CHAPTER 3

Floristic, structural and dynamic features of selected sites.

3.1 Introduction

3.1.1 Rationale

A series of 19 plots was established throughout the region's rainforests. Their environmental, structural and floristic features were recorded. Spatial and temporal trends in the regeneration, growth and mortality of the component species were also examined. These data were used to assess the role of individual species in determining the basic structural and floristic properties of these assemblages.

The reasons for choosing unlogged sites for these studies were primarily related to the assumption that the dynamic characteristics of the component species might be more easily understood if they could be examined in an environment similar to that in which they had evolved i.e. an environment substantially free from human disturbance. Given the complexity of rainforests, it was thought that to have undertaken these studies in logged forests or forests which had been affected by shifting cultivation, could have easily led to a misinterpretation of the influence of normal processes on their structure and floristics. Another less important reason for adopting this strategy was that, although the Queensland Department of Forestry had an extensive series of growth plots in logged and silviculturally treated rainforests, they had only a few small plots on areas which had not been logged.

Plot establishment generally proceeded whenever possible for at the beginning of the study it was apparent that at the then current logging rate, the whole of the accessible forest in State Forest Reserves would soon have been logged (Stocker et al. 1977). Opportunities to observe the dynamics of unlogged forests were therefore diminishing rapidly and, although there are substantial areas of unlogged rainforest preserved in National Parks, none is as accessible as those in State Forests.

3.1.2 Site selection

The sites were chosen to include representative rainforest types in the geographical area from Mackay in the south (Lat. 21° 45' S, Long. 148° 35' E) to Iron Range in the north (Lat. 12° 45' S, Long. 143° 20' E) (Figure 8). The selection of the types was essentially intuitive, since at the commencement of this programme, I had very little data on the range of rainforest types in north Queensland. Subsequently, Tracey and Webb (1975) produced a series of vegetation maps covering the main part of the rainforest region. However, while these maps provide a broad overview, they lack sufficient detail to be of value beyond the early reconnaissance stage of site selection. In the absence of shifting cultivation by the indigenous population, forests disturbed by human activity usually have obvious features such as stumps and snigging tracks. Although such sites were generally avoided, in a few localities there was little choice but to establish plots on sites where loggers could possibly have removed one or two trees many years ago.

Since accessible unlogged sites in State Forests were becoming increasingly difficult to find, the usual strategy was to explore areas of potential interest as access was provided by new logging roads. After selecting an area ahead of the logging face, the co-operation of the Queensland Department of Forestry was sought to reserve that site from logging. Consequently, many of the plots (with associated unlogged buffer areas), are now surrounded by selectively logged forest. In addition to the criteria outlined above, a few of the early plots were deliberately located in forest types containing Flindersia species, in order to obtain autecological data on these commercially important species. However, this group is numerically important in many north Queensland rainforests, and subsequent experience indicated that these early plots were representative of several wide-spread forest types.

3.1.3 Plot size

A plot size of 100x50 m (0.5 ha) was chosen for the series. Larger plots have some advantages, but they are often difficult to position to ensure that all parts have a constant aspect and that the plot was generally free of topographic variability associated with gullies and ridges. (It is noteworthy that Ashton 1964b working in the rainforests of Borneo, found difficulty in establishing plots larger than 0.4 ha without encountering similar problems.) Each plot was divided into 16 subplots 25x12.5 m mainly because it was easier for an observer engaged in data collection to maintain orientation in a small subplot than in the larger area. The subplots were designated A, B, C, etc., for field identification.

The advantages of establishing a smaller number (1 to 3) of very much larger plots, such as that described by Hubbell and Foster (1983), were considered for such plots could be very useful for developing hypotheses on the mechanisms responsible for species distribution patterns in rainforests. However, I decided that, because of the large environmental range occupied by the region's rainforests and the lack of any detailed information on their characteristics, a series of smaller plots established throughout the region, would be more profitable. Unfortunately the resources available would not permit any reasonable compromise.

3.1.4 Plot demarcation

Each of the plots was laid out using a prismatic compass and steel survey band. An Abney level was used to measure slope angles enabling ground distances to be converted to true horizontal projection. Plot corners were marked with chemically preserved wooden pegs (76x7.5x5 cm). Similar but smaller pegs were used to indicate the corners of the subplots. Although some minor understorey brushing of the perimeter was usually necessary to facilitate access for survey and initial measurement, efforts were made to minimize disturbance during establishment. Wherever possible, the location of each plot was established accurately by traverse

tie to a Forestry or Lands Department survey point. This enabled plot locations to be shown on Forestry Department management maps as they were revised.

A buffer zone of at least 30 m width was retained around each plot. Most of the larger trees (especially those of commercial value) in this area were painted with an orange girth band at eye level or slightly above. (Orange is the standard colour used to mark experimental sites in areas controlled by the Queensland Forestry Department. This colour was also used to paint corner pegs and on trees to denote tree numbers and the dbh [diameter at breast height over bark] measurement point band.)

3.1.5 Initial data collection

a) Trees = or > 10 cm dbh.

Each tree in this category was assigned a tree number. For example, tree E23 was the 23rd tree encountered in subplot E. Wherever possible all trees were identified to specific level in the field, usually by the use of leaf and stem features.

The location of each tree was plotted to the nearest 0.5 m. Girth measurements, using tapes calibrated to read diameter, were made 1.3 m above the ground level on the uphill side of the tree. When measurement at this height was not realistic due to buttresses or bole deformities, the measurement point was moved to a more representative point, usually above the irregularity.

The height of the tallest tree in each subplot was determined trigonometrically using an Abney level to measure the angle subtended by the tree and a 30 m tape to measure the distance from the observer to the tree. The heights of the remaining trees were estimated in relation to the tallest trees.

Palms with a trunk dbh = or > 10 cm were regarded as trees even though they do not possess the ability to grow in girth in the same manner as dicotyledonous or coniferous trees. To have not included them in tree density and basal area

calculations would have led to considerable bias in the data from those plots where they were conspicuous.

b) Small trees

These were arbitrarily divided into two groups according to their size (25 cm to 3 m high and > 3 m high but < 10 cm dbh). The presence of species in both of these categories was recorded for each subplot.

c) Other vascular plants

Species lists were made for vines, epiphytes, herbs, sedges and grasses found within the plot.

Specimens of all plant species encountered within each plot were collected and checked against material in the herbarium of the CSIRO Division of Forest Research at Atherton (QRS). Most were retained in that herbarium. A list of tree species is included in Appendix A.

d) Forest structure profiles

Profile diagrams of the forest at each plot site were prepared to illustrate some of their structural features. These diagrams were based on an edge strip (100x5 m) of the plot. The strip originated from the plot corner at subplot A. The diagrams were drawn with identical horizontal and vertical scales. Plants < 6 m high have not been included. These diagrams may be found in Appendix B.

e) Soils

Some general observations were made on the characteristics of soils near the plots from exposures at road cuttings and from pits and auger holes. Within each plot soil samples, 0-30 cm in depth, were taken at specified subplot intersections (ABEF, COGH, IJMN, KLOP, FGJK). These samples were later analysed to provide data for sand, silt and clay content, field capacity and wilting point, soil pH, organic carbon, total phosphorus, total nitrogen, cation exchange capacity and exchangeable calcium, magnesium, potassium and sodium (means for each plot are shown in Table 6).

3.1.6 Remeasures and maintenance

Remeasurements were undertaken at two-year intervals and tree markings repainted as necessary. Structural changes such as windfalls, deaths, stem damage and crown disturbance were recorded during the remeasures. Recruitment was determined by a tally of small trees entering the 10-20 cm dbh class.

3.1.7 Data processing

For convenience data processing was carried out in two parts. The first linked the family, generic and specific names (with authorities) of trees and shrubs found in each plot with the species code number used to identify that species in the second program. The second used the remeasurement data to determine the growth rates of individual trees, size classes and species, and provided information on species density, mortality and recruitment. The latter program also produced an updated tree position map of each plot and had the capacity to detect probable errors and act on comments which may have influenced measurements. The programs were written in Fortran IV for use in CSIRO's Cyber computer.

3.2 Results

3.2.1 General site and vegetation characteristics

The plots were established on a very diverse range of sites (Table 5). Although they were concentrated in the central part of the main rainforest belt, there were 9° of latitude between the most northern (plot 18) and the most southern (plot 14) (Figure 8). Their elevations above sea level ranged from 15 m (plot 17) to 1200 m (plot 7) and average annual rainfall from 1300 mm (plot 16) to 4000 mm (plots 9 and 12). While their topographic situations varied from lowland valley to exposed highland ridge sites, all were within 70 km of the Coral Sea.

The soils within the plots were also quite variable (Table 6). Most were derived from granites, although basalts, rhyolites and some metamorphosed rocks provided parent materials for the soils at some localities.

Cluster analysis (Gower 1971) of site characteristics, undertaken by P. West (pers. comm.), also illustrated their rather divergent nature. However, two groups could be recognized. The most clearly defined was a group composed of plots 11, 14 and 15. The remaining plots formed a second group. The site factors examined and the results of West's analysis are shown in Table 7 and Figure 19.

A summary of the structural and floristic features of the plots (Table 8) revealed considerable variation in these features. The number of vascular plant species recorded ranged from 88 (plot 14) to 184 (plots 4 and 5). However, large tree species were invariably more numerous than those of any other life form recorded. Plot basal area ranged from 14.1 m^2 (plot 1) to 32.3 m^2 (plot 19) and upper canopy levels from 25 m (plot 1) to 50 m (plot 12).

A summary of tree mortality within the plots (Table 9) showed a relatively constant rate through the size classes.

Table 5. Some characteristics of sites occupied by stands in the permanent plot series.

Plot no.	Location		Elevation (m)	Estimated mean annual rainfall (mm)	Topography	Slope/ Aspect	Distance from sea (km)
1	Downfall L.A.	S.F.185	720	1200	Tableland foothill	<5°SE	36
2	Emerald L.A.	S.F.607	1120	2400	Highland slope	10°-15°NE	34
3	Little Pine L.A.	S.F.933	80	2500	Coastal foothill	<5°SW	2
4	Robson L.A.	S.F.185	800	2000	Dissected upland	15°-20°E	30
5	North Mary L.A.	S.F.143	1100	2500	Exposed highland	<5°W	16
6	Burgoo L.A.	Garrawalt	620	2000	Exposed upland	5°-8°SE	45
7	Mt. Fisher	S.F.650	1200	2700	Exposed highland	10°-12°SE	57
8	Agapetes L.A.	S.F.144	980	1500	Upland	5°W	45
9	Barong L.A.	S.F.755	80	4000	Coastal valley	5°S	25
10	McIlwraith Ra.	T.R.14	450	2000	Upland	<5°SW	23
11	Curtain Fig	S.F.452	720	1400	Flat stony tableland	-	43
12	Gosschalk L.A.	S.F.755	380	4000	River terrace	<5°SW	32
13	Chinaman L.A.	T.R.55	230	2900	Low coastal range	5°-10°SE	8
14	Clarke Ra.	S.F.679	920	2400	Upland plateau	3°-5°SE	70
15	The Crater	S.F.194	1000	1800	Upland	5°-8°SE	58
16	Agapetes L.A.	S.F.144	800	1300	Upland ridge	0°-8°N	40
17	Arsenic Creek	N.P.	15	3500	Coastal riverine lowland	<5°SE	1
18	West Claudie R.	Iron Ra.	30	2200	Coastal riverine backwater	0-10°SE	13
19	Compartment 59	S.F.194	1120	2000	Highland slope	15°-20°S	60

L.A. - Logging area
S.F. - State Forest
T.R. - Timber Reserve
N.P. - National Park

Table 6. Some characteristics of the soils of the permanent plots.

Plot no.	Soil Texture	Parent Material	pH	Org.C %	Tot.N %	Tot.P. %	C.E.C.	Ca	Mg	K	Na
								(meq /100g soil)			
1	Sandy loam	Granite	5.3	3.5	0.44	0.018	14.5	0.72	0.51	0.3	-
2	Clay loam	Granite	4.5	7.8	0.51	0.031	26.0	0.32	2.1	0.1	-
3	Clay	Granite	4.8	2.6	0.24	0.017	8.2	0.3	2.2	0.2	-
4	Loam	Granite	4.7	2.9	0.32	0.027	16.4	0.2	1.7	0.2	-
5	Clay loam	Granite	5.1	5.6	0.33	0.050	12.3	0.3	0.3	0.2	0.08
6	Clay loam	Granite	4.1	2.5	0.18	0.076	13.2	0.30	0.5	0.15	0.09
7	Silty loam	Rhyolite	4.3	3.1	0.25	0.066	5.0	0.19	0.21	0.11	0.05
8	Clay loam	Granite	4.4	3.3	0.22	0.013	9.4	0.38	0.66	0.30	0.07
9	Sandy loam	?Metamorphic	4.8	1.6	0.17	0.046	8.2	0.84	0.39	0.17	0.06
10	Sandy loam	Metamorphic	4.3	2.4	0.18	0.047	7.5	0.13	0.25	0.10	0.06
11	Gravelly clay loam	Basalt	6.5	3.0	0.42	0.379	35.1	20.3	3.3	1.01	0.14
12	Sand	Granitic alluvium	4.7	2.7	0.32	0.161	15.2	0.82	0.54	0.28	0.11
13	Gravelly loam	Metamorphic	4.5	1.8	0.17	0.012	9.8	0.12	0.38	0.13	0.08
14	Sandy loam	Basalt	5.1	4.3	0.54	0.259	28.3	2.96	2.05	0.73	0.22
15	Loamy sand	Rhyolite	6.1	5.4	0.57	0.079	30.7	14.6	3.67	0.12	0.14
16	Loam	Granite		1.2	0.08	0.011	4.3	3.13	0.58	0.26	0.06
17	Gravelly loam	Granitic alluvium	4.8	4.8	0.48	0.052	19.1	1.68	1.14	0.15	0.21
18	Sandy loam	Alluvium		2.6	0.23	0.038	12.6	7.64	2.07	0.18	0.11
19	Loam	Rhyolite	4.3	4.5	0.32	0.014	14.5	0.33	0.62	0.20	0.10

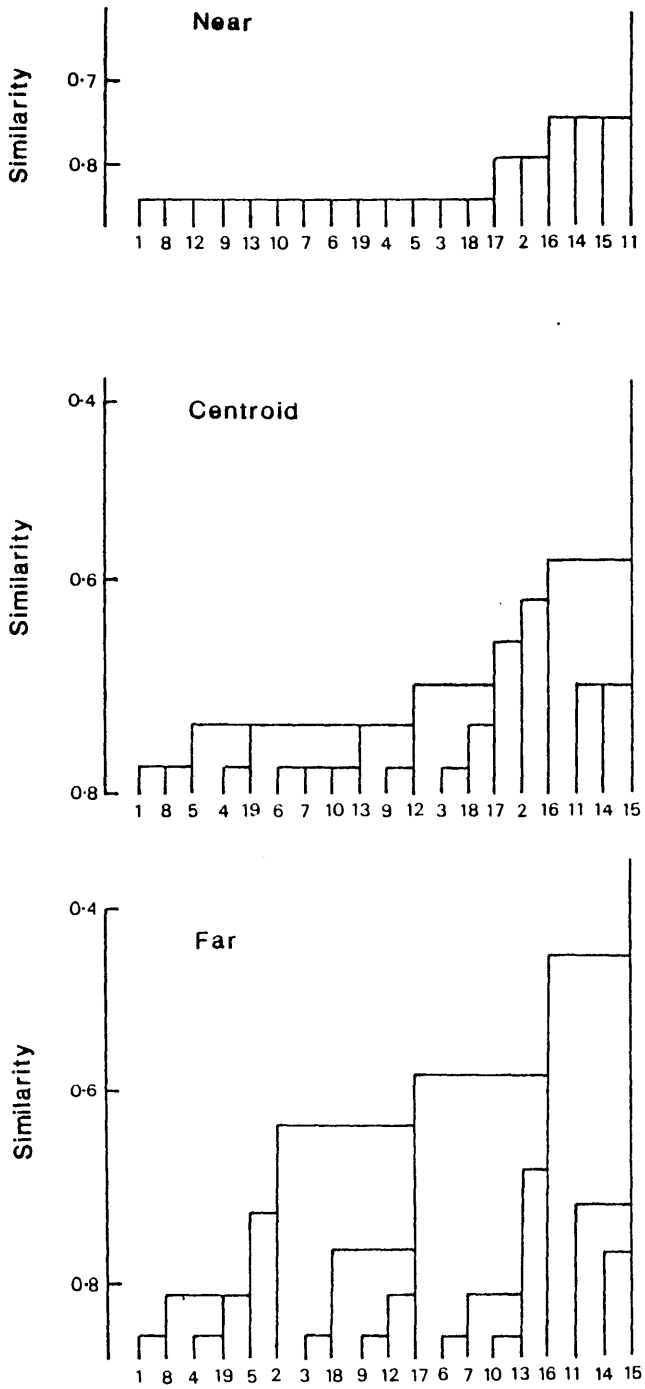

Figure 19. Hierarchical cluster analyses of the plots based on their environmental features.

Table 7. Results from the canonical variate analysis of the site data.

Site factor	Transformation	Canonical Score	Group means (back-transformed)	
			1	2
Altitude (m)	-	19.5	608	880
Latitude (°S)	-	-5.3	16.6	18.7
Distance from coast (km)	-	-3.7	30.7	58.0
Annual rainfall (mm)	-	4.2	2420	1867
Slope (radians)	-	1.5	0.193	0.061
Aspect (radians)	cosine	1.0	2.00	1.71
pH	-	9.1	4.6	5.9
Organic C (%)	-	-8.3	3.3	4.2
Total N (%)	-	-27.1	0.28	0.51
Total P (%)	log	-2.2	0.032	0.198
CEC (m.eq/100g)	log	-16.7	11.1	31.2
Ca "	log	34.5	0.49	9.57
Mg "	log	5.4	0.66	2.92
K "	log	-6.0	0.45	0.18
Na "	log	31.1	0.10	0.16
Total bases "	log	-14.5	1.7	14.0
Base saturation (%)	arcsin √	-24.5	21.5	58.2

Table 9. Mean annual mortality by size classes for all plots except no. 6 (deaths ha^{-1} $annum^{-1}$).

	Size class (dbh cm)									
	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+
Absolute	4.21	1.41	0.55	0.43	0.22	0.09	0.05	0.06	0.03	0.03
% size class total	0.85	0.86	0.75	0.95	1.1	0.83	0.71	1.8	1.1	0.83

Table 8. Some structural and floristic features of the rainforests in the plots.

Plot no	Numbers of vascular plant species							Diversity indices[4]		Basal area	Canopy height
	Total	Large tree[1]	Plot tree > 10 cm dbh	Small tree[2] and shrub	Liane[3]	Epiphyte[3]	Other[3]	Stem numbers	Basal areas	m^2 /0.5 ha	range m
1	92	56	35	10	14	3	9	13	10	14.1	15-23
2	149	105	67	12	14	11	7	26	23	31.7	25-40
3	163	112	68	14	24	5	8	11	21	18.0	16-29
4	184	135	89	14	19	9	7	17	22	25.9	26-38
5	184	127	83	13	20	24	0	30	28	30.4	23-34
6	145	105	64	9	19	5	7	20	13	20.3	22-38
7	121	84	49	16	10	5	6	20	18	20.0	18-34
8	149	105	65	13	17	9	5	12	19	29.4	22-37
9	137	93	46	20	15	2	7	9	2	20.6	21-44
10	114	70	50	8	15	12	9	17	11	14.8	19-30
11	108	75	46	12	15	1	5	15	13	31.5	32-43
12	164	99	64	25	20	5	15	33	19	24.0	27-50
13	111	87	67	15	4	0	5	26	21	19.4	17-35
14	88	52	32	5	12	8	11	7	5	30.1	32-41
15	144	94	61	12	23	4	11	21	14	22.6	27-39
16	121	80	47	18	14	4	5	10	5	27.8	30-42
17	116	83	56	14	11	7	1	6	5	21.9	25-34
18	108	80	58	6	13	2	7	27	12	21.5	24-38
19	153	112	59	12	15	5	11	10	11	32.3	27-42

1. Includes all tree species capable of reaching the upper canopy.

2. Includes tree species which are very rarely, if ever, found in the upper canopy. These species seldom grow beyond 10 cm dbh.

3. Species counts in these categories are based on a preliminary assessment. Many may prove to be underestimates with further study.

4. Based on data for trees > 10 cm dbh using the reciprocal of Simpson's index (Simpson 1949)(see Section 3.3.1).

3.2.2 Individual plot characteristics

a) Data presentation

To accompany the notes on the plots, a series of figures and tables was prepared to summarize their essential features. The diagrams (see the figure for each plot in the next Section) show :-

a) the number of stems falling within each of the diameter classes.

b) the number of individual trees (= or > 10 cm dbh) of each species in the plots. The species sequence is from the most numerous on the left to the least on the right.

c) the percentage basal area increments for the various dbh size classes found within the plot. This parameter was calculated using the mean annual basal area increment for a size class and the basal area of that size class at plot establishment. Since it has often been observed (e.g. Dawkins 1963) that a direct relationship exists between the dbh and the crown diameter of trees, this parameter might be expected to provide some indication of the relative exposure among crowns of stems in various size classes.

(d) biennial changes in total plot basal area.

(e) biennial changes in stem numbers.

The basic data processing program extracted a list of those tree species which contributed either 3% or more to the total number of trees in the plot, or 3% or more to the total basal area of the plot. Brought together these data usually provided a list of 10-15 tree species which could be regarded as the "important" tree species in that plot. The summary Table for each plot lists some characteristics of its "important species". The stem number data are those recorded at the time of plot establishment. Mortality and growth information are for the period indicated in the heading for each Table. The relative increment rate of a species is the mean increment rate of that species in a particular size

class, compared with the mean increment rate of all stems in that size class.

b) Descriptions

Plot 1

This plot was established in July 1971 on the relatively dry southern flanks of Tinaroo Range 18 km north-northeast of Atherton. Several granite outcrops were seen within the plot. The soil was generally shallow and contained a high percentage of partially decomposed granite gravel throughout the profile. Where weathering had been deep enough for the profile to extend beyond the upper, dark brown organically enriched horizon, the soil was yellowish in colour. The texture was sandy loam throughout.

Tracey and Webb (1975) have mapped this area as "complex notophyll vine forest with Agathis robusta emergents". Similar sites are often found on the western edge of the rainforest belt in this region. The upper canopy of the forest was relatively low and open while the shrub layer was well developed. The forest structure was, however, somewhat unusual in that there were a few scattered clumps of grasses (e.g. Panicum lachnophyllum), sedges (Gahnia aspera) and herbs (Dianella and Alpinea spp.) on the forest floor. Epiphytes especially Platycerium superbum and Asplenium australianum were conspicuous in this plot probably because so much light penetrated to within a few metres of the forest floor.

As far as can be ascertained the plot had not been logged. Similar sites do however, occasionally support scattered large trees of Agathis robusta and it is not inconceivable that one or two trees of this species could have been taken from either the plot or its surrounds 40-50 years ago.

Figure 20 shows that stem numbers in size classes declined rapidly with increasing size class. West et al. (1981) noted that in temperate forest stands where most species were shade tolerant, a concave semilogarithmic density-diameter curve with a rotated sigmoid shape at the mid diameter size class

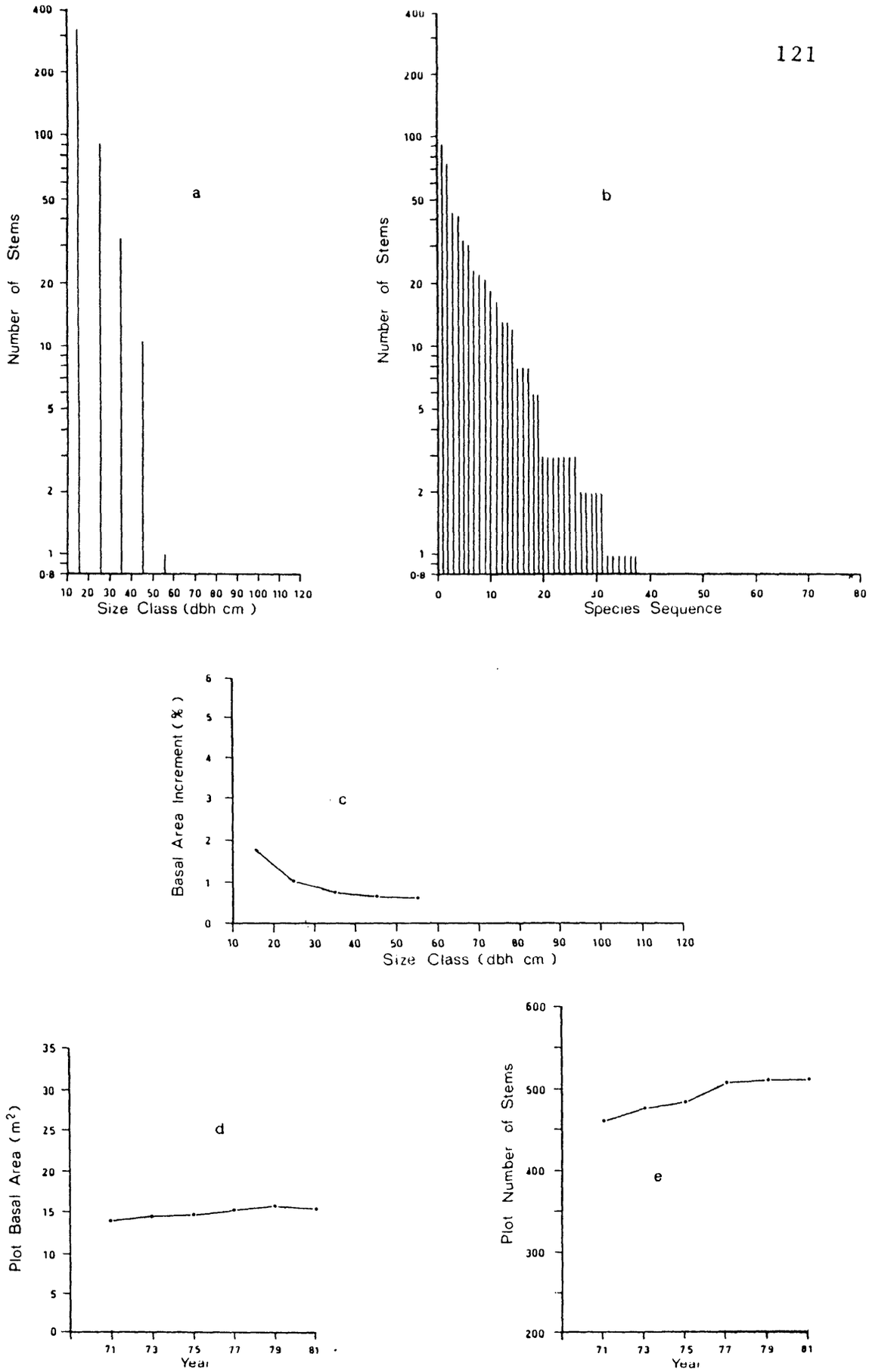

Figure 20. Some characteristics of plot 1 are illustrated :-
a) stem numbers in dbh size classes,
b) stem numbers for each species with the species arranged (left to right) from the most to the least numerous,
c) the basal area increment percent for each size class,
d) temporal trends in plot basal area,
e) temporal trends in the number of stems in the plot.
For further explanation see Section 3.2.2.

Table 10. Plot 1 - Initial stem numbers, mortality and basal area increment by dbh size classes (cm) with recruitment to the 10-20 cm class and an indication of regeneration stocking in subplots for important species. Data from 1971-81.

Species	Regen. stock. a. A	B	Initial stem numbers 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Init. tot.	Recr. b.	Mortality 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Basal area increment c. 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+
Cleistanthus semiopacus	8	10	39	30	13	1							83	8				1	1						B	C	C	E						
Erachychiton acerifolius	15	9	6	10	5	1							22												D	D	B	B						
Croton insularis	15	12	22	13	2								37	7	5	8	1								B	C	B							
Pseudoweinmannia lachnocarpa	16	14	19	1	4	1	1						26	7											C	C	D	E	C					
Acronychia laevis	13	15	62										62	14	9										D									
Melicope erythrococca	15	14	29	4	2								35	11	1										C	B	C	C						
Homalium circumpinnatum	13	7	13	2		2							17	2	1										C	B	C	C						
Alstonia muellerana	13	10	21	7									28	5											D	C								
Glochidion sessiliflorum	6	1	7	5	2								14	3		1	1								C	C	C							
Euroschinus falcata	2		4	1	3								8	1											A	B	A							
Austromyrtus hillii	5	15	20										20	5	2										B									
Rhodamnia glauca	13	15	18										18	9	1										C	C								

a) the number of subplots (max. 16) containing 1 or more small trees 0-3 m high (A) and 3 m high to 10 cm dbh (B).

b) the number of small stems entering the 10-20 cm dbh class.

c) basal area increment - relative rates are indicated by :- A = 100% over, B = 25-100% over, C = within 25% of, D = 50-100% below and E = over 100% below. plot mean for that size class.

range, was characteristic.

The stem numbers distribution of the larger tree species was log normal in shape - a pattern which May (1975b) suggested is the consequence of the statistical Central Limit Theorum applicable to established assemblages. The growth rates were highest in the 10-20 cm dbh size class.

Most of the important tree species (Table 10) appeared to have stem number/size distributions of the normal type (i.e. stem numbers declining steadily as size classes increase). Exceptions were several of the species growing to larger sizes e.g. Brachychiton acerifolius, Pseudoweinmannia lachnocarpa and Euroschinus falcata. The first and last of these species are partially deciduous. While E. falcata was the fastest growing species, it was the only one for which the long term prospects for recruitment appeared limited. The most actively recruiting species was the small tree Acronychia laevis - the second most common tree species at the time of plot establishment. Mortality was highest for Croton insularis. Overall the number of stems in the plot increased slowly over the study period but no important long term trends were discernible.

Average annual stem mortality for the plot has been 0.85% with the highest rate (1.3%) in the 20-30 cm dbh class.

Plot 2

This plot, established in October 1971, was located near the crest of the Tinaroo range 25 km north-northeast of Atherton. The soil was derived from deeply weathered granite and had a well developed, organically enriched, loamy surface horizon above a red clay loam subsoil. The vegetation appeared representative of the upper mid altitude (900-1200 m) forest found in the region and is sometimes locally and informally described by forestry personnel as "wet highland rainforest on granitic soil". Tracey and Webb (1975) have mapped it as "simple microphyll vine/fern forest often with Agathis

Plate 7. The interior of part of plot 1 showing the large epiphytes, Platycerium superbum (upper) and Asplenium australasicum, unusually close to the ground.

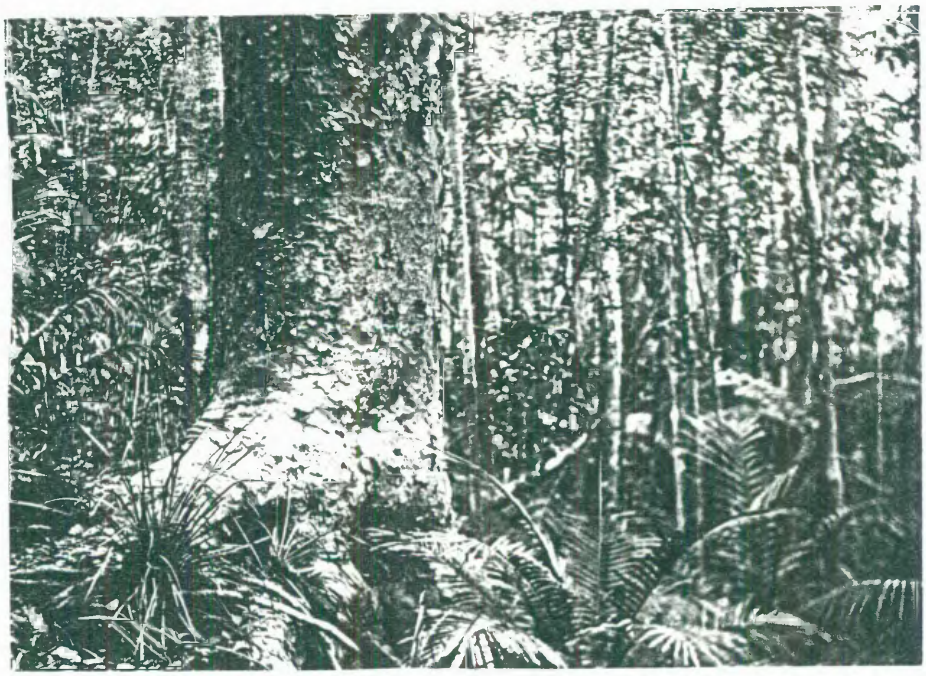

Plate 8. The interior of part of plot 2 showing the butt of a large tree of Agathis atropurpurea.

montana[1] emergents". The site did not appear to have been logged although there was evidence of past logging along the ridge top above the plot. The general impression gained on entering the plot was of tall trees with tight crowns of small leaves and of an open low sparse fern dominated ground layer. Epiphytes were not particularly conspicuous for many were small and only found high in the canopy. Vines also appeared to be a relatively minor component of this assemblage. The species/stem numbers/size class relationships appeared to be fairly normal (Figure 21). Features of the upper canopy were several large trees of Agathis atropurpurea. This species and two others (Musgravea stenostachya and Elaeocarpus sericopetalis) made up a large part of the plot basal area and their dynamics appear to provide some interesting similarities and differences (Table 11). These three species have more or less the same stem numbers in each of the size classes in which they occur. The relatively low early growth rate of A. atropurpurea appears to be a characteristic of the genus. Musgravea stenostachya seems to be slow most of its life and only faster than the others in particularly favourable circumstances. E. sericopetalis seems to be able to grow rapidly under a wide range of conditions. Several of the most numerous tree species in this plot Brackenridgea nitidula and Antirhea myrtoides rarely grow beyond 25 cm dbh. Their relatively slow growth rate seems to be characteristic of a group of small tree species which rarely, if ever, reach the upper canopy.

There has been a steady increase in plot basal area except during the last two years of the record when a very slight drop was recorded (Figure 21). The basal area of this plot is one of the highest of those in the series and continued increase would not be expected, although in view of the number of A. atropurpurea trees contained within it, the possibility of further basal area accumulation cannot be discounted. Growth percentages by size classes (Figure 21) were not very high. The peak was in the 20-30 cm dbh class. Smaller stems

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1. This name cannot be applied to any Australian species. A. atropurpurea appears to be the species referred to by Tracey and Webb.

Table 11. Plot 2 - Initial stem numbers, mortality and basal area increment by dbh size classes (cm) with recruitment to the 10-20 cm class and an indication of regeneration stocking in subplots for important species. Data from 1971-81.

Species	Regen. stock. a.		Initial stem numbers										Init. tot.	Recr. b.	Mortality										Basal area c. increment									
	A	B	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+			10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+
Agathis atropurpurea	11	5	2	4	3	2	1	2	3			1	18												E	A	A	A	A	C	B			*
Musgravea stenostachya	13	4	2	1	2	4	2	1	1	1			14												D	E	D	D	D	B	E	B		
Elaeocarpus sericopetalus	13	9	4	5	2	2	4						17		1	1									A	A	A	B	C	B				
Planchonella euphlebia	4	2	2	3		5		1	1				12												B	D		E		E	E			
Garcinia sp. aff. G. hunsteinii	5	8	7	9	7	2							25			1									B	C	D	D						
Ceratopetalum succirubrum	14	2	15	6	3	1	1						26		1										C	B	B	E	D					
Beilschmiedia sp. aff. B. obtusifolia	13		6	5	1	2	1						15												D	B	C	D	C					
Balanops australiana	7	8	1	2		1		1	1				6	1											C	C		C		C	D			
Syzygium sp. (WESA) RFK 3030	10	8	1	1		1					1		4												D	D			C				*	
Flindersia pimenteliana	6	3	2	2	2	1			1				8	1											A	B	B	B			E	A		
Brackenridgea nitida ssp. australiana	15	12	54	4									58	10	3										C	D								
Sphenostemon lobosporus	13	9	9	6	3	1							19												B	D	D	E						
Cryptocarya cinnamomifolia	15	11	11	10	1								22			1									B	D	D							
Antirhea myrtoides	15	13	36	3									39	4	1										E	E								

a) the number of subplots (max. 16) containing 1 or more small trees 0-3 m high (A) and 3 m high to 10 cm dbh (B).

b) the number of small stems entering the 10-20 cm dbh class.

c) basal area increment - relative rates are indicated by :- A = 100% over, B = 25-100% over, C = within 25% of, D = 50-100% below and E = over 100% below, plot mean for that size class.

* - only one tree in that size class.

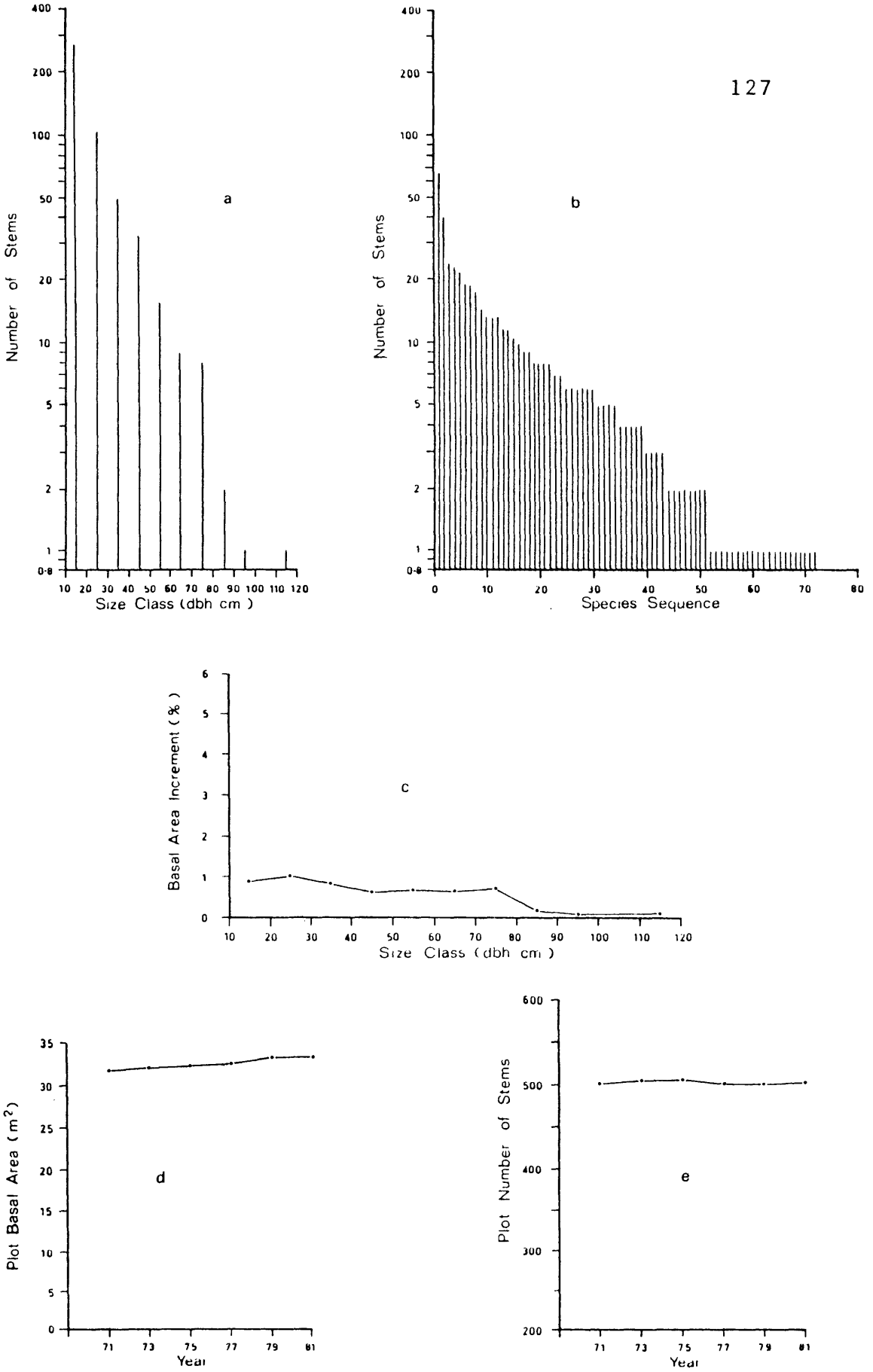

Figure 21. Some characteristics of plot 2 are illustrated :-
a) stem numbers in dbh size classes,
b) stem numbers for each species with the species arranged (left to right) from the most to the least numerous,
c) the basal area increment percent for each size class,
d) temporal trends in plot basal area,
e) temporal trends in the number of stems in the plot.
For further explanation see Section 3.2.2.

may suffer severe competition whereas the very low values for the largest stems may be indicative of advancing senility. Tree numbers within the plot appeared to be fluctuating without sign of any particular trend. Annual tree mortality averaged 0.54% with the 20-30 cm dbh class being most affected (0.87%).

Plot 3

This plot was established in August 1972 on the foothills of the Malbon Thompson Range, 7 km south-east of Cairns. The forest is locally described as "low wet coastal rainforest on granitic soil". The granite has been deeply weathered producing a massive red clay subsoil beneath 5-10 cm of surface soil containing most of the root mat. Tracey and Webb (1975) have mapped the forest in this locality as "medium woodland" but the vegetation of this plot was clearly not of this type and in their classification, would more appropriately be described as "notophyll or mesophyll vine forest". The vegetation on this site appeared typical of lowland forests on soils with heavy clay subsoils derived from either granitic or metamorphic parent materials for it was characterized by a more or less continual mid canopy layer of the palm, Licuala ramsayi. Although there was no evidence of recent logging, the site was close to an old logging road and it may have been selectively logged in the past. Damage from recent cyclones (perhaps from the one of 1958) was, however, strongly suspected for the canopy was rather irregular and "large gap" tree species, especially Acacia aulacocarpa, were relatively abundant. However, the stem number distributions, both by species and size class, showed a large degree of normality (Figure 22).

The numerical importance of Licuala ramsayi in this assemblage is easily seen in Table 12. While most of the species listed here have normal size/stem number distributions several, particularly Acacia aulacocarpa and Alstonia muellerana, seemed destined to decline. The absence of regeneration of A. aulacocarpa in small sizes was particularly noteworthy. However, recruitment to the > 10 cm dbh size class for the remaining species exceeded their mortality

Plate 9. The fan palm, Licuala ramsayi, shown here in plot 1 is a conspicuous feature of the mid canopy level in many north Queensland lowland rainforests. While this species is unable to expand the girth of its bole, limited dbh increment has been observed in the two Archontophoenix spp. (e.g. see plot 14).

Plate 10. The interior of plot 9 showing a butt of the dominant tree species, Backhousia bancroftii, and numerous fronds of Calamus spp..

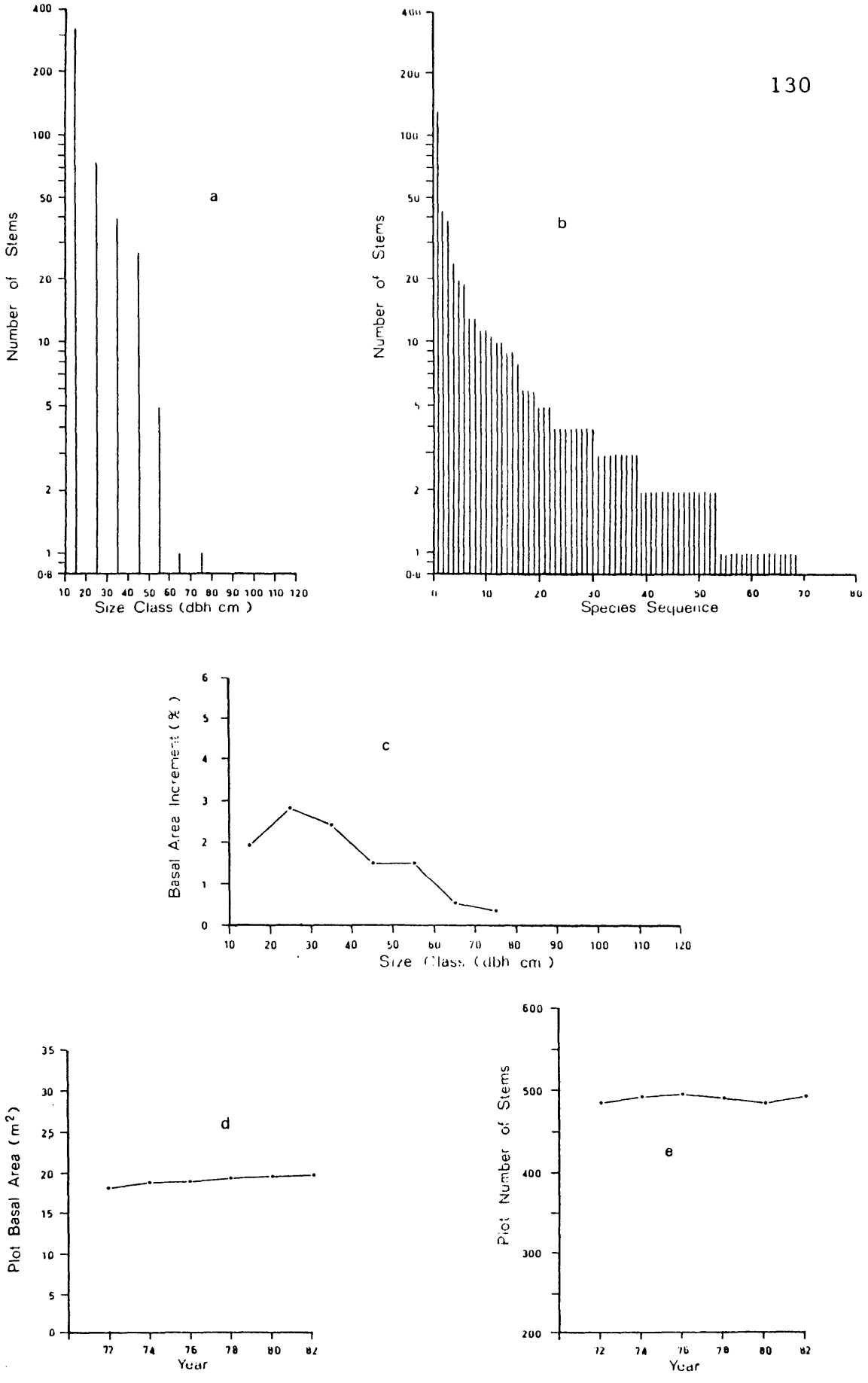

Figure 22. Some characteristics of plot 3 are illustrated :-
a) stem numbers in dbh size classes,
b) stem numbers for each species with the species arranged (left to right) from the most to the least numerous,
c) the basal area increment percent for each size class,
d) temporal trends in plot basal area,
e) temporal trends in the number of stems in the plot.
For further explanation see Section 3.2.2.

Table 12. Plot 3 - Initial stem numbers, mortality and basal area increment by dbh size classes (cm) with recruitment to the 10-20 cm class and an indication of regeneration stocking in subplots for important species. Data from 1972-82.

Species	Regen. stock. a. A	Regen. stock. a. B	Initial stem numbers 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Init. tot.	Recr. b.	Mortality 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Basal area increment c. 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+
Licuala ramsayi	16	16	134										134	5	4										E									
Acacia aulacocarpa		7	19	4	1	2	2	1					29	13	5			1							A	A	A	A	D	E				
Elaeocarpus bancroftii	13	13	7	4	5	4							20					2							A	D	E	E						
Carnarvonia araliifolia	15	5	2	5	3	5							15			1									C	E	E	E						
Sterculia laurifolia	16	10	11	9	4	1							25	1		2	2								A	C	B	B						
Alstonia muellerana	9	7		7	3	2							12	1		3	1	2								E	E	E						
Podocarpus neriifolius	13	3		1	2	2	1						6				1		1							E	D	E	E					
Flindersia pimenteliana	12	11	6	5	4	1							16	3	1		1								A	B	B	C						
Flindersia bourjotiana	15	7	4	1	2	2							9		1										A	D	C	C						
Macaranga subdentata	15	16	35	3									38	8	3										C	E								

a) the number of subplots (max. 16) containing 1 or more small trees 0-3 m high (A) and 3 m high to 10 cm dbh (B).

b) the number of small stems entering the 10-20 cm dbh class.

c) basal area increment - relative rates are indicated by :- A = 100% over, B = 25-100% over, C = within 25% of, D = 50-100% below and E = over 100% below, plot mean for that size class.

rate.

The pattern of percentage increment in size classes was interesting, for following a peak in the 20-30 cm class a decline occurred (Figure 22). The low growth in the 10-20 cm class was undoubtedly heavily biased by the exceedingly low (sometimes negative) diameter "growth" of L. ramsayi but again the fall in larger size classes cannot be readily explained.

Overall the plot basal area increased steadily although tree numbers seemed to have reached a steady state. Annual mortality was relatively high at 1.09%, reaching 2.1% in the 40-50 cm dbh class.

Plot 4

This plot was established in March 1972 on the southern flanks of Tinaroo range 24 km north-east of Atherton. The forest here is locally described as "tall wet upland rainforest on granitic soil". Despite the relatively steep slope of the plot site, the granite is overlain by several metres of deep red loamy soil containing a small amount of weathered granitic gravel.

Tracey and Webb (1975) have mapped the vegetation of this locality as "simple notophyll vine forest". The site seemed to have a much higher rainfall than Plot 1 (Table 5) although it was at a similar altitude. The forest was tall and well developed with few signs of past logging. Some old gaps, either from natural tree falls or logging were indicated by the presence of two "large gap" species (Polyscias murrayi and Alphitonia whitei) of mature size. Several small recent gaps due to natural tree deaths (perhaps lightning strike) contained abundant regeneration of tree species and thickets of the climbing palm, Calamus australis.

Only three of the important species (Melicope fareana, Sterculia laurifolia and Citronella smythii) listed in Table 13 had normal distributions. The remainder of the important species appeared to recruit, if not regenerate, in pulses. The presence of a large tree of Endiandra palmerstonii, without any sign of regeneration of any size, was particularly

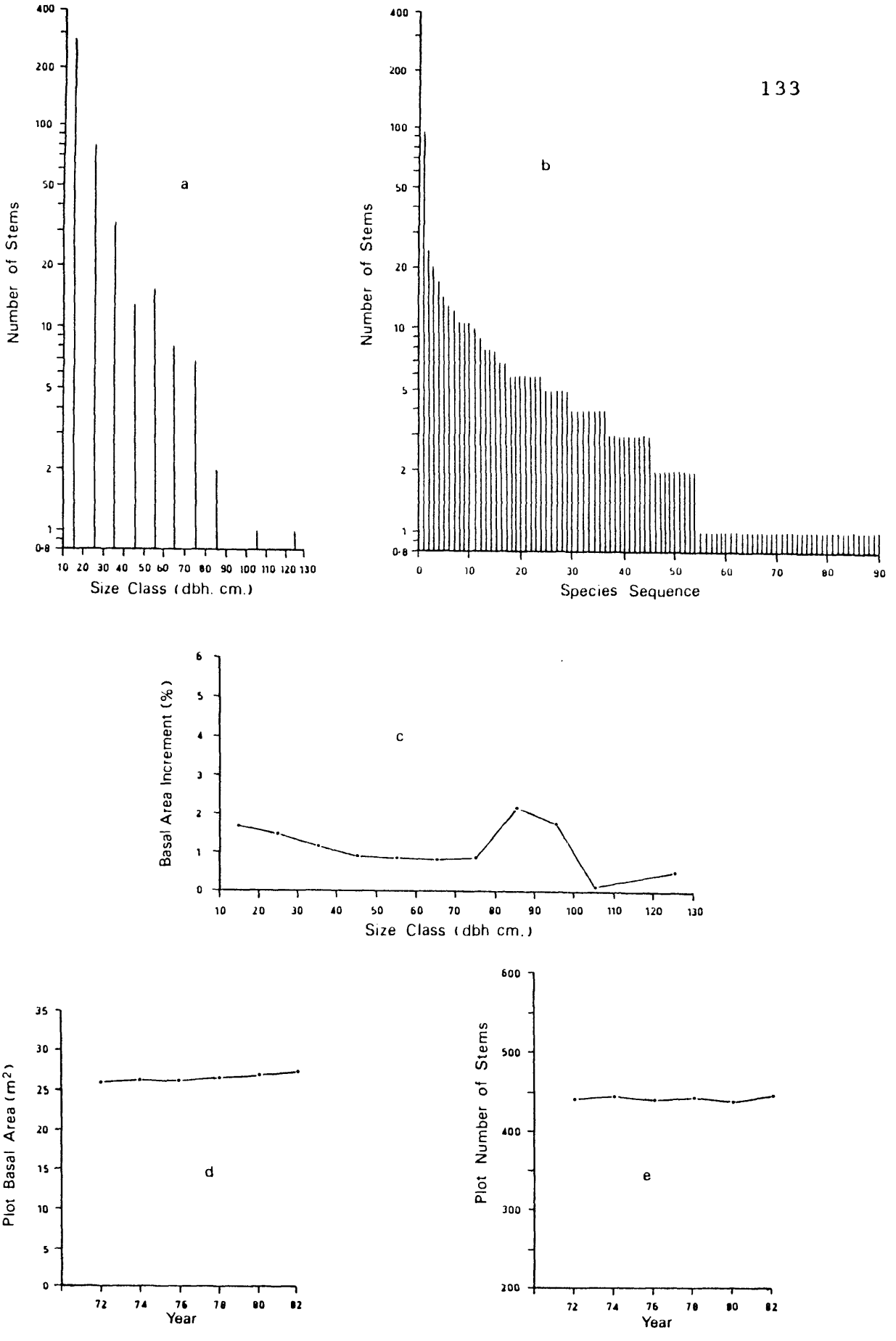

Figure 23. Some characteristics of plot 4 are illustrated :-
a) stem numbers in dbh size classes,
b) stem numbers for each species with the species arranged (left to right) from the most to the least numerous,
c) the basal area increment percent for each size class,
d) temporal trends in plot basal area,
e) temporal trends in the number of stems in the plot.
For further explanation see Section 3.2.2.

Table 13. Plot 4 - Initial stem numbers, mortality and basal area increment by dbh size classes (cm) with recruitment to the 10-20 cm class and an indication of regeneration stocking in subplots for important species. Data from 1972-82.

Species	Regen. stock. a. A	Regen. stock. a. B	Initial stem numbers 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Init. tot.	Recr. b.	Mortality 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Basal area increment c. 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+
Flindersia laevicarpa	8	12	1	1	4	3	6	1					16	3											B	E	C	B	B	B				
Ceratopetalum succirubrum	12	7	3	3	1			3				1	11												E	B	D			B	A			C
Melicope fareana	16	16	77	17									94	5	7	2									E	E								
Flindersia pimenteliana	5	7	3		1		1	1	1	1			8												A	A		B	C	C	E	E	C	
Beilschmiedia bancroftii	10	7	2						2	1			5												A						E	C	C	
Opisthiolepis heterophylla	9	6	3	1		2	1	1	1				9	1											A	B	E	C	E	E	E			
Cerbera inflata					1	1		1	1				4							1							C	E	E		E			
Sterculia laurifolia	16	13	16	3	4	1							24	2	3										B	B	B	C	C					
Endiandra palmerstonii												1	1																					E
Citronella smythii	16	13	14	4	3								21			1									E	E	E							

a) the number of subplots (max. 16) containing 1 or more small trees 0-3 m high (A) and 3 m high to 10 cm dbh (B).

b) the number of small stems entering the 10-20 cm dbh class.

c) basal area increment - relative rates are indicated by :- A = 100% over, B = 25-100% over, C = within 25% of, D = 50-100% below and E = over 100% below, plot mean for that size class.

interesting. The only species where there was a marked difference (in this case negative) between recruitment and mortality was with the commonest species in the plot, Melicope fareana. Individuals of this species are rarely found > 30 cm dbh.

The growth rates in size classes by the important species were quite variable (Table 13). A few showed consistent, relatively low growth rates but most of the remainder showed no clear pattern. Overall percentage growth was highest in the 80-90 cm dbh class - a very different pattern from the previous plots. The smaller size classes were however, still growing relatively faster than those of intermediate size. The high levels of the 80-100 cm classes could perhaps be explained by vigorous emergents with free access to light. Overall the plot basal area increased slowly but again tree numbers seemed relatively stable (Figure 23). Annual mortality has averaged 0.94% and was highest in the 30-40 cm dbh class (1.17%).

Plot 5

This plot was established during September 1973 on the main range 14 km south-west of Mossman. The forest is locally described as "wet highland rainforest on granitic soil". The red loamy soil was very variable in depth and appeared to contain numerous granite "floaters".

Tracey and Webb (1975) have typed the forest in this vicinity as "simple microphyll vine/fern forest". Although the site was relatively exposed, the forest was well developed and had a high diversity. The forest in this locality has never been logged and although it seems to have escaped damage from any recent cyclones, there was a number of old fallen stems within the plot. These stems were of decay resistant species (apparently Proteaceae of indeterminate genera) and suggested some past catastrophe.

Emergent species on the plot included Ceratopetalum succirubrum, Flindersia brayleyana, Acmena sp. aff. A. smithii, Syzygium sp. RFK 3030, Planchonella euphlebia,

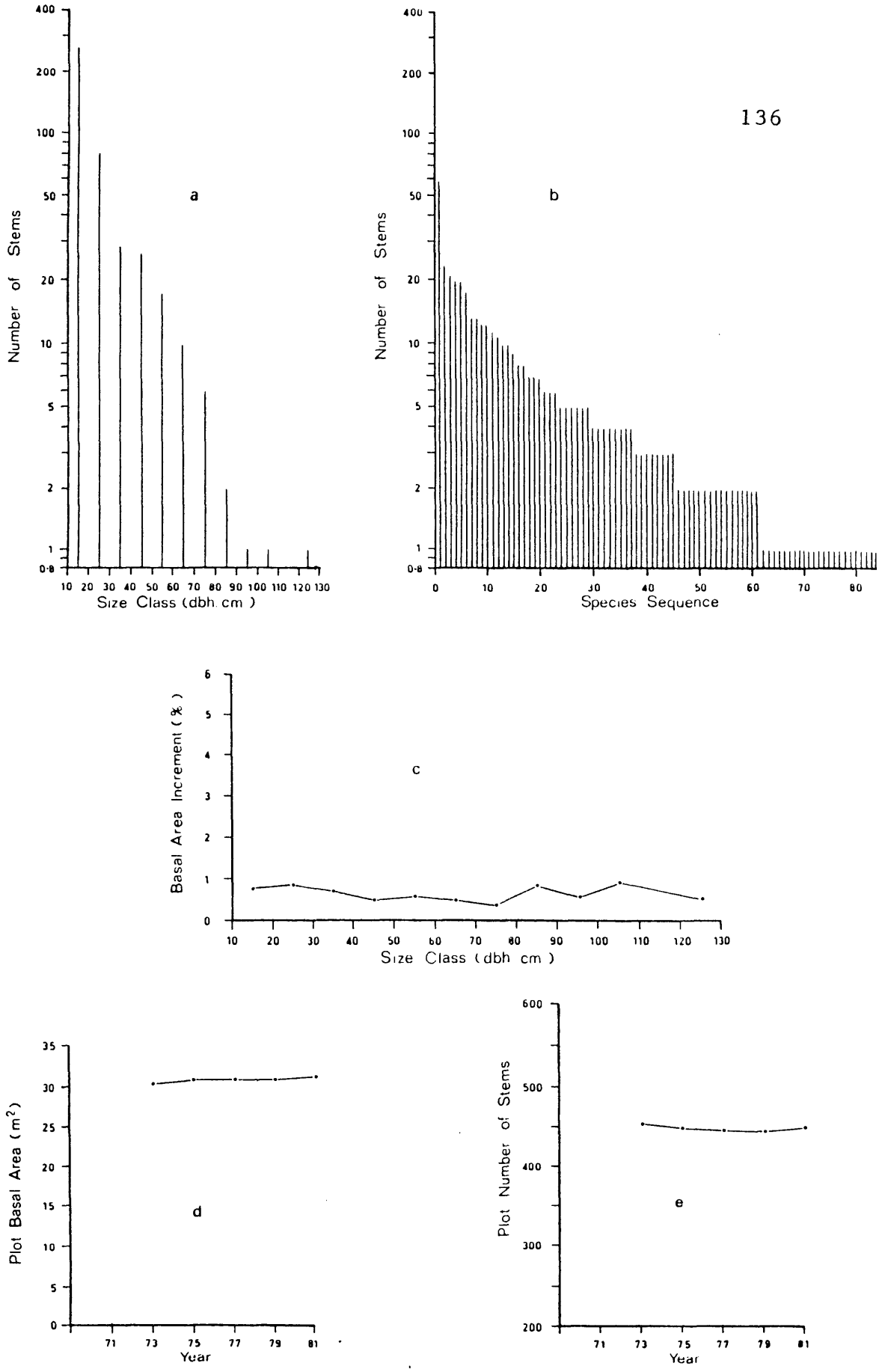

Figure 24. Some characteristics of plot 5 are illustrated :-
a) stem numbers in dbh size classes,
b) stem numbers for each species with the species arranged (left to right) from the most to the least numerous,
c) the basal area increment percent for each size class,
d) temporal trends in plot basal area,
e) temporal trends in the number of stems in the plot.
For further explanation see Section 3.2.2.

Table 14. Plot 5 - Initial stem numbers, mortality and basal area increment by dbh size classes (cm) with recruitment to the 10-20 cm class and an indication of regeneration stocking in subplots for important species. Data from 1973-81.

Species	Regen. stock. a. A	Regen. stock. a. B	Initial stem numbers 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Init. tot.	Recr. b.	Mortality 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Basal area increment c. 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+
Flindersia bourjotiana	14	7	1	2	2	3	1	1	3				13				1								D	C	A	D	A	E	C	C		
Chrysophyllum sp. RFK 3144	15	13	26	22	6	1							35	2	1										D	D	D	E						
Stenocarpus sp. RFK 3174	1	2						1	1		1	1	4																E	D		E	*	
Planchonella euphlebia	9	7	6	4	2	3		1	1				17	1											C	C	D	E		E	C	E		
Syzygium sp. (WESA) RFK 3030	7	7						1				1	2																	A				C
Flindersia brayleyana	8	4				1	1					1	3															A	B					C
Synoum muelleri	6						3	1					4						1										E	E				
Darlingia darlingiana	12	10	2	3	6			1					12		1										E	C	B			E				
Garcinia sp. aff. G. hunsteinii	11	10	2	6	4	2							14												C	E	E	D						
Cardwellia sublimis	14	11	1	3	1	1	1	1					8	1											B	C	A	E	C	C				
Placospermum coriaceum	10	5	2		1	2	2						7												B		D	B	C					
Beilschmiedia sp. aff. B. obtusifolia	9	11	13	5		1							19	1											B	B	A	A						
Xylopia sp. RFK 2013	11	14	16	5									21			1									D	D								
Cryptocarya sp. RFK 2436	9	6	24										24												D									
Synima cordieri	16	14	17	2									19	1											C	C								
Cryptocarya sp. aff. C. hypospodia	12	13	13	1									14		1										B	D								

a) the number of subplots (max. 16) containing 1 or more small trees 0-3 m high (A) and 3 m high to 10 cm dbh (B).

b) the number of small stems entering the 10-20 cm dbh class.

c) basal area increment - relative rates are indicated by :- A = 100% over, B = 25-100% over, C = within 25% of, D = 50-100% below and E = over 100% below, plot mean for that size class.

* - only one tree in that size class.

Placospermum coriaceum and Beilschmiedia bancroftii. Although the upper canopy was fairly continuous at a height of 20-25 m, an understorey, mainly of small vines, shrubs (especially Ardisia brevipedata) and tree species regeneration, was much more conspicuous than in any other of the highland plots.

Although the species/stem numbers curve (Figure 24) followed the expected log normal pattern, it was not quite as steep as that for many of the other plots. The stem numbers distribution by size classes for the important species (Table 14) in general suggested irregular regeneration patterns with only a few species (notably Chrysophyllum sp. RFK 3144) providing any evidence of a normal pattern. While the relative increment rates of the important species varied greatly between size classes, continuous slow growth was evident for some species (e.g. C. sp. RFK 3144); faster growth for others (e.g. Beilschmiedia sp. aff. B. obtusifolia) and erratic growth rates for a third group (e.g. Flindersia bourjotiana).

Despite the irregular regeneration patterns, prospects for the continued presence of most of the important species in the plot appeared good for all, except Stenocarpus sp. and Synoum muelleri, were well represented as saplings. Although recruitment to the 10-20 cm dbh class was low, it appeared sufficient to balance mortality.

When all species were considered, the stem numbers distribution within size classes was close to normal. While percentage increments within size classes were irregular and relatively low, some high values occurred in the upper size classes. The general trend in plot basal area has been a slow rise while tree numbers have been relatively stable. Annual stem mortality averaged 0.61% with the highest level (1.2%) occurring in the 30-40 cm dbh class.

Plot 6

This plot was established during June 1975 on the eastern fall of the dividing range 48 km west-northwest of Ingham, in the southern most portion of the main rainforest belt. The

vegetation may be briefly described "moist upland rainforest on granitic soil". The yellowish clay loam soil appeared variable in depth and merged with a coarse, partially weathered granitic parent material.

Tracey and Webb (1975) have placed the vegetation of this region in the "simple microphyll vine/fern forest" type. Large areas of eucalypt forest which had recently been invaded by rainforest, were seen in the general area and it was suspected that the rainforest species on this plot may not have been there for much longer than the age of the oldest tree.

This plot was of special interest for soon after establishment, deaths due to the root pathogen Phytophthora cinnamomi began to occur, providing an opportunity to study aspects of the spread and the lethal and non lethal effects of this disease.

The main structural feature of the plot were the small tight crowns of emergent species. Flindersia bourjotiana was the commonest species in the upper strata. Although it was occasionally an emergent, it was also conspicuous in the upper canopy layer which it often shared with Canarium muelleri and Flindersia brayleyana. The mid and lower levels of the canopy were more floristically diverse, if rather sparse. Conspicuous in the ground layer was a scrambling Freycinetia sp., the tree fern Cyathea robertsiana and the ground fern Blechnum cartilagineum.

The species/stem numbers curve was approximately normal (Figure 25). The stem number/size class distribution data for the important species (Table 15) showed that while several species, notably Flindersia bourjotiana and Cryptocarya mackinnoniana, appeared to be regenerating continuously, several others, particularly Canarium muelleri and Sloanea macbrydei, seemed to regenerate infrequently. The relative increment rates of individual species in size classes (Table 13) were variable but trends indicating that there were some fast growing species (e.g. Flindersia bourjotiana) and other slow growing species (Canarium muelleri), were observed. The data must, however, be interpreted with caution because of the

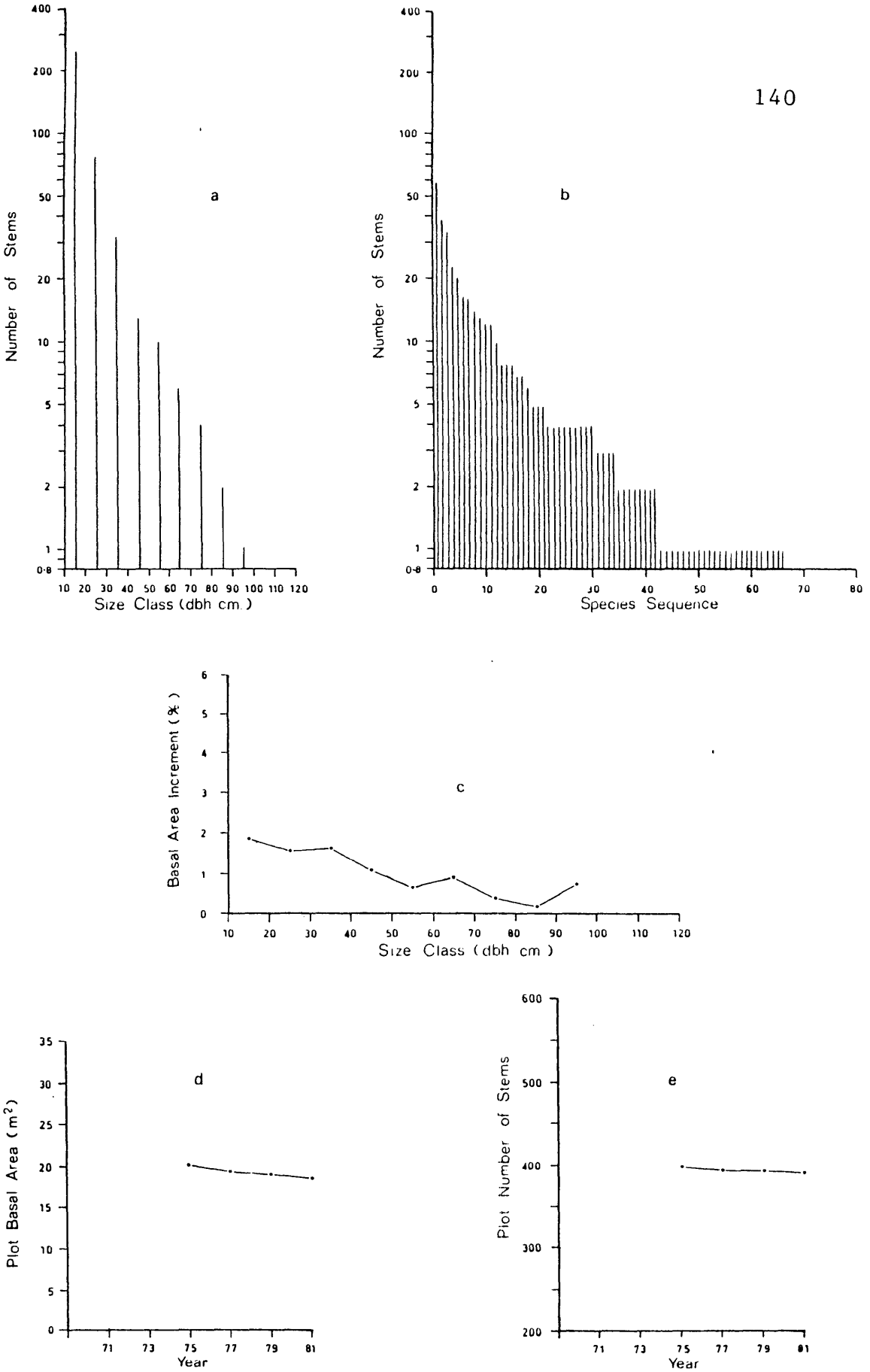

Figure 25. Some characteristics of plot 6 are illustrated :-
a) stem numbers in dbh size classes,
b) stem numbers for each species with the species arranged (left to right) from the most to the least numerous,
c) the basal area increment percent for each size class,
d) temporal trends in plot basal area,
e) temporal trends in the number of stems in the plot.
For further explanation see Section 3.2.2.

Table 15. Plot 6 - Initial stem numbers, mortality and basal area increment by dbh size classes (cm) with recruitment to the 10-20 cm class and an indication of regeneration stocking in subplots for important species. Data from 1975-81.

Species	Regen. stock. a. A	Regen. stock. a. B	Initial stem numbers 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Init. tot.	Recr. b.	Mortality 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Basal area increment c. 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+
Flindersia bourjotiana	16	16	11	6	7	4	5	3		1			37	2		1			1						B	B	B	C	B	B		C	B	
Cryptocarya mackinnoniana	15	11	7	3	6	4							20		2		1								B	C	E	C	B					
Euodia haplophylla	8	14	40	15									55	4	5	5									C	E								
Canarium muelleri	2	2			1	1	1				1		4														E	C	E				E	
Flindersia brayleyana	12	5	2	1					1	1			5								1	1			A	B					D			
Cryptocarya angulata	14	12	10	2	3				1				16	2			1								B	B	C				E			
Pullea stutzeri	14	7	7	3	1	1	1						13												A	C	B	D	B					
Sloanea macbrydei	3	5	1			1			1				3	1							1				C			C	B					
Melicope fareana	16	14	25	6									31	5	4										D	E								
Brackenridgea nitida ssp. australiana	16	15	22	2									24		2										E	E								
Cryptocarya murrayi	9	6	15	1	1								17		1										B	D	E							
Apodytes brachystylis	14	13	13	1									14												C	E								
Antirhea tenuiflora	16	7	14										14	1	1										D	D								

a) the number of subplots (max. 16) containing 1 or more small trees 0-3 m high (A) and 3 m high to 10 cm dbh (B).

b) the number of small stems entering the 10-20 cm dbh class.

c) basal area increment - relative rates are indicated by :- A = 100% over, B = 25-100% over, C = within 25% of, D = 50-100% below and E = over 100% below, plot mean for that size class.

outbreak of Phytophthora cinnamomi which occurred in this plot. The effects of this outbreak on floristics, structure, growth and mortality in this plot will be discussed in Chapter 4.

Plot 7

This plot was established during November 1975 near the summit of Mt Fisher, 8 km south-west of Millaa Millaa, on a rather exposed wind-swept site. Locally the forest here is described as "low wet highland rainforest on acid volcanic soil". The red silty clay soil appeared to have been derived from rhyolite although it may also have been influenced by the younger basalts which are conspicuous on most of the remainder of the mountain. Although the soil seemed relatively deep, some outcropping rock was observed near the plot.

Tracey and Webb (1975) have mapped the vegetation in this area as "complex notophyll vine forest". The canopy level of the vegetation in the plot was relatively low but dense. Most of the trees had short boles with well developed branches. There were no signs of recent or past disturbance although logging had occurred in some of the surrounding forest.

The most prominent tree species in the upper canopy were Elaeocarpus foveolatus, Syzygium sp. RFK 42, Halfordia scleroxyla, Rhodamnia blairiana and Sphenostemon lobosporus. The mid canopy was somewhat more diverse containing small trees of most of the above together with other species. An unusual feature in this plot was the multistemmed habit (usually a main stem with smaller coppice shoots) developed by some of the mid canopy species. The undergrowth was relatively sparse except for a rather prolific development of the dwarf palm, Laccospadix australasica in some parts of the plot.

The species/stem numbers curve for the plot followed the normal pattern as did the overall distribution of stems in size classes (Figure 26). An examination of the stem numbers distribution in size classes and subplot stocking figures for important species (Table 16), suggested that most, except

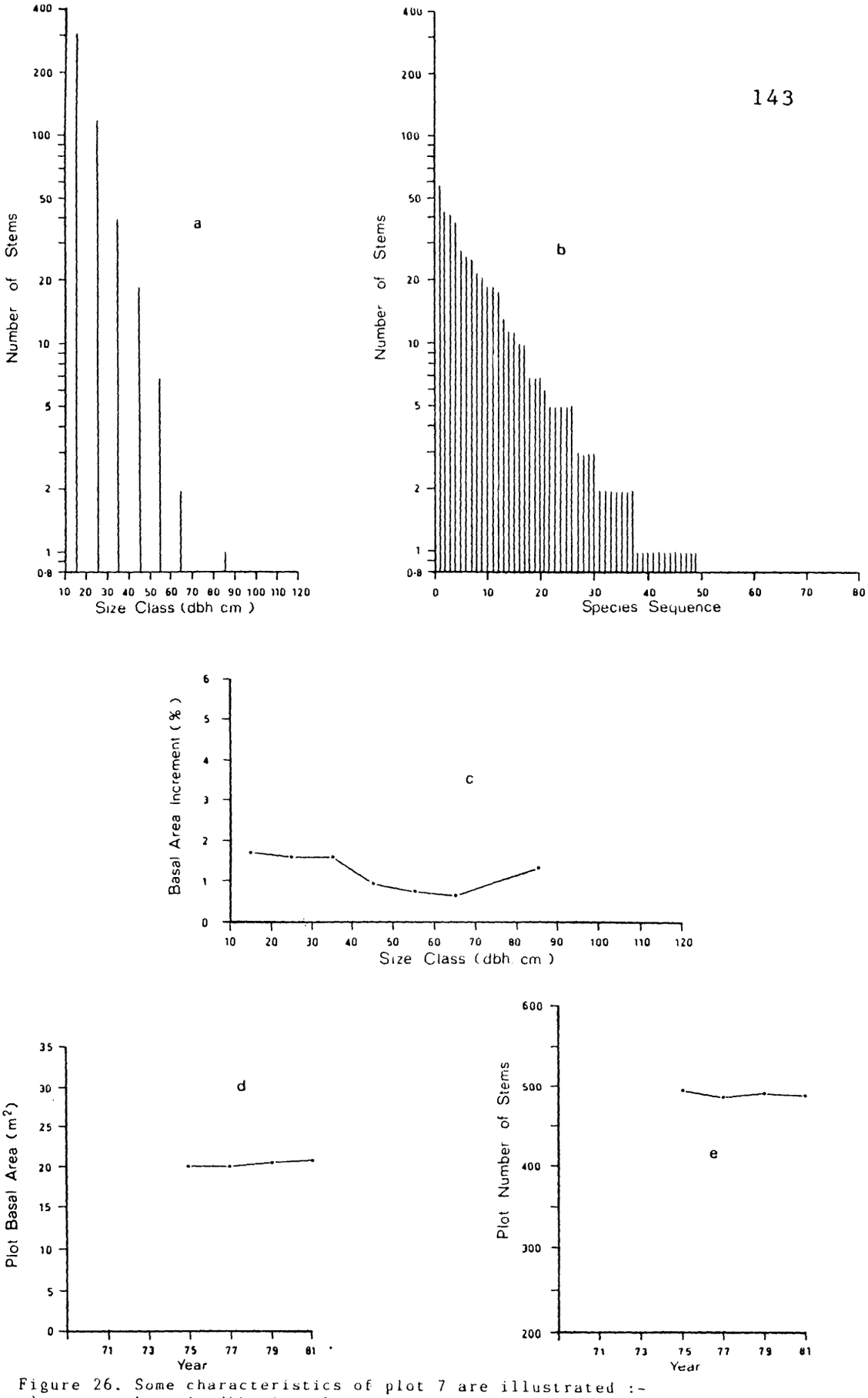

Figure 26. Some characteristics of plot 7 are illustrated :-
a) stem numbers in dbh size classes,
b) stem numbers for each species with the species arranged (left to right) from the most to the least numerous,
c) the basal area increment percent for each size class,
d) temporal trends in plot basal area,
e) temporal trends in the number of stems in the plot.
For further explanation see Section 3.2.2.

Table 16. Plot 7 - Initial stem numbers, mortality and basal area increment by dbh size classes (cm) with recruitment to the 10-20 cm class and an indication of regeneration stocking in subplots for important species. Data from 1975-81.

Species	Regen. stock. a. A	Regen. stock. a. B	Initial stem numbers 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Init. tot.	Recr. b.	Mortality 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Basal area increment c. 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+
Sphenostemon lobosporus	13	9	12	17	11	2							42				2								D	E	E	E						
Elaeocarpus foveolatus	13	12	17	10	5	3	1	1					37	4	2					1					A	A	A	B	B					
Cryptocarya cinnamomifolia	14	15	32	19	3	1							55	5		1	1								C	E	E							
Rhodamnia blairiana	13	5	10	9	4	2	1						26												C	D	E	E	E					
Elaeocarpus ferruginiflorus			8	9	1	2							20	2											A	A	A	C						
Cryptocarya angulata	11	10	7	9	2	1							19	1											A	C	C	D						
Syzygium sp.	10	11	2		2	1	1	1					7												E		D	C	C	*				
Cryptocarya hypoglauca	15	7	11	8	2								21			1									D	E	E							
Halfordia scleroxyla	11	5	1	1		1	2						5												E		E	D	E					
Acronychia doggrellii	1					1				1			2															E					*	
Apodytes brachystylis	15	13	35	4									39	3	1										C	E								
Cryptocarya corrugata	15	10	8	1	1	2							12	1	1										D	E	B	B						
Endiandra dichrophylla	10	15	24	3									27	1	2										E	E								
Bleasdalea bleasdalei	11	5	13	4									17	2		1									E	E								
Steganthera macocraia	13	12	28										28		7										E									
Chionanthus axillaris	13	13	17										17	1	1										E									

a) the number of subplots (max. 16) containing 1 or more small trees 0-3 m high (A) and 3 m high to 10 cm dbh (B).

b) the number of small stems entering the 10-20 cm dbh class.

c) basal area increment - relative rates are indicated by :- A = 100% over, B = 25-100% over, C = within 25% of, D = 50-100% below and E = over 100% below, plot mean for that size class.

* - only one tree in that size class.

perhaps for Halfordia scleroxyla, Syzygium sp. RFK 42 and Aceratium doggrellii, had continuous regeneration and establishment patterns and appeared able to persist on this site. However, the high mortality experienced by Steganthera macoorii may, if continued, mean that its importance will decline.

The relative increment rates of the important species seemed rather more clearly defined than in most of the other plots. For example both Elaeocarpus species were fast growing while most of the remaining species were consistently slow. The percentage growth rates in various size classes (Figure 26) were highest in the 10-20 cm dbh class and gradually tapered off to rise again in the largest size class (80-90 cm dbh). The general trend in plot basal area has been a slow increase. Total stem numbers have been relatively stable. Annual mortality has been rather high at 1.05% and reached 1.16% in the 10-20 cm dbh class.

Plot 8

This plot was established during June 1976 on the Windsor Tableland, 45 km north-west of Mossman. The forest here is locally described as "moist upland rainforest on granitic soil". The yellowish clay loam soil contained an increasing quantity of partially decomposed granitic gravel with depth.

Tracey and Webb (1975) would describe the vegetation on the site as "simple microphyll vine/fern forest". While the forest had never been logged, the canopy was quite variable in height and density. This suggested past disturbance, probably from cyclones. As a consequence of the variations apparent in the canopy, the understorey through the plot varied from dense to almost absent.

Tree species reaching the emergent and upper canopy levels of this plot included Flindersia bourjotiana, Cardwellia sublimis, Sterculia laurifolia, Syzygium sp. RFK 3030, Planchonella papyracea, Flindersia brayleyana and F. acuminata. Many of these species were also found at lower levels in the canopy with several additional species,

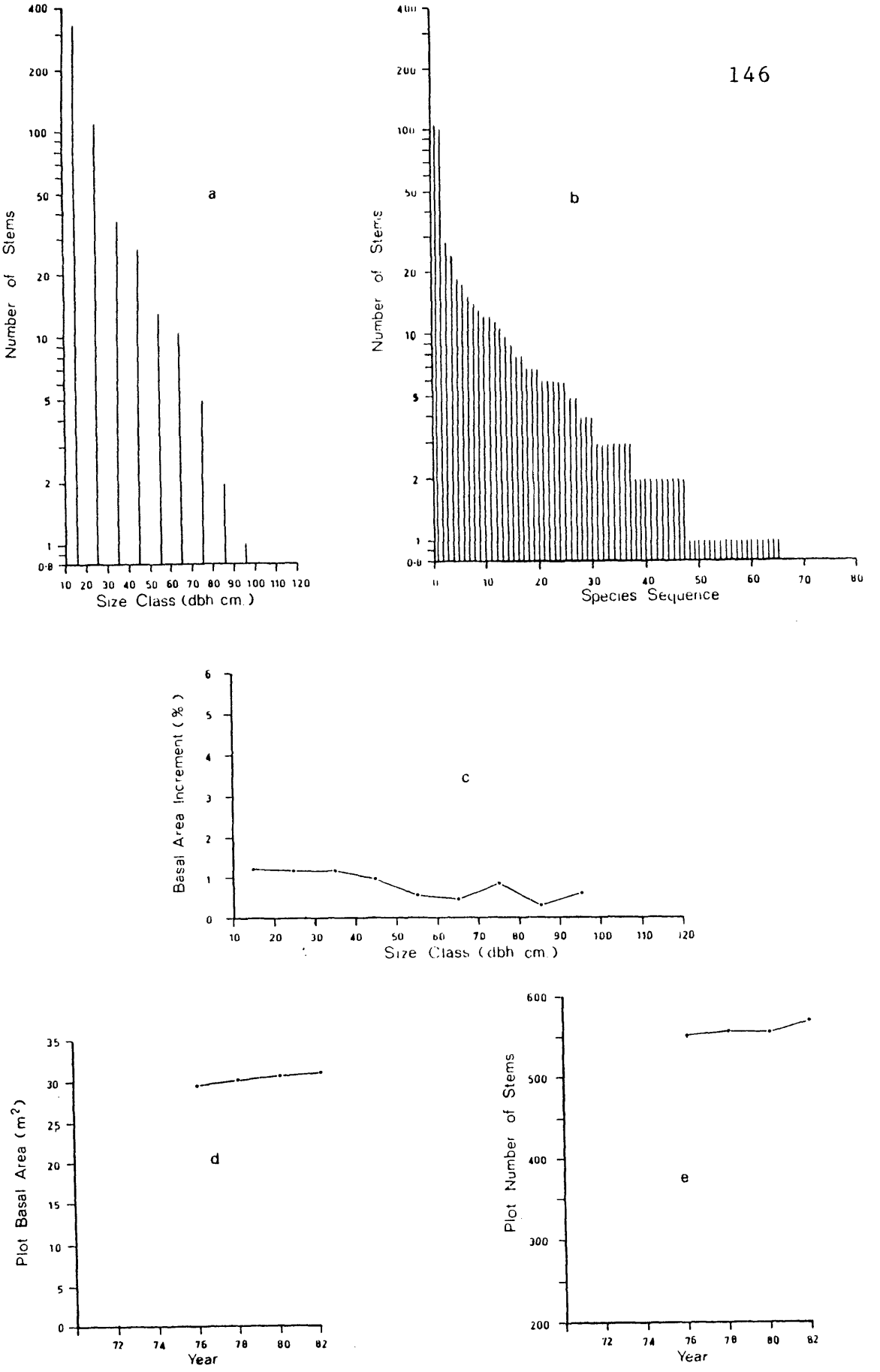

Figure 27. Some characteristics of plot 8 are illustrated :-
a) stem numbers in dbh size classes,
b) stem numbers for each species with the species arranged (left to right) from the most to the least numerous,
c) the basal area increment percent for each size class,
d) temporal trends in plot basal area,
e) temporal trends in the number of stems in the plot.
For further explanation see Section 3.2.2.

Table 17. Plot 8 - Initial stem numbers, mortality and basal area increment by dbh size classes (cm) with recruitment to the 10-20 cm class and an indication of regeneration stocking in subplots for important species. Data from 1976-82.

Species	Regen. stock. a. A	Regen. stock. a. B	Initial stem numbers 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Init. tot.	Recr. b.	Mortality 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Basal area increment c. 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+
Ceratopetalum succirubrum	13	16	71	26	8	1							106	9											C	C	C	E						
Planchonella papyracea	9	3	1	2	1		4	2	1		1		12												D	D	E		E	E	E	C	*	
Syzygium sp. RFK 3030	15	14	5	2	1	3		2	2				15												C	D	C	D		D	D	B		
Euodia haplophylla	11	13	84	18									102	6	1										D	E								
Flindersia bourjotiana	14	16	18	3	2	2		2	1				28		1										B	B	C	C		B	A			
Flindersia brayleyana	15	11	3	2	2	4	3						14												B	B	C	C	D	C				
Flindersia acuminata	2	3	2	5		3		2					12			1									E	C		E		E				
Sterculia laurifolia	14	13	6	7	3	2							18					1							E	D	E	B	A					
Cardwellia sublimis	14	5	4	3	2	4							13												A	D	B	B	E					
Darlingia darlingiana	11	7	5	7	1		2						15	1											D	D	C		E	A				
Planchonella euphlebia	5	6			1			1		1			3	1														D		B		D		
Eugenia kuranda	15	11	18	6	1								25	1											C	D	E							
Polyscias australiana	11	16	18	1									19		1										E	E								

a) the number of subplots (max. 16) containing 1 or more small trees 0-3 m high (A) and 3 m high to 10 cm dbh (B).

b) the number of small stems entering the 10-20 cm dbh class.

c) basal area increment - relative rates are indicated by :- A = 100% over, B = 25-100% over, C = within 25% of, D = 50-100% below and E = over 100% below, plot mean for that size class.

* - only one tree in that size class.

particularly Ceratopetalum succirubrum. The understorey consisted mainly of small trees and the tree fern Cyathea rebeccae.

The initial fall in the species sequence/stem numbers histogram (Figure 27) was rather abrupt with two species, Ceratopetalum succirubrum and Euodia haplophylla having 106 and 102 individuals respectively while the next most numerous species, Flindersia bourjotiana had only 28. The stem numbers distribution by size classes for important species (Table 17) suggested that many of the species do not regenerate continually. Ceratopetalum succirubrum and Eugenia kuranda seemed important exceptions. However, the only species without sufficient sapling regrowth to maintain its numbers in the plot was Flindersia acuminata. The high recruitment and low mortalities recorded for C. succirubrum and E. haplophylla seemed to assure the continued numerical dominance of these two species in the plot.

There were few consistent patterns in the relative increment rates of the important species (Table 17). The Flindersia species, F. bourjotiana and F. pimenteliana, were growing faster than most, while F. acuminata and Planchonella papyracea were somewhat slower.

When all species were considered, the distribution of stems within diameter classes appeared close to normal (Figure 27). While percentage increments were highest in the 10-20 cm dbh class and in general fell steadily with increasing dbh, the 70-80 cm class did contain some vigorous emergents. The general trend in plot basal area has been for a slow increase. The number of stems increased slightly. Annual stem mortality was relatively low at 0.3%.

Plot 9

This plot was established in August 1976 in lowland forest at the foot of Mt Bartle Frere. Locally the vegetation is described as "tall wet coastal rainforest on metamorphic soil". The deep red sandy loam soil in this plot did not appear to have the massive clay subsoil characteristic of many

soils derived from metamorphic parent materials. Surrounding soils of basaltic origin may have also influenced its properties.

Tracey and Webb (1975) have mapped the vegetation in this area as "complex mesophyll vine forest". Like much of the forest in this general area it was dominated by a single tree species, Backhousia bancroftii. While there was no evidence of logging or cyclone damage within the plot, the results of past severe cyclone damage were obvious in nearby areas where dense thickets, locally known as "cyclone scrubs", were a feature of the landscape. The upper canopy of the trees in the plot was dense and well developed. It was, however, open enough to allow moderately dense clumps of Calamus spp. to survive in a suppressed state on the forest floor. Few other tree species reached the upper canopy although aerial photographs revealed that large crowns of the woody hemiepiphyte[2], Schefflera actinophylla, were much more prominent than would be expected from a ground view. The most conspicuous species at mid canopy level was Myristica insipida.

The dominance of Backhousia bancroftii has not greatly influenced the general shape of the species/stem numbers histogram (Figure 28) but this histogram does reflect the low diversity of this plot. The stem numbers distribution by size classes for important species (Table 18) generally showed continuous species regeneration patterns except for Castanospermum australe and Cardwellia sublimis. This data also suggested that C. sublimis could easily disappear from the plot if present trends continued. A comparison of relative increment rates of the important species did not provide very much information as the larger size classes were so heavily dominated by a single species, B. bancroftii. Nevertheless, this species grew as fast, if not faster than any other of the important species.

When all species were considered, the distribution of stems

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2. A plant which is epiphytic for only part of its life cycle - Hanson (1962).

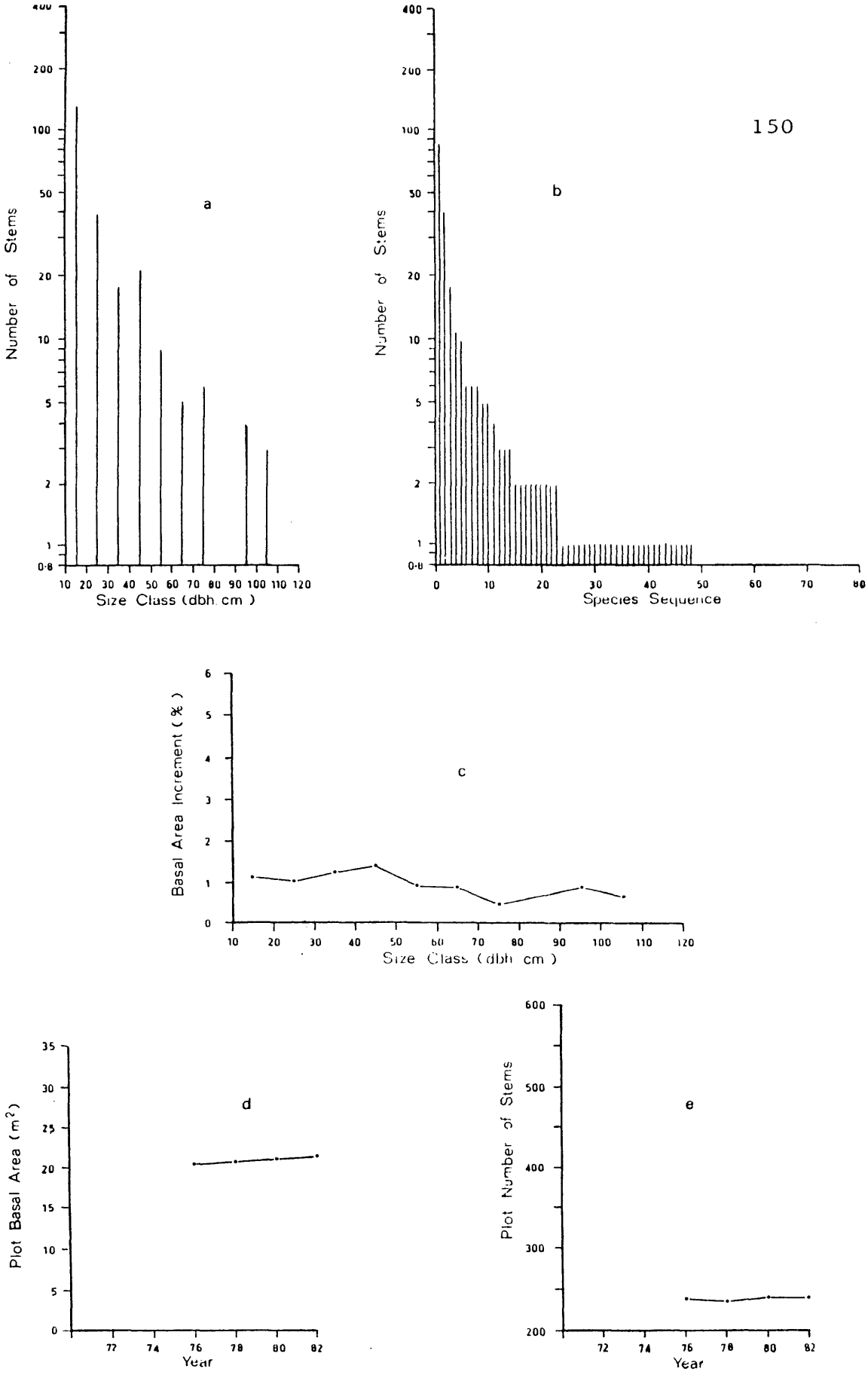

Figure 28. Some characteristics of plot 9 are illustrated :-
a) stem numbers in dbh size classes,
b) stem numbers for each species with the species arranged (left to right) from the most to the least numerous,
c) the basal area increment percent for each size class,
d) temporal trends in plot basal area,
e) temporal trends in the number of stems in the plot.
For further explanation see Section 3.2.2.

Table 18. Plot 9 - Initial stem numbers, mortality and basal area increment by dbh size classes (cm) with recruitment to the 10-20 cm class and an indication of regeneration stocking in subplots for important species. Data from 1976-82.

Species	Regen. stock. a. A	Regen. stock. a. B	Initial stem numbers 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Init. tot.	Recr. b.	Mortality 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Basal area increment c. 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+
Backhousia bancroftii	14	13	28	10	11	12	7	4	5		4	2	83	2											B	B	C	C	C	C	C		C	B
Myristica insipida	14	13	22	13	3	2							40												B	B	C	B						
Castanospermum australe	10	9	4	2		3	2						11					1							D	D		E	E					
Cardwellia sublimis	8											1	1																					E
Dysoxylum oppositifolium	8	8	4	4	1	1							10			2									C	E	E	E						
Rockinghamia angustifolia	4	14	15	2									17	1	1										D	D								

a) the number of subplots (max. 16) containing 1 or more small trees 0-3 m high (A) and 3 m high to 10 cm dbh (B).

b) the number of small stems entering the 10-20 cm dbh class.

c) basal area increment - relative rates are indicated by :- A = 100% over, B = 25-100% over, C = within 25% of, D = 50-100% below and E = over 100% below, plot mean for that size class.

within size classes was not as close to the normal pattern as it was in most other plots, for stem numbers in the 20-30 and 30-40 cm dbh classes were rather low (Figure 28). The percentage increments were highest for trees in the 40-50 cm dbh class category. This may reflect the minimum tree size necessary before a space can be secured in the rather uniformly dense upper canopy. The general trend of total plot basal area has been for steady increase. The number of stems appeared to be relatively stable. Annual stem mortality has been relatively low at 0.7% with the highest level in the 20-30 cm dbh class (1.28%).

Plot 10

This plot was established in September 1975 near the headwaters of Leo Creek in the McIlwraith Range. The vegetation in the plot could be briefly described as "moist upland rainforest". Webb (1959) would describe it as "notophyll vine forest". The deep reddish sandy loam soil appeared to be derived from metamorphosed shales although most of this poorly known region is underlain by granite.

While this plot was north of the main rainforest belt, its floristic affinities were with rainforests to the south rather than with the nearby lowland rainforests typified by plot 18. Like many of the mid to low altitude sites with clay subsoils, it had a well developed mid canopy strata formed by the palm Licuala ramsayi. There was no evidence of past cyclone damage or of logging. However, in recent years there has been an unknown pest or disease which has resulted in the death of a number of Podocarpus neriifolius trees within this stand. The extent and nature of this phenomenon are reported in the next Chapter.

One of the most prominent species in this plot was Xanthostemon chrysanthus, a species more characteristic of stream sides further south. Other conspicuous species in the upper canopy included Calophyllum sil, Blepharocarya involucrigera, Grevillea pinnatifida and Cryptocarya sp. aff. C. hypospodia. Licuala ramsayi was often seen in the mid canopy while the moderately dense understorey was composed

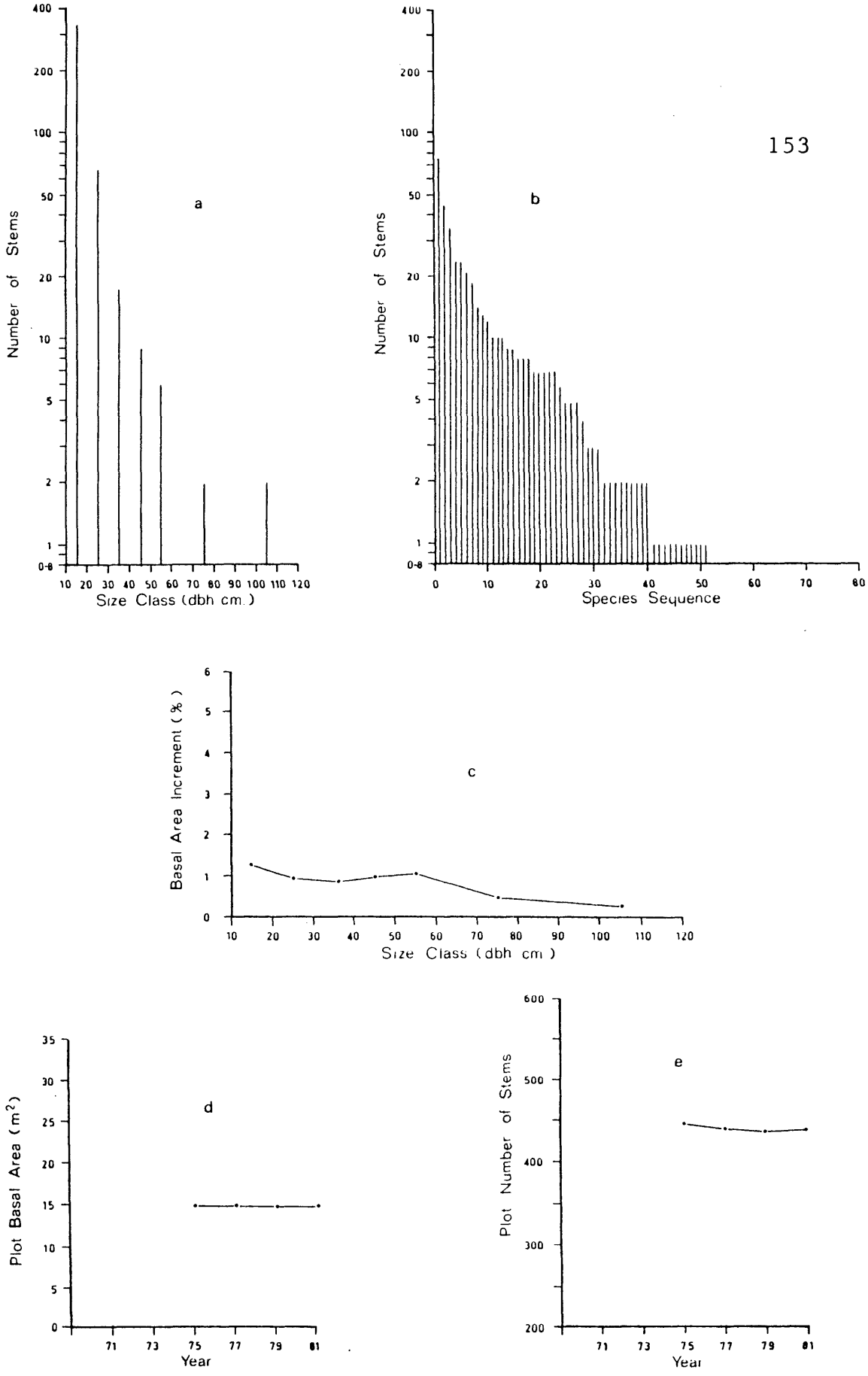

Figure 29. Some characteristics of plot 10 are illustrated :-
a) stem numbers in dbh size classes,
b) stem numbers for each species with the species arranged (left to right) from the most to the least numerous,
c) the basal area increment percent for each size class,
d) temporal trends in plot basal area,
e) temporal trends in the number of stems in the plot.
For further explanation see Section 3.2.2.

Table 19. Plot 10 - Initial stem numbers, mortality and basal area increment by dbh size classes (cm) with recruitment to the 10-20 cm class and an indication of regeneration stocking in subplots for important species. Data from 1975-81.

Species	Regen. stock. a. A	Regen. stock. a. B	Initial stem numbers 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Init. tot.	Recr. b.	Mortality 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Basal area increment c. 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+
Xanthostemon chrysanthus	3		4			3	3		1			2	13		1										E			D	C		B			C
Cryptocarya sp. aff. C. hypospodia	10	11	22	15	7	1							45	2	4	1	1								B	C	C	D						
Xanthophyllum octandrum			15	8	2								25	1											D	E	E							
Licuala ramsayi	16	16	73										73	3											E									
Calophyllum sil	8	5	3	1	2	1	1						8	1	1				1						A	C	B	C	E					
Blepharocarya involucrigera						1	2						3															B	C					
Grevillea pinnatifida	6	4	4	2	2	1							9	1			1								B	B	A	C						
Cryptocarya mackinnoniana	13	14	33	1									34	3	2										C	C								
Polyscias australiana	13	14	21										21	2	2										C									
Antirhea tenuiflora	5	5	18										18	1	2										C									
Elaeocarpus eumundi	8	9	13	2									15	2	1										B	C								
Cleistanthus hylandii	15	14	22										22												D									

a) the number of subplots (max. 16) containing 1 or more small trees 0-3 m high (A) and 3 m high to 10 cm dbh (B).

b) the number of small stems entering the 10-20 cm dbh class.

c) basal area increment - relative rates are indicated by :- A = 100% over, B = 25-100% over, C = within 25% of, D = 50-100% below and E = over 100% below, plot mean for that size class.

of tree species regeneration, vines and pandans.

The species sequence/stem numbers histogram was close to normal (Figure 29). The stem numbers distribution by size classes for the dominant species, X. chrysanthus, (Table 19) suggested a very irregular regeneration pattern. The stem numbers distribution of another important species, Blepharocarya involucrigera, indicated that recent conditions did not favour its regeneration. The continued persistence of the remaining important species, except perhaps Xanthophyllum octandrum, seemed assured. The relative increment rate patterns were generally erratic but Grevillea pinnatifida and Xanthophyllum octandrum were recognizable, respectively, as the fastest and slowest growing of the important species.

When the dbh class distributions of all species were considered, the resulting histogram was relatively normal in outline (Figure 29). The percentage increments were roughly constant up to the middle of the dbh size class range although they then fell, indicating that the larger emergents may have lost much of their vigour. The basal area of the plot was surprisingly low and quite static. If any trend was evident in the number of stems on the plot, it was one of decline. Annual stem mortality was relatively high at 1.2%. Most of the deaths occurred in the 10-20 cm dbh class.

Plot 11

This plot was established during March 1976 in rainforest on a comparatively recent vesicular basalt flow 2 km south-west of Yungaburra on the Atherton Tableland. The forest is locally described as "tall dry upland rainforest on basaltic soil". The dark brown gravelly clay loam soil appeared to be several metres deep. However, the soil volume was very restricted by numerous basalt boulders throughout the profile. Basalt boulders and stones also covered most of the floor of the plot.

Tracey and Webb (1975) have mapped the vegetation in this area as "complex notophyll vine forest". The forest in which this plot was located is now isolated from the main rainforest

belt but it was sufficiently large (190 ha) to contain representatives of most of the original fauna and flora (the Cassowary, Casuarius casuarius, was a notable exception). The area of the plot seemed to have escaped logging although some nearby parts have been selectively logged. The vegetation on the plot was at least superficially similar to other remnants in the area suggesting that it might be broadly representative of that which was once widespread on the Atherton Tableland. Most of this forest has now been cleared for agriculture (mainly maize and peanuts) and pasture for dairy cattle.

Prominent tree species as emergents and upper canopy species included Argyrodendron peralatum, Dysoxylum pettigrewianum, Aleurites moluccana and Toona australis. A little lower in the canopy Dendrocnide photinophylla, Flindersia brayleyana, Endiandra pubens, E. cowleyana and Tetrasynandra laxiflora were also conspicuous. The understorey varied from sparse to moderately dense. In it the shrub Hodgkinsonia frutescens and the climbing palm Calamus caryotoides, were particularly conspicuous and indeed are characteristic of the forests in this area. The large epiphytic ferns, Platycerium superbum and Asplenium australasicum, were prominent on the branches of mid and upper canopy trees.

The species sequence/stem numbers histogram (Figure 30) followed a fairly normal pattern. The overall stem numbers distribution by size classes was rather irregular in the larger size classes. An examination of the latter parameter for the important species indicated that most of the larger species have an irregular pattern of recruitment. Some, such as Aleurites moluccana and Flindersia brayleyana, seemed destined to disappear from the stand unless conditions favourable for their regeneration return. Several large trees of A. moluccana (a "large gap" species) in the forest surrounding the plot have died in recent years and many others appeared close to death. It is suspected that this species, and possibly Toona australis and F. brayleyana, may have been favoured by a past catastrophe, perhaps drought and fire during 1915 (Section 2.1.5b). The butts of several large Castanospermum australe trees growing in and near the plot appeared to have been scarred by fire.

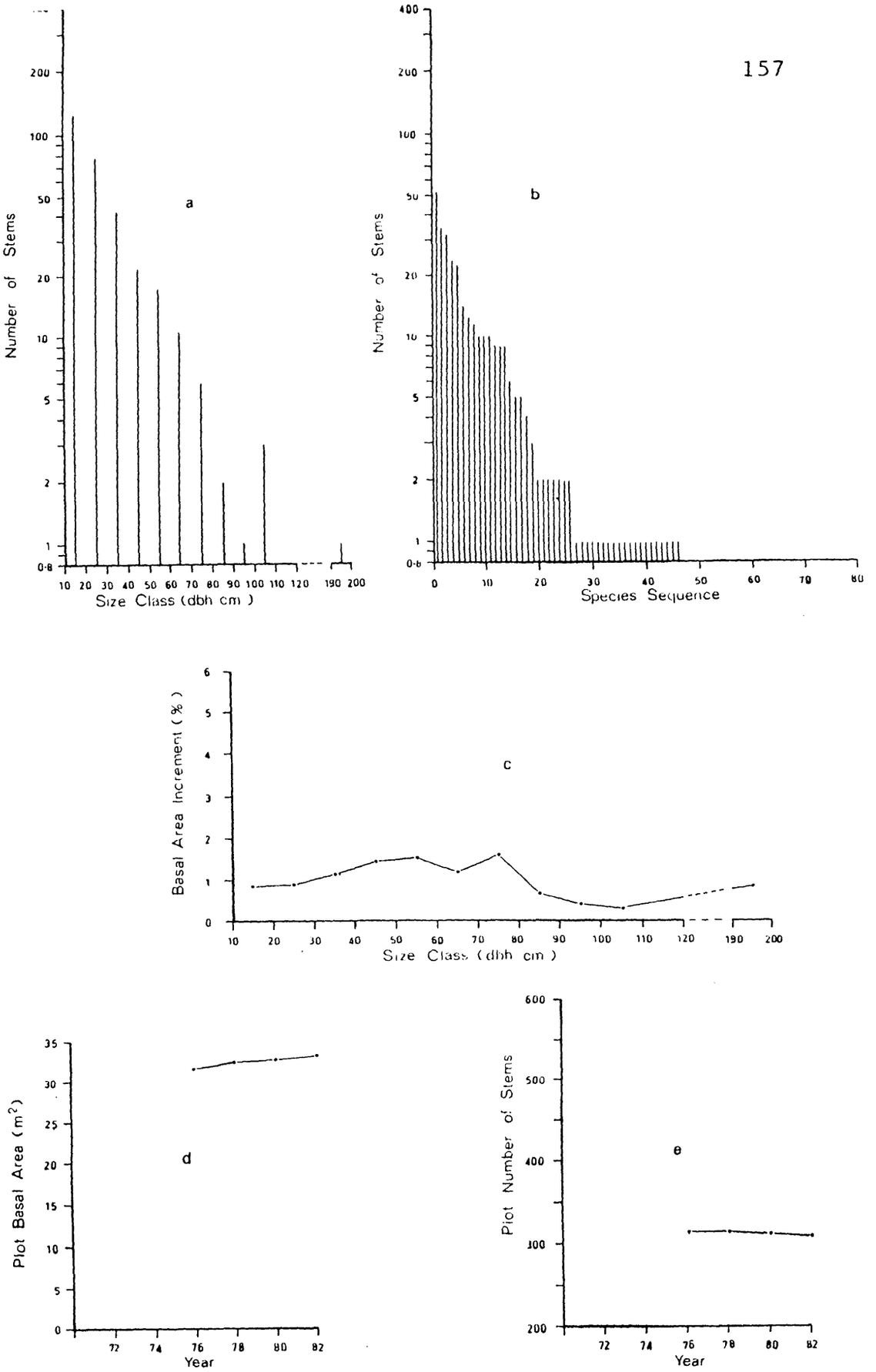

Figure 30. Some characteristics of plot 11 are illustrated :-
a) stem numbers in dbh size classes,
b) stem numbers for each species with the species arranged (left to right) from the most to the least numerous,
c) the basal area increment percent for each size class,
d) temporal trends in plot basal area,
e) temporal trends in the number of stems in the plot.
For further explanation see Section 3.2.2.

Table 20. Plot 11 - Initial stem numbers, mortality and basal area increment by dbh size classes (cm) with recruitment to the 10-20 cm class and an indication of regeneration stocking in subplots for important species. Data from 1976-82.

Species	Regen. stock. a. A	Regen. stock. a. B	Initial stem numbers 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Init. tot.	Recr. b.	Mortality 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Basal area increment c. 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+
Dendrocnide photinophylla	3	7	23	16	6	1	1	1	2	1			51		1										E	C	C	E	E	E	E	E		
Dysoxylum pettigrewianum	11	10	22	2	2	1	1				1	2	31												C	B	B		B	C			*	D
Argyrodendron peralatum	13	14	22	2	1	3	1	2	1			1	33	2											C	A	A	A	D	C	E	D		E
Toona australis		2	4	6	3	3	5	1	1				23			1									C	B	A	B	A	B	B			
Ficus watkinsiana	3											1	1																					A
Aleurites moluccana						1	3	3	1	1			9															D	D	E	C	E		
Flindersia brayleyana				2	2	2	3	1					10													C	C	B	B	B				
Castanospermum australe	15	15				1	2	1	1				5															B	E	E		A		
Endiandra cowleyana		1	1	4	3		2						10												A	B	B		E					
Daphnandra repandula	1	3	14	6	3	1							24												C	E	E	E						
Tetrasynandra laxiflora	7	2	2	5	6								13		1										E	E	E							
Endiandra pubens		2	5	8	1	1							15	1		1									D	E		E						
Litsea leefeana	5	5	6	2	3	1							12				1								A	A	B	C						
Mallotus polyadenos	2		7	2	1								10												E	B	E							

a) the number of subplots (max. 16) containing 1 or more small trees 0-3 m high (A) and 3 m high to 10 cm dbh (B).

b) the number of small stems entering the 10-20 cm dbh class.

c) basal area increment - relative rates are indicated by :- A = 100% over, B = 25-100% over, C = within 25% of, D = 50-100% below and E = over 100% below, plot mean for that size class.

* - only one tree in that size class.

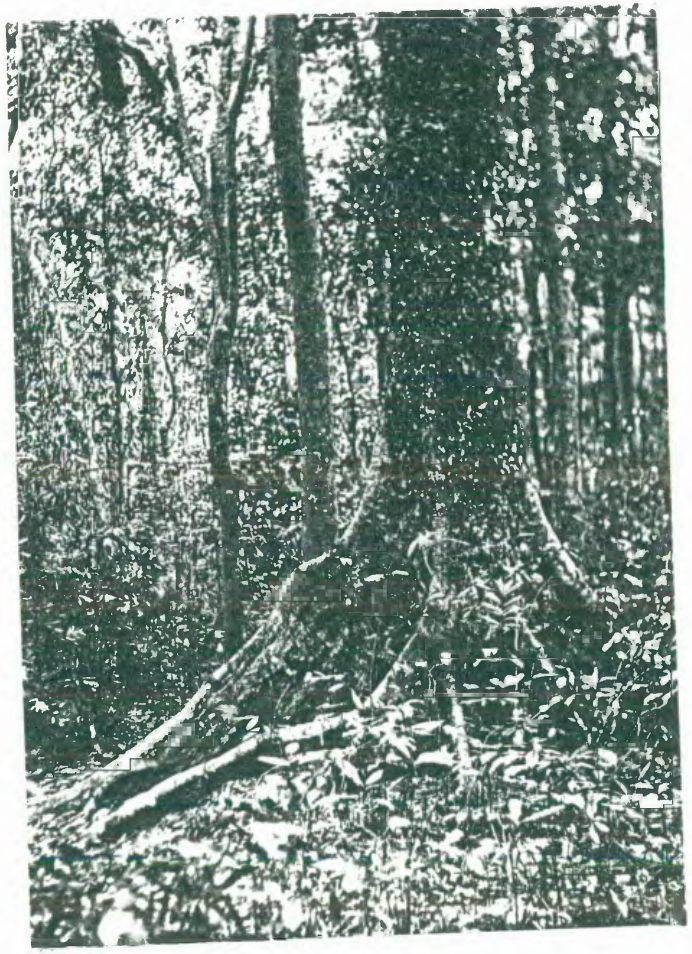

Plate 11. The large flanged buttresses of Argyrodendron peralatum were a conspicuous feature of the interior of plot 11.

Plate 12. A 1:3000 scale vertical aerial photograph of the canopy of plot 11. Other photographs at various scales and based on a variety of photographic materials, are available for this plot and also numbers 1, 2, 3 and 9.

The relative increment rates of the important species showed more consistency within individual species than was observed in many of the other plots (Table 18). Although the mean increment rate of smaller sized individuals of Toona australis was only average, many of those of larger size grew rapidly. Argyrodendron peralatum seemed to do well when individuals were in the 20-50 cm dbh range but the growth of larger sizes was lower. Dendrocnide photinophylla showed persistently slow growth especially in the larger sizes.

The overall distribution of species in diameter classes was close to normal. Percentage increments were highest in the 70-80 cm dbh class and their pattern was unusual in that the general trend was a continued increase from the smallest size class until this level and a falling off with larger size classes. While the plot basal area seemed to be steadily increasing, the number of stems slowly declined. Annual stem mortality averaged 0.53%, with the highest levels in the 40-50 cm dbh size class.

Plot 12

This plot was established in November 1976 near the upper reaches of the Russell River just to the south of Mt Bartle Frere. This forest could be briefly described as "tall wet riverine rainforest on alluvial soil". The deep brown sandy soil appeared to be derived mainly from granites.

Tracey and Webb (1975) have typed the forest in this area as "complex mesophyll vine forest". This very diverse plot contained the highest trees yet recorded in this region's rainforests with many emergents reaching 45 m. Another very noticeable feature of the physiognomy was the presence of many herbaceous to semi-woody climbers (mainly Pothos, Freycinetia and Piper spp.) on the boles of almost all the trees. The area had not been logged and showed no signs of past cyclone disturbance.

The three species which were truly emergent in this plot were Argyrodendron peralatum, Alstonia scholaris and Beilschmiedia bancroftii. They towered above a general canopy

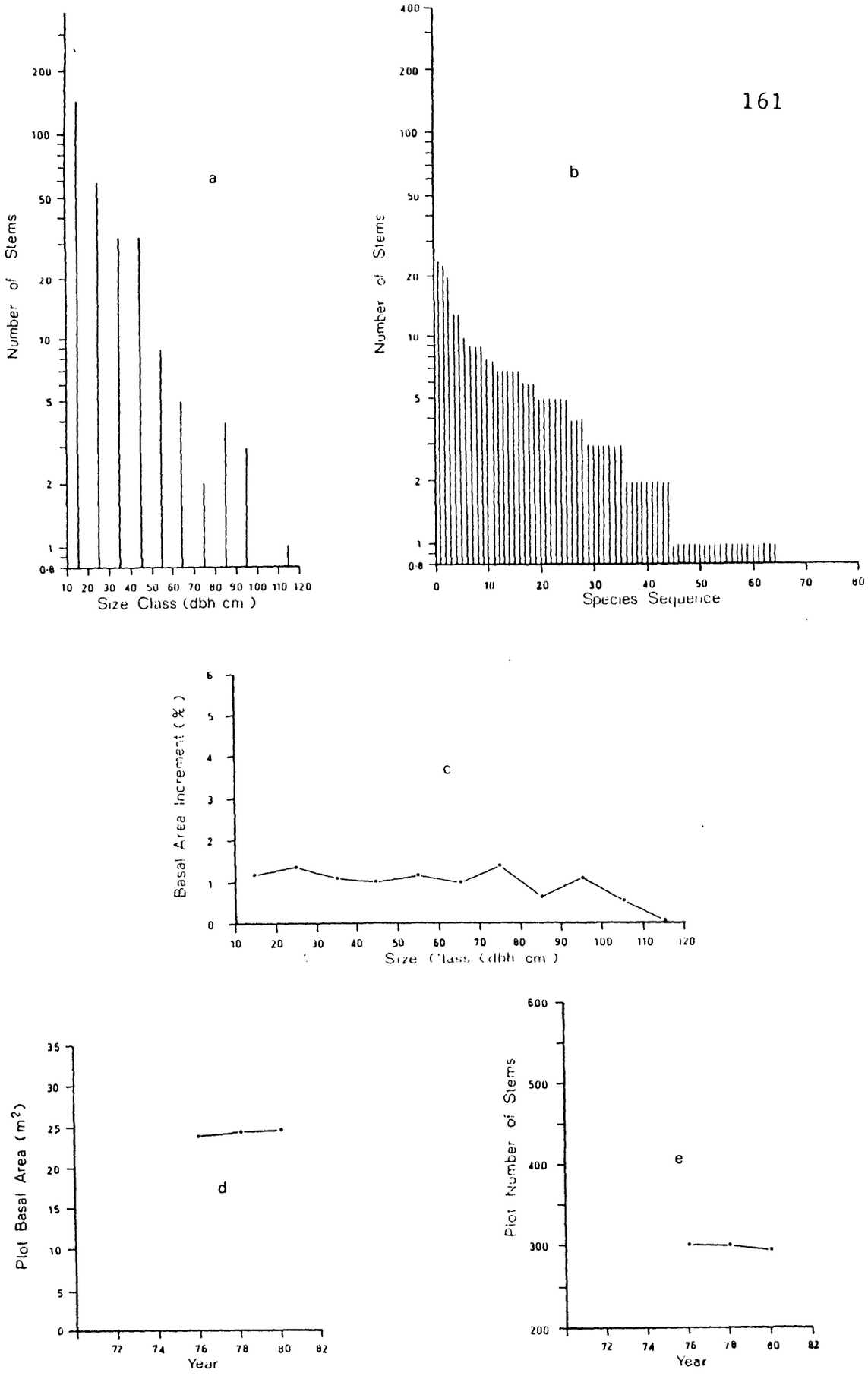

Figure 31. Some characteristics of plot 12 are illustrated :-
a) stem numbers in dbh size classes,
b) stem numbers for each species with the species arranged (left to right) from the most to the least numerous,
c) the basal area increment percent for each size class,
d) temporal trends in plot basal area,
e) temporal trends in the number of stems in the plot.
For further explanation see Section 3.2.2.

Table 21. Plot 12 - Initial stem numbers, mortality and basal area increment by dbh size classes (cm) with recruitment to the 10-20 cm class and an indication of regeneration stocking in subplots for important species. Data from 1976-80.

Species	Regen. stock. a.		Initial stem numbers										Init. tot.	Recr. b.	Mortality										Basal area increment c.									
	A	B	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+			10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+
Tetrasynandra laxiflora	13	6	2	3	5	6	3	1					20		1										B	E	E	E	E	E				
Argyrodendron peralatum	13	3	1	3	1	1	1				1	1	9												E	A	A	B	B				C	E
Alstonia scholaris						2				2	1		5															A				C	E	B
Opisthiolepis heterophylla	13	5	5	5	10	3	1						24		1										E	B	B	B	C					
Castanospora alphandii	15	8	3	3	1	1	1	1					10												A	B	D	B	A	D				
Myristica insipida	13	5	5	5	2	2							14												A	B	D	C						
Beilschmiedia sp. AFO 1479	5				1			1		1			3														E			A		B		
Cryptocarya angulata	11	2	2		1	1				1			5												C		B	D				E		
Beilschmiedia bancroftii	7	5	3								1		4	1											E								E	C
Litsea leefeana	15			2	3	2							7													D	D	D						
Endiandra pubens	9	10	3	2	1	3							9												B	C	E	E						
Rockinghamia angustifolia	9	12	21	4									25												C	E								
Citronella smythii	6	10	11	3									14												D	C								

a) the number of subplots (max. 16) containing 1 or more small trees 0-3 m high (A) and 3 m high to 10 cm dbh (B).

b) the number of small stems entering the 10-20 cm dbh class.

c) basal area increment - relative rates are indicated by :- A = 100% over, B = 25-100% over, C = within 25% of, D = 50-100% below and E = over 100% below, plot mean for that size class.

composed of many species including Opisthiolepis heterophylla, Castanospora alphandii, Endiandra pubens, Myristica insipida, Tetrasynandra laxiflora, Sloanea australis and Litsea leefeana. The mid levels of the canopy and the understorey consisted of scattered small trees and vines.

While the species sequence/stem numbers histogram (Figure 31) showed a normal pattern, the stem number values were lower for the more numerous species than they were in any other plot. This was reflected in this plot's high floristic diversity (Table 8). The stem numbers distribution by size classes for the important species (Table 21) suggested that most of the species in this plot were recruited rather irregularly. However, there seemed to be enough advanced growth present for all these species, except perhaps Alstonia scholaris, to maintain themselves in this stand under present conditions. Although the relative increment data indicated some relatively fast growing species (e.g. Argyrodendron peralatum) and other slow growing species (e.g. Tetrasynandra laxiflora), growth rates within species were quite variable.

When all species were considered, the stem numbers distribution by dbh classes followed normal trends but the number of small trees (those in the 10-20 cm dbh class) was quite low. Percentage increments, although variable, remained relatively high for all except the two largest size classes. While the total number of stems in the plot has declined slightly, the plot basal area has steadily increased. Annual stem mortality averaged 0.58%.

Plot 13

This plot was established in May 1977 in lowland rainforest on poor metamorphic soil 16 km north of Mossman. It is locally described as "low wet coastal rainforest on metamorphic soil". The gravelly reddish loam surface soil was underlain by a massive clay subsoil.

Tracey and Webb (1975) have mapped this forest as "mesophyll vine forest". In general aspect the vegetation appeared closest to that on plot 3. While the canopy level was fairly

low (> 30 m) it was relatively compact and except in recent openings, the understorey was sparse. While the site appeared not to have been logged, there were many signs of repeated cyclone damage with some "cyclone scrub" patches and recent windfalls within a few hundred metres of the plot.

Upper canopy species in this plot included Flindersia bourjotiana, Acacia aulacocarpa, Alstonia muellerana, Eugenia kuranda, F. pimenteliana and Musgravea heterophylla. The mid canopy and understorey layers were mainly composed of scattered tree seedlings and saplings while the tree fern, Cyathea rebeccae, was abundant in some parts.

The species sequence/stem numbers histogram followed the normal pattern (Figure 32). Most of the important species (Table 22) appeared to follow a regular regeneration pattern although obvious exceptions were Acacia aulacocarpa and Flindersia pimenteliana. Both these were fast growing species. It was observed that the larger specimens of A. aulacocarpa had started to die and that recruitment and regeneration of this species were absent. F. pimenteliana will probably follow a similar course unless the site is severely disturbed (as it may well be) within the next 50-100 years. If it is not disturbed some of the slower growing large tree species, such as Eugenia kuranda, E. johnsonii and Musgravea heterophylla, could be expected to become more prominent.

When all species were considered, the distribution of stems within diameter classes at establishment was normal except for two large trees in the 80-90 cm dbh class. One of these (an Acacia aulacocarpa) has since died while the other (a slow growing Backhousia hughesii) was probably a relic from forest which existed prior to the last catastrophic disturbance. Except for the size class categories containing the two trees discussed above, the relative increment rates in this plot have been very high peaking at 3.4% in the 50-60 cm dbh class. This high growth rate was, however, balanced by high average annual mortality (1.7%) and the death of one of the largest trees. Consequently plot basal area was steady and a decline was recorded in tree numbers during the period of

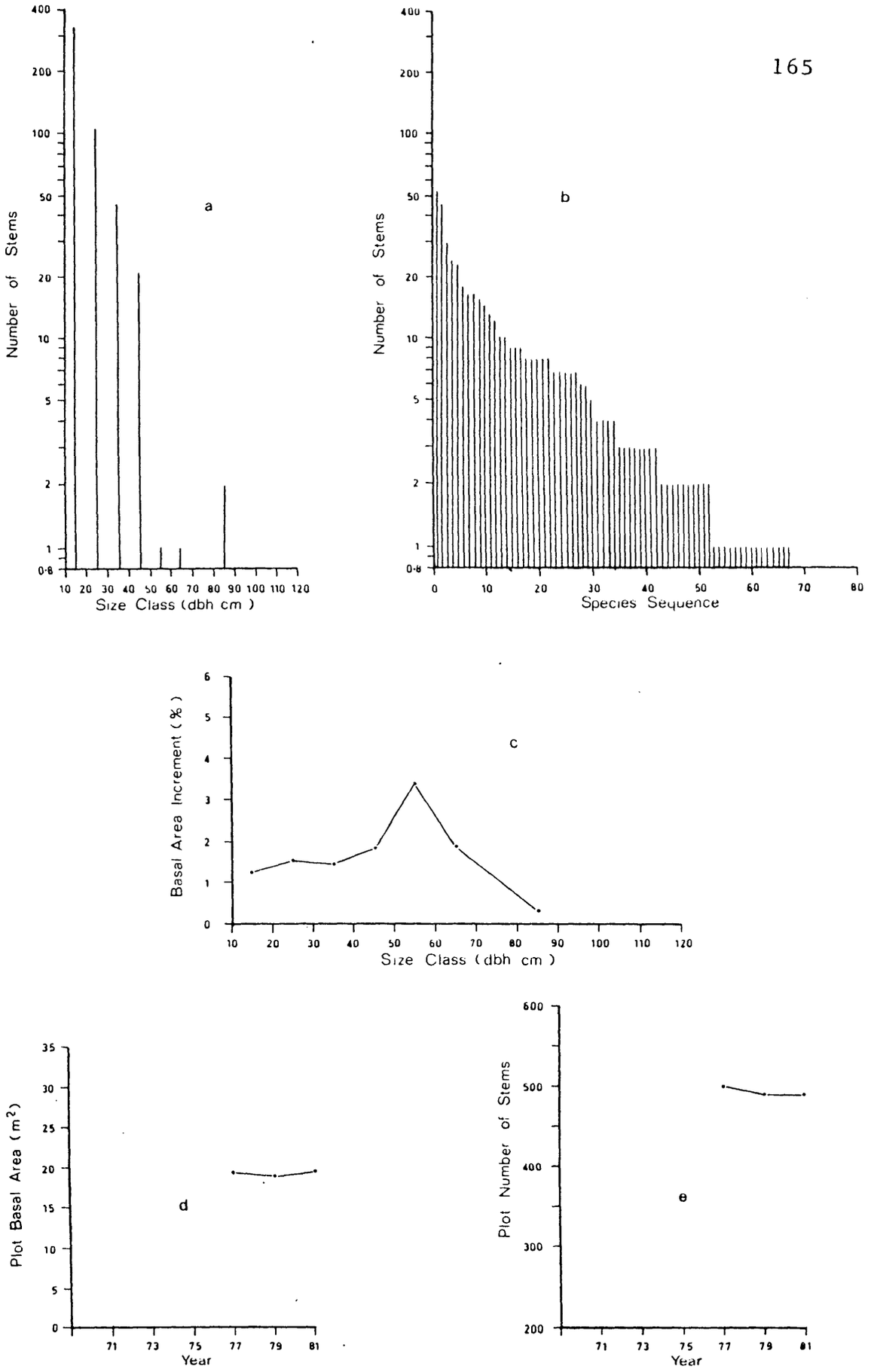

Figure 32. Some characteristics of plot 13 are illustrated :-
a) stem numbers in dbh size classes,
b) stem numbers for each species with the species arranged (left to right) from the most to the least numerous,
c) the basal area increment percent for each size class,
d) temporal trends in plot basal area,
e) temporal trends in the number of stems in the plot.
For further explanation see Section 3.2.2.

Table 22. Plot 13 - Initial stem numbers, mortality and basal area increment by dbh size classes (cm) with recruitment to the 10-20 cm class and an indication of regeneration stocking in subplots for important species. Data from 1977-81.

Species	Regen. stock. a. A	B	Initial stem numbers 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Init. tot.	Recr. b.	Mortality 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Basal area increment c. 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+
Acacia aulacocarpa				1	3	8		1		1			14									1				A	A	A	B	*				
Flindersia bourjotiana	13	9	12	8	8	1							29	1	1										B	A	B	D						
Eugenia kuranda	10	13	11	6	7	1							25												B	B	D	C						
Eugenia sp. RFK 1101	16	15	34	9	3								46				1								C	E	E							
Flindersia pimenteliana	2	1	5	4	5	1							15		1		1								A	A	B	C						
Endiandra sp. aff. E. hypotephra	14	16	46	5									51	1	1	1									E	E								
Eugenia johnsonii	4	7	8	6	2	1							17												C	C	C	E						
Musgravea heterophylla	13	11	10	4	3	1							18												B	D	D	E						
Backhousia hughesii						1				1			2															E					*	
Xanthophyllum octandrum	12	13	9	7	1								17												C	E	D							
Elaeocarpus sp. aff. E. ferruginiflorus	5	4	11	5									16			1									A	A	A							
Cryptocarya sp. RFK 2423	15	14	22	2									24												C	D								

a) the number of subplots (max. 16) containing 1 or more small trees 0-3 m high (A) and 3 m high to 10 cm dbh (B).

b) the number of small stems entering the 10-20 cm dbh class.

c) basal area increment - relative rates are indicated by :- A = 100% over, B = 25-100% over, C = within 25% of, D = 50-100% below and E = over 100% below, plot mean for that size class.

* - only one tree in that size class.

observation (Figure 32).

Plot 14

This plot was established in June 1977 in the Eungella Range west of Mackay. In brief the vegetation on the plot can be described as "tall wet upland rainforest on basaltic soil" and would best appear to fit the type "complex notophyll vine forest" of Webb (1959). The soil was a typical krasnozem - a red well structured sandy loam with the clay content gradually increasing with depth.

The stand developed on the site was most impressive with a well developed upper canopy and a mid canopy dominated by the palm Archontophoenix cunninghamiana. In the few places where sufficient light found its way through to the forest floor, a dense mat of Pollia macrophylla developed. The lower boles of most of the larger trees were festooned with semi-woody climbers of Pothos, Piper and Freycinetia spp.. The forest on this plot did not appear to have ever been disturbed although signs of past logging were obvious in surrounding areas.

Tree species in the upper canopy included Syzygium sp. RFK 3030, Acmena sp. aff. A. smithii, Argyrodendron actinophyllum ssp. diversiflorum and Cryptocarya angulata. Although several additional tree species were found in the understorey, the overall species richness of the plot was rather low (only 32 tree species with at least one stem > 10 cm dbh). The species sequence/stem numbers pattern was close to normal (Figure 33).

The stem numbers distribution by size classes for important species (Table 23) suggested that the three tree species with the largest individuals (S. sp. RFK 3030, A. sp. aff. A. smithii, and A. actinophyllum ssp. diversifolium) all regenerated periodically although recent conditions on the plot may not have allowed A. sp. aff. A. smithii to regenerate at all. Another smaller species, Dendrocnide photinophylla, may also be in decline for although its growth rate in the 20-40 cm range was relatively good, this species had little regeneration, no recruitment and an annual

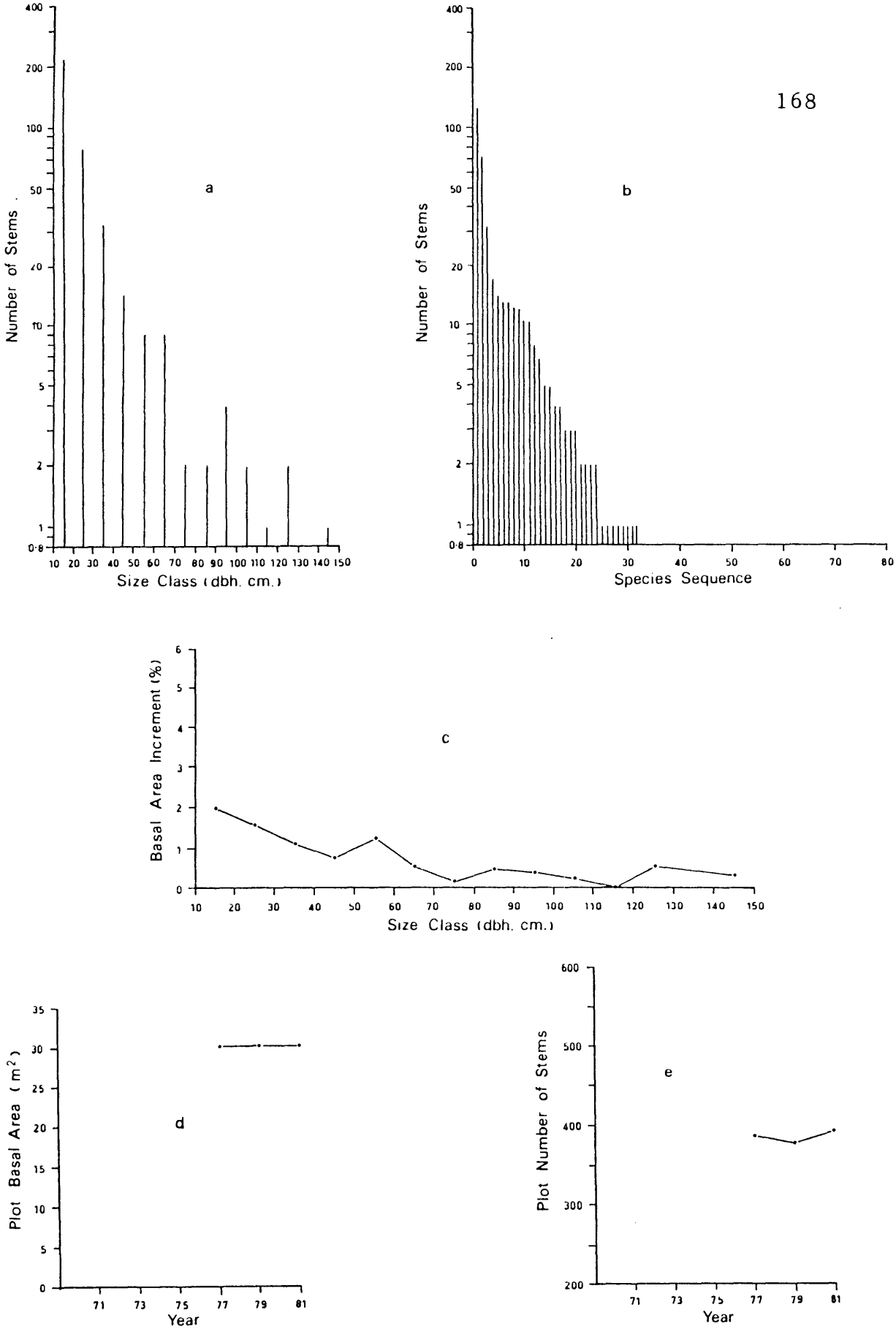

Figure 33. Some characteristics of plot 14 are illustrated :-
a) stem numbers in dbh size classes,
b) stem numbers for each species with the species arranged (left to right) from the most to the least numerous,
c) the basal area increment percent for each size class,
d) temporal trends in plot basal area,
e) temporal trends in the number of stems in the plot.
For further explanation see Section 3.2.2.

Table 23. Plot 14 - Initial stem numbers, mortality and basal area increment by dbh size classes (cm) with recruitment to the 10-20 cm class and an indication of regeneration stocking in subplots for important species. Data from 1977-81.

Species	Regen. stock. a.		Initial stem numbers										Init. tot.	Recr. b.	Mortality										Basal area increment c.									
	A	B	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+			10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+
Acmena sp. aff. A. smithii	1						3	1	1	1	3	6	15																B	E	C	E	C	C
Cryptocarya angulata	15	11	31	25	13	4		1					74	2		2			1						C	C	C	D		B				
Argyrodendron actinophyllum ssp. diversifolia	13	4	1		2	1	5	3	1				13							1					B		C	C	D	E	C			
Syzygium sp. RFK 3030	6	1	1	2	3	3		2		1	1		13												C	E	C	C	B	D		B	C	E
Archontophoenix cunninghamiana	16	16	100	12									112	18		4									B	C								
Dendrocnide photinophylla	1	3	18	10	5								33			2	2	1							E	B	B							
Cryptocarya sp. aff. C. cinnamomifolia	16	14	11	4	3								18												C	C	C							
Tetrasynandra laxiflora	16	8	7	4	3								14												D	D	E							
Litsea leefeana	16	14	11	3									14												B	B								

a) the number of subplots (max. 16) containing 1 or more small trees 0-3 m high (A) and 3 m high to 10 cm dbh (B).

b) the number of small stems entering the 10-20 cm dbh class.

c) basal area increment - relative rates are indicated by :- A = 100% over, B = 25-100% over, C = within 25% of, D = 50-100% below and E = over 100% below, plot mean for that size class.

mortality rate of 3.8%. The relative increment rates for all of the larger species were quite variable and no clear trends were evident.

When all species were considered the stem numbers/size class distribution histogram was distorted from the normal pattern by the numerous large individuals of A. sp. aff. A. smithii. This observation and other attributes of this species (see above) suggests that it may be something of a relic out of tune with the recent environment. Overall percentage increments were highest in the 10-20 cm dbh class and with some irregularities, tended to decline steadily as dbh increased. The overall trend in plot basal area has been for a slight rise. The number of stems in the plot fluctuated without showing any upwards or downwards trend. Annual mortality in the plot averaged 0.97%.

Plot 15

This plot was established in September 1977 close to the crest of the Herberton Range 13 km south-west of Atherton. The vegetation is locally described as "moist highland rainforest on acid volcanic soil". While outcrops of rhyolite were seen on the ridge above the plot, the reddish sandy loam soil within the plot appeared to be several metres deep.

Tracey and Webb (1975) have typed the forest in this area as "simple notophyll vine/fern forest (often with Agathis 'montana')". The plot was close to the eucalypt forest edge and evidence collected by Unwin (1983) suggested that this site may have recently been occupied by tall open eucalypt forest dominated by Eucalyptus grandis. Although it was suspected that one corner of the plot may have been logged 30-40 years ago, the canopy was well developed and the understorey relatively sparse. There were no signs of past cyclone damage.

Prominent upper canopy species included Flindersia brayleyana, Geissois biagiana, Sterculia laurifolia and Cryptocarya rigida. Very noticeable at lower levels were Litsea leefeana, Stenocarpus sinuatus, Myristica insipida and

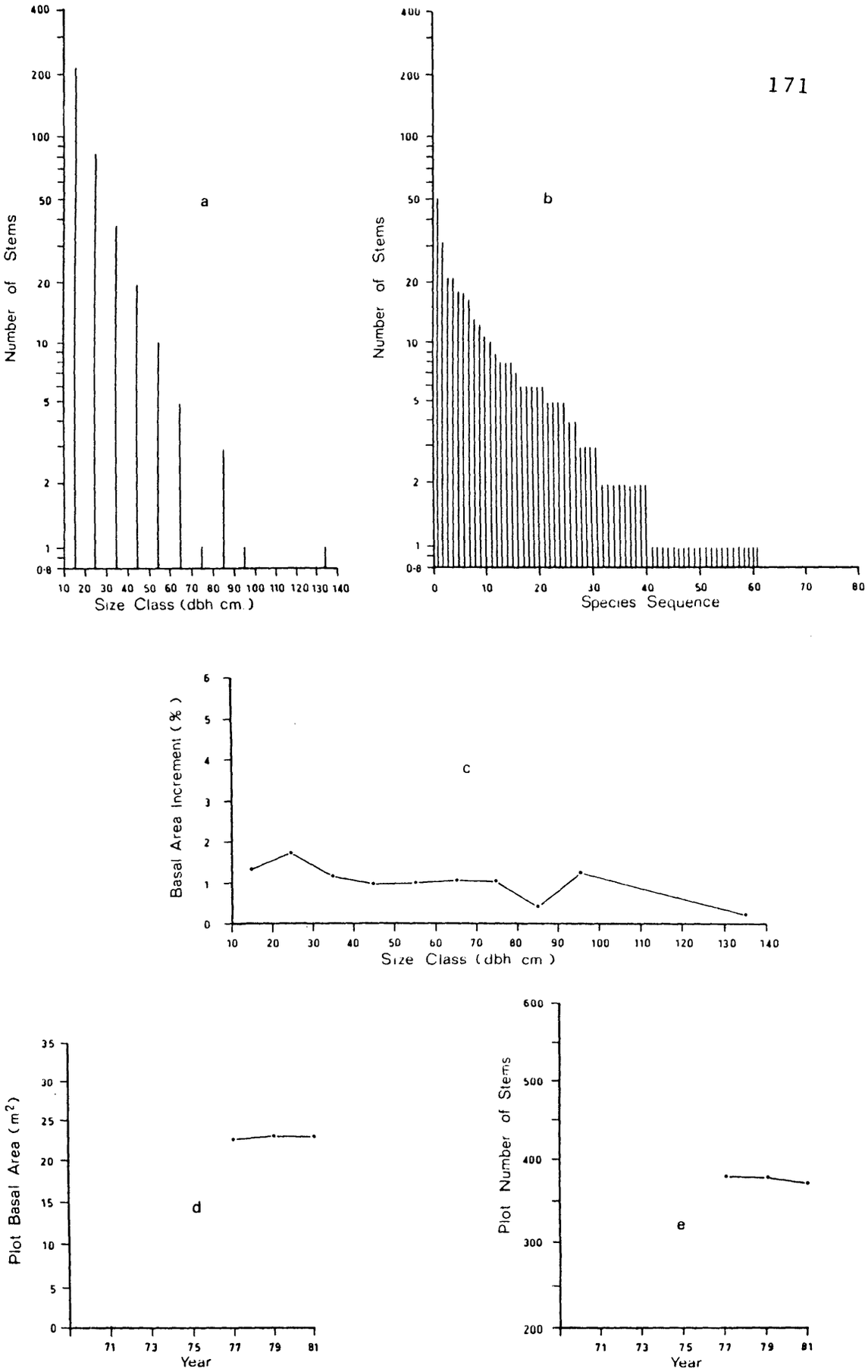

Figure 34. Some characteristics of plot 15 are illustrated :-
a) stem numbers in dbh size classes,
b) stem numbers for each species with the species arranged (left to right) from the most to the least numerous,
c) the basal area increment percent for each size class,
d) temporal trends in plot basal area,
e) temporal trends in the number of stems in the plot.
For further explanation see Section 3.2.2.

Table 24. Plot 15 - Initial stem numbers, mortality and basal area increment by dbh size classes (cm) with recruitment to the 10-20 cm class and an indication of regeneration stocking in subplots for important species. Data from 1978-80.

Species	Regen. stock. a. A	Regen. stock. a. B	Initial stem numbers 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Init. tot.	Recr. b.	Mortality 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Basal area increment c. 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+
Geissois biagiana	5	6	1						1	2	1	1	6												E						E	C	E	*
Cryptocarya rigida	11	14	27	14	5	3		2					51					2	1						B	B	B	B		D				
Sterculia laurifolia	16	15	22	8	3	6	2						41	1											B	C	B	C	B	E				
Flindersia brayleyana	11	4	2	1		1		2		1			7												A	B		E		A	A		B	
Litsea leefeana	6	2	2	3	5	2	1						13												C	C	D	C	C					
Stenocarpus sinuatus	14	11	9	4	1	1	2						17												B	B	A	D	C					
Endiandra pubens	11	8	3	8	3								14												B	D	C							
Acronychia acidula	9	9	9	12									21		1	1									B	C								
Myristica insipida	15	15	11	4	3								18			1									C	E	E							
Fontainea picrosperma	16	16	21										21												E									
Eupomatia laurina	14	15	17										17	2	1										E									

a) the number of subplots (max. 16) containing 1 or more small trees 0-3 m high (A) and 3 m high to 10 cm dbh (B).

b) the number of small stems entering the 10-20 cm dbh class.

c) basal area increment - relative rates are indicated by :- A = 100% over, B = 25-100% over, C = within 25% of, D = 50-100% below and E = over 100% below, plot mean for that size class.

* - only one tree in that size class.

Eupomatia laurina. In the understorey Alpinea modesta, Blechnum cartilagineum and Calamus caryotoides were the most conspicuous species.

The species sequence/stem numbers histogram was normal and indicated that strongly dominant species were absent (Figure 34). The size class distribution of the important species suggested that most, except possibly G. biagiana, regenerated readily under present conditions (Table 24). While relative increment rates within species were quite variable, some species, such as Flindersia brayleyana, had, on average, good growth rates while others, such as Myristica insipida, were rather slow.

When all species were considered their stem numbers distribution in size classes was relatively normal (Figure 34). Percentage increments were highest in the smaller size classes but some high levels were apparent for trees of emergent size. The general trend has been for the basal area of the plot to increase steadily while the number of stems has fallen. Annual stem mortality averaged 0.85%.

Plot 16

This plot was established during October 1978 on the drier lower slopes of the Windsor Tableland. Locally the forest here is described as "tall dry upland rainforest on granitic soil". The yellowish loamy soil contained quantities of gravel derived from partially decomposed granite. Although some granite outcrops were observed near the plot, these seemed to be "floaters" and the general weathering depth probably exceeded 5 m.

Tracey and Webb (1975) would have described the forest here as "complex notophyll vine forest (with emergent Agathis robusta)". Although the vegetation appeared to have some structural and floristic affinities with Plot 1, tree development was much greater and Agathis robusta much more conspicuous as the dominant emergent. The site had not been logged and showed no sign of past cyclone damage.

While A. robusta was the only clear emergent in this plot

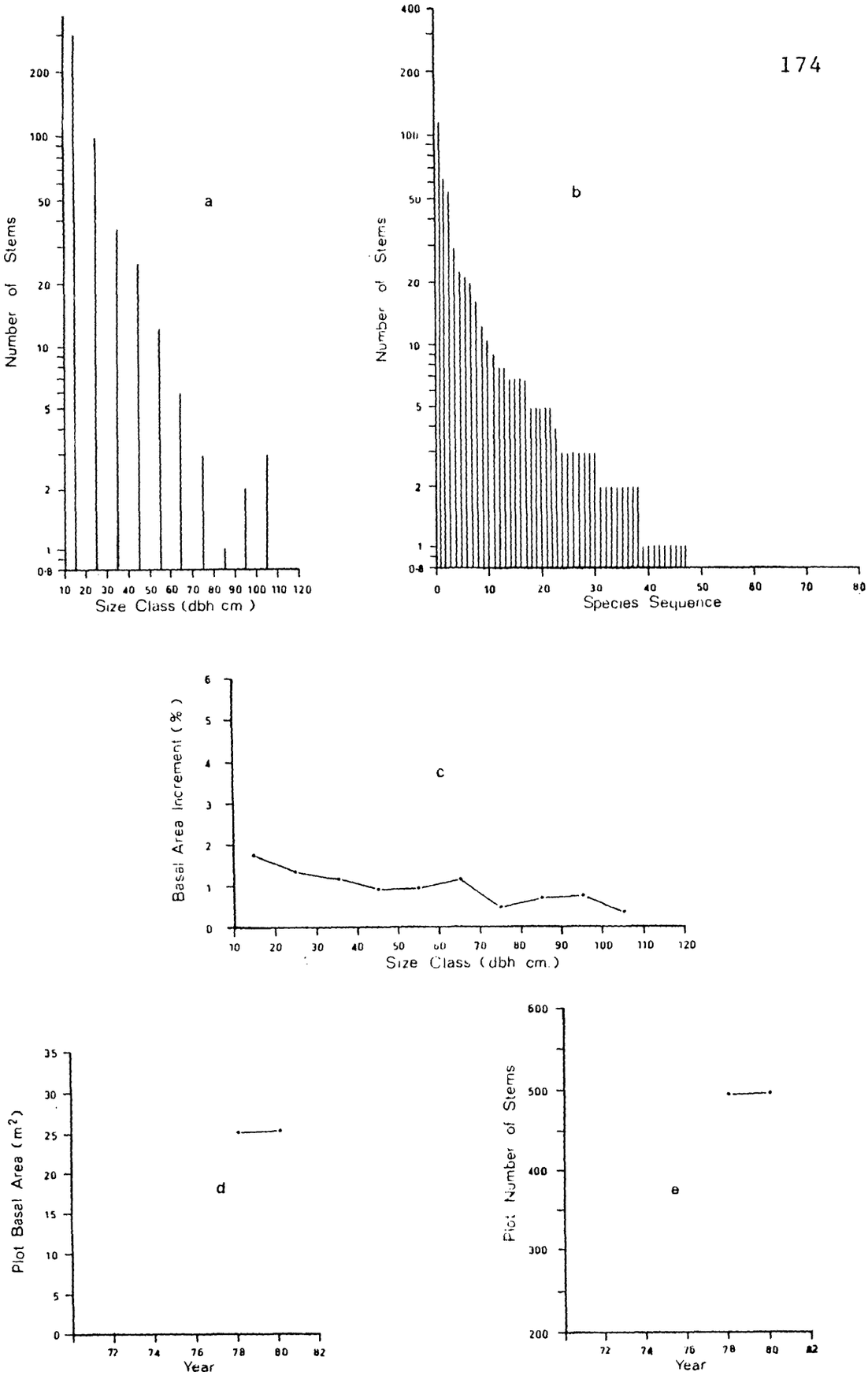

Figure 35. Some characteristics of plot 16 are illustrated :-
a) stem numbers in dbh size classes,
b) stem numbers for each species with the species arranged (left to right) from the most to the least numerous,
c) the basal area increment percent for each size class,
d) temporal trends in plot basal area,
e) temporal trends in the number of stems in the plot.
For further explanation see Section 3.2.2.

Table 25. Plot 16 - Initial stem numbers, mortality and basal area increment by dbh size classes (cm) with recruitment to the 10-20 cm class and an indication of regeneration stocking in subplots for important species. Data from 1978-80.

Species	Regen. stock. a. A	Regen. stock. a. B	Initial stem numbers 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Init. tot.	Recr. b.	Mortality 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Basal area increment c. 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+
Agathis robusta	12	4	2	1	1	4	3	4	2	1	2	3	23												E	C	A	C	B	C	B	*	C	C
Backhousia hughesii	16	16	53	37	14	8	5	2	1				120												C	C	C	B	C	C	E			
Argyrodendron polyandrum	14	16	17	18	12	5	3						55	1											C	C	C	C	E					
Flindersia ifflaiana	6	11	16	6	3	5							30												C	D	C	D						
Mallotus polyadenos	15	14	62										62	1	1										C									
Polyalthia nitidissima	15	13	20	1									21	1											C	B								
Randia fitzalanii	16	14	16										16	1	1										C									
Elaeodendron australe	15	14	19										19	1											D									

a) the number of subplots (max. 16) containing 1 or more small trees 0-3 m high (A) and 3 m high to 10 cm dbh (B).

b) the number of small stems entering the 10-20 cm dbh class.

c) basal area increment - relative rates are indicated by :- A = 100% over, B = 25-100% over, C = within 25% of, D = 50-100% below and E = over 100% below, plot mean for that size class.

* - only one tree in that size class.

several other species made up a continuous upper canopy. These included Backhousia hughesii, Argyrodendron polyandrum and Flindersia iffliana.

The species sequence/stem numbers histogram for the plot was of normal shape (Figure 35). Although all the important species had a continuous regeneration pattern, the dominant species showed some tendency toward a more intermittent pattern than the remaining important species (Table 25). All these species appeared to have a continuing role in the plot while present conditions were maintained. The relative increment rates in this plot were rather uniform. A. robusta again showed a pattern of good growth after a slow start. The very slow growth of B. hughesii and A. polyandrum in the 70-80 and 50-60 cm dbh classes respectively, suggested that at these sizes these species begin to become senescent.

The overall diameter class distribution in the plot (Figure 35) was close to normal but with a few more individuals in the larger size classes than expected. The relative increment rates were highest in the 10-20 cm dbh class but again some of the smaller emergents also seemed to be growing rapidly. The general trend has been for plot basal area to increase while the number of stems has been relatively constant. The annual mortality has averaged 0.4%.

Plot 17

This plot was established in November 1977 in lowland rainforest 37 km north of Mossman. The forest here is locally described as "wet coastal rainforest on colluvial soil". The red brown loamy soil were derived from metamorphic and granitic parent materials washed down from surrounding hills. Large rounded stones were conspicuous in the soil profile and on the floor of the plot.

Tracey and Webb (1975) have mapped the vegetation surrounding this site as "complex mesophyll vine forest". The forest within the plot appeared to be free from past human interference and although there was plenty of evidence of cyclone damage in the vicinity, it did not seem to have been affected by cyclones for a long time. A relatively continuous

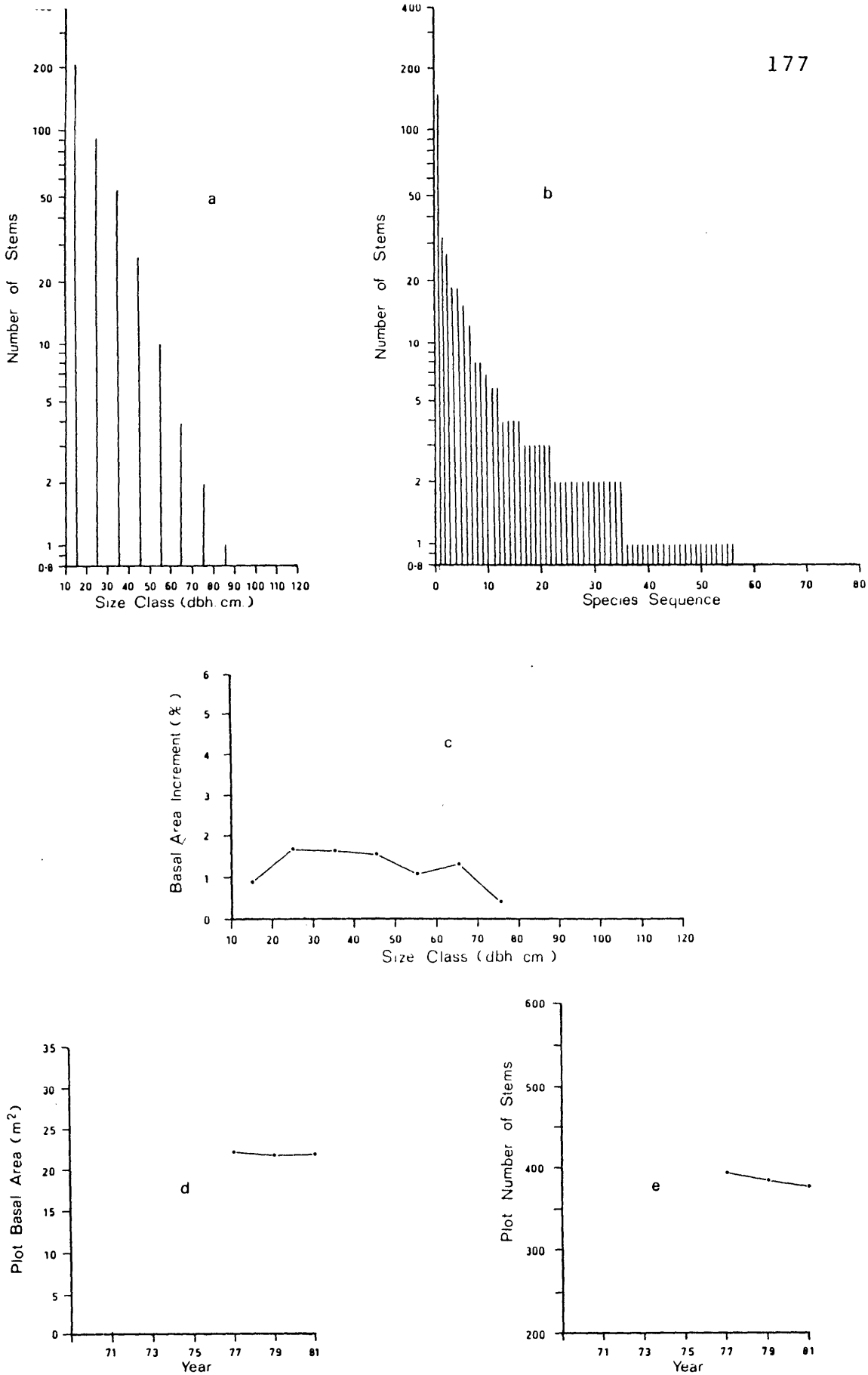

Figure 36. Some characteristics of plot 17 are illustrated :-
a) stem numbers in dbh size classes,
b) stem numbers for each species with the species arranged (left to right) from the most to the least numerous,
c) the basal area increment percent for each size class,
d) temporal trends in plot basal area,
e) temporal trends in the number of stems in the plot.
For further explanation see Section 3.2.2.

Table 26. Plot 17 - Initial stem numbers, mortality and basal area increment by dbh size classes (cm) with recruitment to the 10-20 cm class and an indication of regeneration stocking in subplots for important species. Data from 1977-81.

Species	Regen. stock. a. A	Regen. stock. a. B	Initial stem numbers 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Init. tot.	Recr. b.	Mortality 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	Basal area increment c. 10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+
Lindsayomyrtus brachyandrus	15	16	75	42	21	10	3	1		1			153		4		1					1			C	D	D	C	E	E				
Idiospermum australiense	16	7	8	4	6	2	4	1	2				27												E	B	C	B	B	D	C			
Storckiella sp. (RFK 1079)	5	9	4	5	5	2	2	1					19			1									A	B	B	C	C	B				
Beilschmiedia bancroftii	15	9	2		3	2		1					8												B		A	B		D				
Ryparosa javanica	11	14	22	7	3								32			1									D	D	E							
Litsea leefeana	1			1	2	4							7													E	C	C						
Xanthophyllum octandrum			5	4	4								13												C	C	E							
Cleistanthus myrianthus	13	10	13	3									16			1									A	C								
Melicope fareana	8	11	18	1									19	1	1										C	E								

a) the number of subplots (max. 16) containing 1 or more small trees 0-3 m high (A) and 3 m high to 10 cm dbh (B).

b) the number of small stems entering the 10-20 cm dbh class.

c) basal area increment - relative rates are indicated by :- A = 100% over, B = 25-100% over, C = within 25% of, D = 50-100% below and E = over 100% below, plot mean for that size class.

canopy extended from 15 to 25 m and the understorey was rather poorly developed. While the vegetation has little in common with Plot 9 at a species level, it is interesting to observe again the dominance of a wet lowland rainforest site by a species of Myrtaceae - this time by Lindsayomyrtus brachyandrus.

With L. brachyandrus in the upper canopy were Idiospermum australiense and Storckiella sp.. Somewhat lower down Litsea leefeana, Planchonella obovoidea and Beilschmiedia bancroftii joined smaller individuals of the three dominants. Ryporosa javanica, Xanthophyllum octandrum, Cleistanthus myrianthus and Melicope fareana were conspicuous as small trees. The understorey was sparse consisting of tree seedlings (especially L. brachyandrus and I. australiense), a few shrubs and vines (especially Calamus spp.).

The species sequence/stem numbers histogram (Figure 36) emphasised the dominance of L. brachyandrus in this plot, but otherwise the normal pattern was apparent. The stem numbers distribution by size classes for important species (Table 26) indicated that most have a continuous regeneration pattern. Notable exceptions were Litsea leefeana and Xanthophyllum octandrum. The absence of regeneration and the stem numbers pattern of L. leefeana suggested that this species may be on the decline. Relative increment rates were again rather variable. Of the species growing into the upper size range Storckiella sp. was probably the fastest and L. brachyandrus the slowest.

When all tree species were considered, the distribution of stems within diameter classes was very close to normal. Although relative increment rates were highest in the 20-30 cm dbh class, those in all other size classes, except the largest (70-80 cm), were not much lower. Despite moderate growth rates, the overall plot basal area and the total number of stems fell slightly due to relatively high mortality (1.14%) and low recruitment.

This plot, established in November 1977, was the most northern in the series. It sampled the tall seasonal riverine rainforest on the deep sandy loam alluvial soils on the banks of the Claudie River. In many respects the floristics of this plot, especially the presence of Anthocephalus, Maniltoa and Tetrameles species, suggested that the rainforest here had greater affinity with the rainforests of parts of southern New Guinea than with those further south in the Cooktown to Townsville region.

Webb (1959) would describe this forest type as "complex mesophyll vine forest". The upper canopy at this site was irregular and the dominant trees included several deciduous species. The understorey was quite variable being least in those parts of the plot flooded for the longest part of the year. During 1979 a cyclone passed across the area. While associated winds caused little direct damage to the trees, high stream flows caused stream bank erosion which uprooted trees in one corner of the plot. Feral pigs were very numerous in the area and their extensive rooting could be expected to alter significantly the future development of regeneration. The only signs of direct interference by man was a Castanospermum australe stump. This tree was probably removed to provide a bridge girder when the access road was constructed early in the 1940s.

Species reaching the emergent and upper canopy levels included Castanospermum australe, Nauclea orientalis, Dysoxylum decandrum and Tetrameles nudiflora. Mid canopy species included Wrightia laevis ssp. milgar, Beilschmiedia obtusifolia, Cordia dichotoma, Miliusa horsfieldii, Pisonia umbelliflora, Myristica insipida, Mitrephora sp. and Cleistanthus apodus. Where present, the understorey consisted mainly of the regeneration of tree species.

The species/stem numbers histogram (Figure 37) showed a tendency to evenness in the most frequently encountered species. The stem numbers distribution by size classes for the important species (Table 27) suggested that most if not all of the emergent and canopy level species regenerated

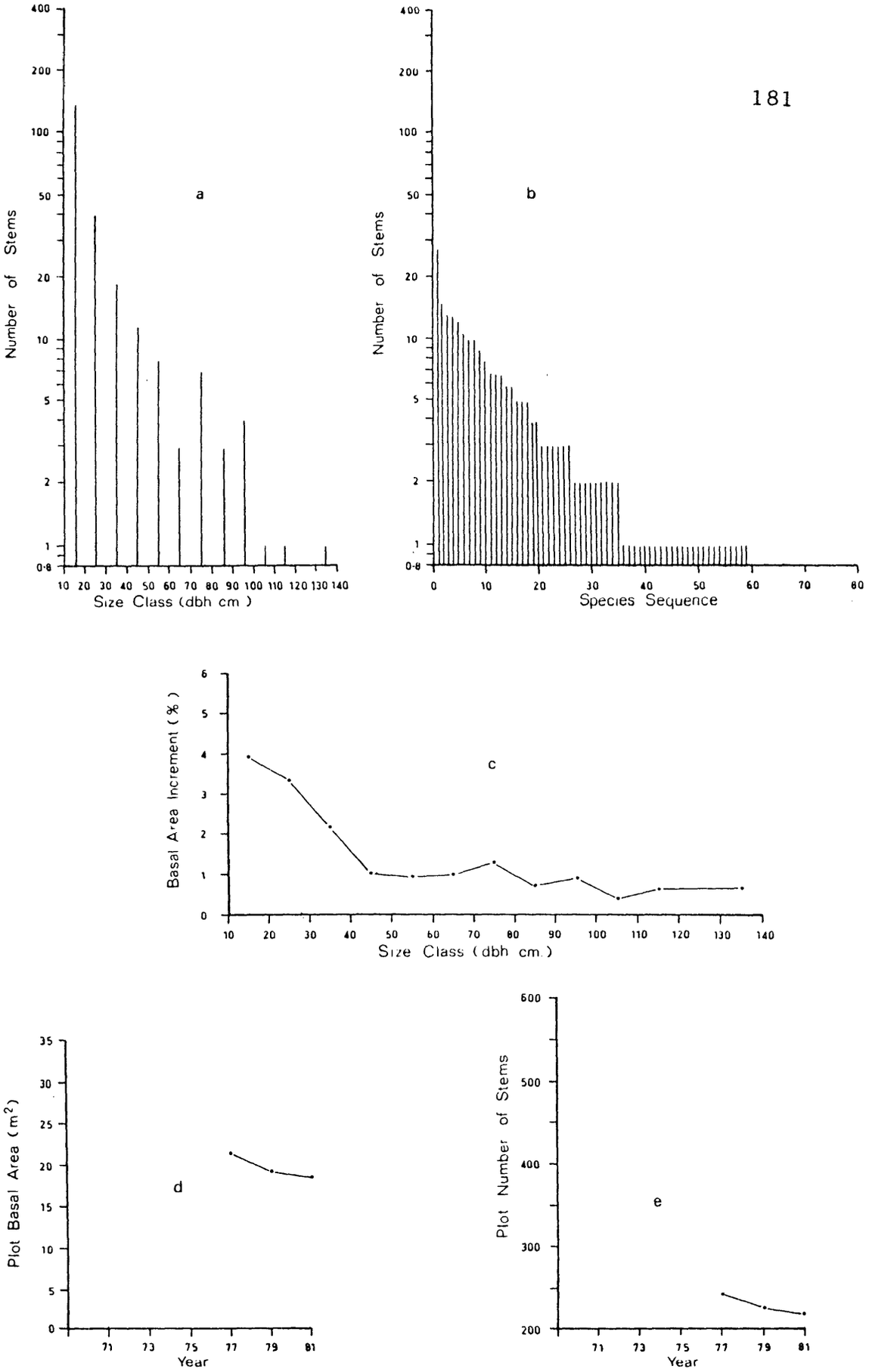

Figure 37. Some characteristics of plot 18 are illustrated :-
a) stem numbers in dbh size classes,
b) stem numbers for each species with the species arranged (left to right) from the most to the least numerous,
c) the basal area increment percent for each size class,
d) temporal trends in plot basal area,
e) temporal trends in the number of stems in the plot.
For further explanation see Section 3.2.2.

Table 27. Plot 18 - Initial stem numbers, mortality and basal area increment by dbh size classes (cm) with recruitment to the 10-20 cm class and an indication of regeneration stocking in subplots for important species. Data from 1977-81.

Species	Regen. stock. a.		Initial stem numbers										Init. tot.	Recr. b.	Mortality										Basal area increment c.									
	A	B	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+			10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+
Castanospermum australe	16	8	3		2	1		2	1	2		1	14							1	1				B	D	C	C		E	C	E		C
Nauclea orientalis			3	2			1			1	2	1	10				1								A	A			E	C		E	D	D
Beilschmiedia obtusifolia	1		4	3	4	2	2		1				16					1	1		1	1			D	A	A		A	A				
Pisonia umbelliflora	8	4	13	9	4	1	1						28		1		2	1	1						B	D	E	D	E					
Tetrameles nudiflora									1		1		2																		B		A	
Antiaris toxicarya												1	1																					C
Dysoxylum decandrum	6	5							2				2																		D	B		
Miliusa horsfieldii	15	8	1	4	3	1	1						10							1					A	C	C	B						
Anthocephalus chinensis								1	1				2																	E	E			
Cordia dichotoma				2		1	2						5						1	1						C	C	E	C					
Wrightia laevis ssp. millgar	3	3	3		1	2	1						7							1					E		E	D	E					
Litsea glutinosa											1		1										1										E	
Myristica insipida	12	15	10	2									12	1	2										C	C								
Cleistanthus apodus	14	11	14										14												D									
Mitrephora sp. RFK 2673	12	9	10										10	1	2										C									
Lepidopetalum subdichotomum			8										8	2	1										C									

a) the number of subplots (max. 16) containing 1 or more small trees 0-3 m high (A) and 3 m high to 10 cm dbh (B).

b) the number of small stems entering the 10-20 cm dbh class.

c) basal area increment - relative rates are indicated by :- A = 100% over, B = 25-100% over, C = within 25% of, D = 50-100% below and E = over 100% below, plot mean for that size class.

either periodically or under different conditions to those recently occurring in the plot. While one species, Beilschmiedia obtusifolia, appeared to be growing rapidly most of the others seemed to have either erratic or slow growth patterns. However, B. obtusifolia has not recently regenerated and its mortality rate was relatively high. Future trends in the floristics of this plot seem very difficult to predict.

When all species were considered, the distribution of stems within diameter classes revealed more stems in the larger size classes than might be expected. Percentage increments were surprisingly high reaching a maximum in the 10-20 cm dbh class but again some emergents showed higher growth rates than some intervening size classes. The general trend for plot basal area was, however, one of decline. This can probably be attributed to tree losses from disturbance which was also mainly responsible for the decline in tree numbers. The annual stem mortality has been 3.9%; considerably higher than recent recruitment.

Plot 19

This plot was located near the crest of the Herberton range 7 km west of Atherton. It was established in June 1978 and contained forest locally described as "tall moist highland rainforest on acid volcanic soil". Although the site was relatively steep and occasional surface rock was observed, the red loamy soil appeared to be more than 2 m deep.

Tracey and Webb (1975) have typed the general area as "simple notophyll vine forest". Structurally and floristically it seemed to be related to plot 15. It appeared not to have been logged and contained no evidence of cyclone damage. Large tall trees were very obvious and understorey development was limited.

Conspicuous species in the emergent and the upper canopy strata of this plot included Cardwellia sublimis, Canarium baileyanum, Flindersia pimenteliana and Galbulimima belgraveana. At slightly lower levels these species were

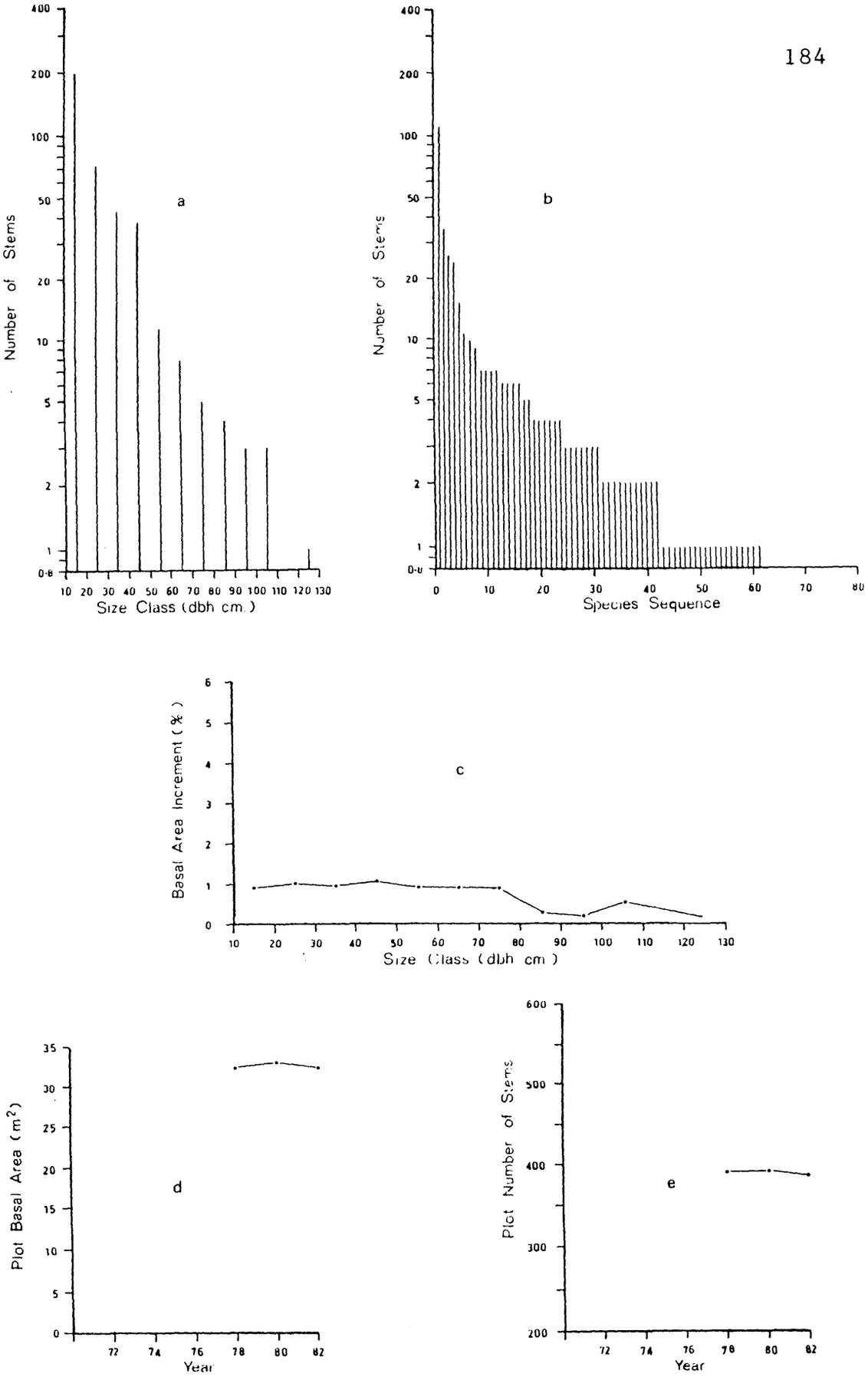

Figure 38. Some characteristics of plot 19 are illustrated :-
a) stem numbers in dbh size classes,
b) stem numbers for each species with the species arranged (left to right) from the most to the least numerous,
c) the basal area increment percent for each size class,
d) temporal trends in plot basal area,
e) temporal trends in the number of stems in the plot.
For further explanation see Section 3.2.2.

Table 28. Plot 19 - Initial stem numbers, mortality and basal area increment by dbh size classes (cm) with recruitment to the 10-20 cm class and an indication of regeneration stocking in subplots for important species. Data from 1978-82.

Species	Regen. stock. a.		Initial stem numbers										Init. tot.	Recr. b.	Mortality										Basal area increment c.									
	A	B	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+			10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100+
Sterculia laurifolia	16	14	47	23	18	16	7	1					112	1				1							B	B	C	B	C	B				
Canarium baileyanum	9	11	7		3	2		1		3			16												E		B	B		E		C		
Cardwellia sublimis	15	6	1			1		1				2	5											1	E			B		C				E
Flindersia pimenteliana			1		2			1			1	1	6												A		A			B				C
Doryphora aromatica	10	13	10	13	7	5							35	1											C	C	C	D						•
Cinnamomum laubatii	8	8		2		1		1	3				7													C		C		B	B			
Galbulimima belgraveana	3							1		1	1		3																		E	D	D	
Halfordia scleroxyla	9	6	3	2	1	4	1						11	1											C	B	E	D	D					
Rockinghamia angustifolia	14	13	21	5	1								27				1								D	E	E							
Citronella smythii	6	9	20	5									25												B	C								

a) the number of subplots (max. 16) containing 1 or more small trees 0-3 m high (A) and 3 m high to 10 cm dbh (B).

b) the number of small stems entering the 10-20 cm dbh class.

c) basal area increment - relative rates are indicated by :- A = 100% over, B = 25-100% over, C = within 25% of, D = 50-100% below and E = over 100% below, plot mean for that size class.

joined by Halfordia scleroxyla, Sterculia laurifolia, Cinnamomum laubatii and Doryphora aromatica. Small trees were the most obvious part of a rather open understorey.

The species sequence/stem numbers histogram for this plot was characterized by a very abrupt fall in stem numbers between the first and second species. Otherwise the expected pattern was followed (Figure 38). The stem numbers distribution pattern of the important species suggested that most of those growing into size classes above 70 cm dbh regenerated irregularly (Table 28). Other smaller species, including S. laurifolia, D. aromatica and H. scleroxyla appeared to regenerate regularly. The relative increment rates of the important species were irregular but some trends such as consistently fast growth for F. pimenteliana and slow growth for Rockinghamia augustifolia were evident.

When all species were considered the size class distribution was relatively normal (Figure 38). Plot basal area has remained virtually static as have the number of stems on the plot. The average annual stem mortality has been 0.51%.

3.3 Discussion of plot data

3.3.1 Floristics

The numbers of tree species with individual stems = or > 10 cm dbh, within each plot (range 35-89)(Table 8) illustrated the relatively low species richness of these rainforests in comparison with many of those within the nearby Malesian region. For example species richness in the rainforests of north-east Australia seemed similar to the poorer heath and limestone forests and were only about half that of the alluvial and dipterocarp forests of Sarawak (Proctor et al. (1983). They did, however, appear to be a little richer than the isolated forests of the Solomon Islands (Whitmore 1974; 1975).

An analysis of the tree species/stem numbers data was undertaken using ordination methods (detrended correspondence analysis - Hill and Gauch 1980) by P. West (pers. comm.) He showed (Figure 39a) that plot 18 and plots 1 and 16 were quite distinct from the remainder. Plot 18 was located on the banks of the Claudie River in northern Cape York Peninsula, a region which has more biotic affinities with lowland New Guinea than with the Cooktown to Townsville sector of this region. Its separation was therefore not surprising. Although rather different in structure (particularly height development) the other two plots (1 and 16) have many common species not encountered elsewhere in the series and indeed the vegetation on both sites was a rather distinctive rainforest type often found on drier sites where the soils are shallow and derived from granitic rocks (Tables 5 and 6). The ordination was repeated omitting these three distinctive plots (Figure 39b and c). While some trends were apparent, further analysis of these data did not produce any statistically meaningful relationships between floristics and structural or environmental parameters. Some of the trends are discussed later in this section.

P. West (pers. comm.) also attempted a floristic classification of the plots using the dissimilarity measure of Gower (1971) with joint absences ignored. An analysis was carried out using both the stem numbers of individual species

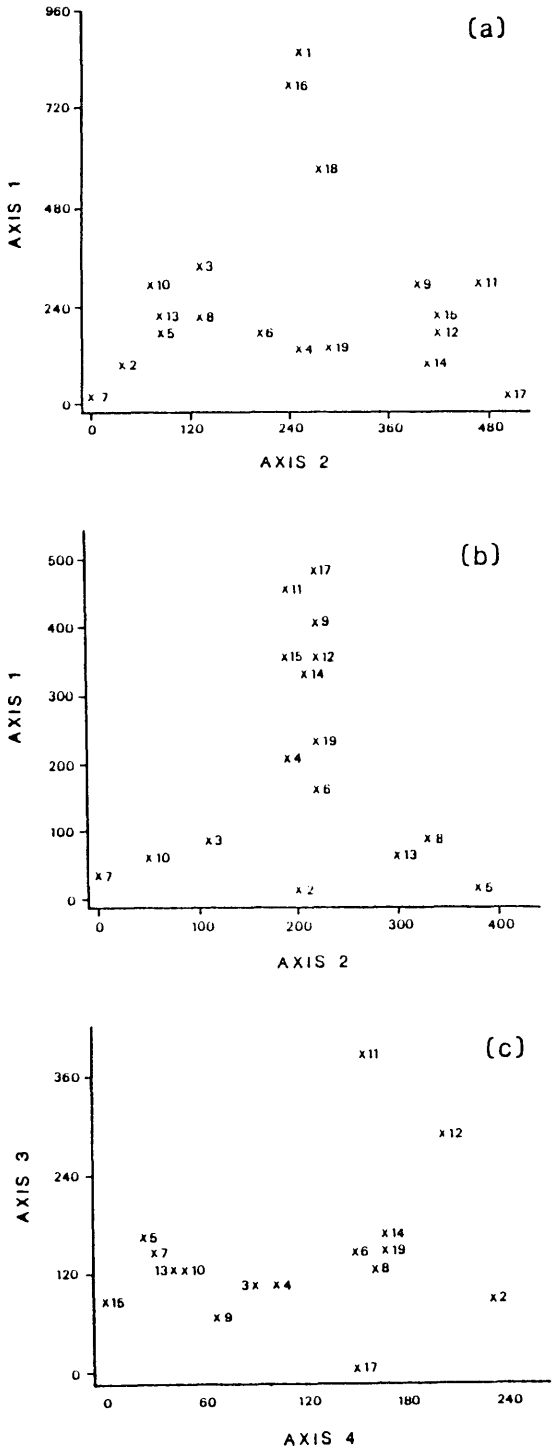

Figure 39a. Ordination of the tree species / stem numbers data for all 19 plots. In b. and c. the ordination was repeated leaving out the three most distinctive plots (1, 16 and 18).

and tree species presence/absence data. Some divisions among the plots were apparent but all occurred at high dissimilarities. This result suggested that the plots were really very divergent in their floristic composition and that there was no reason to consider any of them together. Dissimilarity was greatest when species presence/absence data were used. The matrices are shown in Appendix C1.

Diversity indices based on tree species with stems > 10 cm dbh in the plots are shown in Table 8. One index is based on stem density while the other is based on basal area. Both were derived from the reciprocal of Simpson's index (Hill 1973; Simpson 1949)[3]. Both were also correlated with species number (r=0.52 and r=0.78 respectively). The indices derived from basal area data may have produced a higher correlation coefficient than those from species/stem numbers data because several plots contained one or two species with large numbers of individuals just within the 10-20 cm dbh class. For example, plot 3 contained many individuals of the palm Licuala ramsayi; most of these were just over 10 cm dbh. The diversity index by species/stem numbers for this plot was 11: by basal area it was 21. The latter figure is much closer to that normally expected for a plot containing more than 60 tree species.

Diversity on the basis of species/stem number was lowest on plot 17 - a lowland site with very marked dominance by a single species Lindsayomyrtus brachyandrus. Another lowland plot (# 9) with a single species dominant (Backhousia bancroftii) also had very low diversity. A third plot (# 14) with low diversity was in an isolated patch of rainforest well to the south of the main Cooktown-Townsville belt. While the reasons for the low diversity of the last plot may be isolation, this factor cannot account for the low diversity of plots 17 and 9. The most probable hypothesis is that these

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3. Simpson's index = $\sum_{i=1}^{S} [n_i(n_i - 1)]/[N(N - 1)]$

Where S = the number of species in the sample; N = the number of individuals in the sample; n_i = the number of individuals of the ith species in the sample.

dominants (both of family Myrtaceae) have structural properties, such as timber strength and leaf shedding characteristics, which cause them to be much more resistant to cyclonic winds than their competitors. It may be observed that both plots were in areas frequently devastated by cyclones and that other cyclone induced vegetation types such as "cyclone scrub" were conspicuous in the general area of both plots. Whitmore (1977) observed that in Malesia several dipterocarps sometimes formed pure stands. He attributed this tendency to either a response to major disturbance, specific soil conditions or reproductive pressure. Although none of these seems to fit the circumstances described above, the possibility that these stands may have resulted from cyclone and/or fire disturbance could also be investigated.

The highest diversity index on a stem numbers basis, was found for plot 12 - the site which contained the tallest trees. The diversity index for this site was just ahead of that for a highland site (plot 5) which had the highest diversity on the basis of basal area distribution. Plot 12 had, however, a rather low basal area diversity index for, while the number of trees of each species was fairly even, mean dbh varied considerably amongst species.

The value of diversity measures based on stem numbers are, in rainforests, somewhat questionable. For instance a slight lowering of the arbitrary lower diameter limit for contributing stems would in some plots have added several hundred individuals of a single small tree species, thus greatly affecting the value of the diversity index for that plot. Slightly raising the limit may have the opposite effect. For example, if stems of the lower canopy palm Licuala ramsayi were left out of the data set for plot 3, the stem numbers based diversity index would increase from 11 to 20.

Although the diversity patterns and the related species sequence/stem numbers histograms were of some interest, they appeared to be unrelated to any of the other floristic (except species richness), structural or environmental parameters measured. Since wind speeds associated with cyclones fall as

the cyclone centre moves inland (Table 2), some correlation of diversity with distance from the sea might be expected if the "intermediate disturbance" mechanism favoured by Connell (1978) to explain the development and maintenance of high diversity in rainforests, had been operating. However, a scatter diagram did not indicate the existence of a relationship of this kind.

While a summary of the species frequency and density data from the plots (Table 29 and Figure 40a) suggests that there are many localized and rare tree species, it appears that this finding is as much an attribute of the sampling method used as it is a reflection of biological reality. For example, if an artificial group of 19 plots, each containing the same number of species as an actual plot, is constructed using species selected at random from the total tree flora (803 species), a similar reverse J curve is produced (Figure 40b). The differences between these curves are probably due to the densities characteristic of localized and abundant species. The data summarized in Table 29 suggest that species which are widespread are more likely to have densities in the abundant and intermediate categories than are localized species. Overall these data suggest that the number of truly localized species is not as great as might initially appear. Although there are undoubtedly many rare species in tropical rainforests (e.g. Hartshorn 1980; Lang and Knight 1983; Bourgeron 1983), claims concerning their relative or absolute abundance, need to be carefully assessed.

Most of the species which appear to be localized are "small gap" species. A few are species which seem to be restricted to the northern sector (e.g. Tetrameles nudiflora and Anthocephalus chinensis) or are specialized species such as hemiepiphytic Ficus spp.. The widespread group are mostly "small gap" species but include some species of intermediate shade tolerance such as Cardwellia sublimis and Flindersia bourjotiana. The two most prominent "large gap" species, Acacia aulacocarpa and Alphitonia petriei, were of intermediate frequency.

The simple statistical consequence of sample plot size in

Table 29. The distribution of tree species in plots and their stem numbers (only stems > 10 cm dbh considered).

Stem number (% total plot stems)	No. species present (% of grand total) 4 or more plots (widespread)	2 or 3 plots (restricted)	only 1 plot (localized)	Total
>3 (abundant)	14(3)	15(3)	37(9)	66(15)
>1 - <3 (intermediate)	42(10)	30(7)	19(4)	91(21)
<1 (rare)	52(12)	90(21)	133(30)	275(64)
Total	108(25)	135(31)	189(44)	432

Table 30. The altitudinal range of tree species (> 10 cm dbh) occurring in four or more plots.

Altitudinal range	No. species
Low, intermediate and high	59
Intermediate and high	31
Intermediate and low	12
High and low	4
High only	2
Intermediate only	0
Low only	0
Total	108

Data from - 7 plots at 880 - 1200 M elevation (high)
- 6 plots at 450 - 800 M elevation (intermediate)
- 6 plots at 15 - 380 M elevation (low)

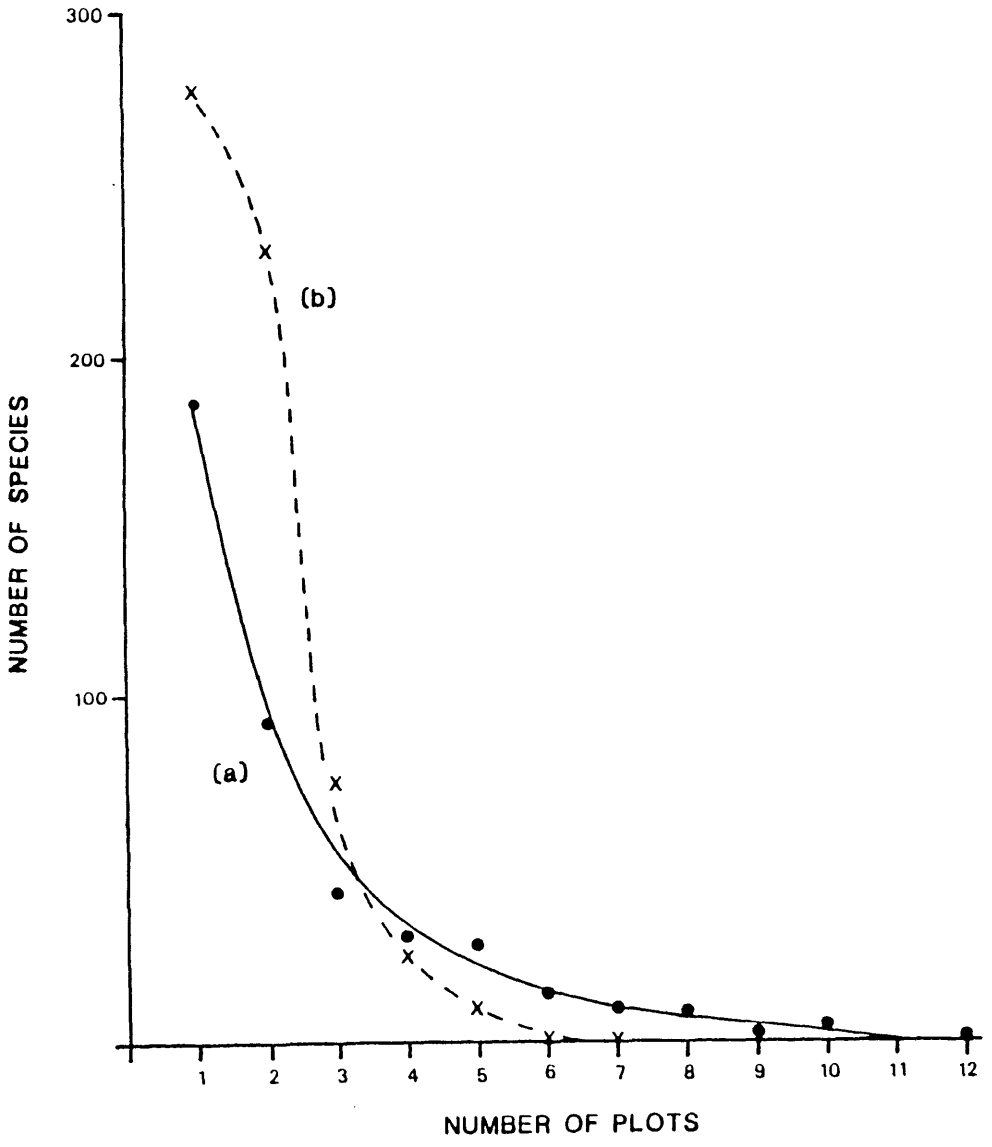

Figure 40a. The tree species distribution in the plot series is illustrated by plotting the number of species which occur in only one plot; the number in only two plots; etc. Curve b. was drawn from a similar artificial data set obtained by randomly selecting the species for each plot from the regional species pool.

relation to species number and density, suggests that, unless the rainforests considered here can be shown to have more species which are actually widespread, it will be difficult to develop simple floristic classifications which could be used in intensive forest management operations. While sample plots larger than 0.5 ha may help overcome this problem, larger plots are usually not feasible, for larger size inevitably seems to widen within-plot environmental gradients to beyond acceptable limits and the additional floristic data would be time consuming to collect. The many additional tree species present as seedlings and saplings (see Table 8) could also be used to improve the chances of a successful floristic classification but unfortunately, without much more experimentation and observation, it is not possible to know whether species present as seedlings are potentially capable of growing to reproductive size in that stand.

The age of rainforest trees in relation to climatic fluctuations, the reverberating influence of past catastrophes and the possibility that the primary determinants of rainforest floristics may be factors other than the usually assumed species spread along environmental gradients (Hopkins 1981), also suggests that caution must be exercised in evaluating floristic classifications for management purposes. Nevertheless, the broad scale studies undertaken by Williams and Tracey (1984) and Webb et al. (1984) have shown that species presence and absence data can be used to produce floristic classifications of Australian rainforests at inter- and intraregional levels.

The diagrams showing the numbers of stems of individual species in each of the plots (part b. of Figures 20-38) all suggested an approximately lognormal pattern (i.e. a bell shaped Gaussian distribution in the logarithms of the species' abundances). May (1975b) indicated that this pattern is a consequence of the Central Limit Theorum which could be expected to apply to species rich assemblages where the pattern of relative abundances arises from the interplay of many more-or-less independent factors. May found that alternative distribution types - "broken stick", geometric and logseries - appeared to be characteristic of relatively simple

assemblages whose dynamics were dominated by some single factor. The "broken stick" was seen as the statistically realistic expression of an ideally uniform distribution. May noted that "broken stick" distributions would form roughly a straight line when abundances were plotted against log (rank). At the other extreme, the logseries was often the statistical expression of the uneven niche-preemption process, of which the ideal form was the geometric series distribution. May observed that these series distributions formed roughly a straight line when log (abundance) and rank were plotted.

The floristic and species stem numbers data from this plot series do not exclude the hypothesis that most species encountered in the plots have environmental tolerances wide enough to encompass most of the rainforest sites examined and that the species composition and species stem numbers on a site may often be related more to factors such as aspects of the disturbance regime and biogeographical history. For example the summary of the altitudinal ranges of widespread tree species (Table 30) showed that over half of this group were tolerant of a fairly wide range of altitudinally controlled environmental factors and that remarkably few were confined to a single, relatively broad, altitudinal zone. However, the data in this Table also suggested that these widespread species were less likely to be found at low elevations (15-380 m) than in intermediate (450-800 m) or higher (880-1200 m) zones. Similar conclusions concerning environmental tolerances have been reached in some studies elsewhere in the tropics. For example Whitmore (1977) noted that in north-east Malaya nearly all the species occurred within the four habitats studied but that the frequency of occurrence varied; Hubbell and Foster (1983), in studies of species pattern in a 50 ha plot on Barro Colorado Island, observed that species which were otherwise clumped and associated with specific environmental features, could always be found as scattered individuals throughout the rest of the plot.

The data for the species/stem numbers distribution, relative increment rates, recruitment and mortality (summarized for the important tree species in each of the plots in Tables

10-28), appeared to provide a useful insight into the behaviour of different species in the stand and often an idea of the past and probable future trend of stand structure and floristics. In later parts of the thesis some of these trends will also be discussed in relation to aspects of the reproductive biology of these species (see also Knight 1975). At this point it is sufficient to note that the pattern of species/stem numbers distribution often provided a very useful indication of the periodicity of regeneration and/or disturbance events. The growth data were useful to decide if anomalies in species/stem number patterns were real or merely a reflection of changing growth rates as individuals moved through diameter classes (c.f. Hartshorn 1975). Recruitment and regeneration data were also useful supplementary information for interpreting the stem number distributions and predicting the long term consequences if the current trends continued.

The variability of the data used to provide an indication of the relative increment rates was high. Part of the variability was without doubt real, due to annual fluctuations in the growth rates of individual trees in response to climatic influences, competition and probably shifting demands on available resources (for instance H. Brasell and G. Stocker [unpublished] found some evidence which suggested that normal vegetative growth cannot be sustained during periods of high reproductive activity). The other important contributing factor was the physical difficulty of making the girth measurements (especially the complications associated with repeated re-measurement at the same point and the effects of bark flaking and bole irregularities). Compounding these difficulties were the very low growth rates (usually only 0.1-0.5 cm annum^{-1} dbh) usually encountered. However, many of the problems will lessen as more re-measurements are made. Despite the limitations of the absolute growth values they have already provided some useful information. For example the relative increment data for the important species (Tables 10-28) showed that most species eventually attaining large sizes have moderate to high early growth rates while those rarely or never finding a permanent place in the upper canopy were often persistently slow growers. Agathis spp. appeared

to be interesting exceptions to this generalization and their slow early growth will be commented on again later in the thesis.

3.3.2 Structure

Although satisfactory quantitative comparisons are difficult to make, the average canopy heights of rainforests in north-east Queensland (Table 8) appear to be lower than those often shown in profile diagrams of equatorial lowland forest, particularly the dipterocarp forests of Malesia (e.g. Ashton 1964a). Although maximum height growth could be restricted by the effect of hurricane force winds associated with periodic cyclones, height limitations imposed by water stress during the dry season may be significant. Trees over 45 m high are certainly extremely rare in the rainforests of north-east Queensland.

The average basal area of the plots (48.1 m^2 ha^{-1}) was somewhat higher than the pantropic mean (36 m^2 ha^{-1} given by Dawkins (1958; 1959). This finding is consistent with observations of Baur (1964a) and Whitmore (1975). An examination of the relationship between plot basal area and stem density in the 6 plots with the highest basal areas (Table 8) suggested that in 3 of these plots the high basal area was largely the result of high stem density while in the other 3 it was the result of the large size of the individual stems. Although the range of stem densities was large (486-1104 ha^{-1}), the mean (869 ha^{-1}) was above the range observed for plots studied by Proctor <u>et al.</u> (1983) in Sarawak, even though the mean tree basal area was about the same for both sets of plots. The high basal area of rainforests in north-east Queensland is difficult to explain but could be related to a hypothesis concerning an observed inverse relationship between plot basal area and elevation (discussed below).

The diagrams illustrating stem density-diameter relationships (part a. of Figures 20-38) reveal a general trend of decreasing stem numbers as size classes increased. When considered with growth and mortality data, this pattern

indicates that overall, recruitment is continuous. Nevertheless, the important species data suggest that disturbance and/or the regeneration characteristics of the component species contribute to the establishment, and periodically to the distortion, of the overall pattern.

The rotated sigmoid semi-logarithmic density-diameter curve found in data from North American forests by West et al. (1981) was not readily apparent even when the size class width was reduced from 10 to 4 cm (Figure 41). Indeed a negative exponential pattern is indicated. While West et al. suggested that harvesting could have distorted their density-diameter distributions from the negative exponential pattern, they also presented evidence that stand age and composition, in terms of species shade tolerance, could cause deviations.

The inverse relationship ($P < 0.05$) between plot basal area and elevation (Figure 42), was one of the most interesting to emerge from efforts to relate stand structural features to environmental parameters. This relationship was not entirely unexpected for it is widely accepted by local foresters that timber yields from previously unlogged rainforests are usually highest from upland and highland forests. In attempting to explain this phenomenon, it should be observed that basal area could be regarded as a measure of the ability of an assemblage to accumulate stem biomass and thus stem mortality rates are just as important as the proportion of net primary production allocated to stem growth. In the absence of apparent relationships between elevation and site factors such as soil fertility or rainfall, the best hypothesis to explain this phenomenon seems to be as follows :-

> Lowland rainforests have characteristics (especially proximity to the sea) which cause them to be more vulnerable to cyclone damage than forests of the uplands and highlands. Because of this vulnerability, gaps in the canopy are larger and more frequently formed than those elsewhere. As a consequence a greater proportion of the individuals are "large gap" species which are capable of high initial growth rates if given sufficient resources, particularly light. Other important properties usually associated with these species are short lives and decay susceptible wood (see also Budowski 1963).

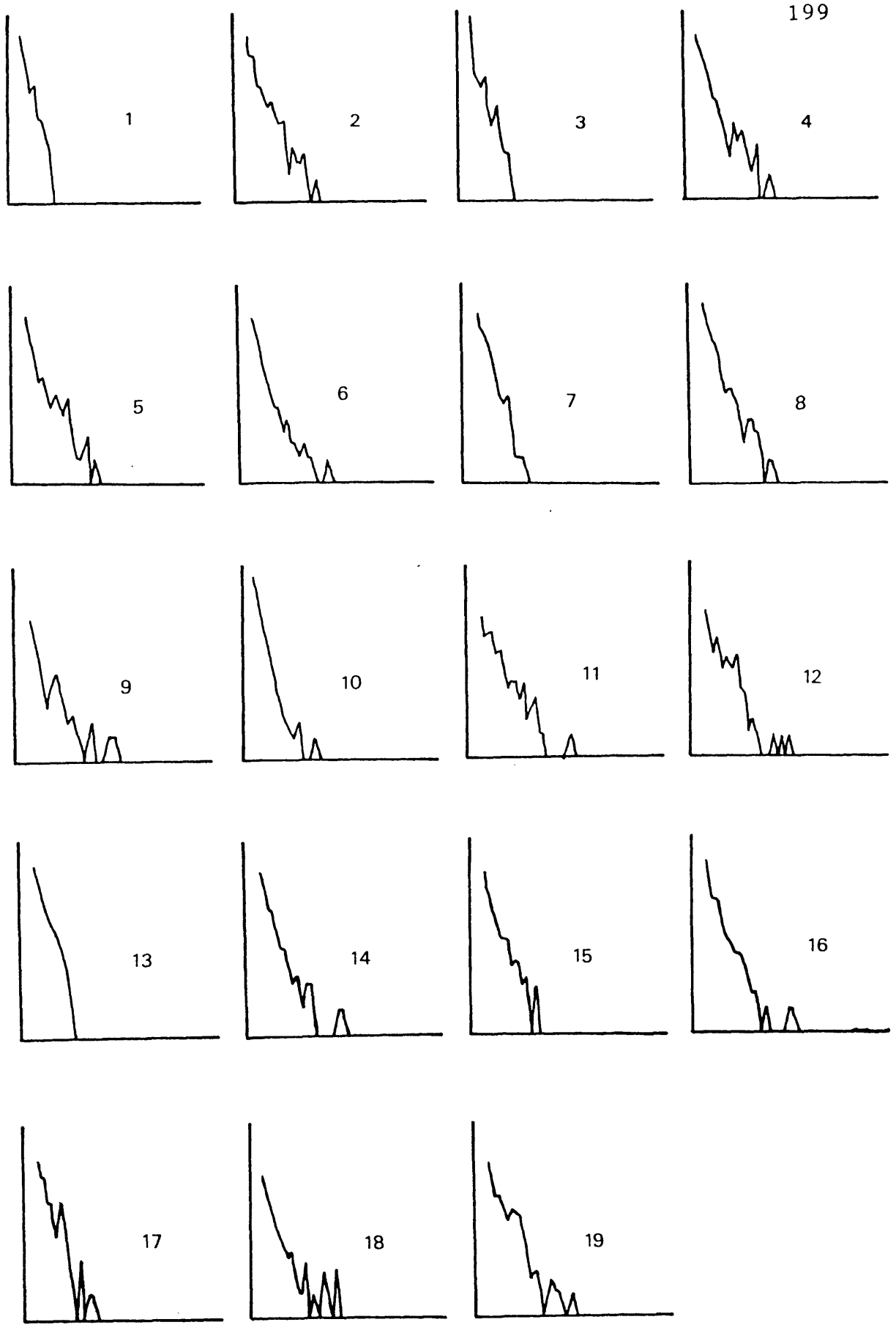

Figure 41. The relationships between the $\log_e$(stem numbers) and diameter classes (4 cm width) for each of the plots. The y axis extends from 0-5.4; the x axis from 0-200 cm in 4 cm

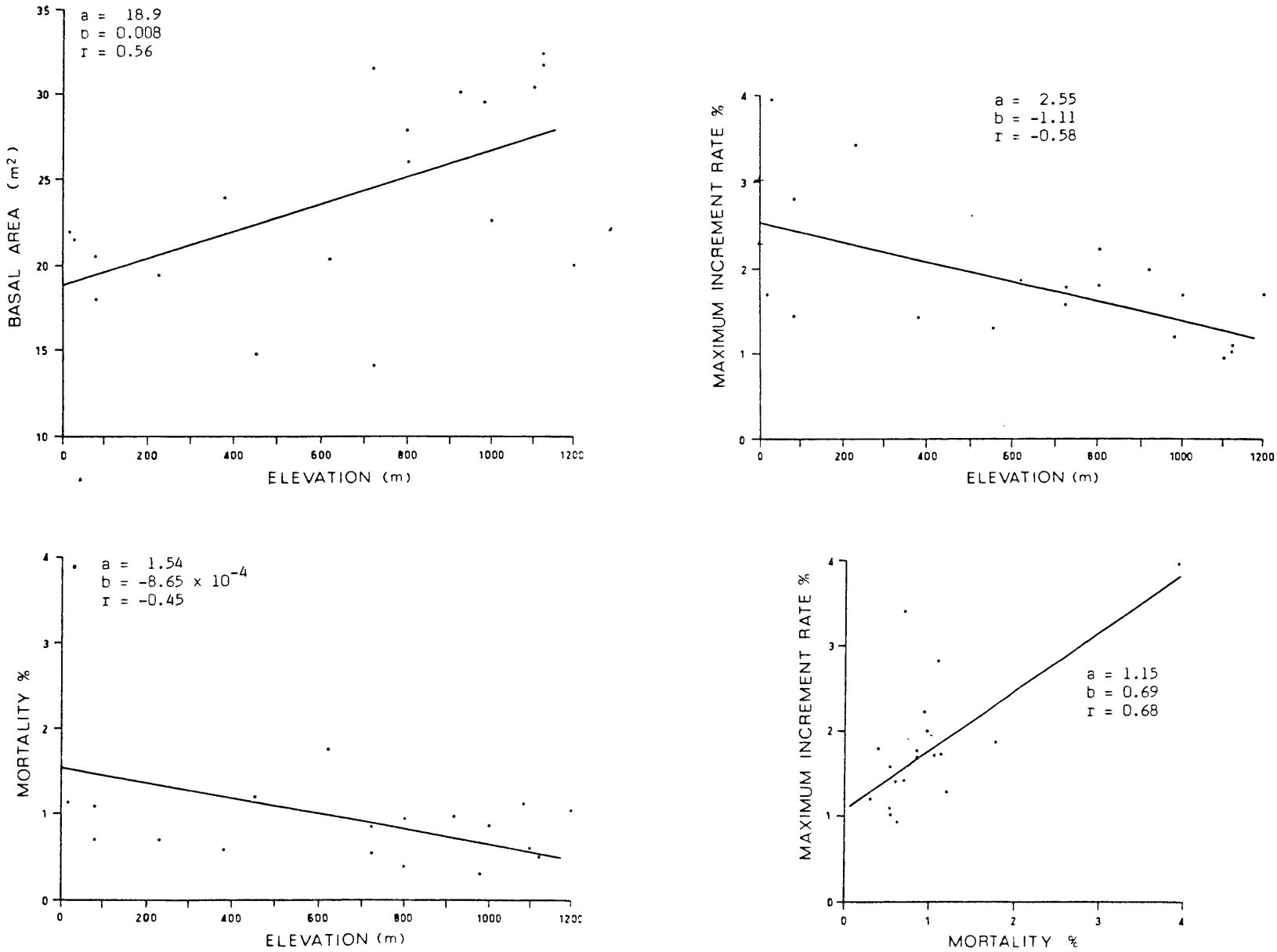

Figure 42. Some relationships between plot elevation, growth, basal area and mortality are illustrated.

The relationships ($P < 0.01$) between maximum relative increment rate and elevation and mortality (Figure 42) tended to support this hypothesis. However, the very high maximum increment and mortality levels of plot 18 exerted a considerable influence on these relationships and if the data from this plot are excluded, these trends are much less defined. The collection of growth and mortality data over longer periods may resolve the situation. There was also an indication that there was a higher proportion of rapidly growing tree species in plots at low elevations (Figure 43) but again the growth data available for individual species were not really adequate for the apparent relationship to be relied upon. Somewhat unexpectedly plot basal area did not correlate well with maximum percentage growth rate ($P < 0.1$) or at all with percentage mortality.

The long term average level of mortality in lowland forests will probably be higher than suggested by the currently available data used in Figure 42 for observations and meteorological records (Chapter 2) indicate that as well as steady ongoing mortality, pulses of unusually heavy mortality due to cyclonic disturbance can be expected at intervals of from 20-50 years. This type of disturbance regime would also favour the development in these forests of specialized life forms, particularly robust woody lianes and climbing aroids. Both these life forms are characteristic of the "complex" rainforest types of Webb (1959). "Complex" types, especially "complex mesophyll vine forest" are most conspicuous at low elevations in the forest type maps prepared by Tracey and Webb (1975).

The mean annual increments for 14 tree species which were both widespread and well distributed throughout the altitudinal range of the plots were examined in order to see if the growth rates of any of these species could be correlated with their elevation (Table 31). None could, although the correlation coefficient for *Xanthophyllum octandrum* was almost significant ($P < 0.05$). It was interesting to observe that the species listed in Table 31 were representative of a wide range of "ecological" types.

Table 31.

The mean annual percentage increments for species selected because their wide altitudinal and geographic range.

Species	Mean annual increments (% of initial ba.; plots in order of increasing elevation)																		
Plot	17	18	3	9	13	12	10	6	1	11	4	16	14	8	15	5	2	19	7
Acacia aulacocarpa			7.2		3.4		2.6	0.9	6.6			4.7		2.0					
Alphitonia whitei			0.4		1.8	1.6	1.8				3.4			0.5	0.9		0.3	0.8	1.3
Beilschmiedia bancroftii	2.2		6.4		0.6	0.5					1.3			1.6		0.7			
Cardwellia sublimis			1.7	0.3	1.1	0.7		4.5			0.4			1.0		0.7		0.3	2.2
Citronella smythii	0.4		0.6		0.0	0.9	0.7	-0.3			0.3							1.0	
Cryptocarya mackinnoniana	2.6		1.5	0.3	0.5	3.7	0.7	0.9		0.0	3.5			0.5	1.7			1.9	
Endiandra sp. aff. E. muelleri	0.9		0.5			1.9		1.2		1.3	0.3		0.2	0.9	0.9			0.8	
Eugenia johnsonii			0.4		1.1		1.3	1.3						0.8		2.7	0.5		0.7
Flindersia bourjotiana			2.4		2.2			1.6			1.9			1.3		0.6	1.3	1.5	1.9
Litsea leafeana	1.8				0.4	0.5		0.3		1.7			2.2		0.9				0.3
Myristica insipida	0.8	3.1		1.6		1.1		0.0		0.3	0.6				0.6				
Neolitsea dealbata						0.5		2.1			3.7				0.5	0.0		0.9	
Sterculia laurifolia			3.8	1.4	0.9						1.6			1.1	1.2	0.7	0.6	1.3	
Xanthophyllum octandrum	1.2		0.6	0.2	0.6	0.8	0.5	0.9			0.4					0.3	0.3	0.2	0.3

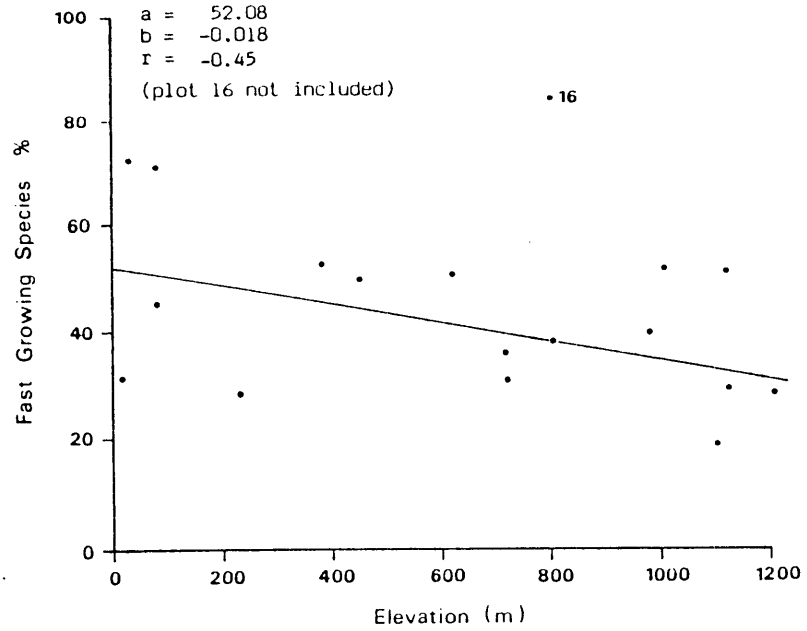

Figure 43. The relationship between the percentage of individuals of species with growth rates in the fast and intermediate categories in the important species lists for each plot (Appendix A, Tables 10-28) and plot elevation is shown. The regression is not significant at the 5% level unless the data for plot 16 are excluded. Much of the departure of individual plots from the regression line appears to be due to the arbitary definition of the growth classes. For example if the lower limit for the intermediate growth category were raised from 1.0 to 1.2% then plot 16 would fall below the present regression line.

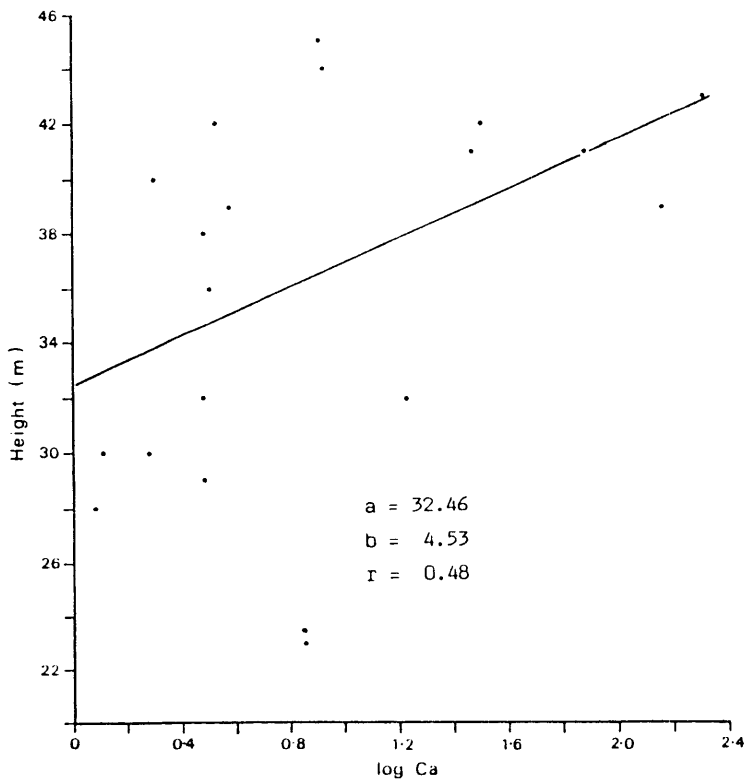

Figure 44. The relationship between log(exchangeable soil calcium) and the height of the tallest tree in each of the plots is shown.

One (Acacia aulacocarpa) could be described as "large gap" species; others (e.g. Flindersia bourjotiana and Cardwellia sublimis) as "intermediate gap" species while others were typical "small gap" species (e.g. Myristica insipida, Xanthophyllum octandrum and Citronella smythii). It was also observed that while A. aulacocarpa may have exceptionally fast growth rates, sometimes conditions in the plots do not allow it to grow any faster than a slow growing species (e.g. compare its growth with that of Xanthophyllum octandrum in plot 6). The growth of species in the second and particularly the third group may on average be slower than those in the first but rather more consistent. Rai (1983) observed similar trends in the growth rates of trees assigned to a range of shade tolerance classes, in the rainforests of southern India. Although an inverse relationship between maximum potential growth rate and degree of shade tolerance, has often been observed in both tropical and temperate mixed forests, the mechanisms responsible have not been thoroughly explored. This potentially important matter is discussed again in the next Chapter.

Declines in growth rate with elevation similar to those recorded here, were noted by Ashton and Brunig (1975) in the mixed dipterocarp forests of Borneo and Crow and Weaver (1977) for tree species in the rainforests of Puerto Rico. In the light of these finding the influence of the supposed very high rates of respiration in tropical lowland rainforests (e.g. Evans 1972) on their net primary production (Grubb 1973) should be re-examined.

The overall growth rates reported here were similar to those observed by Crow and Weaver (1977) and Kato et al. (1978) for Puerto Rican and Malayan rainforests respectively. However, as indicated by Table 31, growth rates within and between species were extremely variable. Baur (1964b) noted that it was usual to find wide variations in growth rates among individuals in tropical rainforests.

P. West (pers. comm.) also used the plot data to examine other relationships amongst stand and site parameters. The statistical methods adopted and the results obtained for these

detailed studies, are summarized in Appendix C2. However, West's analyses yielded little additional information relevant to studies of forest dynamics. For example, soil organic carbon and nitrogen were found to be related to basal area ($P < 0.05$) but this is to be expected for basal area may be directly related to site biomass - the primary source of soil organic carbon and associated nitrogen. Perhaps more important were indications that stand stocking declined with increasing soil calcium levels and rainfall. I would interpret these relationships in terms of the more favourable sites allowing larger trees to develop at the expense of total stem stocking. Some decline in species richness was also found in plots with high calcium level and I suspect that there was some specialization among the species in these plots to high fertility environments. I found that calcium levels were also related ($P < 0.05$) to the height of the tallest tree in each of the plots (Figure 44) and thus appeared to be important in stand height development.

Overall the lack of relationships between stand structural features and environmental parameters demands further study with supplementary environmental data and a refinement of analytical techniques. The intensive study of the soils within the plots currently being undertaken by I. Webb, should provide better data for future analyses. It would also appear necessary to use more sites. However, it may well be that these relationships do not exist beyond the general trends already identified and that many aspects of both structure and floristics are primarily determined by stochastic events and environment parameters which are not readily evaluated. Studies in other regions (reviewed in Section 2.3.2) have shown inconsistent relationships between measures of soil fertility and the structural features of rainforests.

Final resolution of the problems discussed above, would appear to demand advances on two fronts. Firstly, the role in determining stand characteristics, of stochastic events such as those associated with the reproductive biology of stand components and stand disturbance histories, must be thoroughly understood. Secondly, the rate of recruitment, growth and mortality of important stand components must be able to be

predicted. While direct observations of these dynamic parameters are essential, studies of the factors underlying physiological processes (especially transpiration, photosynthesis and respiration) may permit the establishment of models with broad applicability.

Further interpretation of the plot data would be greatly aided by reliable estimates of the ages, for various size classes, of the important species. Unfortunately there appear to be many problems associated with age determination especially for tropical trees (Dawkins 1966; Bormann and Berlyn 1981). A few relevant studies (outlined below) have been made in this region.

Although Ash (1983) found that late-wood formation was almost annual for Agathis robusta and more than annual for Araucaria cunninghamii, the apparent absence of clear annual growth rings from most of the region's tree flora makes it very difficult to determine age from ring counts. A new technique involving the periodic injection of dye to mark developing tissues in living stems with later coring and examination of subsequent growth patterns (J. Ogden pers. comm.), may permit further development of ring counting methods. D. Nicholson (pers. comm.) explored alternative carbon dating and growth projection techniques. Neither method was really satisfactory. The first provided some data (Table 32) but proved to be too expensive to replicate adequately; the second required good dbh growth data over substantial periods. When better growth records become available, there are various statistical tools (Enright 1982) which will allow age estimates based on growth projections to be much improved on those obtained with the methods used by Nicholson (1965).

Table 32. Radiocarbon ages for some large tree species from north Queensland's rainforests.

ANU C_{14} no.	Species	dbh cm(measurement height)	Age B.P.
1070	Xanthophyllum octandrum	58(0.7m)	620±100
1071	Agathis microstachys	213(0.8m)	1060±65
1256	A. microstachys	218(2m)	490±70
1255	Flindersia brayleyana	155(1m)	630±70
1504	F. brayleyana	126(2.6m)	340±80
1505	F. brayleyana	128(3m)	360±70
1506	F. brayleyana	126(2m)	420±70

In summary an analysis of data from the permanent plot series suggested that :-

a) When compared with Malesian rainforest, the rainforests of this region tended to be floristically impoverished and of lower stature. They also seemed to have a greater stem density and higher basal area.

b) The observed inverse relationship between basal area and elevation seemed best explained by a consideration of forest dynamics, namely the floristic and structural implications of severe disturbance by tropical cyclones to lowland stands because of their proximity to the sea. This disturbance pattern caused lowland forests to contain a larger proportion of "large gap" tree species. It has been widely observed that these species are faster growing but much shorter lived than "small gap" species. The net effect on the forests of this region has been that those in the lowlands have been able to accumulate less biomass (and thus have lower basal areas) than those at higher elevations.

c) The most plausible explanation of the tendency for two lowland stands to be dominated by a single species is that on these sites, the two species concerned have some inherent properties (possibly wood strength, rooting characteristics and/or twig brittleness) which enable them to withstand cyclonic winds better than competing species.

d) While the regeneration of many tree species appeared to be a continuous process, it was for others a periodic phenomenon. There were good indications that some species in the plots were not able to regenerate in the present plot environment and will eventually disappear unless more favourable conditions for their establishment and/or early growth return.

e) Ecologically important relationships between structural and environmental factors (excluding those discussed in b), above) were few. Of the soil fertility parameters measured the most important appeared to be exchangeable calcium which was related to stand stocking (inversely) and maximum tree

height (directly).

f) A diversity index based on the numbers of stems of individual tree species could not be correlated with any of the observed environmental, structural or floristic parameters except for species richness. A similar index based on species basal area did correlate with exchangeable soil calcium as well as species richness and seemed a more stable, and perhaps more useful, index for investigations of other relationships between forest diversity and the environment.

g) The size group in each plot exhibiting maximum increment rate varied considerably and probably depended on canopy height and roughness and stem density-diameter relationships. With a few notable exceptions large upper canopy and emergent individuals were extremely slow growing and it is suspected that they may be devoting the greater part of available resources to maintenance and reproduction.

h) While the relative increment rates of some species were consistently high and others were consistently low, those of many species were quite variable and probably reflected the ability of the individuals in that size class to capture sufficient resources, particularly light. The highest increment rates were invariably associated with "large gap" species.

i) For the differences between average recruitment and mortality to be eliminated, periodic catastrophes must add to deaths caused by the ongoing process of suppression.