed do not extend to the southern gradsect.

In the Clyde gradsect intermediate-inland section two distinct major low altitude rainforest types were found. The first (community-type 6 dominated by Citronella moorei and Dendrocide excelsa and many subtropical species) occurs on the more fertile soils as described above. The second (community-type 9) which is dominated by Ceratopetalum apetalum, forming structurally simpler forests with fewer subtropical species, occurs on the less fertile soils on Ordovician sediments. This supports the findings in northern New South Wales of workers such as Baur (1957) who claims that C. apetalum is outcompeted by subtropical species on richer soils, but dominates forests on poorer soils.

In the third major northern low altitude community-type 10 Ceratopetalum apetalum is an important component, but is codominant with many tree species. This complex community-type is classified as subtropical/warm temperate and occurs only in the coastal zone at Durras Mountain. It falls on the low fertility side of axis 3 as described in Section 5.6.3. This result was unexpected because it had been suggested (Florence pers. comm., Laut and Basinski 1978, and Russell-Smith 1979) that these soils were enriched by the basalt cap of Durras Mountain. Soil analysis results (Fig. 10) indicated that fertility (in terms of available phosphorus and exchangeable calcium) of these

soils is not high. There is a possibility of poor results because of the limited soil sampling and analysis methods used (see Section 4.3.4) but as methods were consistent over the whole study and two other community-types (5 and 6) produced a positive fertility result it is assumed that poor sampling method can be discounted as an explanation. At worst the method used would only create noisy data within the general fertility trend. This leaves two possible explanations. Firstly the Durras Mountain soils may no longer be enriched from above as the basalt cap no longer exists. The soils are therefore similar to the others on Permian sediments as indicated by the soil results though they may not have been earlier in the history of the rainforests growing upon them. Secondly the warm maritime environment and shelter of Durras Mountain may facilitate high rates of productivity and rapid turnover, with nutrients being present at high levels in biomass but not in soils. The answer to these questions is beyond the scope of the present study.

Considering soil fertility alone in the northern gradsect, community-type 6 (without Ceratopetalum apetalum) is found on rich soils and community-types 9 and 10 (with C. apetalum) on poor soils, where C. apetalum competes successfully with subtropical species. In contrast the difference between types 9 (strongly dominated by C. apetalum) and 10 (dominated by a mixture of C. apetalum and subtropical species) may reflect climatic differences resulting from location. Community-type 10 at lower altitude, at the coast and often having northerly aspects, is likely to be much warmer than type 9. That C.

apetalum is present in type 10 therefore suggests influence of low fertility, and the fact that the subtropical species are present at all suggests that low soil fertility is compensated for by higher temperatures to give a C. apetalum/subtropical mixture.

The difference between the two most complex community-types (6 and 10) is not restricted to presence and absence of Ceratopetalum apetalum. On the other hand there are many similarities such as the presence of Acmena smithii, Doryphora sassafras, Cryptocarya glaucescens and Schizomeria ovata and occasional Ficus obliqua. Community-type 6 is dominated by Citronella moorei and Dendrocnide excelsa along with other species. Although C. moorei was found to be present but rare in community-type 10, D. excelsa was completely absent. In contrast the subtropical palm species Archontophoenix cunninghamiana was present, and also abundant, only in community-type 10. Thus dominance by C. moorei with D. excelsa or by Ceratopetalum apetalum with A. cunninghamiana are mutually exclusive.

Dispersal

Dispersal mechanisms play an important role in species distributions and account for the tightness of some assemblages. A large tree with succulent fruit is likely to attract frugivorous birds such as pigeons and catbirds, as well as the less habitat specific (Osborn 1982) bowerbirds, currawongs, rosellas and parrots. These birds may introduce seeds of plant species from previously visited areas, although there is much

variability in the duration of seed's passage through birds' digestive systems, and subsequent viability (De Vlaming and Proctor 1968; Barlow 1972). The process has the effect not only of spreading succulent-fruited species long distances, but of aggregating them into communities which are more likely to attract frugivorous birds. The previously mentioned single sapling occurrence of Sarcomelicope simplicifolia at Spring Mountain may have resulted from dispersal by a bird attracted to the patch to feed on fruits of Acmena smithii or Ficus rubiginosa, indicating the interdependence between bird-dispersed species and their vectors.

The rainforest patches in the study area are likely to provide islands of the food supply for migratory birds. Occasional Emerald Doves and Rose-Crowned Fruit Doves, which are predominantly northern, have been sighted this far south (Pizzey and Doyle 1980). During the survey a large flock of Topknot Pigeons was observed in the lower stretch of Musgrave Creek, feeding on a very large Ficus obliqua. Other forests with such large figs occur along Currowan Creek and these, along with all the large Citronella moorei, Acmena smithii, Schizomeria ovata, Cryptocarya glaucescens and other succulent-fruited species would provide a significant food source for these pigeons which are believed from observations to be resident in the area (V. Plumwood pers. comm.).

Topknot Pigeons were also observed at Mount Dromedary, and Green Catbirds at Leechey Creek. The Brown Cuckoo-Dove was

observed in a number of areas, including Mount Dromedary where it is resident (M. Dibden pers. comm.) and around Mount Peak Alone. The more generalist Wonga Pigeon was commonly seen and heard throughout the study area.

The inconsistency of environments of sites forming subgroups within community 12a may be explained by chance dispersal factors. Some sites in close proximity or in the same rainforest patch separate to join with others in quite different environments (including different gradsect). Further work could be done to investigate the differences between Acmena smithii-dominated patches and Backhousia myrtifolia-dominated ones by examining the distances separating patches, and the successional process including presence of succulent-fruited species.

Vegetation history

Of particular importance to the present patchy distribution of rainforest is the retreat to sheltered 'refuges' since the last interglacial as a result of increased fire activity and of cold dry climates. Webb and Tracey (1981) stressed the importance of these refuges as a source flora for reinvading surrounding areas as the climate has ameliorated.

Current southern New South Wales rainforest distribution must be considered in the light of both long-term and short-term climatic changes. The period between 1946 and 1976 was a wet one in modern climatic terms (O. Williams pers. comm.) and should therefore have assisted rainforest expansion, through extra moisture availability and expected resultant

reduction in fires. Severe bushfires over recent years (Duggin 1976; Peick 1983) have not only checked this expansion in many places, but also made inroads into well established rainforests, such as those around the Deua River (section 7.2), Mount Dromedary and Mumbulla and Murrabrine State Forests (Floyd 1982). Increasing fuel accumulation as a result of a wet period may however increase fire hazard in the following dry period. Seasonal variability may thus be more important than total precipitation for fire regime. Duggin (1976) says that during the 1942 and 1952 fires "conditions were so bad that many rainforest gullies on Mount Dromedary were destroyed by fire." Only the most protected gullies survived. It seems generally therefore that rainforest distribution has been subjected to a process of fluctuation with long and short-term changes in climate and disturbances, in particular fire. Where undisturbed it is currently advancing in favourable sheltered environments within the study area. The major factors reducing rainforest in the area since European settlement have been early clearing for dairying, and more recently intensive logging operations, and associated changes in fire regimes.

The low, vine-tangled sites of outlier group 5a, some of which contain the exotic Lantana camara, were probably affected in the clearing last century of the Dromedary lower slopes. Another influence of land use of agricultural areas on adjacent rainforest can be seen in a site at Cockwhy Creek where the rainforest margin is abrupt to the extreme of there being a fence line with dense rainforest on one side and cleared grazing land on the other.

7.2.2 Rainforest types

Introduction

The lack of recognition of the variation in and importance of southern New South Wales rainforests can now be replaced by a new understanding of these forests based on detailed documentation. The robustness of different community-types can be measured by their relative cohesion through all the classifications. On this basis the large high-medium altitude community-types 1 to 4 and low altitude warm temperate/subtropical types 5 to 10 are fairly stable. The subgroups of community-type 12 fluctuate through the classifications, and the fact that types 12 and 13 intermix, particularly in the non-tree classification, indicates that tree species make an important contribution to their robustness. Three of the four small community-types (11, 15 and 16) each having only three sites, remain relatively intact (at least two sites) through the different analyses. The implication of this is that these community-types, although small, may warrant full community-type status, rather than being purely ragbag groups. However three sites barely provides sufficient information to justify such a decision. In contrast community-type 14 can be discounted as a non-meaningful type in its own right, warranting status more as a subgroup of community-type 13.

The pool of available subtropical species decreases with increasing latitude (Tables 15 and 16) as was described in Section 5.4 and can be seen from the main classification (Appendix 3). The large number of species reaching southern

limits in or near the study area highlights the biogeographic importance of this area as the cut-off point of the more subtropical rainforest type of the north. It also reflects the artificiality of the New South Wales-Victorian border, which does not reflect biogeographic patterns.

The reduction in subtropical species may be explained in terms of climatic conditions, presumably of cooler temperatures, frosts and reduced rainfall, which are presented in Table 3 and Fig. 2. These may be interacting with edaphic and competitive factors.

Austin's (1978) model of rainforest in southern New South Wales (Figs 5a-c) is reliable at a very broad scale, and can be expanded by information from the present study. That Eucryphia moorei dominates forests over 600 m altitude is born out, as is its co-dominance with Doryphora sassafras in the lower part of its altitudinal range. In the northern area, on sediments, Austin records rainforests between 200 and 500 m altitude as dominated by D. sassafras and Ceratopetalum apetalum plus "other rainforest communities". This can now be elaborated to include community-types 3, 6, 8, 9 and 11, of which three are major types.

In the southern area on sediments the prominence of Acmena smithii-dominated forests at low to intermediate altitudes, and of dry rainforest at lower altitudes, is supported by the present study. The rainforest pattern for Granites is less clear, as shown by Austin, because of agricultural clearing of granite forested areas. Austin's model does not adequately

include the subtropical rainforest on monzonite, which proved to be an important component of the region's rainforest. A further complication is the virtual lack of cool temperate rainforest where it would be expected inland at high altitudes, in the centre of the study area, such as on the Minnuma and Donovan Ranges. In such places of parallel ridge terrain an effective rainshadow may be operating, but it was also evident that at Mount Donovan a severe fire history has destroyed E. moorei forest, and prevented its re-establishment.

Floyd's (1982b, 1982c) model of southern New South Wales rainforests is based on Warm Temperate forest dominated by Acmena smithii with or without Ceratopetalum apetalum (Fig. 01). Decreasing soil moisture leads to Dry rainforest, increasing coastal exposure to Littoral rainforest, increasing soil fertility to Subtropical rainforest, and decreasing temperature and increasing rainfall (due to increasing latitude or altitude) to Cool Temperate rainforest. The present study supports this model, but suggests Doryphora sassafras should be included in the focal Warm Temperate category because it is prominent in forests in the north and south of the region. An additional radius for latitude is suggested in order to account for the loss of C. apetalum from the Warm Temperate forests in the south. This also accounts for the reduction in richness of the Subtropical/Warm Temperate forests, so it is virtually impossible to make a simple model to explain the results of such a complex system of environmental interactions.

Subtropical and warm temperate rainforest

Southern New South Wales contains a mixture of rainforest species from northern and southern floras. The subtropical rainforest provides a large number of species (particularly trees and vines, listed in Chapter 5) which are found in relatively complex forests, mainly in coastal areas, as around the bases of Durras Mountain and Mount Dromedary and in some other sheltered low altitude locations with warm aspects or rich soils. The subtropical/warm temperate community-type 10 exists as well-developed stands of complex notophyll vine forest in the western gullies of Durras Mountain, and contains many species at their southern limit. One such species, the palm Archontophoenix cunninghamiana (Plate 13) is one of the codominant canopy species and is more prominent here than in many stands further north in its range. This makes these stands particularly interesting biogeographically.

The warm temperate/subtropical community-types 5 and 6 are also notable for their number of species at southern limits, the latter particularly, because of its dominance by Citronella moorei and Dendrocnide excelsa specimens of large dimensions. For example the specimen in Plate 9 is at least equal in diameter to the largest recorded D. excelsa specimen in Baur's (1981) list of unusual dimensions of trees in State Forests.

Warm temperate rainforests are dominated by fewer species, occupy less favourable topographic and geographic positions and are less complex. Dominance by Ceratopetalum apetalum at its southern limit in the northern gradsect is of

interest. Dry rainforest occurs in more fire-disturbed locations, as described in Sections 5.3.4.

The structural Table 18 illustrates the characteristics of these forests. They are dominated by species which reach their southern limits within the study area or in East Gippsland in northern Victoria. Table 16 shows the importance of different parts of the study area in this latitudinal filtering of species. Mount Dromedary plays a significant role in the sifting process. One patch segment at low altitude on the southern side of this mountain had the highest segment species number with 65 species, despite the fact that the community-type it is part of only has intermediate mean species per site (33) and total species (88). This may partly be a function of the diversity of environments within this patch, as site 18 on the north facing side of the creek comprised a different species mixture than the two south facing ones in this segment, (although this situation occurred in other patches too).

Many of the subtropical and warm temperate species, such as Acmena smithii and Schizomeria ovata, achieve a role in development of mature rainforest in the study area, but generally function as marginal species further north. This is presumably a result of reduced competition from the profusion of species in the more distinctly subtropical areas of northern New South Wales and southern Queensland. It is interesting to note the two different responses (abrupt or gradual decline) shown by species at their southern limits in the area. Ceratopetalum apetalum, Citronella moorei, Archontophoenix cunninghamiana and Callicoma

serratifolia stop in the vicinity of Bateman's Bay and are very common in places at that latitude to the extent that the former often strongly dominates stands (Plate 12). C. moorei is in places a codominant with other tree species such as A. smithii, Dendrocnide excelsa, and D. sassafras and occasionally with C. apetalum. It was found to diminish in numbers between the Clyde Mountain, which was previously considered its southern limit, and Goodenough Gully at Araluen, its new southern limit, although this is a relatively small distance for a reduction from abundant to absent. C. apetalum is an extreme example, having not been found south of the Clyde Mountain area at all.

The abrupt disappearance of the above species ^{at this latitude} contrasts markedly with the gradual tapering out of many other species such as A. smithii, Cryptocarya glaucescens, Livistona australis, Dendrocnide excelsa and Ficus obliqua. The latter type seems to be reducing gradually through the interaction of limiting climatic factors and competition from other species.

A possible explanation for some species being dominant at their southern limits may be that they have evolved ecotypes which are adapted to the environmental extremes and therefore compete more vigorously in these conditions than their northern relatives would. The reason for abruptness of cut-off is not clear. It can be speculated that distributional boundaries are not in equilibrium with environment, and abrupt species may be advancing south. This hypothesis needs further study. This pattern bears resemblance to the distribution of C. apetalum in northern New South Wales, which is out-competed on rich soils but

becomes dominant on less fertile soils (Baur 1957). A similar pattern occurs in the results of the ordination in this study as discussed in Section 7.2.1.

Cool temperate elements

At the other extreme of environmental conditions in the study area (i.e. at high altitudes and inland) is cool temperate rainforest dominated mainly by Eucryphia moorei (Plate 7). This type of forest occupies the mist belt above about six hundred metres mainly on protected southern and eastern slopes. These southern New South Wales cool temperate forests have been neglected in the literature and it is only recently that their importance (or for many people, existence) has come to light. For example, the recently published (Groves 1981) version of "Australian Vegetation" makes no mention of these forests. The northern tropical, subtropical and temperate forests are well documented in the chapter by Webb and Tracey, and Howard's chapter on southern closed forests documents the Tasmanian and Victorian Nothofagus-dominated cool temperate forests. A large gap between these two major types is filled by the Eucryphia moorei and Elaeocarpus holopetalus forests, but neither of these species is mentioned. The former is listed as "at risk" by Leigh et al. (1981). In "Ecological Biogeography of Australia" (Keast 1981) Webb and Tracey present a comprehensive account of Australian rainforests, but with less attention paid to southern ones than those of the north. In this account E. moorei's role in dominating the southern New South Wales high altitude forests

is briefly mentioned. Baur (1977) describes cool temperate rainforest in New South Wales as dominated by Nothofagus moorei, but this is the case only for a small area in the north of the State. In the same publication Hitchcock (1977) pays little attention to warm or cool temperate forests as his chapter "Rain Forest Types" concentrates on tropical rainforest. This is unfortunate as tropical rainforest is considered by some (e.g. Webb 1959; Baur 1964a) not to exist in the State. Even subtropical rainforests do not comprise the majority of the rainforests of New South Wales. A table of Rainforest Preservation in the State lists Eucryphia moorei as occurring in warm temperate forests. In Beadle's "The Vegetation of Australia" (1981) the role of E. moorei in southern New South Wales cool temperate rainforests is described but with little detail. However the popular misconception that all cool temperate rainforest is dominated by Nothofagus species continues. There is now sufficient information to dispel this myth. Another generalization which should be clarified is that the cool temperate forests are dominated by single-stemmed trees (Specht 1970), which is certainly not true in the case of E. moorei (5.5.1 and 7.2.2).

Eucryphia moorei has a characteristic habit of regeneration by coppicing, successive generations of stems forming concentric rings around the original old stems which are often decayed and gone. Plate 5 shows this habit in the largest (in ground area) individual tree observed in this survey. This habit was also observed in Doryphora sassafras in the cool

temperate forests at the top of Mount Dromedary, and is suggested by Floyd to be a response to very wet, cold conditions. Hore-Lacey (1963) said coppicing in Nothofagus moorei at Point Lookout in northern New South Wales is a cool climate adaptation. Howard and Ashton (1973) found that Nothofagus cunninghamii coppicing increases with increasing altitude (and decreasing canopy height). Johnston and Lacey (1983) claim this suggests that in N. cunninghamii "the development of multiple stems is inversely related to the vigour of the stand, which is in turn related to environmental conditions." E. moorei, in southern New South Wales, shows extreme coppicing in apparently vigorous stands not only in the south of its range, thus appearing to coppice far more readily than either of the Nothofagus species. This contrasts with Johnston and Lacey's statement that this phenomenon occurs near the limits of a species' distribution. E. moorei appears to coppice as a response to death of the original stem through age as well as to disturbance such as fire or wind damage. It may also be a normal process of continual regeneration independent of loss of the main stem. Johnston and Lacey (1983) suggest this regeneration method "compensates for lack of seedling regeneration on the forest floor" and say that the swollen base of E. moorei resembles a lignotuber. Coppice regeneration is an effective mechanism for long-term survival of an individual as well as a community in a particular place but not an effective way of expanding. Floyd (1982) suggests that individuals may survive for thousands of years by this method.

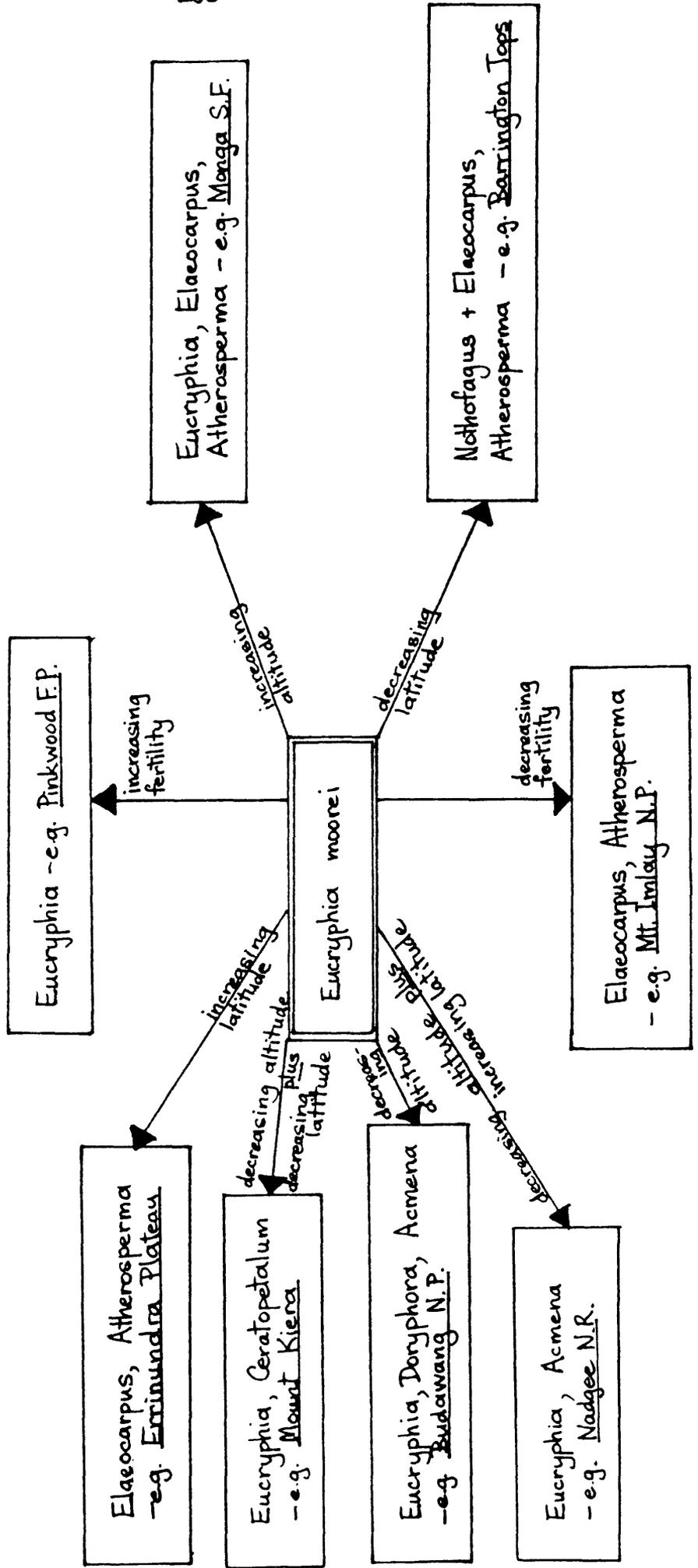
Eucryphia moorei is virtually endemic to southern New South Wales, Victorian occurrences being restricted to the Howe

Range just south of the border. The northern limit is west of Wollongong in the Illawarra area. E. moorei often forms monospecific stands, but is often codominant with Doryphora sassafras. In the very large patch at the top of Mount Dromedary D. sassafras becomes more abundant on the exposed margins and crests, while E. moorei dominated the more cool and moister sheltered environments (Floyd 1982).

Less commonly E. moorei occurs in conjunction with Elaeocarpus holopetalus or Atherospermum moschatum. In the cool temperate stands at the south of its range it is replaced by the latter two species (Floyd 1982). This variation in dominance within the cool temperate forests is described in Section 5.3.2. In the north of its range Eucryphia moorei outcompetes Elaeocarpus holopetalus, always remaining dominant over it, whereas in the south the latter replaces E. moorei (Floyd 1982). Fig. 17 shows the dominance patterns of the cool temperate rainforests of southern New South Wales and East Gippsland.

Elaeocarpus holopetalus extends over a slightly larger latitudinal range than E. moorei, extending from East Gippsland to northern New South Wales (the Dorrigo region) and also extends further west to the Gourock Range. In the north of its range it occurs with Nothofagus moorei, while in the centre it is found either with or without Eucryphia moorei. Floyd (1982) says that in southern New South Wales E. moorei occupies the cool temperate forests on richer soils and E. holopetalus does so on the poorer soils. E. holopetalus does not extend to such low altitudes as E. moorei, being generally above 600 m. Floyd suggests that the

Fig 17 Dominance patterns in Cool Temperate rainforests of New South Wales and East Gippsland.



fleshy, easily-dispersed fruits, large, persistent seeds and robust seedlings confer advantages on this species (with effective bird dispersal, longevity of seeds and less susceptibility to grazing) over E. moorei in the limiting conditions of the southern part of E. moorei's range. Similarly, he says it outcompetes N. moorei in the southern part of the latter's range in northern New South Wales in cold conditions on poor soil. At the southern end of its range, for example on the Errinundra Plateau of East Gippsland, E. holopetalus replaces Eucryphia moorei and becomes codominant with Atherosperma moschatum, whereas at its northern extremes it occurs with Nothofagus moorei. Elaeocarpus species are associated with Nothofagus species in New Zealand and also in New Guinea and Tasmania, but the family Elaeocarpaceae reaches its best development in the tropics (Floyd 1982).

Atherosperma moschatum is a more southern species extending from Tasmania to northern New South Wales in a very scattered distribution. In the south of New South Wales it occurs on the highlands (Geehi, Mount Kosciusko), tablelands and escarpment to Brown Mountain, in the centre in restricted locations of the Blue Mountains, and in the north at the Barrington Tops. Floyd (1982) says it is "unique in being the only tree species present in all three associations of cool temperate rainforest in Australia", growing in different areas in conjunction with Nothofagus moorei, Eucryphia moorei and Nothofagus cunninghamii. It belongs to a monospecific genus in the southern family Atherospermataceae which differs from its

close relative Monimiaceae in having dry fruits and therefore being less easily dispersed. The study area is important as the meeting point of the southern and northern sassafras (A. moschatum and Doryphora sassafras), both being present in forests in the Clyde Mountain region, although never observed in the same stand.

Eucryphia moorei and Elaeocarpus holopetalus form an interesting latitudinal break in the dominance of cool temperate rainforests by Nothofagus species. Tasmanian and southern Victorian forests are dominated by Nothofagus cunninghamii while Nothofagus moorei dominates northern New South Wales and southern Queensland forests. A Eucryphia shrub species has recently been discovered in north Queensland (B. Hyland pers. comm.) another part of eastern Australia lacking Nothofagus at the present time though it grew there until late Tertiary times (Sluiter and Kershaw 1982). Nothofagus species continue to dominate such forests in Papua New Guinea where there are no Eucryphia species. The reason for the replacement of Nothofagus by Eucryphia spp. in southern New South Wales and north Queensland probably lies in the vegetation history of the areas. As the genus Nothofagus once formed a continuous strip down the east coast of Australia (Sluiter and Kershaw 1982; Owen 1975, quoted in Lange 1982) ancestral forms of Nothofagus and Eucryphia would have coexisted in southern New South Wales, although the former was eventually replaced by the latter. Since the breakup of the rainforests during climatic upheavals since the mid Tertiary Nothofagus has not successfully reinvaded southern New South Wales.

Of these two Gondwanic genera ten species of Nothofagus now exist in South America, two in Tasmania and one in New South Wales, while for Eucryphia the distribution is two, two, and one, and now one in Queensland. Within the monogeneric family Eucryphiaceae Eucryphia moorei is the main member in Australia which grows large enough to compete with Nothofagus species. Eucryphia lucida in Tasmania can be found as a tall tree (Curtis and Stones 1967) but generally forms a low canopy on the edge of rainforests (D. Peters pers. comm.). Eucryphia milliganii never forms a tall canopy.

Floyd (1982) presents a hypothesis about the competitive superiority of E. moorei over Nothofagus species through germination and establishment methods. Both Eucryphia and Nothofagus species have wind-dispersed seeds, although those of the latter are less effectively dispersed (Floyd 1982). E. moorei has fruit which are very hard and sharp and often lodge in the fibrous trunks of the tree fern Dicksonia antarctica, which commonly forms an understorey in these forests (Plate 19). Here they have a moist, nutrient-rich medium on which to germinate, free from the competition on the forest floor, and are also more protected from wallaby grazing. Such grazing pressure was often observed on ferns at ground level during the present survey. Seeds germinate, seedlings establish under the rainforest canopy, thus conferring an advantage in obtaining light from gaps and margins. Many large specimens of E. moorei were observed in the study area with networks of roots enmeshing tree fern trunks (Plate 20), indicating its success as a hemi-epiphyte. Floyd (1982)



Plate 20. Advanced 'strangling' regeneration of *Eucryphia moorei* on *Dicksonia antarctica*, Budawang National Park.



Plate 19. Seedlings of *Eucryphia moorei* established on leaning trunk of the tree fern *Dicksonia antarctica*, Munga State Forest.

commented that this method of establishment is more successful on leaning tree fern trunks, because of the increased landing target area and the accumulation of humus. Dicksonia antarctica trunks often lean out like this towards the light at the edge of gaps, which then gives the E. moorei seedling an added advantage. Because it is a hemi-epiphyte relying on its host only for support, E. moorei also occasionally establishes in the litter accumulating on large flat rocks. That D. antarctica trunks provide an attractive medium for germination and growth is evidenced not only by the mass of epiphytes they support, but also by the large number of tree species observed to establish there. It is a common location for germination and establishment for members of Cunoniaceae, a close southern relative of Eucryphiaceae, and also of Quintinia sieberi in Escalloniaceae. The importance of this regeneration method is clear, but less so are its implications for distribution and structure of these forests. One question worthy of further investigation is whether or not E. moorei is limited by the distribution of the tree fern D. antarctica.

By contrast Nothofagus moorei germinates only on bare mineral soil in large openings such as after wildfires, and the seeds have short viability (Floyd 1982). In these circumstances it is likely to suffer from lack of moisture, and also be vulnerable to competition and grazing. Growth is slow, and the seedlings are easily outcompeted.

A feature of the cool temperate rainforests of southern New South Wales and East Gippsland is that many tree and shrub

species reach unusually large dimensions there. This was observed by the author at the Errinundra Plateau and in the study area, and is also documented by Floyd as in Table 24.

Classification problems

The problem of trying to pigeonhole vegetation along gradients has been mentioned in Section 2.1.2 and discussed by Webb and Tracey (1981) with particular reference to rainforest. The classification results can be interpreted at a range of levels, but that which best defines groups identifiable in the field and retains reasonable discrimination, results from a splitting of the dendrogram (Appendix 3). The classification is preferred for communication of the range of rainforest community-types, but similarity and overlap between groups can cause confusion in interpretation of the dendrogram. The ordination is therefore preferable for environmental interpretation.

The 16 rainforest community-types thus produced from these different dendrogram levels include transitional types between the major types described in the results. These community-types can be distinguished, except for site 14, as discussed in the introduction to this Section, and three other small types (11, 15 and 16) which could be considered as successional to types 8, 12c and 9 respectively. Because of their small site numbers, these were discounted as separate rainforest types. This leaves 12 functional community-types. Three of the community-types (5, 8 and 13) could be alternatively regarded as successional to other types but have been given

TABLE 24. Some exceptional dimensions in species of southern N.S.W.
cool temperate rainforests (Floyd 1982)

	Locality	Diameter in cm		Height in m	
		Current	Previous	Current	Previous
Australian Mulberry (<i>Hedycarya angustifolia</i>)	Mt. Dromedary	40	10	20	7
Black Olive Berry (<i>Eleocharis holopetalus</i>)	Brown Mtn. F.R.	200	80	25	25
Blackwood (<i>Acacia melanoxylon</i>)	Mt. Dromedary	100	90	35	30
Howitts Muttonwood (<i>Rapanea howittiana</i>)	Brown Mtn. River	60	25	23	18
Musk Daisy Bush (<i>Chamaecrista</i>)	Mt. Imlay	40	25	15	10
Pittosporum new species	Brown Mtn. River	25	-	18	-

community-type status because of their high site numbers (type 5 has 14 sites and type 13 has 22) or their distinctiveness. For example type 8, although having only six sites, is a very rich warm temperate type on Devonian sediments in which Ceratopetalum apetalum is not dominant. Successional community-type 8 was not clearly recovered in the patch analysis, which suggests it is not a very robust group. It may have been absorbed into community-type 9 because the walk around species list omitted some successional species.

Such a breakdown of groups is inevitably subjective although based on the classification results and knowledge of the vegetation in the field. Groups which can be identified readily in the field are important if the information is to be usable by such groups as management authorities. Although the classification used in this study has attempted to be compatible with other Australian rainforest systems the terms used will always be relative to the area under study in a different way from their relativity over the whole of Australia. For example a 'complex' (CNVF) rainforest in southern New South Wales will never be as complex as some of the more northern ones in terms of number of tree species and life-forms.

The difficulties involved in using classification systems are evident in Table 9. For detailed classification in a region a combination of floristics and structure is desirable. The first two columns of Table 9 present the community-type numbers and climatic-types of the present study. As some climatic types include a number of community-types, reference must be made to

the floristic descriptions of the dendrogram (Appendix 3) to differentiate to community-type level. This problem occurs in all broad-scale classifications - Webb's (1959) structural types, Webb and Tracey's (1981) floristic provinces, Floyd's (1981b, 1981c) subformation approach and the New South Wales (anon. 1981) types. The latter classification, being extremely broad, fails to record much of the variation in the southern New South Wales rainforest types. The floristic alliances and associations of Baur (1957) similarly fail to incorporate the variation in the present study area. The recent descriptive classification by Walker and Hopkins (in press) overcomes this problem by combining structure and floristics, and is also capable of incorporating intermediate and successional types. Unfortunately the long detailed type names produced by this method may be clumsy to use.

7.3 Methodology for Inventory of Patchy Vegetation

7.3.1 Survey design

Mapping

Problems in air photo interpretation stem from age, scale and quality of photography, as mentioned in Section 4.2.3. Time of year and day are particularly important for rainforest interpretation because shadow often masks sheltered locations. Another problem is the definition of rainforest and discrimination between rainforest proper and other dense vegetation such as post-fire Acacia species regrowth (in particular Acacia silvestris thickets as described by Austin (1978)), tree fern forest, and vine tangles where rainforest may have occurred prior to disturbance. Area of rainforest can be deceptive, as found high on Mount Budawang and Mount Peak Alone, and on slopes above Musgrave and Currowan Creeks in the Budawang National Park. In these situations projected area on a map is not representative of real ground area on slope because of steepness of terrain.

Mapping problems can be subjectively evaluated by checking in the field and with maps produced by Austin (1978) and the New South Wales Forestry Commission (anon 1981). The overall pattern of distribution in the area, as mapped by the Forestry Commission, is matched by the mapping of the present study, with some discrepancies in detail. Some inconsistencies appear in the Forestry Commission mapping. Biases were introduced because a number of different people did the air photo interpretation, and possibly because of different quality and age of photography for

different areas. An extreme example is the very sparse representation of extensive high altitude rainforests in the southern end of Budawang National Park as opposed to the extensive mapping of limited rainforest in the headwaters of Coondella Creek, in the Deua National Park. The latter gullies have virtually no rainforest, whereas slightly northwest of them, below the Merricumbene Fire Trail Floyd (1982c) examined well developed rainforest which did not appear on the Forestry Commission maps. In some areas small but distinct patches, mapped and verified in the present study, were not included. In others, small patches which would not qualify as rainforest in the present study, were mapped.

The large gap in mapped rainforest between Bateman's Bay and Moruya, although representing an area of poor rainforest development (as discussed in Section 7.2.1, fire), still includes a number of neglected but significant rainforest patches. This omission probably mainly results from the inability to recognise or accept the vined-tangled rainforest resulting from fire disturbance (Floyd pers. comm.).

The present study was undertaken with preconceived ideas about rainforest extent in the area. The author, although inexperienced in air photo interpretation, knew from observation and the literature that there were many rainforest patches, but the number which appeared on initial air photo mapping seemed unbelievably large. Some patches were therefore mapped as 'possible rainforest', the assumption being that these would prove in the field to be Acacia thickets or rainforest regrowth.

Field checking proved that the majority were in fact rainforest. In very few instances were such patches found ineligible for rainforest classification. One such ineligible patch northeast of Durras Mountain comprised an open eucalypt overstorey above abundant rainforest transitional species. Another near Lyons Road comprised an open sclerophyll forest with dense treeferns. Impenetrable Lantana camara thickets dominated two patches on the northern slopes of Mount Dromedary, but there may have been rainforest at the centre of these patches.

A number of small patches could not be classed as rainforest when visited, because they had been recently badly burnt, and perhaps repeatedly so in some cases. These patches would possibly have qualified as rainforest when the air photographs were taken. They included a patch on the northwest lower slopes of Mount Dromedary, one in the forest about four kilometres to the north and a very small patch north of Mount Peak Alone. Other patches were found to be reduced in size, mainly because of fire. These include two patches running southwest on Mount Peak Alone and one at Sunday Hill in the Wadbilliga National Park. In the latter the limited gully rainforest is now surrounded by Acacia silvestris thicket.

The author's surprise at the extent of rainforest, although at the time already reasonably well informed on the subject, reflects the general lack of knowledge of south coast rainforests. Indeed, on repeated occasions, when discussing this southern New South Wales rainforest project with others (professional as well as lay people) the response was "is there

any?" This results from the lack of work done in the area, with very little other than the superficial rainforest survey in the CSIRO South Coast Study (as discussed in Sections 1.1 and 3.7.2). The situation is changing rapidly as interest in the area and in rainforest in general has developed in recent years, resulting in the Forestry Commission mapping and the survey done by Floyd for the New South Wales National Parks and Wildlife Service.

The extent of rainforest as mapped in the gradsects is fairly accurate. Outside the gradsects the South Coast Study provides a broad guide and the Forestry Commission mapping provides a good generalization of rainforest and indicates a similar overall pattern to that found in the gradsects. The discrepancies between and within the rainforest mapping projects examined highlights the problems of definition, identification, individual bias and dependence on limited air photographic resources. It is concluded from these comparisons that a consistent approach using a single observer for air photo interpretation has advantages. Recognition of patchy vegetation can be improved by use of special purpose air photography, to give more accurate and current information.

Gradsect approach and stratification

The background to adoption of the gradsect approach and stratification on the basis of altitude, geology, geography and patch size is explained in Sections 4.2.3 and 4.2.4.

Latitude

The two gradsects could be assumed to give an indication of latitudinal influence, but it is risky to interpolate between only two areas. More confidence could have been held in the apparently strong latitudinal trends if the third, southern gradsect had been surveyed. Reconnaissance visits to a number of patches outside the gradsects partly compensated for this constraint by providing a subjective picture of the distribution of rainforest types. This was supplemented by Floyd's (1982b, 1982c) recent work in the area. Late in the study period the sampling of 40 field random sites (Section 4.4.3), which all fell either north of the Clyde gradsect or between the gradsects, provided a further check. Latitude, like altitude is an indirect gradient (Austin and Cunningham 1981), affecting vegetation mainly through climatic factors, and its influence on the rainforest distribution is discussed in Section 7.2.1.

Inclusion of latitudinal range in the survey design proved justified, despite its restriction to only two gradsects, because of the large number of species having southern limits in the region.

Altitude

The gradsect method ensured sampling over the altitudinal range, which is reflected in the domination by altitude in the results. Stratification ensured that samples included each of the six 200 m altitude zones.

It may be argued that the use of methods which assumed altitudinal control over vegetation prejudiced results. However,

random sampling without stratification on obvious factors will be inefficient and require larger numbers of samples to reach a similar conclusion. It may also be argued that the result obtained was to be expected. This may be true when there is no replication within strata. Replication should indicate other factors which if important for many sites would influence results. Given the results of species distributions correlated with altitude, it would be alarming if results did not reflect such an obvious environmental influence.

It can therefore be concluded that within the study area altitude is the dominant influence over distribution of rainforest species and community-types and that stratification on altitude proved justified.

Geology

Although at high altitudes the influence of soil parent material was not clear, at lower altitudes clear differences indicated that stratification on geological type was justified. Location of the gradsects was designed to utilize access roads and to incorporate a range of geological types (4.2.4). This location incorporated the rainforest island areas of Mount Peak Alone, Durras Mountain and Mount Dromedary which may all have been excluded had the gradsects been placed differently (as evidenced in the field random sample discussed under sampling omissions). Without these, particularly the latter two which were selected through the maximisation of geological types (and for Dromedary also through presence of higher altitudinal zones in the coastal area), the survey results would have been

significantly different, as these areas represent unusual examples of the subtropical rainforest type for these latitudes.

Although the sites west of Durras Mountain did not prove to be supported by soils of high fertility as had been anticipated, they form a discrete rainforest type for other reasons (e.g. topographic shelter and mild climate as discussed in Section 7.2). It is possible that had these sites not been included by the geological stratification, they may not have been sampled at all, leading to complete omission of an important community-type.

The geological stratification proved justified in ensuring the sample included many rainforest types, which could otherwise have been omitted.

Geography

Geographical location, another indirect gradient, proved to be of importance through the interaction of terrain and climate, e.g. by providing areas of forest in coastal mountainous regions, such as Mount Dromedary, as opposed to inland mountainous areas such as Mount Peak Alone. The inclusion of the small category 'on coast' (see Section 4.2.4) to accommodate the rainforest on the east side of Durras Mountain and at Kioloa did not prove as straightforward as it had seemed, possibly because of the small number of sites involved and because of heterogeneity between these sites. Thus this fourth category within the geographic stratification did not prove justified. However, some of these sites were placed in a subgroup of the warm temperate subformation, which mainly included sites from the

coastal zone with some 'littoral' or 'dry' species. Many of these sites show signs of disturbance with lower canopies and smaller stem diameters than the other warm temperate sites. The other three eastern sites were placed in the Ceratopetalum apetalum-dominated warm temperate group as this species was well-developed in all three. A further influence of geographical location occurs through terrain, with the middle zone containing reduced occurrences of rainforest because of the interaction of its low topography and fire.

Geographical stratification thus proved important in sampling the range of rainforest types.

Size

Patch size appears to reflect a number of environmental factors, in particular terrain and fire regime. There are fewer small patches at high altitudes and inland, where rainforests remain undisturbed for long periods. Patch size showed some correlation with rainforest type, with the largest patches comprising only high altitude forest and the smaller patches predominantly dominated by Backhousia myrtifolia. Its inclusion in the stratification was therefore justified.

Sampling omissions

Some rare species and rainforest communities were omitted by the survey system adopted. The northern gradsect is located just north of the town of Monga. South of Monga, in the Milo Forest Preserve of the Monga State Forest the southern sassafras Atherosperma moschatum was observed in a sparse and

patchy distribution amongst Eucryphia moorei in cool temperate rainforest. This species, which was not found in either of the gradsects, was also found at Brown Mountain by Floyd (1982c), where it grows in association with Elaeocarpus holopetalus. Brown Mountain is located at the southwestern corner of the study area (that is, south of the Dromedary gradsect).

Elaeocarpus holopetalus, which was sampled in the northern gradsect only (on Mount Budawang) and in small numbers, was observed to grow in a subdominant association with Eucryphia moorei in a tall, well developed cool temperate rainforest south of Monga. Floyd (1982c) found this species to dominate the cool temperate forest of Brown Mountain. One sapling of this species was found in the southern gradsect, near sample patches by the Wadbilliga River, in an unusually low (about 300 m) exposed location.. It was assumed that this individual had been dispersed from the well developed E. holopetalus forests observed some seven km away at the top of the Wadbilliga catchment, south of the gradsect.

Eucryphia moorei, which was not found in sample patches in the inland section of this southern gradsect, does occur in the headwaters of the Brogo River, a few kilometres to the south (Blay pers. comm.).

These gaps in the sample are a product of the survey method, and are inevitable because of the rarity of some rainforest types. They do not create serious problems in the broad-scale picture of rainforest type distribution, but cause reduced information on unusual species or types. The selection

of sites to include specific known rainforest types would have destroyed the objectivity of the survey. However, it may have been appropriate to survey such sites as additional to the main sample, as was suggested by Noy-Meir (1971) as a way of coping with this problem. Such inadequacies in survey results also suggest that existing data from other workers should be used where possible as a cost-effective means of supplementing survey data. Visits to patches both in unsampled parts of gradsects and outside the gradsects, although time-consuming, together with information from other workers, gave evidence of the degree of incompleteness. Visits of this kind to Quartpot and Bumbo Creeks and Goodenough Gully played an important role in detecting southern range limits of species which were known to fall out between the two gradsects.

The weakness of gradsect sampling in this study is like the problem of size and location of plots in heterogeneous vegetation, where no matter what method of plot location is used, differences in vegetation dictate that information will be missed. This problem can not be overcome by any sampling method other than a complete census or very large random sample which are both logistically impossible. Rainforest types are scattered in patches over the area, not randomly, but in a pattern controlled by many factors. Any random sample of plots assumes the population is homogeneous subject to random variation. If the population is heterogeneous a random sample is inefficient.

Conclusions

Random sample analyses (6.2.3 and Fig. 15) show that a less clear picture of the distribution of rainforest types is gained by removal of the stratification controls. The discrepancies between results of random subset analyses highlight the role of chance in over or undersampling within heterogeneous vegetation types. These pseudo random samples (Section 4.5.3) indicate that the pattern of rainforest type distribution is less clear than in a sample based on stratification. This result justifies the adoption of stratification. The field random result strongly supports the argument for stratification by failing to recover six of the rainforest types. The severe undersampling of the high altitude types, and complete omission of the subtropical/warm temperate type indicate serious inadequacy, as these are two of the most interesting (biogeographically) types in the area.

The stratified gradsect approach can be considered an appropriate method of surveying the range of rainforest types over the present study region. Minor deficiencies were compensated for by reference to the work of others.

7.3.2 Measurement and analysis

Plot and patch sampling

The collection of data by both plots and patches proved complementary (Section 6.1.3). Although the analysis results did not vary considerably, much additional biogeographic information about species distributions was gained from the patches (Table 25).

TABLE 25. Effectiveness of different samples for recovery of rare species and range extensions

Species	Patch	231	91	41	Southern limit		
					extended	at	near
S <u>Omolanthus populifolius</u>	2	2	2	1			✓
S <u>Rhodamnia rubescens</u>	2	2	2	1	✓	✓	
S <u>Ficus rubiginosa</u>	2	2	2	1	✓	✓	
O <u>Ehretia acuminata</u>	2	2	2	0			✓
O <u>Emmenosperma alphitonioides</u>	2	2	2	0	✓	✓	
O <u>Guioa semiglauca</u>	2	2	2	0	✓	✓	
O <u>Alphitonia excelsa</u>	2	2	2	0		✓	
S <u>Commersonia fraseri</u>	2	2	1	1			✓
O <u>Ficus obliqua</u>	2	2	1	0		✓	
O <u>Quintinia sieberi</u>	2	2	1	0	✓	✓	
O <u>Sarcomelicope simplicifolia</u>	2	2	1	0	✓	✓	
S <u>Myoporum acuminatum</u>	2	1	1	1		✓	
* <u>Diploglottis australis</u>	2	0	0	0	✓	✓	
* <u>Howittia trilocularis</u>	2	0	0	0			✓
* <u>Pennantia cunninghamii</u>	2	0	0	0	✓	✓	
* <u>Trema aspera</u>	2	0	0	0			✓
O <u>Polyscias murrayi</u>	1	2	2	0			✓
+ <u>Endiandra sieberi</u>	1	1	0	0	✓	✓	
* <u>Cyathea cooperi</u>	1	0	0	0	✓	✓	
O <u>Symplocos cochinchinensis</u>	0	2	1	0			✓
+ <u>Melodinus australis</u>	0	1	0	0	✓	✓	

* = only found in patch sampling (5 species, of which 3 are range extensions)

+ = only found in 231, except one also in patch (2 species, both extensions)

O = found in 91 but not 41 (9 species, 4 extensions)

S = found in 41 but as single records (5 species, 2 extensions)

0 (zero) = not recorded

1 = only one record

2 = more than one

On the other hand patches proved less consistent than sites in recording inconspicuous species. The 50 x 20 m rectangular plots proved workable in the field, and similarities between results of patch and patch/site analyses suggest that this size was adequate.

Thus there is a trade-off between recovering detail at a small scale through site recording (as with the inconspicuous high altitude indicator species in Section 6.1.3) or collecting detail at a broad level with recovery of rare species and southern limit information by patch recording (Table 25). A byproduct and disadvantage of the latter approach is the recovery of more generalist and transitional species, which may mask other more informative species. The survey aim should be considered when data collection methods are planned. In this study both methods were appropriate as the general analysis was designed to elucidate patterns in rainforest distribution but information on southern limits and rare species is an important component of the results for conservation planning.

Attributes

The adequacy of the quantitative data was supported by the similarity between quantitative and qualitative results, with interpretation favouring the former as the most ecologically informative (Section 6.1.1). The small amount of extra time involved in collecting the full data set seemed insignificant once effort to get to the patches was expended. Although the use of structural data or tree species only is worthwhile to give a

broad ecological perspective, and for regional studies, (Webb 1968; Webb, Tracey, Williams and Lance 1967, 1970; Webb and Tracey (1981) say "to make the fullest use of the ecological information stored in vegetation patterns it is necessary to examine floristic data". For the purposes of this study the extra floristic information gained justified time spent recording all vascular species.

The abundance rating clearly differentiated sites with common species assemblages (Section 5.3), despite its simplicity. Had an attempt been made to use a more complex ranking scheme, the returns would have been unlikely to justify the extra effort. The basal area measurements made on large trees, which involved considerable time, have not been used in the analysis. These data have only been referred to subjectively in determining detailed differences between some sites. A further analysis using these data could produce more information on dynamics, an area little touched upon within the study.

Thus a more comprehensive picture of species distributions in the study area was gained, and this has already proved useful in conservation planning by the New South Forestry Commission. It has been used in a study by G. Aiken (see Section 2.12). Further use of the data has also been made in a vegetation survey of Budawang National Park (Gilmour and Plumwood, 1982), a study in Kioloa State Forest (Davey and Russell-Smith pers. comm.) and a study of the distributional limits of rainforest plant species (G. Werren pers. comm.). Further information has been made available to an Australian

rainforest study currently being undertaken by Werren et al., and to D. Cameron, who has been attempting to interpret a context for the rainforests of East Gippsland. An even fuller picture would have been provided had the author been sufficiently familiar with the bryophyte flora to incorporate that over the whole survey.

7.3.3 Exploratory data analysis

Classification

The classification using the Bray-Curtis measure and unweighted paired group averages produced a meaningful result. Decisions to use this method were made in Section 4.4.1 on the basis of characteristics of the present data set. Thus no attempt was made to use different analysis methods and compare results. Groups were defined by the dendrogram, but relationships between them became clearer when ordination was used.

Ordination

Principal coordinates analysis (Section 4.4.2) clearly displayed the interrelationships of groups along axes correlating with altitude, disturbance and soil fertility (Section 5.6).

7.3.4 Survey efficiency

Travel time

Section 4.2 presents a justification for incorporation of a variety of methods of data collection on the basis of the large amount of time necessary to conduct even the most basic survey. Table 22 shows a breakdown of time spent in different

survey activities. This does not include preliminary reconnaissance work, investigation of non-sample areas or travel to and from Canberra. It is clear that driving and walking comprised the majority of time in the survey. The only way of significantly reducing travelling time would have been to reduce driving time by systematically working from one end of each gradsect to the other end, instead of working along each gradsect a number of times. This was not considered a real alternative, however, because of the long periods of time involved, requiring regular visits to base locations outside the gradsects in order to replace supplies, refuel et cetera.

Reduced samples

Analyses reducing site number to 91 and 41 (Sections 4.5.2 and 6.2.2) repeated the same basic classification and ordination results in general as the 231 sites analysis. This suggests that for an overall picture of rainforest type distribution, a smaller sample, removing replicates and patch size (Section 4.5.2) would suffice. The interpretation of the 231 sites species-area curve supports this. Planners of this type of survey may be tempted to consider this approach as a way of reducing travelling time. The merits of such an approach should be considered cautiously for two reasons.

First, the reduction in travel time is unlikely to be proportional to the reduction in site number because of constraints imposed by the stratification, which is necessary as seen in Section 6.2.3. It can be argued that time involved in

visiting each gradsect cell is enormous compared to time in sampling a number of 'patches in that cell.

A second argument against reduction of sample size is based on the community-type species-area curves of Fig. 6 (Section 4.4.3). It appears that some community-types at least are not fully sampled even within the 231 site analysis. One reason for this is that for logistic reasons some community-types were combined in this exercise (e.g. 7 and 8, 9 and 10). Although each of these composite types is fairly homogeneous, the differences between their component types (Section 5.3) result in a degree of heterogeneity. The group comprising community-types 7 and 8, reflecting a degree of disturbance, contains many successional and 'weedy' species, which is likely to continue this rise in species numbers with further site increases. Community-type 10 is very diverse and thus many sites would be required to recover the majority of species. The curve for community-types 12, 13 and 14 reached the asymptote well before the final sample, indicating only small differences between sites, but also the large sample number for this group.

A third important reason for concern is that a reduced sample size gives reduced information about rare species and distributional range limits of species. As explained in Section 6.2.2 this information was an important component for achieving the aims of the present study. Although others may believe that for an efficient general survey such information is not of high priority, the argument of efficiency must be re-examined. It has already been shown that this type of survey can not be done

quickly (Section 4.2 and earlier in this Section), and that efficiency has to be considered in relative rather than absolute terms. It may accordingly be argued that in such inaccessible country any efficient survey should obtain maximum possible data as a resource to other interested bodies.

The analyses of reduced and random samples (Sections 4.4.2 and 4.4.3) suggest that a random sampling method within gradsects would produce less informative results (Sections 6.2.2 and 6.2.3) than the stratified one. A random sample over the entire area is likely to be even less satisfactory and would certainly be less efficient because the adoption of gradsects reduced the area to be travelled from 6000 to 1200 sq. km.

Reduced measurements

Analyses of the various reduced forms of data all showed the same general trends as the full 231 quantitative analysis, but with reduced discrimination.

Binary data

Whereas quantitative data emphasize abundant species, presence/absence data place equal weight on all species, as described in Section 6.1.1. The different affinities of community-types 3 and 4 in the binary result stem from the many lower altitude species which are abundant at low altitudes, but only present in small numbers at intermediate altitudes, weighting the binary classification to override the influence of abundant high altitude species. The presence of many uncommon transitional species which would be overridden by dominance of

other species in the quantitative analyses, also influences the qualitative result.

The separation of within-patch sites by the binary classification (Section 6.1.1) may have resulted from small differences in species present outweighing overall dominance. The quantitative result is therefore useful in associating sites on dominance rather than on (possibly) random addition of extra species.

A small gap in the canopy of a tall, well-developed and undisturbed forest may register presence of sufficient successional species to outweigh the general maturity and lack of disturbance. A significant difference between the quantitative and binary analyses is therefore the expression of long-term or short-term dynamics. In the present study the potential for development of different rainforest types under the present climate regime is a major objective although current status is also important. Information on dynamics under different disturbance regimes is of interest, but to be covered adequately would require more detailed analyses.

The problem of separation of sites 123 and 124 (Sections 5.3.2 and 6.1.1) is interesting. This may be a case where a similarity measure using double absences would have been more informative. This is because the species having absences from both sites are lower altitude species, at their altitudinal limit in site 73, and their absence from the two higher altitude sites is therefore ecologically significant.

The internal chaining of community-type 12 in the binary analysis suggests lack of robustness in the three communities 12a, b and c.

The little extra time recording abundance ratings (i.e. less than five minutes per plot when presence/absence data takes about twenty minutes and driving and walking much more) justifies the use of quantitative data.

Tree and non-tree data

The similarity in result of the tree classification and binary one with respect to community-types 3 and 4, suggests that trees are linked with species presences, whereas other vascular species cover more of the influence of abundances. Fern indicators of high altitude affect the quantitative placement of intermediate altitude sites, while the large number of lower altitude tree species affect placement in the binary dendrogram. Thus tree and non-tree analyses can help to explain differences between the quantitative and binary results.

The arrangement of the moderately rich subgroup of community-type 6 (Section 6.1.2) indicates that degree of floristic richness may be more important than gradsect affinities in the non-tree analysis, whereas the quantitative one recovers more gradsect influence.

As community-type 11 disappears in the tree result it can be assessed as not being robust. The lack of cohesion in the dry rainforest group in both analyses suggests again that although community-type 12 is fairly robust its component communities are less so.

The highest altitude sites 123 and 124 are fused in both classifications, as in the binary one, which validates the assumption that the outlier 124 in the quantitative classification should be rotated to join the highest altitude group as described in Section 5.3.2.

The tree and non-tree classifications helped to explain the mechanism of difference between the binary and quantitative results. Tree species data can only provide a broad outline of rainforest types. The use of only tree species as indicators would be valid as a quick survey method over a large area, but for the present study the extra information gained by total vascular species (e.g. on southern limits, but also on species assemblages) has been justified, considering the time getting to and from each plot. Using tree species only, plot floristic time could have been reduced from twenty minutes to less than five minutes per plot.

Vascular, bryophyte and combined vascular/bryophyte data

Section 6.1.4 describes the results of these analyses. The bryophyte dendrogram produces a clearer community-type 1 than either of the others (particularly vascular only) indicating importance of bryophytes in defining this highest altitude group. Had bryophyte data been included in the 231 site quantitative classification fusion of sites 123 and 124 would have been ensured. The intermediate altitude community-type 4 is similarly differentiated more clearly by the bryophyte data.

The bryophyte result is the least clear of all the dendrograms, though still recovering the major general patterns.

The dry and successional group is fragmented, indicating the importance of vascular species in determining this group.

Bryophytes thus contribute significantly to the data, but mainly in the highest altitude community-type.

7.4 Recommendations

Results of the present study provide information enabling the following recommendations to be made on survey methods and data types, as well as management of the rainforest resource. Suggestions for future studies will be included.

7.4.1 Survey methods

The stratified gradsect approach proved valuable as a logistically feasible survey method which sampled patches of rainforest over a wide range of environments in this large study area. This method could be useful in detailed survey of rainforest in areas such as northern New South Wales and Queensland, where the altitudinal gradient is similarly important. It is also appropriate for non-rainforest vegetation as evidenced by a recent survey by Austin et al. (pers comm.) of eucalypt communities on the south coast of New South Wales. Other patchy vegetation types such as swamps or heaths could be effectively surveyed by this method.

7.4.2 Data types

The base data set of 231 sites with quantitative data for all vascular species provided detailed information in the

form of a rainforest inventory for the area. Information on distribution and composition of rainforest types, as well as on distribution of rare species and species' southern limits, together provide background data for conservation planning.

A large proportion of the inventory information could have been recovered by less time in the field, so reduced sampling must always be considered. The purpose of any study should dictate methods selected. If, for example, the area were to be examined as part of a broad survey of the rainforest of New South Wales the level of resolution required may be lower than in the present study. In such a case a base data set of 40 sites (Section 7.3.1) using qualitative data and tree species alone may suffice. Care must be taken to avoid false economy, as dissatisfaction of results of rapid methods may lead to the need for supplementary field work, or to repetition by other workers. It is therefore suggested that in order to maximize the large proportion of travel time in field work (Section 7.3.4) rainforest researchers should attempt to collect as extensive a data set as possible within logistic constraints. This applies equally to surveys of other vegetation types in inaccessible terrain.

7.4.3 Management

The information on rainforest types presented in this study provides a data base for assessment of the conservation status of southern New South Wales rainforest, and subsequently planning for management of this resource. Within the study area

National Parks, Flora Reserves and Forest preserves currently conserve samples of some rainforest types, with varying degrees of protection. Baur (1981) describes the preservation system of the Forestry Commission.

Samples of cool temperate and cool/warm temperate forest are conserved in Budawang, Deua and Wadbilliga National Parks, Milo and Pinkwood Forest Preserves and Mount Dromedary and Brown Mountain Flora Reserves. This seemingly large conserved sample is misleading considering the number of associations within these two community-types. Forest canopy may comprise i. solely *Eucryphia moorei*, ii. *E. moorei-Elaeocarpus holopetalus*, iii. *E. moorei-Atherosperma moschatum*, iv. *E. moorei-Doryphora sassafras*, v. *Elaeocarpus holopetalus-A. moschatum*, or vi. solely *Elaeocarpus holopetalus* (personal observation and Baur 1981). The endemic *E. moorei*, which is 'at risk' (Section 7.2.2) because of limited habitat area, has in past years been logged and burnt, and remains vulnerable to the effects of logging of adjacent sclerophyll forests.

The unique lowland stands of subtropical/warm temperate rainforests in gullies at Durras Mountain (Community-type 10) are located in the Kioloa State Forest and therefore afforded no special conservation status or protection. Stands on the east of the mountain, which are in Murrumerang National Park, are quite different because of the influence of the sea, and do not fall into community-type 10 (except for one in the south at Pebbly Beach).

Examples of the warm temperate/subtropical community-types 5 and 6 are conserved in Budawang National Park, Mount

Dromedary Flora Reserve, and Native Orchid and Wallaby Forest Preserves. Many of the stands of these community-types exist on private property and in Currowan State Forest. Because of the importance of rare species and high number of dominants heterogeneity is great, and few small stands do not representatively conserve the range of associations. The warm temperate type 9, dominated by Ceratopetalum apetalum has a well-developed stand protected in Lyrebird Forest Preserve, but most stands are in the surrounding State Forest.

Although some community-types have stands conserved as described above, these were mostly allocated before information on the community-types and their place in the Australian rainforest vegetation was documented. Thus reassessment can now be made to determine representativeness of conserved samples and the need for new or extended conservation areas.

An important aspect of conservation is education of the general public, as conservation areas are often also used for recreation. People need to be aware of the importance of their rainforest resource so they can contribute to its management. A continuing problem is the vandalism of rainforest patches for sale of epiphytes and ferns (Section 3.6.2). It may be argued that this would increase as more people know more about rainforests, and it is policy of the major management authorities to keep recreation areas separate from specific nature conservation areas where possible (Baur 1981). However, it is the belief of the present author that education by dissemination of appropriate information should change values and decrease this problem.

Although the rainforests in the study area are no longer subject to direct logging (Section 3.6.2) they are indirectly influenced by management programmes in surrounding sclerophyll forests. As prescribed burning regimes also affect rainforest boundaries (Section 7.2.1), planning for logging and burning must be done in conjunction with conservation planning.

7.4.4 Future studies

A third, more southern gradsect (as originally planned, see Section 4.2.3), while extending the study area to the Victorian border, would also enable more confidence to be placed in the latitudinal interpretation.

The data could be used to create a predictive environmental model for rainforest in the area by interpolating between gradsects. This model could be tested by a field sample. Conservation status and condition of all rainforest types should be assessed.

Studies of the rainforest/sclerophyll forest margin in southern New South Wales would provide information on dynamics.

Analysis using the stem diameter data collected during the present study should also shed light on the rainforest dynamics.

More detailed work on the history of rainforest in the area would allow better understanding, through its current and previous extents, of rainforest ecology.

More detailed soil and hydrologic studies may yield additional information about the important roles of soil

nutrients, moisture and fertility in determining presence of rainforest and distribution of types.

Study of dispersal, germination and establishment methods should help to explain the patchy distribution and viability of small rainforest patches. Similar studies of the cool temperate tree species may assist in interpretation of the disjunctions in dominance in this rainforest type along the eastern Australian coast.

CHAPTER 8 CONCLUSIONS

The study aimed to survey the little-known rainforest vegetation of southern New South Wales. Vegetation classification (Chapter 5) and discussion (Chapter 7) indicate that the south coast rainforests fall into 12 major floristic community-types. Their distribution correlates strongly with the indirect environmental gradients altitude and latitude, and to a lesser extent with disturbance, soil moisture and fertility, and proximity to coast.

These findings provide the first detailed account of rainforest in the region, and highlight its uniqueness. The cool temperate rainforests at the top of the altitudinal gradient are dominated by Eucryphia moorei which is endemic to this area and listed by Leigh et al. (1981) as 'at risk'. At low altitude, and in the north in the sheltered environment of Durras Mountain subtropical/warm temperate rainforests harbour many species at their southern limit.

Altitude is the major environmental factor controlling distribution of rainforest types in the study area, through the interaction of rainfall, temperature and topographic shelter. Latitude, through the influence of temperature in conjunction with competitive and other factors, is important in the filtering of subtropical species, with 68 at their southern limit in the study area. High disturbance levels, in particular fire, maintain some rainforest types in successional states. Amongst less disturbed types soil fertility and proximity to coast separate species-rich, complex types from species-poor, simple types.

The survey method developed to sample this patchily distributed rainforest vegetation was concluded to be appropriate (Chapter 7). The use of gradsects, while reducing the area sampled for logistic reasons, ensured adequate sampling along the altitudinal gradient. Stratification recovered samples on a range of geological types and from several geographical zones which proved important. The disturbance factor, which also proved important despite its not being incorporated in the stratification, was so widespread that sampling would inevitably include it. Random sampling proved inferior to stratified sampling in recovering the range of rainforest types, thereby justifying the stratification. Whilst samples reduced to 41 sites recovered the general trends in rainforest type distribution, they failed to recover detail. Most significantly they failed to recover a large proportion of the information on southern limits (Chapter 6).

The survey methods are concluded to be appropriate for other surveys of patchy vegetation types, and therefore a useful approach for management planners. With this new information on southern New South Wales rainforest types, representativeness of the types in current conservation areas can be assessed. Management planners will be able to determine conservation priorities, leading to protection of important samples in new or extended conservation areas. A further management implication is the question of protection of rainforest patches in areas under prescribed burn regimes. New survey and analysis methods used in the study contribute to general ecological research in the field of vegetation survey and analysis.

Important forest types revealed by the inventory

include:

- i. the endemic cool temperate and cool/warm temperate rainforest types at high altitudes;
- ii. the subtropical/warm temperate rainforest type in the Durras Mountain area, containing many species at their southern limit;
- iii. the warm temperate/subtropical rainforest type, with a number of species at their southern limit, and dominated by very large tree specimens;
- iv. the warm temperate stands in the northern area, which are dominated strongly by Ceratopetalum apetalum at its southern limit.

Not all rainforest types are adequately represented in National Parks, Nature Reserves or Flora Reserves, though some are protected to a degree in Forest Preserves. Much rainforest has been destroyed in the past by human activities. Although there appears to be a general expansion of surviving rainforest patches in the area under the present climate and land use, there remains cause for concern over vulnerability of small patches under current fire regimes.

The present study thus stresses the importance of the unique array of rainforest types in southern New South Wales. This information is offered as a contribution to our knowledge and understanding of Australian rainforest distribution, composition and ecology at a time when attempts are being made to assess remaining resources and plan for their appropriate management.