CHAPTER 4 SURVEY DESIGN, DATA COLLECTION AND ANALYSIS METHODS

4.1 Introduction

By reference to the literature reviewed in Chapter 2 appropriate methods for the present study can be selected. Major problems faced in the design of the survey are:

a) the large size of the study area (approximately 20 000 sq. km) throughout which rainforest occurs in unevenly distributed patches.

b) the remoteness of much of the study area, with few access routes and extremely rugged terrain.

c) the range of gross environmental variables distributed unevenly through the area, with rainforest patches unevenly represented in different environments.

d) the fact that some rainforest patches span more than one altitudinal or geological zone.

e) the small-scale within-patch heterogeneity; many patches are long, narrow strips along gullies, with changes in dominant species correlating with environmental changes, such as at gully junctions or heads.

f) definition of rainforest, proposed definitions probably being nearly as many as rainforest workers. The diversity of rainforest communities in Australia requires workers to clearly define their use of the term "rainforest", so their work can be communicated to others and used for comparison.

4.2 Survey Design

4.2.1 Subject domain: definition of rainforest

The study aims to examine "properties, patterns and processes" (Noy-Meir 1970) involved in floristic variation between and within the rainforest patches. Of primary importance therefore is floristic diversity, and any environmental factors contributing to this.

Problems in rainforest definition are presented in Chapter 2. Specht's (1970) "closed forest" provides a start, by being restricted to tree-dominated vegetation with greater than 70% projective foliage cover. For the purposes of this study 'rainforest' is defined as closed forest of generally broad-leaved species, with a variety of the following life-forms in different combinations - epiphytes, lianes, ferns, palms, bryophytes, strangler figs, and buttressed trunks. Generally the canopy trees are non-sclerophyllous (e.g. not eucalypts or acacias), mesic species. However, the more sclerophyllous *Backhousia myrtifolia*-dominated communities have been included for the following reasons.

a) They resemble the rainforest communities more than the eucalypt communities on aerial photographs.

b) They form mixtures with other rainforest tree species as well as forming monospecific (in dominance) stands in places.

c) They include many of the rainforest life-forms and species such as epiphytes, lianes, ferns and bryophytes.

d) They often have virtually no shrub or ground layer, but considerable litter and humus.

e) They have been neglected in the past by being considered neither one nor the other forest type.

f) They occur in sheltered environments as do the other types of rainforest.

The rainforest patches show a range of apparent stages in succession and interaction with disturbance regimes. Where a closed canopy of young trees of rainforest species occurred below occasional old emergent eucalypts it was classed as rainforest.

The margin is an integral part of the rainforest, to the extent that it is often difficult to delineate it from the rainforest proper, and a continuous mosaic process of regeneration results in the scattering of marginal species throughout the rainforest. Any decision not to include such species would have to be implemented at the individual plant level, following a decision as to what constitutes a 'rainforest species', because rejection of parts of the forest on a micro-scale would not be feasible. On a broader scale subjective decisions were made in the field for rejection of large disturbed areas, or transitional zones in which the canopy comprised non-rainforest species. In all other circumstances transitional species were included. To ignore them would have resulted in a misleading account of the composition of these dynamic forests. When an occasional non-rainforest species (such as a eucalypt) occurred, it was recorded. All vascular species and bryophytes were sampled, but the study does not extend to lichens or other thallophytes, or to fauna.

4.2.2 Areal domain

The large extent of the study area (southern New South Wales), its nature - including large tracts of country with few access roads (Section 3.3) - and restrictions of time and other resources, dictated that study and sampling areas be defined. A natural reduction to sample only the "south coast" is enforced, because rainforests only occur in the strip between the coast and escarpment.

Rainforest communities between Sydney and Milton have been documented over the years, albeit in an uncoordinated fashion. By exclusion of that area, the planned study area was reduced by half and confined to that southern portion between Milton and the Victorian border in which rainforest had virtually been ignored. Logistic problems resulted in the eventual exclusion of the southern section between Mimosa Rocks National Park and the Victorian border, to reduce the final study area to that between Milton and Mimosa Rocks (Fig.1).

Two approaches to further reducing the sampling area were considered - random sampling and stratification. Sampling sites could either be sparsely and randomly scattered over the entire area, or sections could be sampled more intensively by the adoption of the gradsect method (Section 2.2.1) as a form of geographical stratification. The nature of the study area, which covers almost the same area as the South Coast Study (Austin and Cocks 1978), and resultant access problems, along with the need for a method which samples a wide range of environments, suggested adoption of gradsect sampling.

4.2.3 Gradsect sampling

A series of gradsects (A. Gillison and K. Brewer pers. comm., see Section 2.2.1) - or altitudinal transects - running from coast to escarpment and located at increasing latitudes, suggested itself for maximization of altitudinal and latitudinal ranges covered in the present study.

Location of gradsects could be random, but selection to facilitate access and maximize the range of geological types would be advantageous. Replication (where possible) of geological types between gradsects could be managed and was essential for purposes of comparison.

An exercise comparing randomly located, systematically located, and selected gradsects (based on logistics as described above), as well as random transects, was undertaken. A Land Systems map from the South Coast Study indicates the range of environments to be sampled. These land systems are based on geology, terrain and vegetation (Austin and Basinski 1978). Gradsects and transects of 15 km width were located on the map. Only one set of three selected altitudinal gradsects (chosen for logistic reasons and to maximize geology) was available. Five sets of three random transects (i.e. in any direction), five sets of three random altitudinal gradsects (from random points along a coastal baseline), and five of three systematic altitudinal gradsects, (located at regular, but different from set to set, intervals along the coast), were drawn. The random transects were located by the following method. The study area was enclosed in a circle; a random number between 0 and 360 was determined, and the circle bisected using this angle; a random point along this diameter was determined; from this point a line drawn at right angles to the diameter became a transect.

These sets were compared for the number of land systems sampled. Results favoured first the logistic gradsects, which recovered 52 of the 55 land systems, then systematic gradsects, which recovered a mean of 44.8 (Table 5). A further test compared systematic gradsects of five, ten and 15 km width, and logistic gradsects of less than one km width and five, ten or 15 km width. These results are presented in Table 5.

The number of Land Systems sampled increased markedly between gradsects of less than one km width (32) and those of five km (total 43). A smaller, though still large increase of six land systems occurred between five and ten km gradsects. The yet smaller increase in information gain (three new land systems) between ten and 15 km width may be interpreted as insufficient to warrant the extra area to be sampled, depending on the aims of the survey.

If the gradsect approach was to be adopted in the current survey, three 15 km wide gradsects, totalling 45 km in width, would cover nearly a quarter of the planned study area. Only a small proportion of each gradsect is rainforest, and within that only a proportion of the patches would actually be sampled.

In view of the unique nature of the present study, with its development of appropriate survey methods, the need for a good regional survey of rainforest, and the large component of

TABLE 5. Number of land systems (out of a possible total of 55) recovered by different sampling methods

a. GRADSECTS AND TRANSECTS OF 15 KM WIDTH		Number of landsystems in each transect/gradsect															Mean of five sets	Standard deviation	Standard error of mean
Sample (or replicate) number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15			
Logistic gradsects	individual	24	31	28													'52'		
	*total		52																
Random transects	individual	27	41	14	37	28	17	31	34	20	31	28	17	8	20	38	43.6	4.61	2.06
	*total		46			43			50			38			41				
Systematic gradsects	individual	24	29	29	29	26	34	28	32	32	29	29	36	27	33	25	44.8	3.96	1.77
	*total		40			44			45			44			51				
Random gradsects	individual	29	27	30	27	31	28	31	31	29	31	26	31	29	29	29	41.6	1.82	0.81
	*total		42			41			44			39			42				

* Total land systems for set is not the same as the sum of the three samples within the set, because of the duplication of sampling some systems within each set.

cont.

TABLE 5 - Page 2

Sample (or replicate) number		Length of transect/gradsect (km) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Mean length of five sets
Logistic	individual	38	64	36													'138'
	total		138														
Transects	individual	62	118	33	110	74	27	65	109	38	102	66	59	21	38	118	208
	total		213			211			212			227			177		
Systematic	individual	59	48	55	64	50	54	58	50	55	64	53	54	63	50	38	163
	total		162			168			163			171			151		
Random	individual	64	48	50	59	54	58	50	64	64	56	59	51	64	63	48	170.4
	total		162			171			178			166			175		

cont.

TABLE 5 - Page 3

b. LOGISTIC AND SYSTEMATIC GRADSECTS OF <1, 5, 10 OR 15 KM WIDTH		Number of land systems in each set of transects/gradsects															Mean of five sets
Sample (or replicate) number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Logistic	<1 km		32														'32'
	5 km		43														'43'
	10 km		49														'49'
	15 km		52														'52'
Systematic	5 km			32		40			46			34			45		39.4
	10 km			38		43			49			41			46		43.4
	15 km			43		44			52			44			49		46.4

travelling time (both driving and walking) which could not be reduced, the large gradsect width seemed of little detriment. It was decided to ensure adequate sampling by using the 15 km gradsect width. Tests were planned to indicate efficiency of sampling, to lead to suggestions for modification of methods for future surveys (Section 4.5).

Two gradsects were sampled; a third, more southerly gradsect in the Eden area could not be attempted due to logistic and time constraints. This left a final study area of 150 km x 40 km, of which the two gradsects total one fifth (Fig. 1). The northern gradsect was located to take advantage of the access provided by the Clyde Mountain Road. Further south, the Dromedary gradsect was relatively accessible by the Wadbilliga road, but large parts of it were inaccessible.

Like Noy-Meir (Section 2.2.1, stratification and random sampling) the present author decided that periodic environmental variation coinciding with study transects would not be a problem, as the only detectable pattern of this kind was related to latitude, an important component of this study. The need to know relationships between properties of interest within the reduced sample and the whole domain (Noy-Meir 1970) would not be a problem in the present study because of the information provided in the South Coast Study (Austin and Cocks 1978).

4.2.4 Stratification and random sampling

From the surveys examined in Section 2.2.1 it becomes clear that in large scale surveys some form of stratification is needed to reduce the survey to a representative sample for measurement. An environmental stratification was necessary to ensure sampling in different combinations of altitude, geology and geographic zone. This contrasts with Noy-Meir's stratification on vegetation physiognomy, but is similar to the South Coast Study approach, except that the latter used a two level spatial stratification.

Rainforest patches in each of the gradsects, interpreted from black and white aerial photographs at a scale of 1:25 000, were mapped onto 1:25 000 topographic map sheets (Appendices 1 and 2). Field reconnaissance trips established particular problems for methodology in the study area, some of which are listed in Section 4.1. Accuracy of air photo interpretation was checked on the ground and found to be good.

In order to ensure that sampling included the maximum range within gross environmental variables, the gradsects were stratified on the basis of altitude, geology and geographic zone, (proximity to coast), as in Figs 3 and 4.

1:100 000 contour maps show the altitudinal range in the gradsects to be from sea level to over 1300 m on Mount Budawang, but no rainforest occurs above 1200 m. Altitude was therefore divided into six 200 m zones, which can be seen in Appendices 1 and 2.

Geological maps at 1:100 000 scale and the South Coast Study report (Galloway 1978) provided information for the geological stratification, with seven types recognized for the Clyde gradsect and four for the Dromedary gradsect. Only two geological types were common to both. The South Coast Study emphasizes lithology, which may be considered more important for the current survey than just the stratigraphic data provided by the geological sheets. The sites around the base of Durras Mountain, although on Permian sediments, were treated separately as potentially basalt-enriched sites because of the occurrence of a basalt cap on the mountain.

Geographically the gradsects were divided into three approximately equal categories of distance inland and terrain type representing: 1) the coastal lowlands, (incorporating Durras Mountain and Mount Dromedary), 2) the foothills area of medium relief (and Mount Peak Alone), and 3) the steep escarpment country. Natural apparent boundaries were used for all the categories (Figs 3 and 4, and Appendices 1 and 2). In the northern gradsect the broad Clyde River valley running north/south separates the lowlands and foothills, while a north/south fault delineates the escarpment area. In the southern gradsect, categories (and particularly the escarpment edge) are less clearly defined, with the north/south Yowrie-Wadbilliga River valleys roughly defining the escarpment zone, and the Jeffers Mountain Range separating lowland and foothills.

Early field work indicated another category may be necessary in the Clyde gradsect, as the rainforest floristics on the eastern side of Durras Mountain (i.e. adjacent to the sea) appeared to be different from that on the western side. A fourth geographical category 'on coast' was then introduced to ensure sampling in this littoral environment.

Table 6 summarizes stratification categories.

TABLE 6. Stratification categories

GRADSECT :	Clyde (North), Dromedary (South)	
ALTITUDE :	1. 0 - 200 m	4. 601 - 800 m
	2. 201 - 400 m	5. 801 - 1000 m
	3. 401 - 600 m	6. 1001 - 1200 m
GEOLOGY :	1, 2, 3, 4, 5, 6, 7, 8, 9 (Table 4)	
GEOGRAPHY :	1 Coastal (Lowlands)	
	2 Intermediate (Foothills)	
	3 Inland (Escarpment)	
	(4 coast - Clyde gradsect only)	
PATCH SIZE :	1 small	
	2 medium	
	3 large, elongate	
	4 large, round	

Absolute potential strata :	1080	
minus Non-existent strata	852 -	
	228	
minus Non-existent rainforest (60)		
Inaccessible rainforest (16)	76 -	
	152	
minus Missing sizes	67 -	
	85	SAMPLED STRATA

(Of the 85 sampled, 27 included replicates.)

Patch size was included in the stratification because of its potential (along with isolation) for island biogeographic analysis. It is possible that different sizes support different numbers (and possibly different types) of species. It had been considered that the rainforest patches might be used to test the appropriateness of the equilibrium theory of island biogeography (MacArthur and Wilson 1967) for mainland habitat islands, so a review of the literature was carried out (e.g. MacArthur 1972; Simberloff 1974, 1976; Diamond 1975, 1976; Gilbert 1980). It was decided that rainforest in the present study would not suit such an analysis because of the complex interaction of many factors influencing the many rainforest types. Some rainforest types have low species numbers irrespective of patch size. The edge effect may dictate that small patches in disturbed areas have large numbers of additional 'marginal' species. Number of species may also reflect degree of heterogeneity.

Following examination of the range in patch size within the gradsects four size categories were subjectively determined. These are "small" (less than 40 000 sq. m) "medium" (40 000 to 160 000 sq. m), "large" (greater than 160 000 sq. m, elongate) and "extra large" (greater than 160 000 sq. m, not elongate). The latter two groups were separated because elongate patches could be expected to suffer considerably more edge effect than the broad ones. These size categories were determined on the basis of patches in the study area, and therefore the names have meaning only in the context of this area. The actual sizes may however be useful for comparison with other areas, although the fact that the vast majority are narrow strips must be taken into account.

Selection of 'typical' stands is often used in rainforest studies (e.g. Floyd 1982; Austin 1978). In the context of the diverse rainforest types, aesthetic value judgements (Noy-Meir 1970) could easily influence such selection by biasing towards the more structurally complex and floristically diverse types.

Random or stratified random sampling has been described in Section 2.2.1 as valid on statistical grounds. Within the present study area containing strata of unequal areas, area proportional sampling would be appropriate. However the large number of strata dictated that by taking even a minimal sample of one site per stratum (plus replicates where possible) a total of over 200 sites would be recorded. For logistic reasons a larger sample could not be considered. Thus the stratification and logistics prevented a statistically valid random sample, but location of sample patches within strata was random. In ecological studies this is a constant problem, but the appropriate use of insight in such samples is a valid approach, as long as results are interpreted accordingly (P. Diggle pers. comm.).

Within each stratum, patch(es) to be sampled were determined by the following method. All small patches within the stratum were numbered consecutively. Random number tables produced the sample patch numbers. Where a stratum contained between five and 30 patches a replicate was selected randomly, where more than 30 patches two replicates were selected, but for fewer than five no replicate was sampled. Replicates were considered necessary because of possible differences in patches due to chance, historical factors, or other environmental variables not included in the stratification. This process of random patch selection was repeated to determine the medium, large and extra large patches to be sampled. Table 7 lists strata with number of available patches and number of patches and plots sampled.

Single phase sampling was selected as opposed to Noy-Meir's double phase, because of the unevenness of distribution of rainforest environments, and a decision not to set up permanent plots. Repetition in sampling to cover seasonal changes would not be necessary as annuals are generally absent and rainforest species can be identified by vegetative characters. The nature of the present study region dictated that it would be impossible to reduce travelling time to equal sampling time (cf. Noy-Meir). The only time limits for field work would therefore be those involved in fitting into the total study framework, availability of equipment, particularly four-wheel drive vehicles, and avoiding bad bushfire seasons.

4.3 Measurement

The literature presents much discussion on the relative merits of floristic and structural data, qualitative and quantitative data, canopy trees and other synusiae, as well as plots and plotless sampling and the size and shape of plots,and

TABLE 7. Strata and the number of patch segments sampled

Samples - 1, 2, 3; Non-existent strata - Blank; Non-existent rainforest - #; Inaccessible rainforest - x.

ALTITUDE (m) / GEOGRAPHY (1 - 3) / PATCH SIZE (1 - 4)

Altitude 0 - 200:

Geology/ Gradsect		1				2				3			
		1	2	3	4	1	2	3	4	1	2	3	4
1 ?Basalt-enriched	C	3	3	1									
	D												
2 Permian sediments	C	1	1	1									
	D												
3 ?Cambrian sediments	C	1	1										
	D												
4 Ordovician sediments	C	2	2	1		2	2	2					
	D	3	3	2		3	2	2		x	x	x	x
5 Devonian volcanics	C									1		1	
	D												
6 Devonian sediments	C											1	
	D	1											
7 Essexite	C	1											
	D												
8 Monzonite	C												
	D	1		2									
9 Granite	C									#	#	#	#
	D					#	#	#	#	#	#	#	#

Altitude 201 - 400:

Geology/ Gradsect		1				2				3			
		1	2	3	4	1	2	3	4	1	2	3	4
1 ?Basalt-enriched	C												
	D												
2 Permian sediments	C												
	D												
3 ?Cambrian sediments	C												
	D												
4 Ordovician sediments	C					3	2	2					
	D	#	#	#	#	1	2	2		1	1		
5 Devonian volcanics	C									1	1	1	
	D												
6 Devonian sediments	C									1	3	3	1
	D									1	1	1	
7 Essexite	C												
	D												
8 Monzonite	C												
	D	1	1	2									
9 Granite	C									#	#	#	#
	D					x	x	x	x	1	2	1	

Altitude 401 - 600:

Geology/ Gradsect		1				2				3			
		1	2	3	4	1	2	3	4	1	2	3	4
1 ?Basalt-enriched	C												
	D												
2 Permian sediments	C												
	D												
3 ?Cambrian sediments	C												
	D												
4 Ordovician sediments	C							1					
	D					1	2			x	x	x	x
5 Devonian volcanics	C									1	1		1
	D												
6 Devonian sediments	C											1	1
	D									1	1	1	
7 Essexite	C												
	D												
8 Monzonite	C												
	D	1	1	1	1								
9 Granite	C									#	#	#	#
	D					1	1				1		

cont.

TABLE 7 - Page 2

ALTITUDE (m) / GEOGRAPHY (1 - 3) / PATCH SIZE (1 - 4)

Geology/ Gradsect		601 - 800												801 - 1000												1001 - 1200											
		1				2				3				1				2				3				1				2				3			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1 ?Basalt-	C																																				
enriched	D																																				
2 Permian	C																																				
sediments	D																																				
3 ?Cambrian	C																																				
sediments	D																																				
4 Ordovician	C										1											1	1														
sediments	D						1			#	#	#	#						1			#	#	#	#									#	#	#	#
5 Devonian	C										1		2																								
volcanics	D																																				
6 Devonian	C									1	1	2										1	1	1												1	
sediments	D									x	x	x	x									#	#	#	#									#	#	#	#
7 Essexite	C																																				
	D																																				
8 Monzonite	C																																				
	D			1	1									#	#	#	#																				
9 Granite	C									#	#	#	#									#	#	#	#												
	D										1																										

these have been investigated in Chapter 2. The purpose of a survey should dictate the method used where there is evidence that one method is superior. Time constraints are also important. In the heavily field-oriented present study it seemed sensible to utilize time in the field to gain maximum information.

As the major aims of the current study are twofold (i.e. description and methodology) no single method may be adequate. The experimental nature of the methodology in the study provided an opportunity to further test some measurement problems in a little studied rainforest region.

4.3.1 Patch versus plot sampling

Patch or plot advantages

Reconnaissance field trips revealed that differences in microclimate favour certain species in localized concentrations, and historical or chance factors in regeneration and dispersal, together with available flora also control distributions. Within the study area some more diverse rainforest types form a continuous floristic mosaic of the type described by Herbert (1960), while some simpler types show disjunct heterogeneity. For example dry rainforest of monospecific canopy dominance by *Backhousia myrtifolia* contains small pockets where *Acmena smithii* replaces *B. myrtifolia*. Such marked differences appear to relate to drainage and soil moisture (and perhaps also fire protection), and had to be taken into account in field location of plots.

Results gained through compiling a species list from plots may therefore be less comprehensive than a less quantifiable "walk-around" list, which may provide more information on rare species and also give a more representative species list. A general list covers a larger area with possible loss of detail, but more opportunity to record rare species. On the other hand by working within plots one may be forced to pay more attention to detail, accuracy and precision, thus increasing accuracy in the more restricted sampling area. Both approaches were therefore adopted.

Plot location and number

If plots were to be used, the choice of plot location presented a problem as discussed in Section 2.2.1 regarding Orloci and Stanek (1979) and Noy-Meir (1970). It is difficult in the field to ignore vegetation and choose a site solely on the basis of environment. Selection influenced by vegetation is subject to biases, such as oversampling outstandingly different, unusual or spectacular areas.

Within the diversity of rainforest types, one plot per patch would give a representative and comprehensive species list for some types but not others. However, if extra plots were allocated to more diverse rainforest types they would be unduly weighted in the overall distribution analysis and description.

One plot in a small patch is more likely to be representative than one in a large patch of the same rainforest type. As large patches are more likely to be heterogeneous, it was decided to increase the number of plots with patch size. One plot was allocated to a "small" patch, two to "medium", three to "large" and four to "extra large" patches, (the Section on patch size and shape will explain patch sizes). This was the result of a subjective decision based on practical grounds and in no way attempted to parallel the actual area increase in patch size. The extra weighting given to larger patches in the overall analysis can be considered justifiable because of their greater contribution to the extent of rainforest and their greater potential heterogeneity.

Methods used by Noy-Meir (1970) and Orloci and Stanek (1979), of working from a road baseline, would not be appropriate in the terrain of the present study, where most of the patches are long distances (and elevations) away from roads. The variation in depth of rainforest margin zone, as well as environmental heterogeneity within patches, increased the problem of subjectivity in plot placement. As was done by Noy-Meir, guidelines on maximum distance from vehicle to any patch were set - one km on the map in this case. However, flexibility was required in use of this rule, or some rainforest types would have been completely omitted on access grounds. If a number of patches could be sampled in an area more than one km from the road they were included, by pooling the walking time. This permitted overnight trips into more remote areas.

Within a patch or segment (Section 4.3.2) plots were placed subjectively, to minimize within-plot environmental heterogeneity while maximizing within-patch heterogeneity such as topographic shelter or aspect. In small patches the single plot was placed along the contour, low on the south-east facing slope where possible, in order to have some consistent basis for comparison between patches. In larger patches the first plot was located in the same low south-easterly position, but extra plots attempted to include environmental variation. In many cases, particularly in small patches, no choice was available from the limited areas of sufficient width to accommodate a plot.

Plot size and shape

Plotless sampling methods have been discussed in Section 2.2.1 and rejected as they assume random distribution of trees, and environmental homogeneity. Circular plots have been recommended as suffering less from edge effects than elongate ones (Daubenmire 1968) but they are certainly less easy to set out if large and in dense vegetation. Pacing of square or rectangular plots is possible (but not always easy).

In complex rainforest, plots need to be large in order to include a range of canopy species (Vestal 1949). Richards (1973) found over 200 tree species in a two ha plot in lowland forest of the Malay Peninsula. With the most diverse rainforests in the study area being far less species-rich the problem was not so extreme, and Vestal's five to ten acre (2 to 4 ha) plots would be excessive, but a large plot size was still warranted if a fair representation of canopy trees was to be gained. A practical problem is difficulty of precisely defining very large plots. A plot area of 0.1 ha is common in rainforest studies as described in Sections 2.1.3 and 2.2.1, where the concept of minimal area is also discussed.

A crude species/area exercise was carried out in one of the complex forests in the planning stages of the present study to determine appropriate plot size. By sampling in three adjoining 20 x 20 m plots, it was found that one plot recorded 31 vascular species, two (making a total of 20 x 40 m) recorded only two more, and a third (20 x 60) added another 16 species. The first and second plots were of fairly uniform environment which explains the small increment in Plot 2. In contrast, the third crossed over a small gully and included some wind disturbed canopy, thus contributing many additional species. This exercise did not clearly solve the plot size problem in terms of a species/area curve, but did highlight the local heterogeneity problem.

The small size (20 x 20 m) was considered for its potential restriction to homogeneous environments. However, this was considered too small to gain a representative sample of canopy species variation evident in field observations. By adopting a larger size, some micro-heterogeneity is likely to be incorporated to give a more accurate picture of the patch floristics.

Thus rectangular plots of 50 m x 20 m (1000 sq. m) were chosen because they could be located along the contour to minimize within-plot variation with slope, and because this plot shape and size may be useful for comparisons with others surveys (e.g. Webb et al 1967; Austin 1978).

This plot size would appear to be a fair compromise in this broad-scale survey. It is large enough to incorporate a reasonable number of canopy trees, but sufficiently small to accommodate other life-forms without too much difficulty. Time involved in carrying out a nesting procedure for sampling smaller life-forms did not seem justified by the potential increase in precision. Such nesting could only really involve the ground layer, because the shrub layer, including young tree species,was subject to the same heterogeneity as the canopy. In any case, ground species also varied considerably over small distances.

4.3.2 Terminology

A problem presented by patch sampling is that some patches span a number of environmental types used in the stratification. Terminology and definition of sampling units adopted requires explanation here.

A "patch" is a discrete area of rainforest vegetation as mapped from aerial photographs (and ground checked when sampled): it may be close to another patch, but not joined by a continuous strip of rainforest canopy trees. A "patch" is the highest level sampling unit which, (if of uniform geology and altitude zone), is sampled as a whole. A small patch was allocated one plot, a medium patch two, a large patch three and extra large four plots, as explained in Section 4.3.1. Fig. 06 shows the relationships between patches and plots.

A patch which spanned more than one environmental zone was divided into "patch segments", each functioning in its own

This plot size would appear to be a fair compromise in this broad-scale survey. It is large enough to incorporate a reasonable number of canopy trees, but sufficiently small to accommodate other life-forms without too much difficulty. Time involved in carrying out a nesting procedure for sampling smaller life-forms did not seem justified by the potential increase in precision. Such nesting could only really involve the ground layer, because the shrub layer, including young tree species,was subject to the same heterogeneity as the canopy. In any case, ground species also varied considerably over small distances.

4.3.2 Terminology

A problem presented by patch sampling is that some patches span a number of environmental types used in the stratification. Terminology and definition of sampling units adopted requires explanation here.

A "patch" is a discrete area of rainforest vegetation as mapped from aerial photographs (and ground checked when sampled): it may be close to another patch, but not joined by a continuous strip of rainforest canopy trees. A "patch" is the highest level sampling unit which, (if of uniform geology and altitude zone), is sampled as a whole. A small patch was allocated one plot, a medium patch two, a large patch three and extra large four plots, as explained in Section 4.3.1. Fig. 06 shows the relationships between patches and plots.

A patch which spanned more than one environmental zone was divided into "patch segments", each functioning in its own right as a sampling unit. Each patch segment was allocated one to four plots as explained in Section 4.3.1 depending on the size of the total patch. Size and continuity of patches as defined on air photos did not always correspond well with the reality on the ground. Reasons for the inconsistency are age of air photographs and subsequent disturbance patterns, some air photo interpretation problems such as shadows in gullies, and inability to discriminate real areal extent of steep areas on maps and photographs.

The application of plot number allocation was complex. A large patch on the airphotograph may include a number of segments which are each allocated three plots. On the ground a segment may not be sufficiently large to accommodate three plots. The plot number allocation therefore became a maximum potential, with fewer plots being sampled on some occasions.

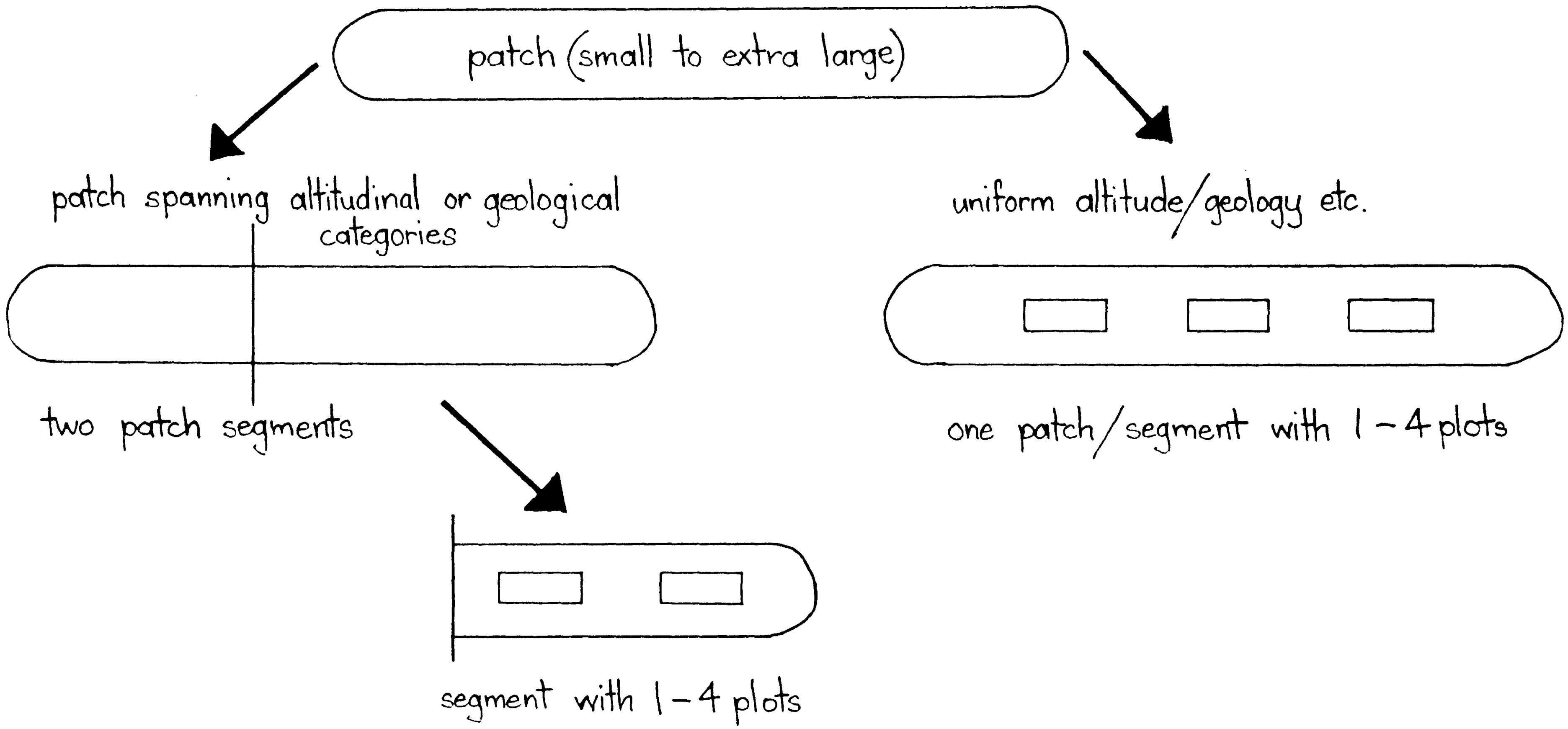
The use of the term "patch" in this thesis generally is synonymous with "patch segment" unless otherwise stated. This is because both were used as the major sampling unit, depending on size and environmental variation within a patch.

4.3.3 Vegetation

Floristic versus structural data

Differences of opinion exist as to the merits of floristic or structural data in rainforest surveys, as explained in Chapter 2, but it seems to be generally accepted that structural data make a valuable contribution to rainforest description and classification in Australia, particularly for

Fig. 06


patch (small to extra large)
patch spanning altitudinal or geological categories
two patch segments
segment with 1 – 4 plots
uniform altitude/geology etc.
one patch/segment with 1 – 4 plots

rapid broad geographical surveys (Webb et al. 1976). As one major aim of the present study was to describe the rainforest vegetation, about which little was known, both types of data were important. Taxonomy was not a serious problem because the author was already familiar with many of the species involved. Time taken to collect both floristic and structural data at a site is a small proportion of time in the field (Section 4.2), so to collect both contributes to survey efficiency. A structural proforma was designed to be compatible with the work of Webb et al. and can be seen in Appendix 4.

Qualitative versus quantitative floristic data

For a straightforward floristic inventory qualitative data are adequate, but for detailed ecological interpretation quantitative data may be necessary. Quantitative data may better reflect small-scale environmental differences or disturbance and regeneration patterns.

The present study used presence/absence data for all vascular species to record taxonomic diversity, but used abundance as a population parameter. Cover was not considered as important (cf. Noy-Meir 1970) because of more uniformity of this measure in rainforest than in surveys incorporating a range of vegetation types, but physiognomic diversity was of importance in delimiting rainforest types.

Presence/absence data were collected over each patch, but in plots all vascular species were given abundance scores, which could also be later reduced to binary data. For the present broad-scale survey, with its particular interest in floristic diversity, estimates of abundance would be adequate. Use of such estimates (Noy-Meir 1970) is adequate for recovering gross quantitative differences (Section 2.2.1). Smartt et al. (1974, 1976) considered abundance ratings satisfactory, and likewise, a subjective abundance scale was adopted for the present study, but in this case of only three points (occasional-1; common-2; very common to abundant-3). Within the third category, species considered dominant were also recorded.

The presence/absence and abundance scale data do not necessarily give information on dynamics or maturity of a forest. For example Acmena smithii may be abundant and dominant but present only as young trees. Structural data on height clarifies the situation to some extent, but stem diameter data are more accurate in depicting forest status. Basal area (diameter at breast height) is a measure of the individual or species' influence and success in the community in terms of competition for resources. By examination of trial plots it was evident that measurement of diameter of "large" trees (of 40 cm D.B.H. or more) would provide considerable information without too much time expenditure. Measurement of smaller trees was considered inefficient in return for time spent.

A problem in determining diameter measurements results from the variation in growth form and disturbance patterns. Some trees have single trunks, while others have multiple trunks due to coppicing. An extreme example is Eucryphia moorei which commonly sports rings of coppice stems of decreasing age and size around a centre from which the previous trunks have long since died and rotted. Such compound individual trees can cover a large area as illustrated in Plate 5. The purpose of diameter measurements in this study was to give some indication of species age and dominance. Dominance is reflected in a number of ways such as cover and basal area (Daubenmire 1968) which are assumed to relate to competition for resources. Therefore multiple trunks, although measured and recorded separately, were combined to give a dominance rating as one individual. The small coppice stems were too numerous to measure, so a minimum for individuals of ten cm was set. The 40 cm minimum stem diameter size could thus be met by the summation of coppice stems of ten cm or more. Thus the smallest coppiced individual to be recorded would be one with four ten cm stems.

The problem of using 'dominants' for data collection has been discussed in Section 2.2.1 with regard to biases in selection of dominance. In the present study it would be easy to overemphasize the importance of the strangler fig *Ficus obliqua*. This species is uncommon in numbers, but gives the impression of importance because of the impressive size of individuals.

Tree data compared with other synusiae and bryophytes

Some rainforest communities exhibit extreme richness in canopy tree species, whilst others, such as the high altitude forests, are extremely (tree-)species poor. The reverse may occur with smaller life-forms, including bryophytes. Bryophytes have been included in the study because of their potential role as ecological and biogeographical indicators in rainforest.

Trees are likely to be good indicators of rainforest types and therefore useful for rapid sampling on a broad scale (Webb et al. 1967b). However, with the present study including the aim of providing a floristic description of South Coast rainforests, it was considered essential that it include all vascular plants. Despite the work of Webb et al. (1967b) on understorey species prediction by tree species, no information is available as to the validity of this in southern New South Wales. The shrub and ground layer variation would be expected to reflect smaller scale envrionmental influences such as soil moisture (e.g. fern gullies) and increased light (e.g. canopy gaps) than the overall suitability of the area for rainforest development.

Unfortunately, lack of expertise in bryophyte taxonomy early in the survey precluded study of this life-form from the Clyde Mountain gradsect. Bryophyte data were collected from the Dromedary gradsect. Inclusion of bryophytes considerably increases time required in both recognition and identification, and on these grounds was restricted to the patch/segment scale (and not to plots), and to presence/absence only.

The survey provides an opportunity to undertake comparative analyses - of tree species/non-tree species, and qualitative/quantitative data for South Coast rainforests.

4.3.4 Environment

Introduction

It can be seen from previous rainforest work (Chapter 2) that factors controlling rainforest distribution and composition are likely to be associated with temperature, water balance, fertility, disturbance and vegetation history. Latitude, altitude and landform interact to dictate temperature and precipation. Topography and geology influence soils and nutrient availability. Water balance is controlled by precipitation, topography (shelter from sun and drying winds) and soil texture and depth. Topography and surrounding vegetation are important influences on disturbance regimes. Historical factors include previous vegetation and changes in climate or disturbance regime, plus dispersal mechanisms. This outline of known relevent environmental factors provides a guide as to environmental measurements for the present study.

Gross environmental features were used to determine the stratification. An environmental/structural plot proforma devised for the study can be seen in Appendix 4.

Soil, litter, charcoal

Soil depth and drainage were to be measured in an auger hole at the centre of each plot. Initial sampling proved this impracticable with given resources, especially as the profusion of scree slope and blocky sedimentary rock often prevented auger penetration. It would have required one person working full-time during field work and still have been unsatisfactory at some sites. Soil depth and drainage were therefore subjectively and rather inadequately inferred.

Soil surface samples (pooled from three scattered locations within each plot) were collected for a series of chemical analyses. Organic carbon, pH, electrical conductivity, available phosphorus and exchangeable potassiun, calcium, sodium and magnesium were measured.

Litter cover and depth, and humus depth were estimated. Charcoal was recorded if present, but its interpretation must be cautious due to possible contamination from outside the rainforest (upslope).

Fire and other disturbance

Presence of burn scars on trunks, or on old logs within the rainforest provide more reliable evidence of fire than soil charcoal. Any other evidence of disturbance, such as windthrows, butts from logging or old tracks was also recorded.

Landform and topography

Landform classes included 'mountainous', 'hilly' and 'rolling' and reflect the general relief of the area on a large scale. Topography, on the other hand, was used to describe the local environment of the patch or plot in terms of aspect, slope, horizon and topographic position. Angles to horizon, taken from plot centre, can be combined with aspect and slope to give a radiation index using the work of Fleming (1971).

Climate

It was not feasible to measure climatic factors at sample sites. With relatively few weather stations in each gradsect, rainfall data are sparse. The revised rainfall surface of Adomeit et al. (pers. comm.) was used along with data from the Bureau of Meteorology to provide information on regional climate (Section 3.4).

4.4 Data Analysis

4.4.1 Classification

For the present study a range of methods was available within the Numerical Taxonomy Package (NTP) developed by L. Belbin on the PDP 11-34 minicomputer at the CSIRO Division of Water and Land Resources. A small amount of work was also done on the Cyber 76 of the CSIRO Division of Computing Research. NTP provides hierarchical, agglomerative classification, using the programmes ASO (for similarity coefficient) and FUSE (for sorting strategy). This is an exclusive, intrinsic classification, therefore it is non-overlapping and derives its groups solely from the attributes.

In the present study both binary and quantitative data sets were to be analyzed as discussed in Section 4.3.3. Single occurrences, while contributing valuable information about distributional ranges of rare species, would contribute little to numerical analysis groupings (Austin et al. 1967) and be likely to add 'noise' to results, so were excluded from the analysis. The data could be considered very sparse, with over 75% paired absences, so adoption of similarity coefficients which remove double zeros, reducing the influence of rare species, seemed more appropriate than attempting to utilize conjoint absences of ubiquitous species.

The nature of the quantitative data used here (ordered multistate with a range from zero to three) excluded the problems associated with outstanding values which could apply in numeric data. The double zero problem in the use of the Canberra metric suggested that the Bray-Curtis measure, which would stress the dominant species, may be the best method. For binary data the Czekanowski coefficient was selected because of its weighting on conjoint presences.

4.4.2 Ordination

In order to overcome the classification problems of information loss by enforced groupings in only one dimension, the data were subjected to multivariate analysis by ordination. Multivariate analysis condenses "multidimensional relationships by projection onto a reduced number of suitable planes" and ordination does this without making "assumptions about the existence or otherwise of groupings among the entities" (Clifford and Stephenson 1975).

Principal coordinates analysis (Gower 1967, 1969) was used in the present study because it operates on the dissimilarity matrix between sites rather than directly on the variance or correlation matrix of attribute scores as principal component analysis does.

4.4.3 Additional forms of data analysis

Sites, and then species, were classified and the results presented in twoway tables by the programme TWAY, which can be useful in showing community-species associations.

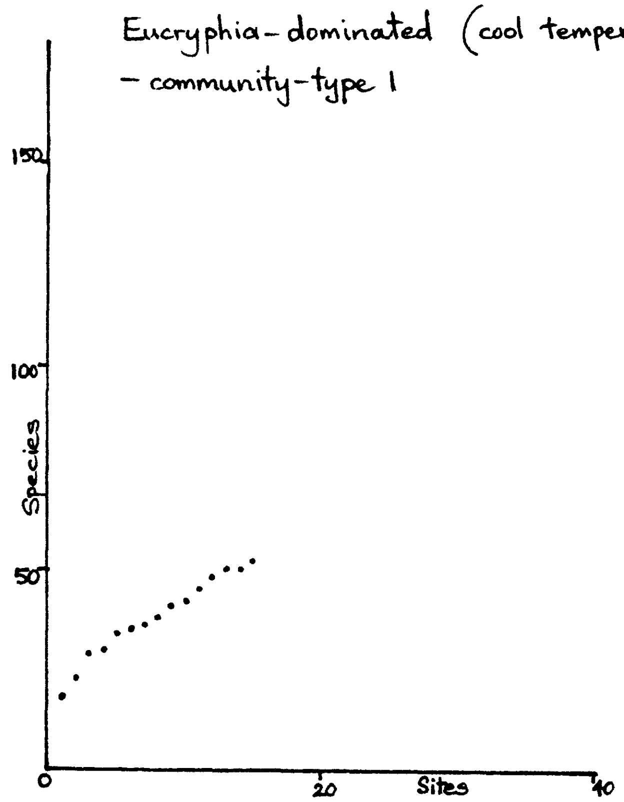
Scatter diagrams using the GLIM package on the PDP 11 34 system showed the behaviour of certain selected tree species with altitude, patch size, radiation index, available phosphorus and organic carbon.

A form of species-area relationship was examined for the total 231 sites, and then for each rainforest type (as defined by the classification), using the programme CUMUL in NTP, followed by PCPLOT, which plotted the curves (Fig. 6). This 'species-area relationship' is different from the normal species-area approach (Braun-Blanquet 1965) which increases area in one environment, because in this case the area is increased by incrementing spatially distinct plots over a large heterogeneous environment. The shape of the curve is therefore affected by the sequence of the plots as will be discussed in Section 7.3.4.

In order to also test whether the ordination axes of the main 231 data set were reproduced by reduced data sets, position of sites on the first vector of each reduced set was hand plotted against position on the 231 analysis (see Section 6.2.3 for results).

Thus many different methods of exploratory data analysis were tried, some proving more advantageous than others. Through the use of such a range of methods different characteristics of the data set were elucidated and suggested areas worthy of more detailed examination.

Fig. 6a Species - site curves



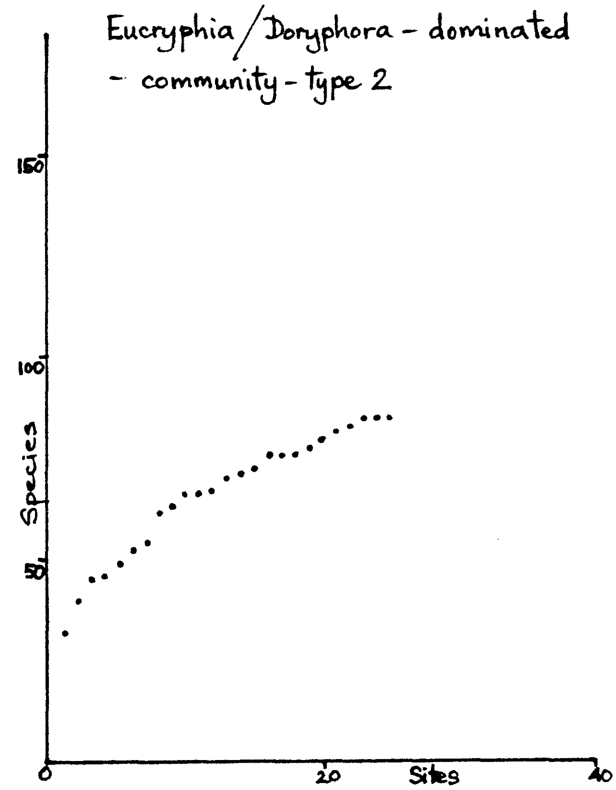
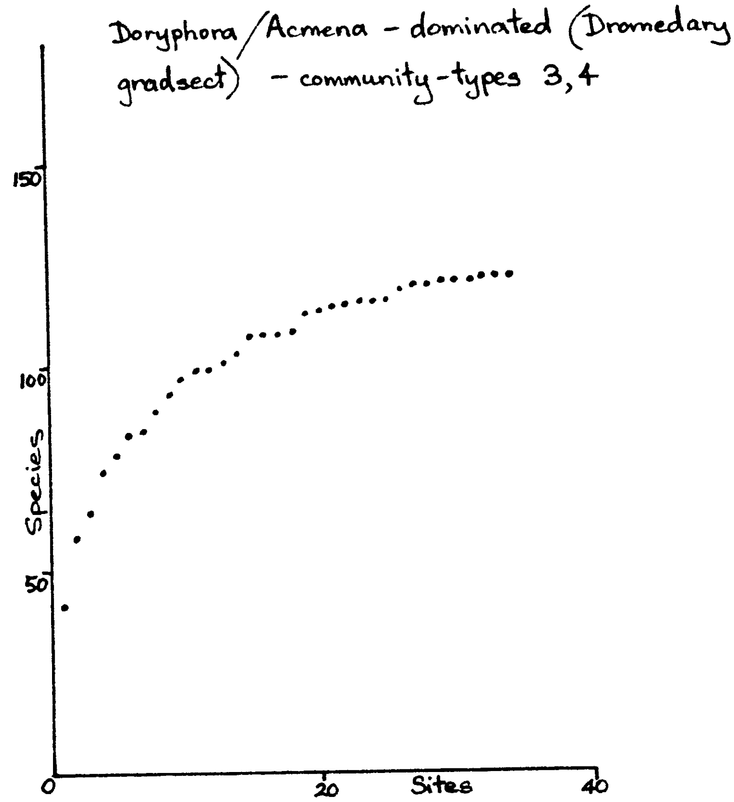


Fig. 6b Species - site curves



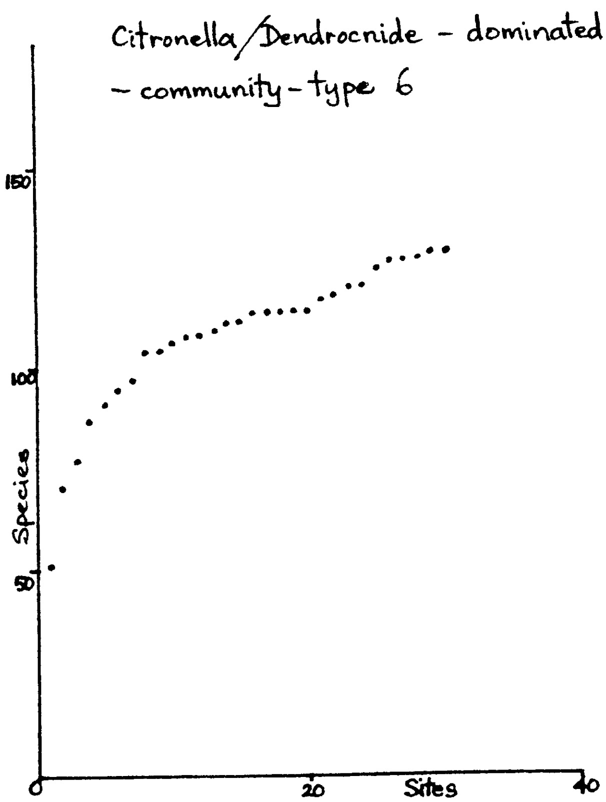
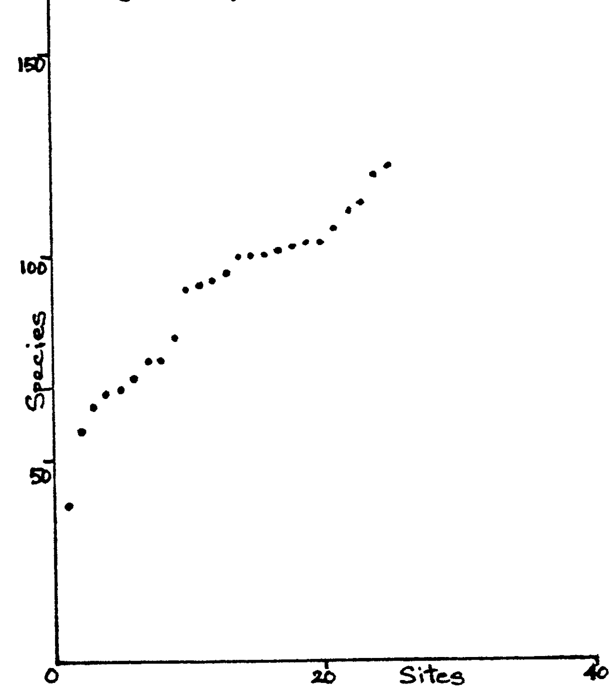


Fig. 6c Species - site curves

Rich Doryphora/Acmena - dominated (Clyde gradsect) - community-types 7,8



Ceratopetalum - dominated - community-types 9, 10

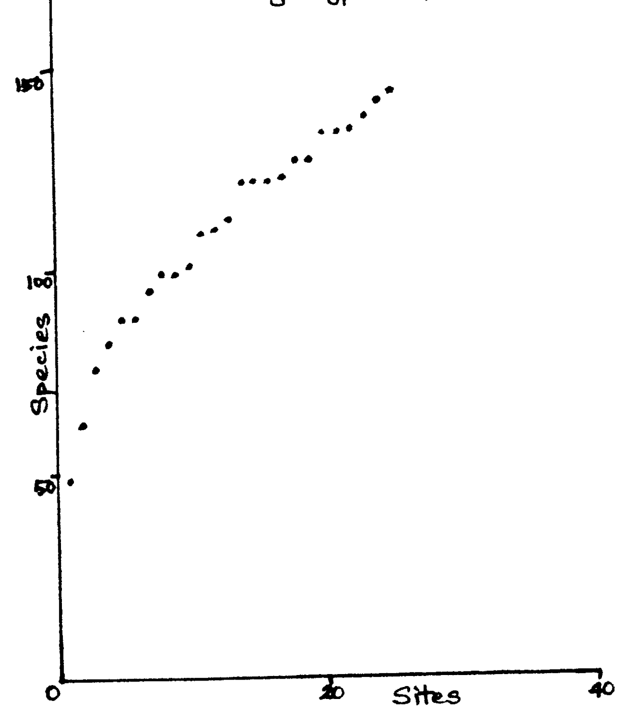
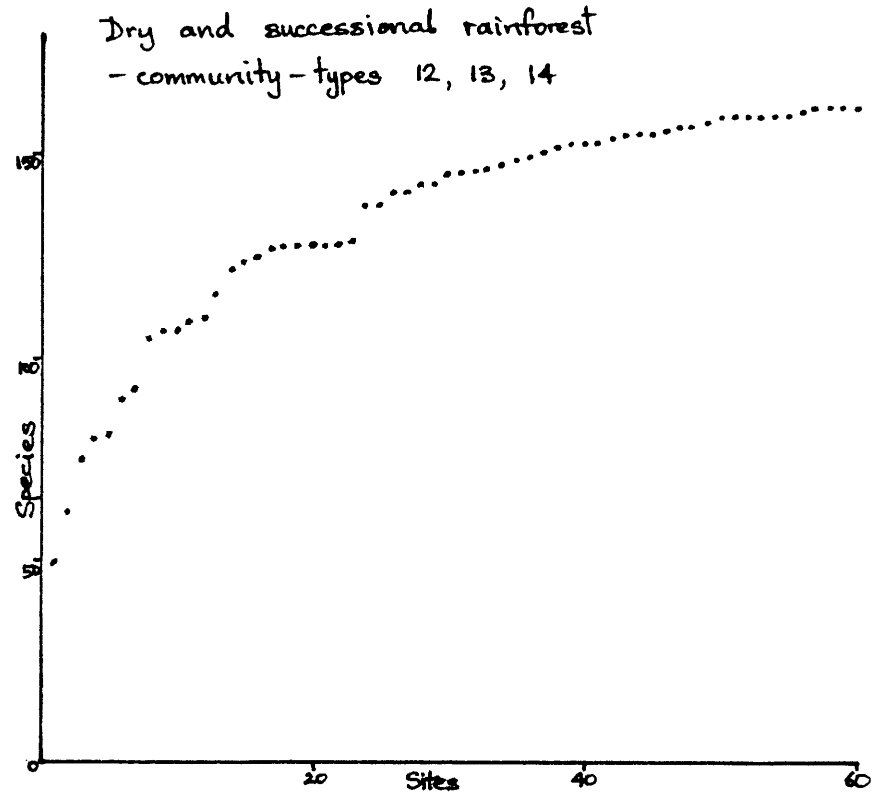
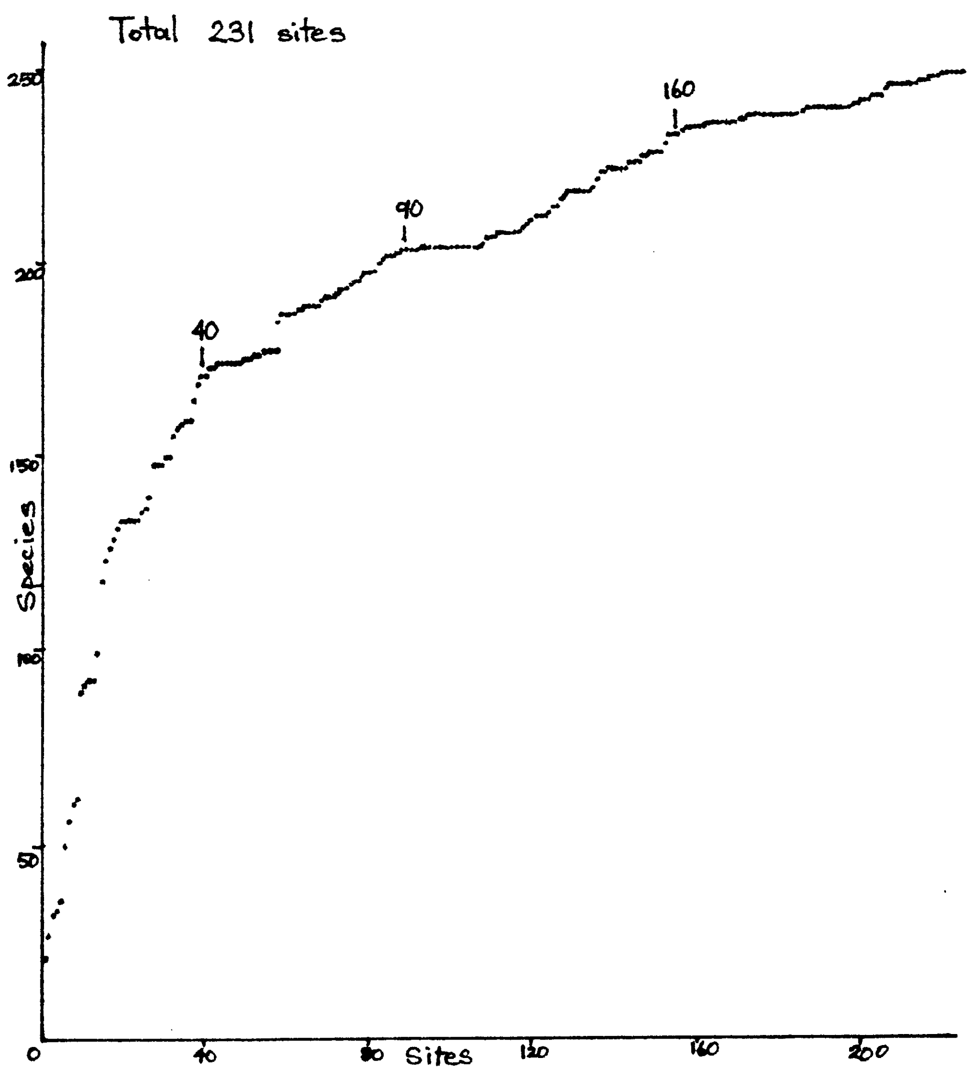


Fig. 6d Species – site curves





4.5 Survey Efficiency

4.5.1 Introduction

Records were kept of the amount of time spent at each field activity in order to assess the return for time invested. It was expected that the majority of time would be devoted to driving and walking, therefore it would be valuable to calculate the additional time required to collect different levels of data.

4.5.2 Reduced sample size

The species-area exercise (Section 4.4.3) using sequentially increasing plot numbers over the 231 data set , indicated that a smaller number of plots would have recovered the majority of floristic/structural information. The most marked reduction in recovered species occurred at approximately 40 sites, with two further marked reductions at approximately 90 and 160 sites. An exercise was therefore devised to test return in terms of environmental correlations, from samples of reduced sizes. Classification and ordination of these reduced samples would show whether the environmental correlation recovered was comparable to that in the 231 data set. Graphs plotting ordination vector scores for sites in reduced samples against the same sites in the total analysis would indicate the degree of similarity of correlations. If the first axis carries a large proportion of the environmental information, and there is strong correlation between the scores of reduced samples and the quantitative analysis, then a consistency of information recovered is proven. This can be taken either as a measure of the robustness of the full data set, or of the adequacy of the reduced samples.

Within the original stratification system all replication (of patches within the strata and plots within patches) was deleted. This was achieved by random selection between replicates, and resulted in a reduced sample of 91 sites. Reduction to a further sample of 41 sites resulted from removal of the patch size criterion in the stratification. Only one patch was selected randomly from all available patches (small to extra large) within a stratum and only one plot from that patch.

4.5.3 Random samples

The results of the stratified 91 and 41 site analyses were compared with subsets of 91 and 41 'random' sites to test the validity of the stratification. As the stratification was designed to ensure sampling in the range of gross rainforest environments recognized in Section 4.2.4 a random sample should produce less clear correlations. One set of 91 sites and three of 41 were randomly selected from within the 231 independent of stratification framework, and these were classified and ordinated. As these subsets were taken from within 231 sites defined by the original stratification, they can not be considered to approximate a sample of randomly located field sites in the survey area, and were labelled 'semi-random'.

The only way to achieve a truly random sample for comparison would be to ignore the stratification, randomly determine 41 sites over the total survey area and sample these in the field. The best substitute (at the time) for this method (which would require considerable additional field work) was to select subsets of 41 sites randomly, but on a gradsect stratum area-proportional basis, and these samples will be referred to as random. This was achieved by the following method.

1) A census of all rainforest patches and their approximate size had been made from air photos.

2) Area of rainforest within each gradsect stratum (x) was calculated by estimating the mean area for each patch size and totalling number of patches in each size in each stratum.

3) Total area of rainforest within the gradsects (T = 3942 ha) was calculated by summing areas of strata. (This gave totals of 1791 and 2151 ha for the Clyde and Dromedary gradsects respectively.)

4) Relative area per one sample (plot) was calculated as: to equal 89 ha for the Clyde gradsect and 102 for the Dromedary one. (41 is the number of samples, with 20 in the Clyde and 21 in the Dromedary gradsect. The gradsects were done separately because otherwise there is an undue bias towards the many small dry and successional sites of the southern gradsect, which would not have influenced the Clyde sampling, as the original stratification was done separately.)

5) Number of samples per stratum was calculated as x divided by the above formula, which is stratum area divided by relative area per sample.

6) Within each stratum these sample plots were then randomly determined from the gradsect sample.

Thus the chance of a sample being taken from each stratum is a function of the relative rainforest area of that stratum within the gradsects. Five sets of such random samples were analyzed. Allocation of extra sites to strata was not random, but done according to area of strata, then randomly determined within each stratum.

Towards the final stages of this study an opportunity arose to collect a random field sample of 40 sites. Although these sites were not confined by the stratification, for logistic reasons they were restricted to four gradsects, which means that a broader altitudinal coverage would be expected than if they were randomly distributed in the study area. The four line gradsect positions were determined randomly along a base line along the coast, and then ten random points were found along each. The closest rainforest patch to each point was sampled.

4.5.4 Adequacy of the quantitative data set

Following the selection of the 231 quantitative data as the basis for the inventory (Section 6.1.1), the adequacy of this base data set can be assessed using the following criteria: data type, sample size, comprehensiveness of result, robustness of result. A number of methods in the study which contribute to this assessment are described in detail in other Sections. These include:

1) data type - Section 4.3.1 (patch/plot) and 4.3.3 (qualitative/quantitative, tree/bryophyte and other synusiae);

2) sample size - Sections 4.5.2 and 4.5.3 (reduced/random

analyses used to test the stratification, and the 231 site species-area exercise to suggest efficiency of number of sites and species recovered);

3) comprehensiveness - Section 4.3.1 (patch/plot) and 4.5.3 (reduced/random) for differences in rare species sampled;

4) robustness - the range of results over all comparative analyses contribute to this, but particularly the reduced and random samples, because if there is strong environmental correlation, then it would be expected to dominate most results.

Two additional approaches could contribute to assessment of the base data set. Firstly species/area curves constructed for individual groups or community-types recognized would show whether each type had been adequately sampled. These were site sequentially cumulative. Secondly additional data from other sources, where possible, would help to test the comprehensiveness of the result.

4.6 Summary of methods selected

Table 8 presents a summary of survey design, measurement and data analysis methods adopted in the present study.

Table 8

PROBLEM	METHODS ADOPTED
Reduction of sample area.	Two altitudinal gradsects.
Location of samples within gradsects.	Environmental stratification (altitude, geology, geography, patch size).
Location within strata.	Random patches (proportional to number of patches in stratum).
Sample unit.	Patch; Plot.
Plot number.	1 to 4 (depending on patch size).
Plot location.	Along lower south-east slope, (then subsequent plots incorporate different environments).
Plot size and shape.	Rectangular 50 x 20 m 'loose' plots (paced).
Vegetation measurement.	Floristics (all vascular species and bryophytes); Structure.
Data type.	Qualitative; Quantitative (Abundance estimates 1-3).
Environmental measurement.	Landform and topography; Aspect, slope, horizon; Soil, litter, charcoal, Fire and other disturbance.
Numerical analysis.	Classification (Bray-Curtis); Ordination (PCOA).
Additional analysis methods.	Two-way tables; Scatter diagrams; Species-area curves, Reduced and random samples.