The Ecology and Forest Types of the Peat Swamp Forests of Sarawak and Brunei in Relation to Their Silviculture.

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Preface

Peat swamps in Sarawak cover 5,660 square miles, and are therefore approximately equivalent to the total area of the northern countries of England. They form an almost continuous belt along the greater part of the coastline, and extend inland in places up to fifty miles. But, except from the air, the great extent of the peat swamp forests is not generally appreciated. One administrative officer, with fifteen years of experience in the country, even doubted their existence in the Rejang Delta. The margins of the swamps are very frequently under cultivation, and proceeding along the rivers little may be seen except the narrow fringe of rubber and sago gardens or rice fields.

Before the war the forests had little economic value; the principal product was chicle gum, obtained by tapping Jelutong (*Dyera lowii*) trees. A small timber industry existed, but this in peat swamp forests was confined to the forest fringes where logs were extracted by hand into readily accessible streams. It was not until two years after the Japanese Occupation that the value of peat swamp forest began to be appreciated. Ramin (*Gonystylus bancanus*) had previously been considered a worthless timber (though before the war it had been successfully marketed in Malaya under the name Melawis), but with the discovery of the value of this timber, and after the immediate problems of treating logs and sawn timber against borers and blue stain had been solved, the timber industry blossomed rapidly. (The year 1948 was the first in which Ramin was mentioned in the annual report of the Forest Department.) The whole industry is based on the export trade, and there is no clearer indication of the spectacular development of the industry than by showing the timber exports from Sarawak for the period 1947 - 1959 :

Timber exports in Hoppus round tons. (One sawn ton taken to be equivalent to two round tons)

Year	Total tonnage exported	Tonnage Ramin exported	Percentage Ramin of Total
1947	5,699	Not recorded.	
1948	19,599		
1949	38,510		
1950	45,846	16,963	37
1951	69,541	32,879	47
1952	127,814	65,118	59
1953	204,222	126,725	62
1954	215,428	157,188	78
1955	316,851	253,161	80
1956	281,376	226,787	81
1957	308,616	247,495	80
1958	295,508	230,233	78
1959	441,353	300,477	68

Over a period of nine years timber exports have increased by a little under 1000 per cent ! It is estimated that at least ninety five per cent of the industry is operating in peat swamp forests. Moreover the peat swamp forests are likely to remain the most important part of the Forest Estate of the country for an indefinite period in the future, provided they can be regenerated with economic species. The deep peats have no agricultural value at present, but the forests are readily accessible and extraction costs are, for tropical forests, very low.

For the Forest Department the rapid development of the timber industry in peat swamp forests has brought in its wake many problems. Over the past ten years these have been largely concerned with management, including reservation of forests, control of exploitation, and preparation of felling and working plans. In the future silvicultural problems will be of paramount importance.

In 1948 little was known on the ecology of the peat swamps, even the botanical identity of the principal dominants was largely obscure, and it was only as a result of enumeration surveys in the Rejang Delta in 1949-50, combined with the interpretation of aerial photographs, that certain forest types were recognised. The study reported here, which has proceeded intermittently over a period of almost ten years, involved initially botanical work, then ecological studies, proceeding from an investigation of the composition of the forest types to a more precise enquiry into their structure and occurrence, and an examination of some of the more important habitat factors. On completion of this an investigation by means of pollen analysis of the hydrosere has been made. Finally with a limited understanding of the floristic composition and ecology of the peat swamp forests the silvicultural problems have been investigated, but these it must be emphasised are only in the preliminary stages.

This study of the peat swamp forests could not have been completed without assistance. The identification of species has been a major problem and I am particularly grateful to Dr. C.G.G.J. van Steenis, the Director of the Flora Malesiasia Foundation, for his encouragement and assistance. I also acknowledge with thanks the following botanists who have examined and named specimens of the groups, families and genera shown : Professor H.J. Lam and Dr. P. van Royen (Sapotaceae), Dr. P.W. Leenhouts (Burseraceae and Connaraceae), Mr. E.J.H. Corner (Moraceae), Palmae (Dr.C.X. Furtado), Dr. Chew Wee Lek (Poikilospermum), Dr. A.J.G.H. Kostermans (Lauraceae and Sterculiaceae), Mr. L.L. Foreman (Menispermaceae), Professor H.C.D. de Wit (Phanera and Cryptocoryne) Mr. J. Sinclair (Myristicaceae and Annonaceae), Dr. R.E. Holttum (ferns). In addition I wish to record my gratitude to the Directors and Curators of the following institutes and herbaria who have allowed me the full use of their facilities and given me every assistance : Royal Botanic Gardens, Kew; Rijksherbarium, Leiden; Botanic Gardens, Singapore; Herbarium Bogoriense, Java Indonesia; and the Forest

Research Institute, Federation of Malaya.

Chemical analyses of peat samples were undertaken by Mr. J.K. Coulter and Mr. G.W. Arnott, of the Department of Agriculture, Federation of Malaya. I am indebted to the Director of this Department for granting permission for this work to be undertaken and to the two Soils Chemists for the analyses. I am also grateful to the General Manager, Brunei Shell Petroleum Company Limited for the assistance of many kinds that I have received from this Company, and I am particularly indebted to Mr. J. Muller, the Senior Palynologist, for the pollen analyses. The section on pollen analysis has been completed as a joint work with Mr. Muller.

The initial programme of ecological work was discussed with Mr. J. Wyatt-Smith to whom I am grateful for his advice and encouragement. I also record my gratitude to Mr. A.J. Vincent for examining certain data on the distribution of Shorea albida. Finally I am grateful to Mr. F.G. Browne, formerly Conservator of Forests, Sarawak, and Mr. B.E. Smythies, the present Conservator of Forests, for allowing me the time and giving me the opportunity to carry out this study, and I am also indebted to the Field Staff, especially Foresters Ahmady bin Derwis and Sanusi bin Tahir, of the Forest Department for their invaluable assistance in undertaking field work.

Some preliminary results of this study were presented as a paper (2) to the Symposium on Humid Tropics Vegetation held at Tjiawi, Indonesia, in December 1958. The contents, somewhat revised and enlarged, of Part 2 on the floristic composition and including Appendix 1 complete are to be published in Volume XVIII of the Gardens Bulletin Singapore. Chapter 16 will be published in Volume 40 (1) of the Empire Forestry Review, and Chapter 17 has been prepared for publication in the same journal. The ecological results will be prepared for submission for publication in one of the ecological journals.

Bomb Experience

Part 1

Introduction and factors of the environment.

Chapter 1

Introduction

Peat swamps are known to cover extensive areas in the humid tropics, and have been recorded from the three principal regions in the rain forest belt: the Malay Archipelago, Tropical America, and Tropical Africa. Richards (44) in his comprehensive work on the Tropical Rain Forest summarizes the available information both on the nature of the peat swamps themselves and on the vegetation. He remarks on more than one occasion that they have been little investigated. It is hardly surprising, therefore, that published information is rudimentary.

2. Beccari (3) was perhaps the first to discover peat in the humid tropics. He described the build up of carbon material in the Kapuas Lakes in Borneo and considered that the origin of coal deposits to be lacustrine, but he does not in fact mention peat as such. The significance of peat deposits was not realized until Potonié & Koorders (43) drew attention to considerable thicknesses of peat in Sumatra. But the emphasis of these early papers is on the tropical origins of coal. Tenison-Woods (57) was concerned with the same problem in an article on the Borneo peats.

3. The most fundamental studies of tropical peat soils were made by Polak (38-40). She recognizes two types: the ombrogenous and the topogenous moors. The former, occurring in areas of high rainfall, are, as Polak points out, analogous to the raised bogs (<u>hochmoore</u>) of the Temperate Zone, whereas the topogenous moors usually develop at high altitude or on lake shores, or along rivers, etc. These are not

the direct equivalent of Temperate fen peats, as they are generally acid rather than alkaline. Both Richards (44) and van Steenis (56) state that the topogenous peats occupy a greater area than the ombrogenous. The latter author (55) in his compilation of the Vegetation Map of Malaysia does not differentiate on the map between the two types so there is little comparative evidence on their distribution.

4. Polak's (38) principal contribution was to describe the structure, hydrology and chemical composition of the moors. She also undertook some preliminary work on the stratigraphy of the peats (cf. Chapter 14). It was found that peat in ombrogenous moors becomes thicker from the edge towards the centre, where the lower surface is below the level of the surrounding land. The upper surface is characteristically lens shaped so that the whole mass is that of a biconvex lens (Richards, l.c.). Underlying the peat there is a bleached clay; black water streams draining from the centre are very acid (pH c. 3.0) and the soils are extremely oligotrophic.

5. In the past ten years Coulter (12-15) has made an intensive investigation of peat swamps in Malaya in order to assess the possibility of using these soils for agricultural purposes. He estimates (15) that there are areas in Malaya totalling close on 2,000,000 acres that are covered by peat. Level surveys proved that the convex surface formation is present in the Kuala Langat F.R. (14), but absent in the Trans-Perak swamp (13). Generally the peats are relatively shallow, depths over eighteen feet are rare.

6. In Indonesian Borneo there has been little recent scientific work on the peat swamps. Van Wijk (72) studied them briefly, but as

his investigations were directed at determining the agricultural possibilities of South Borneo he not unnaturally avoided the deeper peats. In British Borneo a firm of irrigation engineers, Sir Bruce White, Wolfe Barry and Partners (69-71) undertook, on behalf of the Sarawak Government, a comprehensive survey of three of the larger peat swamps. The results of these surveys will be discussed in Chapter 4. Blackburn and Baker (11) include some soil analyses of peat swamps in their report on a soil survey of part of Brunei, but their report adds little to our knowledge of the peat swamps of Borneo.

7. In tropical America and Africa the nature of the peat swamps has not, to my knowledge, been closely studied. Mention however may be made of a recent study by Clayton (10) of the remnants of a shallow raised bog in Nigeria. It is of interest to note that peat had developed in this locality where the average annual rainfall is only fifty-one inches.

8. There has previously been no comprehensive investigation of the floristic composition or ecology of the peat swamp forests of Malaysia. Available information is generally confined to brief accounts or reports on botanical collecting expeditions. Though Polak deals only briefly with the vegetation her account of the swamps of the Paneh Peninsula in Sumatra is of interest in that a concentric zonation of vegetation was observed. The forest on deep peat consisted of four zones: forest with a thick undergrowth of the palms Licuala and Zalacca; (ii) dense forest; (iii) high forest of thin stemmed trees mixed with dwarf trees; and (iv) dwarf forest dominated by Tristania. Sewandano (47) estimates that the total number of tree

species in the Sumatra peat swamp forests to be under a hundred. Endert (20) describes swamp forest from South Sumatra and East Borneo. He records Campnosperma macrophyllum (C. coriaceum) as forming almost pure forests on the Moesi delta in Sumatra. In the centre of these swamps Tristania obovata and Ploiarium alternifolium are dominant. Van Steenis (54) in a brief account of peat forests in Malaysia provides a list of the principal arboreal genera that occur, but mentions by name only three species. As most of these genera are also represented by species in other forest types the list is only of limited value.

9. An account of a peat swamp forest in Lower Perak, Malaya, is given by Durgnat (19). The depth of peat in this area is approximately twelve feet. The principal dominants are Shorea rugosa (almost certainly var. uliginosa, though this is not mentioned), Campnosperma spp. and Cratoxylon arborescens. Wyatt Smith (76) provides a more comprehensive account for the whole of Malaya and includes a list of species occurring in a sample plot in the Telok Forest Reserve. The following species are stated to be common: Amoora rubiginosa, Blumeodendron tokbrai, Cratoxylon arborescens, Dialium patens, Ganua motleyana, Gonystylus bancanus, Koompassia malaccensis, Litsea gracilipes, Parastemon urophyllum, Palaquium ridleyi, Shorea rugosa var. uliginosa, Shorea teysmanniana and Tetramerista glabra. The height of the canopy is about 100 feet and the density of the main canopy is stated to be less than in dry land rain forest. Emergents are generally absent, and the understorey consists of a fairly continuous canopy from about twenty to sixty feet. There are distinct variations in the vegetation on very

shallow peat (one to two feet), on deep peat, and on peat overlying clay or other sub-soil types. Variations consequent of distance from dry land also occur.

10. Kostermans (26-7) in two somewhat controversial papers, which will be discussed later, on peat swamps in Borneo lists the more important species and the habitats in which they occur. Many of the species are the same as those recorded from Malaya.

11. In Sarawak brief accounts of the peat swamp forests, incorporating some preliminary results from this study, are included by Browne (6) in his book on the forest trees of Sarawak and Brunei, in a paper submitted by the author (2) to a UNESCO Symposium, and in Annual Reports (46) of the Forest Department. The zonation of forest types in peat swamp forest was first noted in the Rejang Delta by Smythies (51-3), and the forest types characteristic of the zones were mapped from the results of enumeration surveys and from the interpretation of aerial photographs. The three types recognized were Mixed Swamp Forest, Alan Forest (dominated by Shorea albida), and Padang* Medang Forest (dominated by an unidentified species, previously though to belong to the Magnoliaceae, cf. Chap. 5). In 1957 a Land Use Map was prepared for the whole territory and the areas of peat swamp forest are shown under the previous headings, with the exception that Padang Paya Forest was substituted for Padang Medang Forest. In an article on the Kerangas ('heath') forests of Sarawak Browne (5) put forward the tentative hypothesis that the zonation of

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* Padang in the Malay language literally means a level open piece of land, hence padang football - a football field, but it is also used in referring to primary forest on level land composed of relatively small trees. Paya is the Malay word for swamp.

Photograph 1. Kuala Lawas. The mouth of the Lawas river, showing the flood plain and the Lawas hills (2-3000 ft.) in the background. The mangrove fringe can be seen in the left foreground behind which is peat swamp forest.

Photograph 2. Riparian fringe in the Lawas river. The river at this point is still tidal and saline. Nipa fruticans is the palm in the foreground. The tall palm in the middle distance in Oncosperma filamentosa. Peat swamp forest can be seen in the background.

the forest was caused by subsidence of the coastline and that the original vegetation consisted of conifers and Shorea albida on Kerangas soils.

12. The total area of peat swamp forest in Sarawak covers 5,660 square miles or 12 per cent of the area of the country. In the following table areas, computed from the Land Use Map (47), of the three identified forest types are shown by administrative divisions:

	First Division	Second Division	Third Division	Fourth Division	Fifth Division	Total
			(square miles)			
Mixed Swamp Forest	515	815	1,933	1,116	66	4,445
Alan Forest	58	105	202	77	-	442
Padang Paya Forest	3	152	187	431		773
Total	576	1,072	2,322	1,624	66	5,660

The distribution of the peat swamps is shown on Map 1.

Terminology (Peat swamp and freshwater swamp)

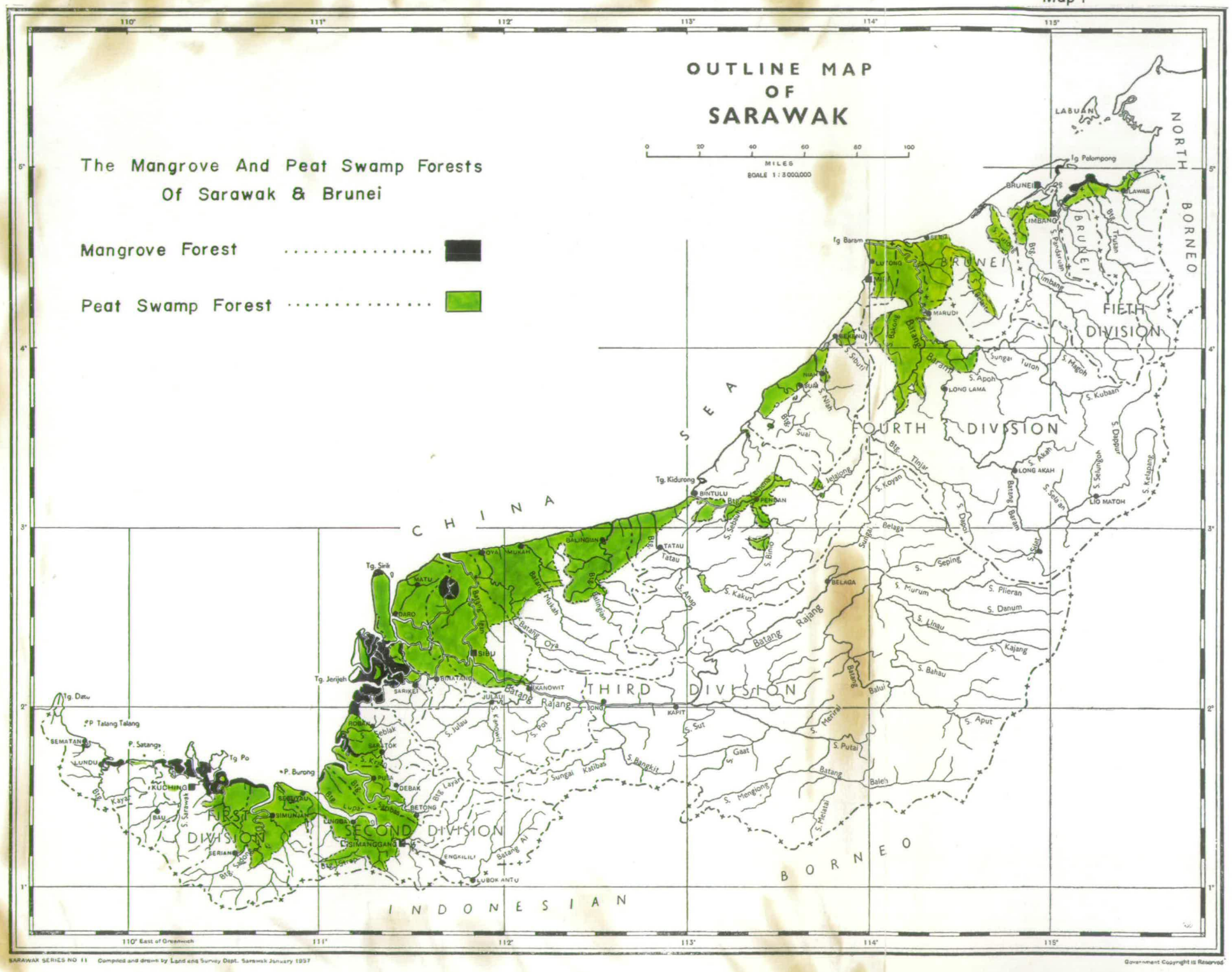
13. It is perhaps advisable at this stage to define, in so far as this study is concerned, ~~to define~~ certain terms that are frequently used. The pedalogical terms 'peat' and 'muck' were defined at the Second International Congress of Soil Science held in Russia in 1930. Subcommission 6, which had been appointed to deal with peat, recommended that the term peat should be restricted to organic soils that are at least ½ metre in depth; 1 hectare in extent and with a content of mineral matter not exceeding 35 per cent in peat (parent organic material) and 65 per cent in muck (organic residence derived

Map I

The Mangrove And Peat Swamp Forests Of Sarawak & Brunei

Mangrove Forest .....

Peat Swamp Forest .....



SARAWAK SERIES NO 11 Compiled and drawn by Land and Survey Dept. Sarawak January 1957

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from peat acted on by soil forming processes) (Coulter, 12). Coulter (l.c.) further divides the peats into three main groups: the 'eutropic' peats, largely derived from marsh and grass vegetation and which have an abundance of mineral matter and are neutral or alkaline in reaction. These are basically the fen peats of the Temperate Zone. They do not occur in Malaya (Coulter, 15) and have not been recorded from Borneo. The second division is the 'oligotrophic' group. These peats are low in mineral content, especially Calcium, and are acid in reaction. Polak (38) states that the peats of eastern Sumatra, western Borneo and southern New Guinea are oligotrophic. The third division is the 'mesotrophic' group which is described as being intermediate between the other two (Coulter, 12), has a pH of about 5 and a rather high base content. These peats are of very localized occurrence in Malaya. Coulter (15) further proposes for Malaya the term 'bog soils' to include in one group both the muck soils and peat. This may be convenient from a pedalogical point of view but it is ecologically confusing in that two separate habitats, freshwater swamp and peat swamp, are contained in the same group.

14. Wyatt-Smith (76) in describing the peat swamp forests in Malaya uses Coulter's bog soils as a basis for the distribution of the peat swamps, though in a previous summary of the forest types of Malaya (75) he includes the same areas under freshwater swamp forest. The two terms are not synonomous and each forest type has a basically different structure and floristic composition (though some species occur in both types). The following brief definitions by van Steenis (55) are also unsatisfactory:

(i) freshwater swamp forest on ± mineral soil and tolerant to climate,

(ii) peat forest on peat and restricted to an ombrogenous climate.

15. It is considered that the two most important factors that differentiate freshwater swamp and peat swamp are the surface structure of the swamp and the degree of flooding. These two closely interrelated factors will largely determine the drainage of the swamp and the mineral content. The following definitions are proposed:

Freshwater swamp has a muck or peat soil with a loss on ignition less than 75 per cent, a pH usually more than 4.0, is subject to regular or occasional flooding, and the surface structure is not or barely convex.

Peat swamp has a peat soil with a loss on ignition greater than 75 per cent, a pH usually less than 4.0, is not subject to flooding, and the surface structure is usually markedly convex.

16. It is admitted that these definitions are imprecise, but further ecological and pedalogical research is required to clarify the definitions. Freshwater swamp may be oligotrophic but probably approaches the mesotrophic group, whereas peat swamp is only oligotrophic. In Sarawak and Brunei freshwater swamps are largely topogenous and occur along rivers where flooding during the wet season is prevalent. In comparison with peat swamps they cover a negligible area. Margins of some peat swamps where flooding occurs and the soils have consequently a relatively high mineral content may perhaps be considered as freshwater swamps (cf. Chapter 4). It will also be realized that where in a freshwater swamp the peat accumulation raises the soil level above the flood level a peat swamp may develop. In this study peat swamps only are considered in detail.

Outline of the study

17. In this study it has not been possible to define the nature of the problem in precise and simple terms. On the contrary the work has consisted in obtaining fundamental botanical and ecological information on the peat swamp forests on which further silvicultural studies may be based. It is convenient to consider the whole investigation in separate sections:

(i) an investigation of the floristic composition of the peat swamp forests (Part 2),

(ii) an investigation of the habitat factors and, in particular, the surface structure of the peat swamps (Chapter 4),

(iii) a study of the ecology of the ecosystem and the delimitation of the forest types (Part 3),

(iv) a study by pollen analysis of the hydrosere and the interpretation of the development of the bog formations (Part 4),

(v) a study of regeneration in primary forest and the development of regrowth following exploitation (Part 6).

In the course of field work two phenomena of ecological significance, climatic damage and the destruction of Shorea albida forest by an unidentified insect, have been encountered. These have been briefly investigated and the results are contained in chapters 15 and 16.

Chapter 2

Climatic Data

18. Sarawak, situated just north of the equator between latitudes 0°75' and 5°00', has a typical equatorial climate of the humid tropics, characterized by a uniform warm temperature without extremes and a high equably distributed rainfall. The two enclaves which constitute the State of Brunei are surrounded on three sides by Sarawak territory and the climate is therefore similar. General statements contained here on the climate of Sarawak may be taken to apply also to Brunei.

19. There is little variation in the air temperature both throughout the territory and during the year. Temperatures exceeding 90°F or minimum temperatures below 70°F are rare and the mean temperature is about 80°F with a variation in the mean in coastal districts of about one degree plus or minus. Data for three coastal stations (the only localities where observations have been recorded for more than ten years) are included in Table 1.

20. The most significant feature of the climate is the amount and distribution of rainfall. Seal (47) in a recent paper has summarized the recorded data, which for coastal stations, is included in Table 2. The stations are arranged in accordance with their geographical position from west to east. The mean annual rainfall ranges between 112 and 167 ins. It is noticeable that the annual rainfall tends to be higher in those stations in the vicinity of mountains or hills and consistently lower in the Rejang Delta. It is generally considered that there are two seasons in Sarawak: the

Table 1. Observations on temperature, relative humidity and sunshine at Kuching Airport, Bintulu and Miri.

	Kuching Airport	Bintulu	Miri
Air temperature in degrees Fahrenheit			
(a) Mean of maximum	87.5	88.5	86.7
(b) Mean of minimum	71.2	73.2	73.8
Mean of (a) and (b)	79.3	80.9	80.2
Absolute extremes:			
Highest maximum	93.0	93.4	92.0
Lowest minimum	65.5	66.6	67.0
Lowest maximum	75.2	80.0	74.9
Highest minimum	74.6	75.4	76.7
Relative humidity			
Mean value at 2 p.m.	70.6	71.7	75.0
Annual mean range at 2 p.m.	63.5 - 76.5	67.5 - 75.9	70.5 - 81.2
Bright sunshine:			
Monthly mean total hours	149.41	179.65	200.63
Daily mean (hours)	4.90	5.89	6.58

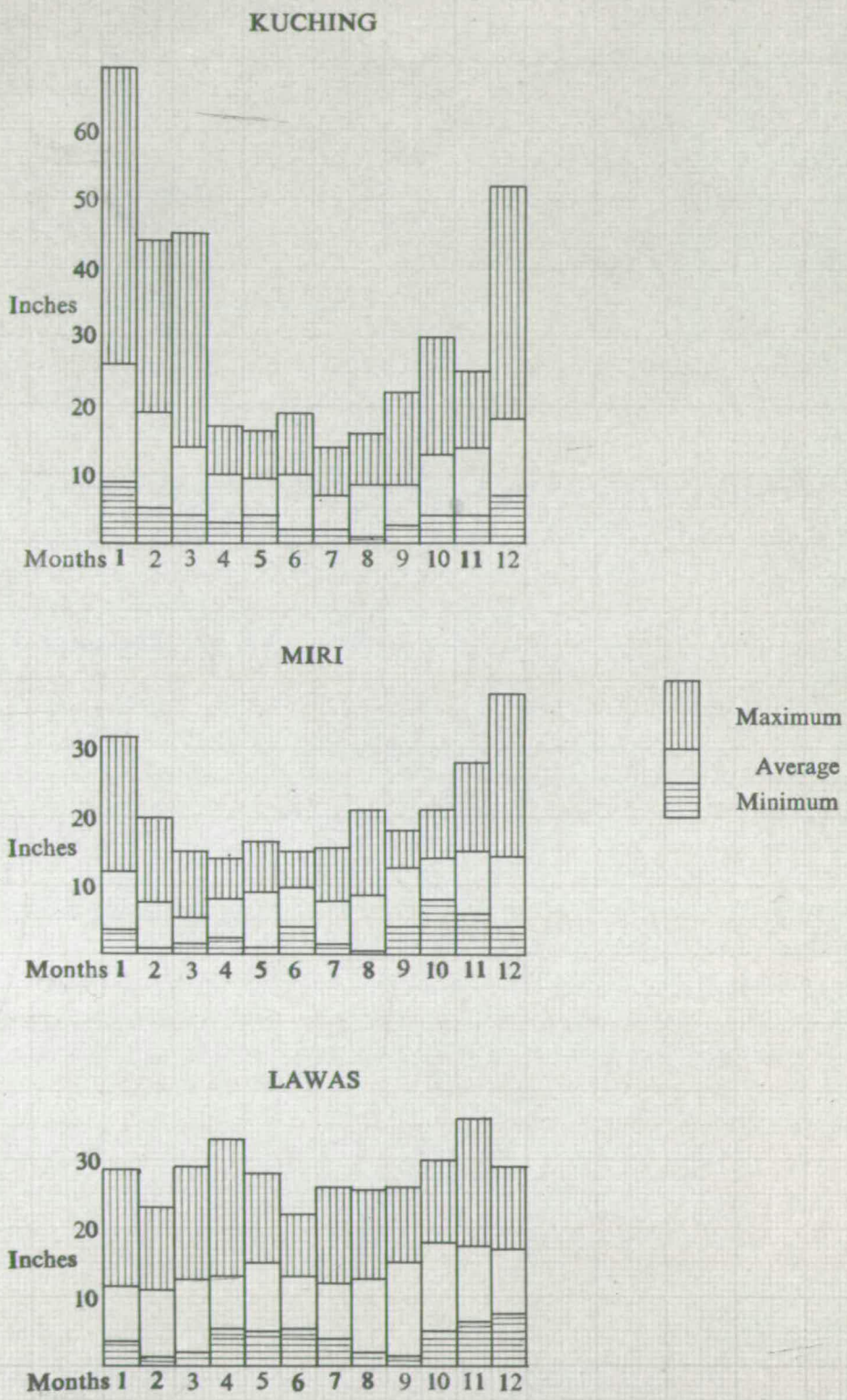
Table 1. Mean monthly and annual rainfall at coastal stations in Sarawak and Brunei.

Mean monthly rainfall (ins)

Sarawak	No. of years recorded	MONTHS 1	2	3	4	5	6	7	8	9	10	11	12	Mean annual rainfall
1.Lundu	18	21.37	18.69	13.91	6.99	7.71	7.95	5.21	5.58	7.45	8.69	11.63	16.88	132.07
2.Kuching	69	26.06	19.37	13.84	10.12	9.43	8.49	7.49	8.50	9.92	12.71	13.45	18.14	158.33
3.Lingga	8	12.66	14.38	9.08	9.84	8.35	5.56	8.04	8.66	10.13	10.49	13.37	15.19	125.64
4.Simanggang	16	17.13	13.61	13.35	15.13	12.09	8.85	9.50	10.73	10.73	15.53	17.57	15.89	160.11
5.Saratok	6	17.11	12.09	11.69	9.39	10.17	6.00	11.47	10.45	12.39	10.81	13.08	16.27	140.91
6.Sarikei	11	13.17	10.92	10.85	10.51	7.26	6.10	6.46	9.03	10.81	11.08	9.90	12.31	118.41
7.Sibu	20	14.14	11.20	12.26	10.83	9.03	7.61	7.90	9.75	10.11	10.63	10.98	12.53	126.98
8.Rantau Panjang	5	12.91	14.18	9.91	7.61	8.65	5.48	7.45	7.41	12.75	11.81	12.30	10.76	121.22
9.Matu	7	17.12	14.80	7.31	7.23	6.51	6.61	5.54	7.54	7.46	9.97	12.45	16.97	119.51
0.Mukah	12	20.35	17.66	13.87	6.22	7.55	6.09	5.48	6.49	11.45	11.83	10.69	20.51	138.19
1.Bintulu	31	14.44	11.63	11.64	11.16	10.43	10.72	9.01	11.04	13.30	15.77	15.74	17.64	152.51
2.Miri	29	12.08	7.05	6.41	7.80	8.97	9.26	7.94	8.23	12.32	13.97	14.95	14.61	123.65
3.Marudi	22	10.21	8.14	9.35	8.67	8.69	7.79	7.39	8.35	10.28	11.61	9.45	12.78	112.78
4. Limbang	19	14.24	10.35	10.02	11.48	12.24	11.34	9.24	11.30	13.24	13.63	13.61	13.87	144.58
5.Sundar	7	9.03	8.97	8.37	12.94	11.39	9.03	10.02	8.70	10.47	13.51	13.11	14.11	129.67
6.Lawas	24	11.68	11.20	12.28	13.08	15.04	13.45	12.15	12.90	15.62	17.12	16.93	16.26	167.72
Brunei														
1.Kuala Belait	4	12.52	10.37	8.89	8.84	7.20	5.30	9.76	7.75	10.23	12.17	11.35	10.92	115.36
2.Badas	4	7.58	8.49	4.92	7.86	8.98	10.70	8.29	9.52	12.77	12.23	11.89	10.51	113.74

dry season from April to September and the wet season from October to March. Seal (l.c.) recognizes two additional seasons each of a period of eight weeks intermediate between the main seasons. The terms wet and dry are, however, only relative as rain falls throughout the year, and prolonged droughts exceeding ten days are of rare occurrence. During the period October to March the country is subject to the north east monsoon which brings moisture from the China Sea, whereas during the dry season the south east monsoon prevails. The pattern of the monsoons is, however, greatly modified by convectional moisture in the form of heavy showers and thunder-storms. At no station is the mean monthly rainfall less than five inches whereas the maximum mean is twenty-six inches (January, Kuching). Precipitation occurs on the average in over two hundred days of the year in all stations. The seasonal distribution of rainfall is most pronounced in west Sarawak and becomes progressively less marked towards the east. This is clearly shown in the histogram in Figure 1 where the distribution at the two extremes, Kuching and Lawas, and at the intermediate station at Miri are compared.

MAXIMUM, AVERAGE, AND MINIMUM MONTHLY RAINFALL FIGURES FOR KUCHING, MIRI, AND LAWAS



Chapter 3

Research Procedure in the Field

21. Research undertaken in this study on the peat swamps has followed no precise and clear cut programme. An initial interest in the purely botanical aspects developed into a study of the ecology of the swamps in a localized area (the Rejang Delta) and the study was later extended to cover the whole country and Brunei. After knowledge had been gained on the distribution and composition of the forest types, related ecological problems were tackled and finally the development of the raised bogs and the ecological succession were considered. Simple ecological techniques were standardized in 1954 so results from all localities are comparable.

22. In 1952-3 basic knowledge on the composition of the swamp flora was gained and a study made of the structure of the swamps by means of level surveys. It was only in February 1954, when the author was released for four months special duties, that a detailed ecological study could be begun. The selection of swamps to be studied and the location of transects were decided from aerial photographs. The selection was largely dependent on two factors: the presence of a sequence of forest types and the accessibility of the area. Field methods adopted were largely based on the work of Wyatt-Smith (74) who advised on the initial lay-out of the sample plots. In the selected swamps a transect was cut from the perimeter to the centre, and half acre plots (5 x 1 chains) were enumerated at regular intervals, usually half a mile. On the first transect, in the Loba Kabang Protected Forest, two plots, set at right angles to

and on either side of the transect, were enumerated at each half mile. Each pair could be analysed as two separate plots or combined as one plot of an acre. Each plot was further subdivided into one chain square sub-plots. After a preliminary analysis of the results of the first survey it was decided that a single half acre plot would give adequate data, except where the forest was composed of a large mixture of species. As the percentage of the area of the swamps sampled was very low - usually less than .1 per cent - an enumeration of the principal dominants was made along the length of transects in the Rejang Delta, Maludam Peninsula, and at Lobok Pasir in the Baram. The location of the transects and numbers of plots enumerated are detailed in Table 3 and shown on Maps 2-4.

23. A hundred per cent enumeration of all trees exceeding twelve inches girth at breast height (4 ft. 6 ins.) was made in each plot; each tree being measured to the nearest one tenth of an inch. Trees with buttresses or stilt roots were measured at twelve inches above the obstruction. Trees were numbered and botanical material was collected from unidentified species. The use of vernacular names was completely avoided. In the initial stages no attempt was made to sample the understorey and ground flora. It was considered that until a thorough knowledge had been gained of the mature arboreal flora - complex enough in itself - a study of the immature stages would involve the collection of immense quantities of sterile material, whose identity would be largely unknown. A study of the understorey and ground flora was only attempted at a much later stage (1958) when the complete flora (flowering plants) of the swamps was to a large extent known, and seedlings and saplings could be identified.

Table 3. Summary of principal ecological field work undertaken.

(i) Sample Plots (half acre) :

	Location	Sample Plot Nos.	Area
Rejang Delta	Loba Kabang Protected Forest	1-12, 15-18	8 acres
	Pulau Bruit Protected Forest	13-14	1 "
Meludam Peninsula	Triso	19-23	2½ "
Baram	Sg. Dua	24-25	1 "
	Tanjong Jaye	26-29	2 "
	Lubok Pasir	30-32	1½ "
Brunei	Badas	33-42	5 "
Lawas	Kayangeran Forest Reserve	43-51	4½ "
Bintulu	Tatau Protected Forest	52	½ "
	Sungei Silai	53	½ "
		Total	26½ acres

(ii) Transects (one chain wide):

	Location	Distance	Area
Rejang Delta	Loba Kabang Protected Forest	350 chains	35 acres
Meludam	Triso	280 "	28 "
Baram	Lubok Pasir	75 "	75 "

(iii) Level Surveys:

	Location	Distance
Rejang Delta	Pulau Bruit	115 chains
	Loba Kabang Protected Forest (Sungei Sawei)	320 "
	do (Rantau Panjang)	380 "
	Daro Forest Reserve	200 "
	Naman Forest Reserve	280 "
Baram	Tanjong Jaye	94 "
	Tanjong Jabai	86 "
	Lubok Pasir	130 "

(iv) Profile Diagrams:

	Location	Diagram Number	Remarks
Rejang Delta	Loba Kabang Protected Forest	1	Phasic Community 1
	do	2	Swamp surface in Phasic Community 1
	do	3	Phasic Community 2
	do	5	Phasic Community 4
	do	6	Swamp surface in Phasic Community 4
Baram	Sungei Dua	4	Phasic Community 3
	Lubok Pasir	7	Phasic Community 5
	do	8	Phasic Community 6

24. Heights of enumerated trees were not measured or estimated. To obtain information on the structure of the forest profile diagrams were made in all the forest types. The size of the area measured and the techniques adopted in the preparation of the profile diagrams were generally similar to those used by Richards (44), with the exception that, whereas Richards felled and measured all trees, it was found more convenient to fell a few trees of secondary species for a distance of approximately one hundred feet from the datum line of the profile, and then using a 'Harga' hypsometer measure all trees in the area to be sampled and accurately prepare the profile diagram on squared paper in the field. This method is less time-consuming and is considered to give a more accurate impression of the structure of the forest.

25. Preliminary investigations into the structure of the peat swamps were started in 1952-3. Precise level surveys were made across four swamps in the Rejang Delta. In parts of these surveys use was made of the rail extraction routes which, provided they were straight, allowed the maximum sight with the Abney level. Difficulty was often experienced in obtaining a completely stable base for the tripod of the instrument and frequent use had to be made of posts driven into the swamp. Minor irregularities in the surface of the swamp, caused by roots and different heights of the litter layer, were another source of error. To overcome these the height of the water table was accurately surveyed, even though this necessitated on occasions digging down a few inches through the litter and humus. This procedure was adopted in the survey along the transect in the Loba Kabang P.F. and on all subsequent level surveys. The depth of

peat was measured at every tenth chain with an extendable auger. It was found that with care the sub-soil would remain adhering to the auger itself when withdrawn though peat was washed off. Initially, extension rods up to twenty-five feet were used but it was found that a further twenty-five feet were required and even then in one locality the subsoil was not reached. Semi-decomposed or almost totally undecomposed material may be found at all levels in the peat and it is often impossible to pierce this with a light auger. Probings had frequently to be made at numerous places before the sub-soil was reached.

26. To measure variations in the height of the water table graduated stakes were driven into the swamp along the transect in the Loba Kabang Protected Forest. The stakes were protected from interference by a fence (see Plate 2) and the water table was exposed. Observations were recorded over a period of five months in 1954. The graduated stakes were correlated with the level survey along the transect.

27. Details of additional research procedure in the investigation of subsidiary ecological problems, i.e. climatic and insect damage, are included in the introduction to the relevant chapters. It is also considered more convenient to include the field and laboratory techniques used in the pollen analysis of a peat bog at the beginning of chapter 14. Details of methods used in the surveys of the regeneration are included in Part 6.

Photograph 3 . This photograph shows the method adopted for measuring the water table of peat swamps. The fence was erected to prevent interference.

Chapter 4

Structure and chemical composition of the peat swamps

28. The coastal and deltaic peat swamps of Sarawak have a convex structure and are markedly oligotrophic. There is abundant evidence to indicate their structural characteristics, especially the convexity of the swamp surface, from three principal sources: first from the level surveys undertaken in the course of this study; second from seismic surveys of petroleum companies; and third from detailed surveys undertaken by a firm of irrigation engineers.

29. Profiles of the five swamps surveyed in the Rejang Delta are shown in Figure 2, and their location can be found on Map 2. It has been necessary of course to exaggerate the vertical scale (the ratio of vertical to horizontal scales is 1:66). The datum lines through profiles indicate the estimated high tidal level or flood mark of rivers on the perimeter of swamps. The convex nature of the surface of the swamps, clearly shown in these profiles, becomes increasingly more pronounced with distance from the sea: on the island of Pulau Bruit the height of the swamp surface rises to 12.96 feet and the gradient is relatively gentle on both sides of the island; maximum recorded heights in the Daro Forest Reserve and the two surveys in the Loba Kabang Protected Forest were 13.13, 15.40 and 13.13 feet respectively. It is significant that the gradients in these swamps are much steeper in the first one hundred chains from the perimeter than in the centre, where the rise is only about one to one and a half feet per mile. The surface structure of the swamp is therefore analogous to an inverted saucer, having in

the centre an almost flat bog plain. The profile in the Naman Forest Reserve, upriver from the apex of the delta and therefore probably the oldest surveyed swamp, is the most remarkable. Here the rise in the first mile is 22.5 feet and the maximum height above the datum in the centre of the swamp is 30.4 feet. Three minor hillocks or undulations were encountered on this survey. These are literally being 'swamped' by the gradual accretion of peat. As may be expected maximum depths of peat also tend to increase from the coast inland: on Pulau Bruit the maximum depth was 21 feet 9 inches whereas in the Naman Forest Reserve the subsoil was not reached in two borings despite extensions to the auger up to fifty feet. In individual swamps the subsoil level below the peat is irregular and peat depths do not necessarily increase towards the centre of swamps. For instance in the Naman Forest Reserve maximum peat depths were found at twenty and a hundred chains from the perimeter, whereas the most central boring was only forty-three feet deep. A similar pattern may be seen in the other profiles. A significant feature, found on all profiles in the Rejang Delta, is the depth of the subsoil below the high tidal or river level. The cause of this will be further discussed in chapter 14. The subsoil was invariably a stiff white or yellow clay.

30. These general features of the structure of swamps may also be seen in the profile diagrams of Baram peat swamps (Fig. 3). The profile of the swamp in the region of the Pagalayan Canal was prepared by the Geological Survey Department, and shows in greater detail the nature of the soil beneath the peat. At Tanjong Jaye there is a sharp gradient in the first ten chains and almost a flat bog plain

thereafter. The swamp levels at Tanjong Jalai show a somewhat different pattern: for the first twenty chains there is no pronounced rise and the peat is comparatively shallow. It is clear from aerial photographic interpretation that this area has been previously eroded by the Baram river and, after the old river course has silted up, accretion of peat has restarted. The Lubok Pasir swamp, further up-river near Marudi, has the steepest gradient recorded on any peat swamp. In the first five, ten and thirty chains heights above the datum of 13.75, 16.25 and 22.5 feet respectively were recorded; towards the centre of the swamp the surface levels to an almost flat central bog plain. The greatest depth of peat recorded in Baram swamps was thirty-nine feet in the centre of the Lubok Pasir swamp. Subsoil levels are generally below the datum (the high water mark of the river) but this feature is not so pronounced as in the Rejang Delta.

31. Further evidence of the surface structure of swamps has been gleaned from reports of seismic parties of the Sarawak Shell Oilfields Limited and the Brunei Shell Petroleum Company Limited. Very extensive level surveys across swamps from the Rejang Delta to Lawas have been made and these were correlated with mean sea level. An accurate comparison can therefore be made between swamp levels in different localities. Data of six level surveys have been plotted on Figure 4. Two (Nos. 1 and 2) of the four surveys in the Fourth Division are of inland swamps, and in the centre of the bogs the surface reaches maximum heights of 14.77 and 13.89 metres above mean sea level. The other two surveys (Nos. 3 and 4) start from the coast and the doming is not so pronounced; maximum heights of the

surface were 6.94 and 4.78 metres above mean sea level. The two plotted surveys (Nos. 5 and 6) from the Third Division cover part of a large peat swamp between the Mukah and Oya rivers. They are of interest in showing the effect of rivers or streams, draining the swamp itself, on the surface levels. The end of the surveys was in approximately the centre of the bog plain where the height above mean sea level was between nine and ten metres. The heights of these bogs are therefore intermediate between the heights of the coastal and inland bogs of the Baram.

32. In 1954-5 a firm of consulting engineers, Sir Bruce White, Wolfe Barry and Partners, was engaged by the Sarawak Government to survey certain swamp areas and report on their suitability for rice cultivation. Three areas had been previously selected: Nonok Peninsula on the coast near Kuching; Maludam Peninsula, a large swamp between the Saribas and Batang Lupar rivers; and a swamp at the confluence of the Tinjar and Baram rivers, above Marudi. In the first and last mentioned areas comprehensive level surveys on a grid pattern were undertaken and from the results the contours of the swamps have been drawn. Though the results of these surveys proved of no economic value they are of scientific interest in providing a comparison of the structures of what is probably a raised bog of relatively recent origin with that of a highly developed raised bog of more ancient origin. The contours of the Nonok swamp (Fig. 5), on the coast near Kuching, are well spaced and the typical surface structure with a relatively steep gradient and flat bog plain is only found near the inland margin of the swamp. Land two feet or more below the arbitrary datum of one hundred feet is still under mangrove

forest, whereas shallow peat to the 105-foot contour has been largely cultivated. The large swamp between the confluence of the Baram and Tinjar rivers (Fig. 6), forty-two miles in a direct line from the mouth of the Baram, shows a highly developed domed structure, with a pronounced bog plain, particularly in the southern portion of the swamp, and a maximum height of over sixty feet above the arbitrary datum of 80 feet on the river bank. The two principal streams draining the swamp, the Sungeis Majau and Peking, form pronounced re-entrants into the bog structure. Peat depths were not measured in excess of twenty feet so it is not possible to show the contrasting profiles of these bogs.

33. A contour map of the Maludam Peninsula was not prepared, but level surveys were made along two transects, shown on Map 3, across the seaward end of this vast swamp. The east-west transect was 17.1 miles long and the north-south 15.6 miles. Plotted profile diagrams are to be found in the Report (70). The general structure of the bog is similar to those already described. The bog plain extends for 9.5 and 6.8 miles along the east-west and north-south transects respectively and variations in surface height do not exceed 2.7 feet over these distances, except where the Maludam river forms a re-entrant.

34. The results of these surveys confirm and enlarge upon the work of Polak on the peat swamps of Borneo and Sumatra. It is clear, as Polak points out, that the structure of the peat swamps is analogous to the raised bogs of the Temperate Zone. Characteristics of Temperate raised bogs - especially those studied in Scandinavia - such as the rand, lagg and bog plain, are also present in the tropical

raised bogs of Borneo; the principal difference is perhaps in the immense size of some tropical bogs, some of which cover over a hundred square miles. The structure of the swamps has been examined in some detail as there would appear to be correlation between this and the distribution of the forest types. This correlation and the morphology and development of the peat bogs will be further discussed in chapters 13 and 14.

35. It is frequently assumed that the coastal and deltaic swamps are liable to extensive flooding during the wet season. The domed structure of the swamps is not generally appreciated and as peripheral villages and creeks are frequently subjected to flooding it is taken for granted that the swamps behind are also flooded. There is no evidence to support this. Precise data on degree of flooding are inadequate for a complete understanding, but tidal and river gauge observations by the aforementioned firm of consulting engineers (69-71) are relevant. During the course of the surveys gauges, correlated to the level surveys of the swamps, were established. Maximum and minimum levels in relation to the mean river level are shown separately for the three areas in Table 4. If the data from this table are applied to the contour maps it will be seen that in the Nonok Peninsula the highest recorded level, which was observed during the period of spring tides, barely reaches the hundred foot contour. It must be a rare occurrence for flooding to penetrate further than the ninety-eight foot contour which approximately marks the limit of mangrove. Tanjong Tahap, near the Baram Tinjar confluence, is barely tidal and flooding is only liable to occur when the rivers are in a spate. A flood mark on a building at Tanjong

Tahap was levelled and found to be 105.89 feet (reduced level). Local opinion stated that flood levels rarely go appreciably higher than this. It is unlikely that a high flood level is sustained for long and doubtful whether it would penetrate far into the forest at the same level. Nevertheless if the 105 foot contour is taken as the approximate flood level it will be seen that flooding seldom exceeds half a mile from the river bank. Flood levels in the Maludam Peninsula indicate that flooding does not exceed one mile from the river bank, and this probably only occurs at spring tides. This evidence confirms the visual impression that peat swamps are not subject to extensive flooding, and they must therefore rely almost entirely for the maintenance of the water table and replenishment of plant nutrients on rainfall and the atmosphere. In coastal areas rivers are frequently broad, and occasionally estuarine, or deltaic. Flood waters tend therefore to be dissipated over large areas, and marginal flooding is probably confined to spring tides. Up-river the steep gradient of the bog itself precludes any possibility of extensive flooding. Marginal flooding and its concomitant deposition of silt is however of importance in maintaining the height of the river levels. This will be referred to again in chapter 14.

36. The water table is stilted and lies close to the swamp surface. During the wet season the water table is frequently above the swamp surface, especially near the perimeter of swamps. The water table itself was taken as the swamp surface in the level survey from Rantau Panjang in the Loba Kabang Protected Forest (Fig. 2) and in the surveys in the Baram (Fig. 3). The stilting of the water table can be appreciated from these figures. Early in this study

the possible ecological importance of variations in the water table was realized and measurements were made in the Loba Kabang Protected Forest over a period of seven months (April to October 1954). The correlated heights of the water table at all stations on two dates are shown in Figure 7, which also includes the maximum and minimum variations on the first reading at each station. The lowest range of variation, 3.7 to 4.2 ins., is found near the perimeter of the swamp and there is a gradual increase in the variation towards the swamp centre as far as station 10, where it is 7.5 ins. The maximum range of variation at each station has no doubt not been recorded, as observations were not taken during the wet season. Nevertheless the pattern of variation is probably established. It is significant that the minimum variation occurs near the perimeter of swamps where the gradient of the bog is highest: presumably excess water tends to drain off rapidly during and after periods of heavy rain (the run-off can be observed with the naked eye), whereas in periods of comparative drought the water table is maintained by a lowering of the water table in the central zone. It will be realized that the converse of this hypothesis is true for the centre of the swamps.

37. It would appear that the drainage of the swamps is entirely at or close to the surface. The heavily compacted peat mass at lower levels probably prevents lateral drainage. Undecomposed woody material ~~after~~ thousands of years old (see Chapter 14), found at lower levels is surely an indication of this complete stagnation. Excess water on the surface collects in depressions which tend to coalesce to form small rivulets and finally drain to larger streams which, as has been shown from level surveys, may form marked depressions in the swamp surface and re-entrants into the bog plain.

Table 4. River level observations at Nonok, Maludam Peninsula and the Baram Tinjar area as recorded by Sir Bruce White, Wolfe Barry and Partners.

Period of observations	River levels in feet			
	Maximum above mean (feet)	Minimum below mean (feet)	Mean (feet) (correlated with level surveys)	Range in feet
Nonok Peninsula				
(i) Kpg. Temburat	+ 7.03	- 7.77	92.38	14.80
(ii) Kpg. Tjg. Separang	+ 7.43	- 8.37	92.33	14.80
(iii) Kpg. Nonok Ulu	+ 3.33	- 3.47	95.57	6.80
Maludam Peninsula				
(i) Bukit Plaku	+ 10.68	- 8.62	88.92	19.30
(ii) Triso	+ 9.40	- 8.30	89.28	17.70
Baram Tinjar confluence				
(i) Tanjong Tahap Sep. - Nov. 1955	+ 11.2	- 11.2	92.83	22.4

38. As forest vegetation entirely covers the peat swamps the physical structure of the peat itself is very different from that of Temperate peats. It consists of a compacted mass of semi-decomposed woody material; roots and stumps are especially numerous, but branch-wood and fallen trunks are also present. The central parts of larger pieces of timber at all peat depths may be entirely undecomposed and these, as has been mentioned previously, frequently cause obstructions when peat borings are made. Plates 3 and 4 show peat profiles in a

Photographs 4,5 + 6 . Three photographs showing a peat profile in a ditch at the side of a road under construction. Undecomposed woody material, especially stumps and roots may be found at all levels in a matrix of amorphous peaty material (Photos BRUNIG).

locality where a drain has been cut to a depth of ten feet. The matrix of the peat is composed of a dark chocolate brown soupy material, largely amorphous, though containing recognisable rootlets, leaves, twigs, etc., in various states of decomposition. This matrix is also rich in pollen. The surface peat in the centre of highly developed raised bogs in the Baram where the forest is open and stunted is of a different texture, more akin to Temperate peat. It is heavily compacted and fibrous, light reddish brown in colour and containing numerous colourless rootlets. The dark soupy matrix is replaced by a thinner watery liquid.

39. Some preliminary information has been obtained on the chemical composition of the peat. A more intensive soil survey is required to determine the distribution and availability of plant nutrients. Samples were collected along the transects in the Loba Kabang Protected Forest (Rantau Panjang) and at Lobok Pasir in the Baram, the object being to determine whether there was any indication of a decrease in nutrients from the permeter to the centre of swamps.

40. The results of the analyses of samples from the Rejang Delta are shown in Table 5. The first two samples, two and ten chains from the river bank, are 'muck' soils with a relatively high mineral content derived from the deposition of alluvium in flood water. The land from which they were taken was under rice cultivation. The remaining samples are true peats (more than 65 per cent loss on ignition) in accordance with the international classification. There is no significant change in the loss of ignition or acidity of the peat from the twentieth chain to the centre of the swamp. Plant nutrients are very low in all samples, as may be expected, but, with the exception

Table 5 . Results of analyses of peat samples from transect at Rantau Panjang in the Loba Kabang Protected Forest, Rejang Delta.

Sample No.	Distance on transect chains	Sample Plot No.	pH	Loss on ignition	Moisture free basis (percentage) N	CaO	P_2O_5	MgO	K_2O	CaO + MgO + K_2O	Chloroform abstract	Alchobol extract
1	2	-	4.65	24	0.826	0.2072	0.0469	0.982	0.4200	.719	4.67	3.85
2	10	-	4.30	37	0.770	0.1568	0.0457	0.070	0.3720	.599	3.25	2.75
3	20	-	3.89	79	1.239	0.1372	0.0142	0.067	0.0234	.234	4.24	5.60
4	30	-	3.97	92	1.491	0.1036	0.0519	0.072	0.0300	.206	5.16	6.95
5	60	1	4.18	87	1.456	0.1260	0.0309	0.070	0.0324	.228	4.28	7.74
6	60	2	3.86	86	1.568	0.1120	0.0852	0.072	0.0240	.208	5.72	5.91
7	100	3	3.93	78	1.659	0.1372	0.0704	0.229	0.0228	.389	4.31	6.03
8	100	4	3.99	86	1.610	0.1876	0.0630	0.112	0.0270	.327	4.95	4.41
9	140	5	3.99	87	1.575	0.1624	0.0451	0.135	0.0300	.328	5.47	1.81
10	140	6	4.00	94	1.610	0.1456	0.0241	0.114	0.0186	.278	5.70	8.69
11	180	7	4.00	76	1.428	0.1204	0.0179	0.077	0.0258	.223	6.58	8.29
12	180	8	3.95	81	1.561	0.1008	0.0154	0.144	0.0168	.262	4.43	8.33
13	220	9	4.00	76	1.351	0.0806	0.0049	0.213	0.0264	.329	5.33	7.57
14	220	10	3.99	77	1.400	0.0980	0.0049	0.112	0.0240	.234	7.47	5.07
15	260	11	3.90	86	1.365	0.1176	0.0191	0.064	0.0216	.203	8.80	5.48
16	260	12	3.97	82	1.491	0.1148	0.0210	0.053	0.0264	.194	7.22	5.96
17	P. Bruit	13	3.85	85	1.540	0.0924	0.0568	0.072	0.0468	.211	3.09	5.67
18	P. Bruit	14	3.85	93	1.428	0.0924	0.0636	0.055	0.0456	.196	3.16	4.20

of the Phosphorus content, there is no significant decrease towards the centre of the swamp. Samples 10 to 16, from the centre of the swamp, are on the average much lower in Phosphorus.

41. The samples from the transect at Lobok Pasir in the Baram were collected to obtain information on the chemical composition of a highly developed raised bog, the vegetation in the centre of which is open stunted forest, representing the final stage in sere (see Chapter 14). Three samples at varying depths were collected from each locality along the transect to determine whether plant nutrients tend to be retained at the surface. This seemed probable as surface rooting predominates and is most pronounced in the forest types towards the centre of swamps. The results of the analysis are included in Table 6.

42. The mineral content of the samples was exceptionally low, the loss on ignition ranging from 98-100 per cent. There is a significant decrease in the easily soluble Phosphorus and Potassium content towards the centre of the bog. This is most marked in the samples from chains 76 and 128. Somewhat unexpectedly the samples from the centre are less acid than those from the peripheral zone. This fact requires to be confirmed in the field. There is a clear indication from the samples at 10, 20, 30, 76 and 128 chains that plant nutrients are stratified and are most plentiful in the top six inches. The significance of this will be further discussed in Chapter 13. By using a Kjellerman borer further samples were collected from the centre of the bog (176 chains), from the surface to a depth of thirteen metres at half metre intervals. It had been hoped to determine whether there was a deficiency of plant nutrients

Table 6. Results of analyses of surface peat samples from the transect at Lobok Pasir, Baram.

Sample No.	Distance along transect (chains)	Depth (inches)	Sample Plot No.	pH Fresh	pH Airdry	Loss on ignition	Easily soluble P p.p.m	Easily soluble K p.p.m.	Na CE p.p.m.
1	10	0-6	30	3.3	3.2	99	230	100	470
2	"	13		3.4		99	145	70	470
3	"	19		3.7		99	90	70	Nil
4	20	0-5		3.8	3.3	99	355	425	590
5	"	9		3.7		98	260	298	590
6	"	13		4.2		99	180	185	530
7	30	0-4	31	3.9	3.3	98	140	232	760
8	"	8		3.9		99	125	170	700
9	"	12		4.1		99	145	170	760
10	34	0-4½		4.1	3.3	99	150	115	290
11	"	8½		4.2		99	165	200	410
12	"	15		4.1		99	90	90	Nil
13	35	0-5		4.0	3.2	99	225	340	1460
14	"	12		4.1		99	165	195	1170
15	"	18		4.2		100	90	140	760
16	76	0-5	32	4.0	3.4	99	75	100	Nil
17	"	10		4.2		99	95	115	"
18	"	18		4.2		100	45	110	"
19	128	0-5		4.1	3.2	99	55	125	640
20	"	10		4.1		100	55	100	700
21	"	16		4.1		99	25	110	880

Table 7. Results of analyses of peat samples from a bore in the centre of the swamp at Lobok Pasir, Baram.

Sample No.	Depth (Metres)	pH (Fresh)	pH (air dry)	N %	C %	Easily soluble K p.p.m.	Easily soluble P p. p. m.	SO_4 %
22	0.5	4.0		2.74		65		
23	1.0	4.1		1.04		50		
24	1.5	4.2		1.18		90		
25	2.0	4.7		1.06		no sample		
26	2.5	4.4		1.04		33		
27	3.0	4.5		0.96		no sample		
28	3.5	4.5		0.84		55		
29	4.0	4.4		1.08		no sample		
30	4.0	4.5		1.19		"		
31	4.5	4.5		0.94		38		
32	5.0	4.7		0.83		70		
33	5.5	4.8		0.88		133		
34	6.0	4.2		0.90		118		
35	6.5	4.2		0.83		100		
36	7.0	4.4		0.87		75		
37	7.5	4.5		1.09		70		
38	8.0	4.5		0.76		60		
39	8.5	4.6		0.81		60		
40	9.0	5.3		0.83		95		
41	9.5	5.9		0.80		95		
42	10.0	6.3	4.4	0.47	19.86	80	26	0.18
43	10.5	4.9	2.1	0.26	8.91	47	26	0.92
44	11.0	5.3	2.8	0.19	7.28	25	17	1.08
45	11.5	6.1	3.3	0.11	3.02	42	36	0.33
46	12.0	5.9	3.6	0.11	2.21	49	30	0.28
47	12.5	6.9	4.1	0.09	2.04	75	34	0.13
48	13.0	6.7	4.1	0.09	2.21	78	32	0.13

in the bog profile. Unfortunately the material that was obtained was insufficient for a complete analysis, though below 10 metres where the mineral soil, a stiff clay of mangrove origin (cf. Chapter 14) was reached, analyses were possible on air dry samples. The results of these analyses are shown in Table 7. An interesting feature is the increase in the pH with depth in the peat; the pH of samples ~~21-27~~ 42-43 fell considerably on drying out owing to the high Sulphur content.

Figure 2

PEAT PROFILES IN THE REJANG DELTA

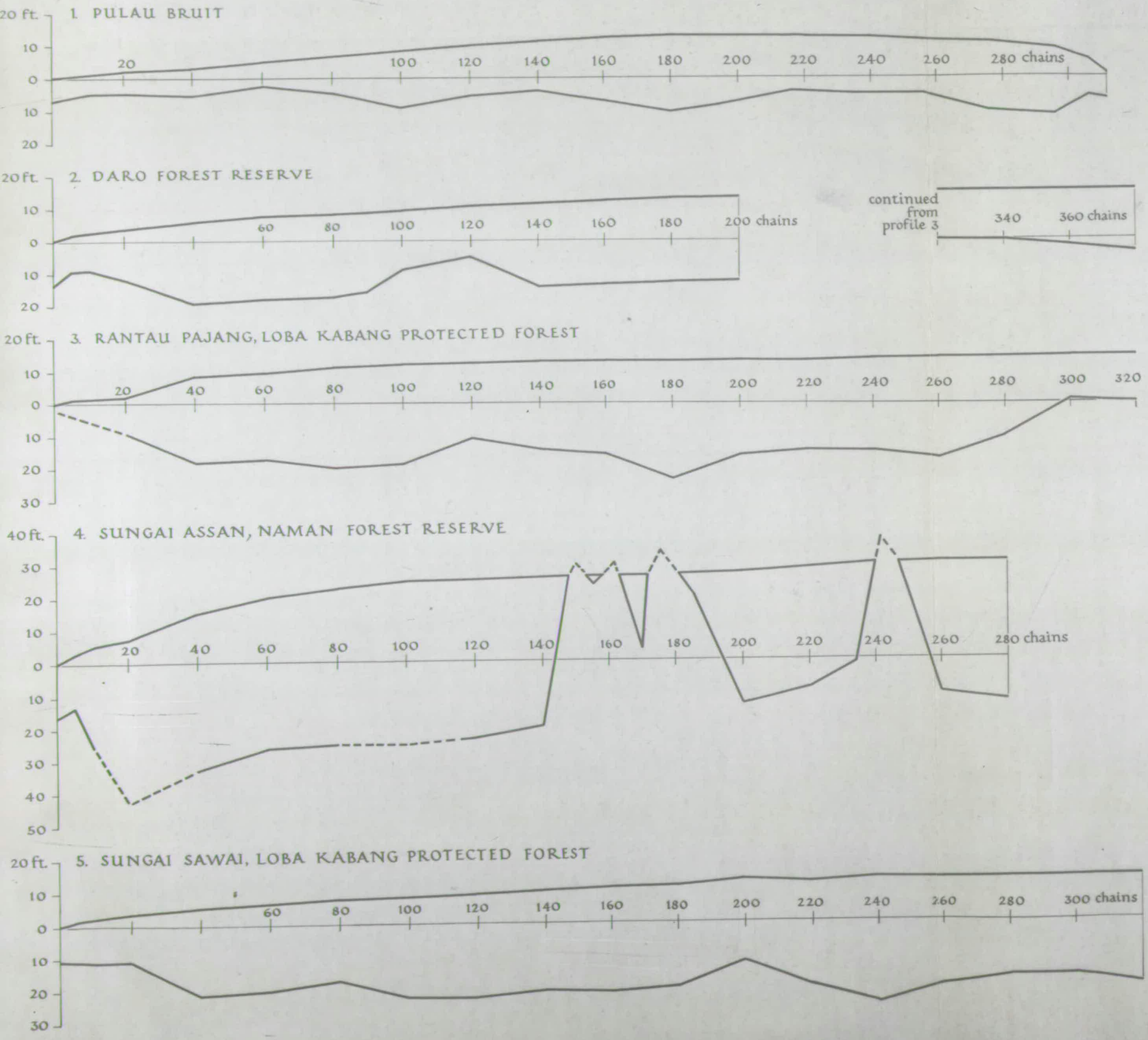


Figure 3

PEAT PROFILES IN THE BARAM

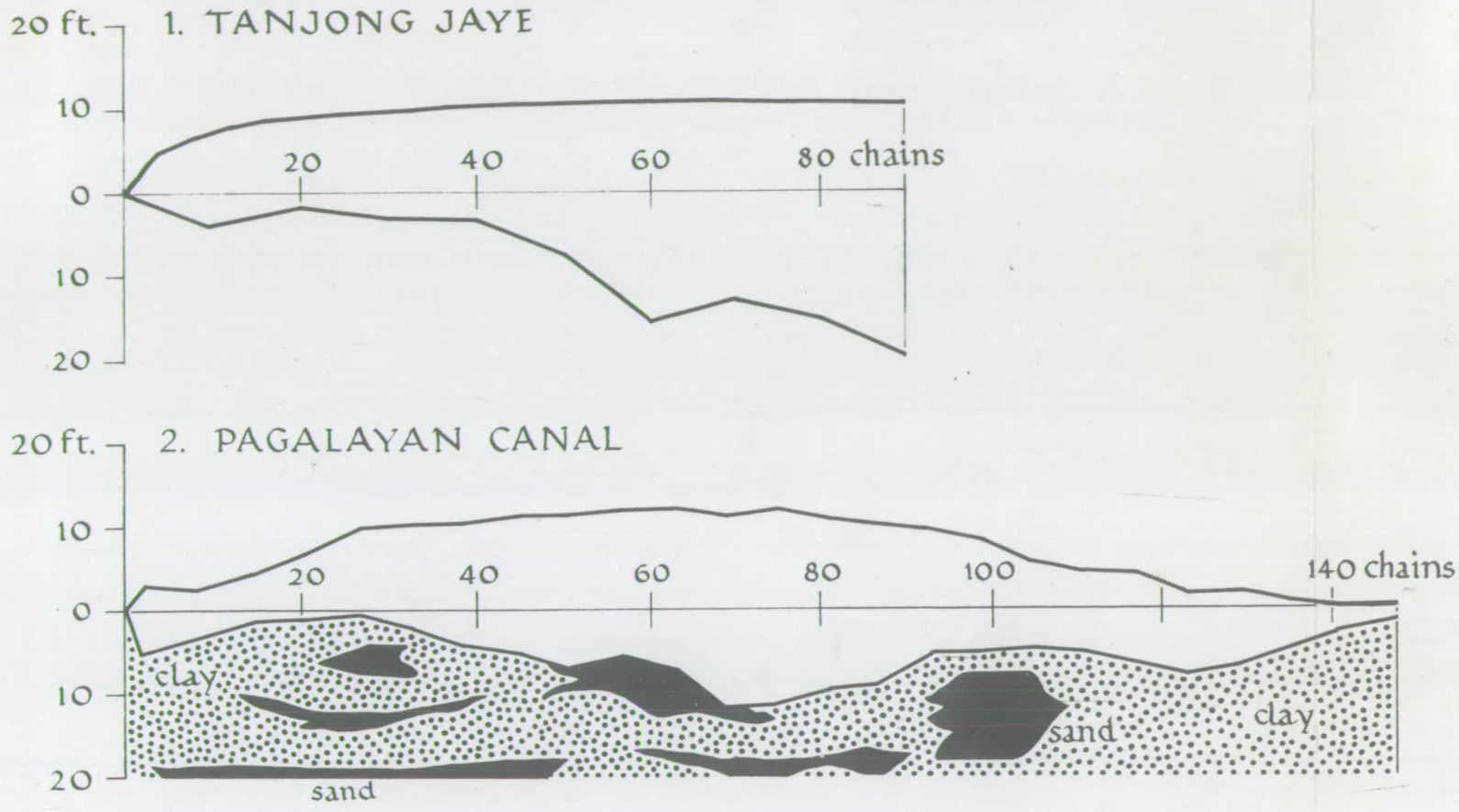
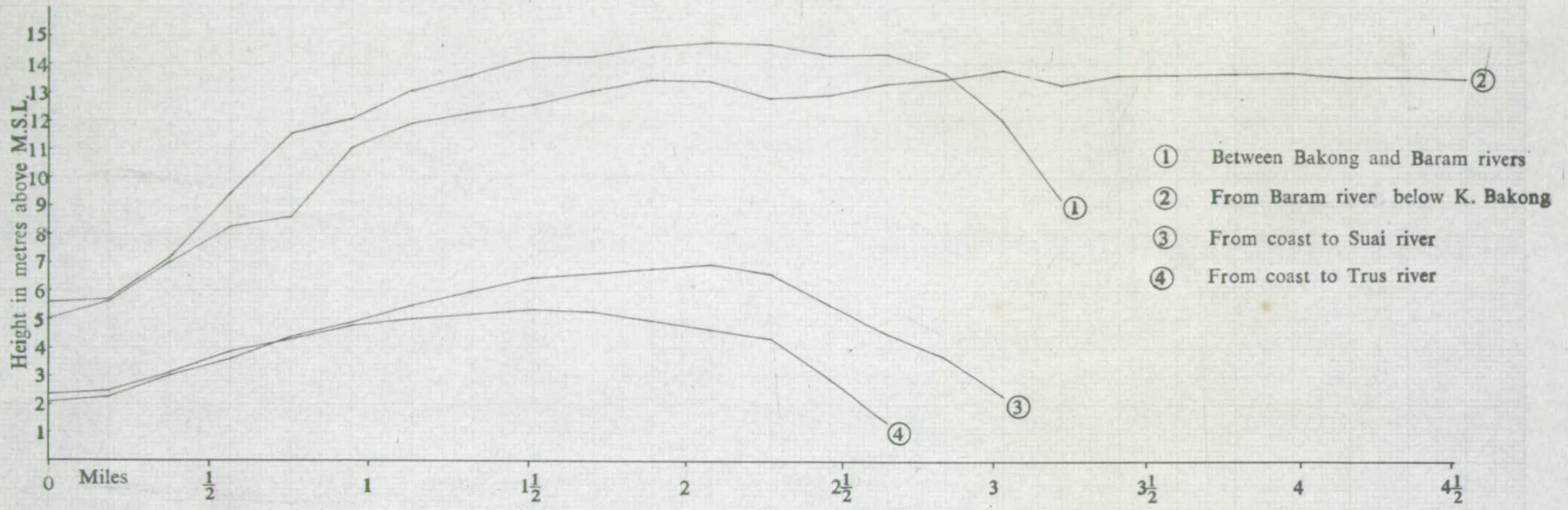


Figure 4

SURFACE LEVELS OF PEAT SWAMPS IN FORTH DIVISION

(Extracted from Seismic Survey field books)



SURFACE LEVELS OF PEAT SWAMPS IN THIRD DIVISION

(Extracted from Seismic Survey field books)

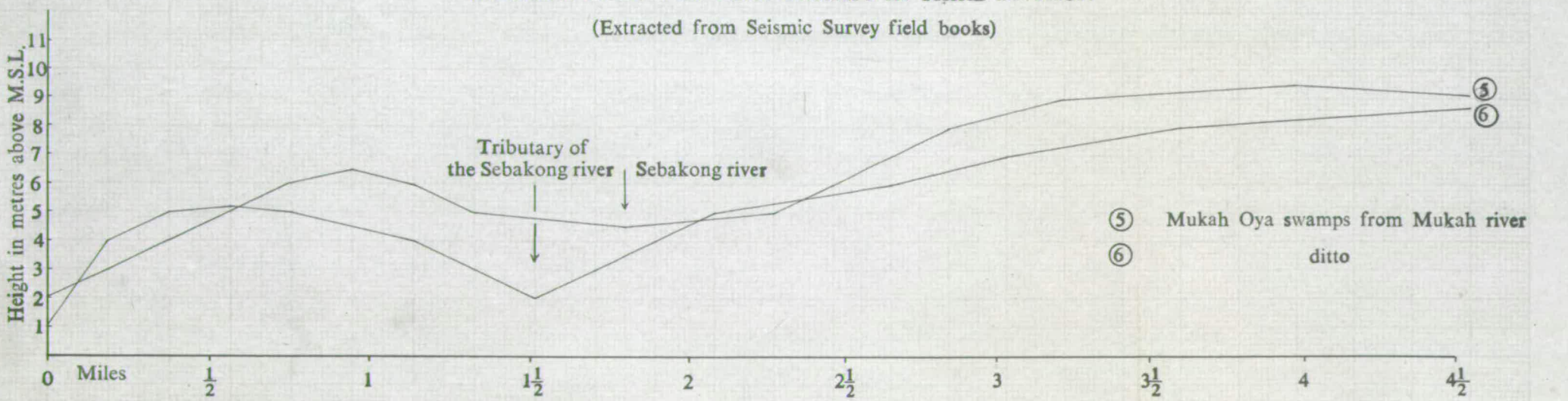


Figure 5

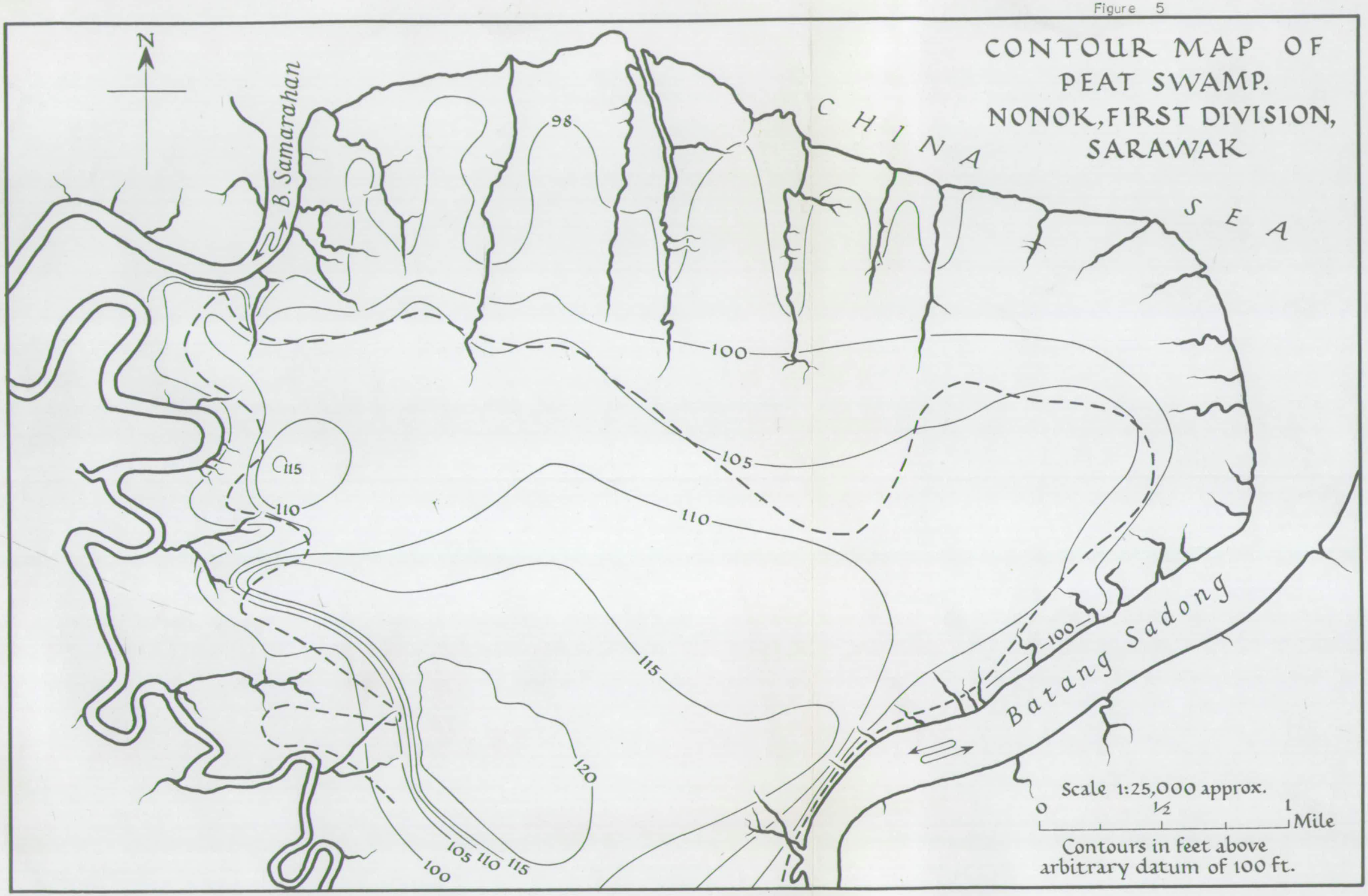
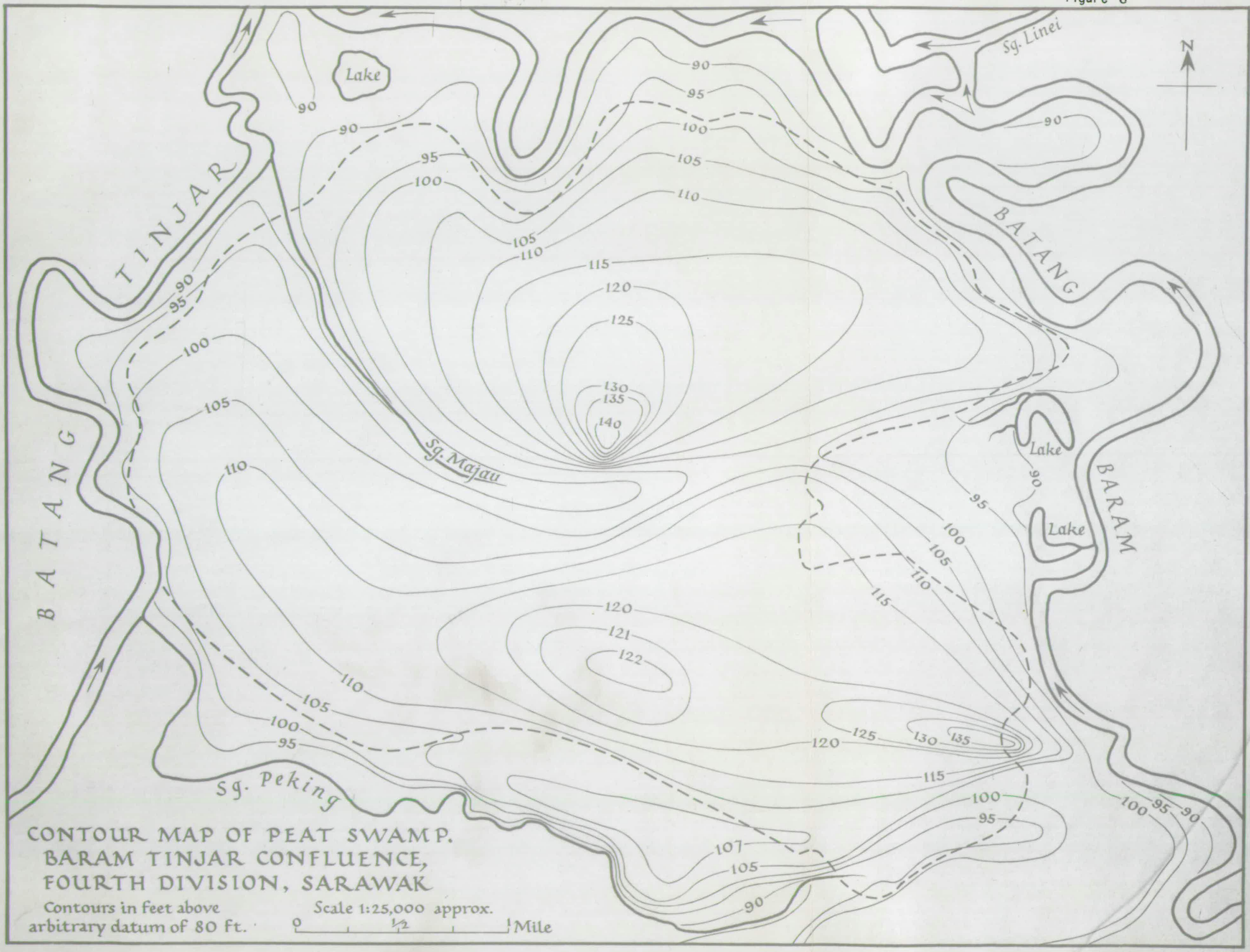

CONTOUR MAP OF
PEAT SWAMP.
NONOK, FIRST DIVISION,
SARAWAK
N
B. Samarahan
CHINA
SEA
98
100
105
110
115
120
Batang Sadong
Scale 1:25,000 approx.
0
½
1
Mile
Contours in feet above
arbitrary datum of 100 ft.

Figure 6



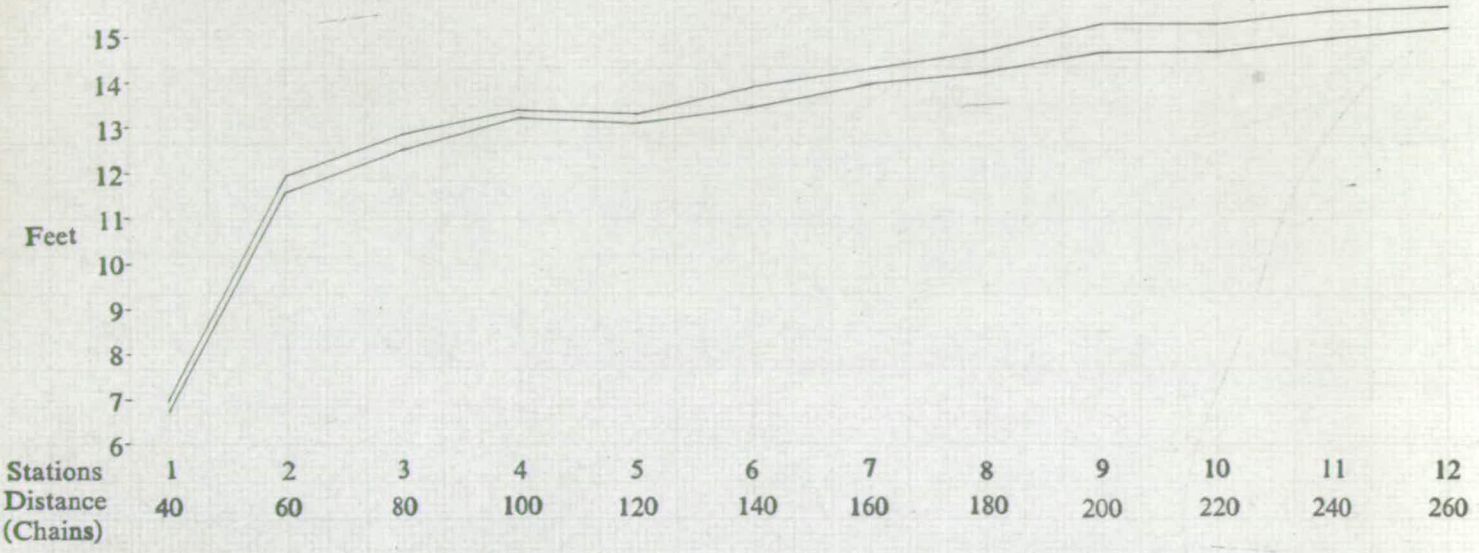
CONTOUR MAP OF PEAT SWAMP.
BARAM TINJAR CONFLUENCE,
FOURTH DIVISION, SARAWAK

Contours in feet above arbitrary datum of 80 ft.

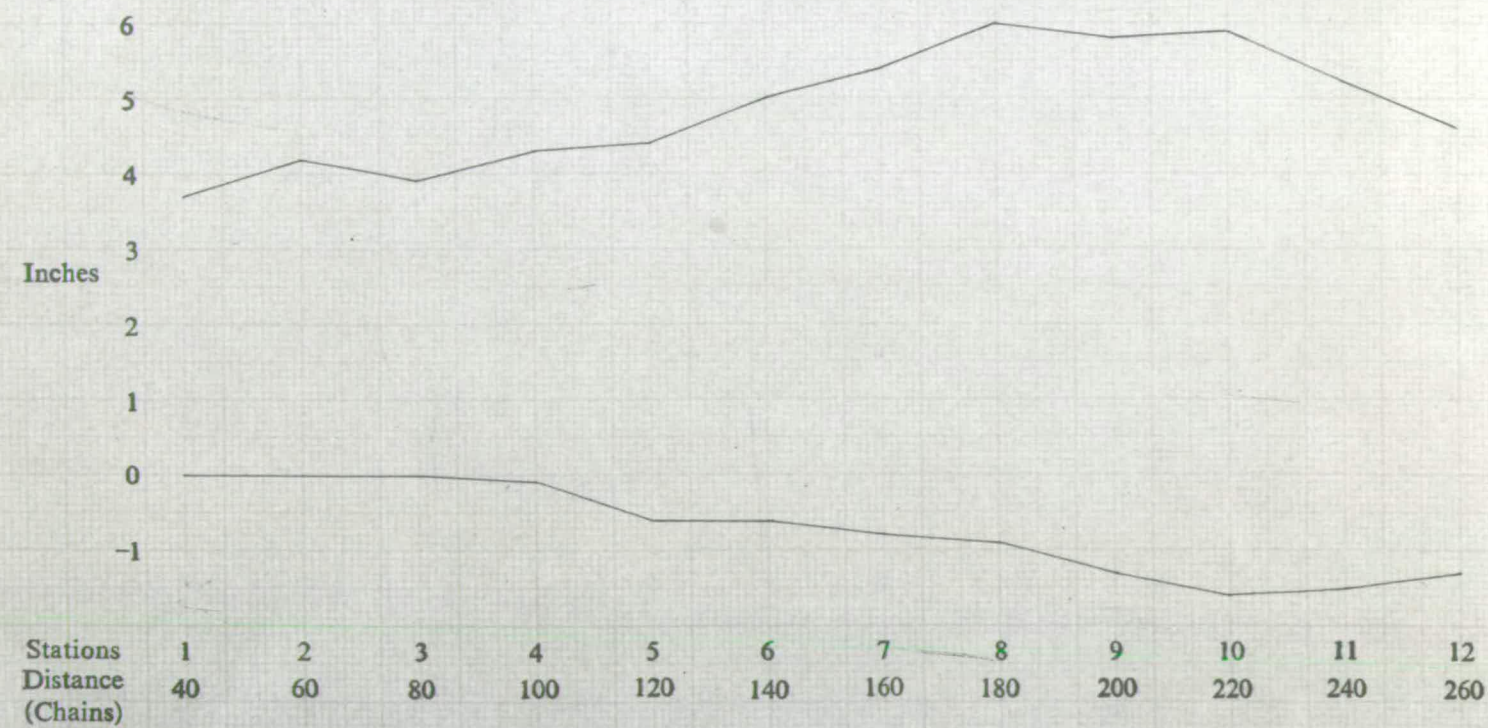
Scale 1:25,000 approx.

0 ½ 1 Mile

HEIGHTS OF WATER TABLE ON 22nd. MAY AND 18th. JULY, 1954, AT TWELVE STATIONS ON TRANSECT IN THE LOBA KABANG PROTECTED FOREST



MAXIMUM AND MINIMUM VARIATIONS ON FIRST READING



Part 2

Floristic Composition

Chapter 5

Floristic composition of the peat swamp forests

43. Malaysia, comprising the Malayan Archipelago, including Borneo, Sumatra, New Guinea and the Phillipines, and the Malayan Peninsula, has in all probability the richest, and the least studied, flora of any phytogeographical region. Van Steenis (54) estimates - only an estimate is possible at present - that there are between 25,000 and 30,000 species of flowering plants in the region. With the notable exception of families revised during the past ten years for 'Flora Malesiana' there is no single botanical work that the botanist or ecologist in Borneo can use with confidence to identify his collections. Merrill's (29) Bibliographic Enumeration of Bornean Plants is of little assistance (Merrill himself realized its limitations), and as this was published in 1922 it is now very out of date. It is therefore essential for the ecologist to make a comprehensive collection of the flora of the habitat in which he is working, and he must be prepared to identify a large amount of the material himself, referring as far as possible to Type specimens. In Sarawak the remnants of the Forest Department herbarium, salvaged after the Japanese Occupation, comprised only a few hundred woody specimens, mainly collected from non-swamp forest, and these were of little assistance in identifying specimens. It has therefore been necessary to build up from scratch a fully representative collection of the flora of the peat swamp forests. This has been the foundation of all ecological studies. It is estimated that at least half the time spent on this study has been devoted to botanical work.

44. Very considerable assistance has been received from botanists revising families or genera for 'Flora Malesia', and in particular from Professor Dr. C.G.G.J. van Steenis, the Director of the Foundation. Specimens of the undermentioned families and genera have been determined by the botanists indicated:

Sapotaceae	Prof. H.J. Lam and Dr. P. Van Royen
Burseraceae and Connaraceae	Dr. P.W. Leenhouts
Moraceae	Mr. E.J.H. Corner
Palmae	Dr. C.X. Furtado
Poikilospermum	Dr. Chew Wee Lek
Lauraceae and Sterculiaceae	Dr. A.J.G.H. Kostermans
Menispermaceae	Mr. L.L. Foreman
Phanera and Cryptocoryne	Prof. H.C.D. de Wit
Myristicaceae and Anonaceae	Mr. J. Sinclair.

The fern specimens were determined by Dr. R.E. Holttum. The floristic composition of the peat swamp forests is shown in detail in the catalogue of flowering plants, ferns and fern allies included in Appendix 1. No attempt has yet been made to study the lower orders of plants.

45. The catalogue of the flora of the peat swamp forests includes all identified species of phanerograms, gymnosperms and pteridophytes collected during the course of the ecological survey of these forests. In compiling this catalogue it had been hoped initially to include records of previous collections, especially those in the Beccari, and Haviland and Hose collections. It was found, however, that these collectors only very rarely recorded the habitat of the plant, and consequently there could be no certainty that the specimen originated

in peat swamp forest; though frequently the locality of the collection indicates that this was probable. The catalogue is confined, therefore, to recent collections, largely by the author and Forest Department staff, but including a few specimens collected by Miss W. Brooke and Mr. J. Wyatt-Smith.

46. The species included in the catalogue are those found in the raised bog type of peat swamp forest. The marginal zones, such as the transitional zone from mangrove and near the inland perimeter of swamps, though including numerous true peat swamp species, have in addition a number of species that are absent from the extensive coastal and deltaic swamps. The inland freshwater swamp forests, which are subject to periodic inundation, and high altitude peat swamps require further investigation. These types cover a negligible area in relation to the area covered by the coastal and deltaic peat swamp forests. It is inevitable in an ecological survey of this nature that a good deal of sterile material is collected. However, during the past five years collecting has been virtually confined to fertile material and about ninety-five per cent of the species is represented by flowering or fruiting specimens, frequently both.

47. 1706 numbers are recorded in the catalogue. This total includes 1528 specimens of dicotyledons, 106 monocotylons, 6 conifers and 66 pteridophytes. The complete collection is housed in separate cabinets in the herbarium of the Forest Department, Sarawak, at Kuching. Duplicates of early collections (1953-5) were went to Singapore, and fertile material has in the past five years been distributed to herbaria at Kew, Leiden, Singapore and Bogor, with additional material of certain families to other herbaria. Wood

specimens are available for most arboreal species.

48. The catalogue of phanerograms is arranged by families in accordance with the Bentham and Hooker system of classification with certain generally accepted exceptions. In those families revised for Flora Malesiana the nomenclature of the revision has been followed. For the classification of pteridophytes the system adopted by Holttum (24 and 25) has been used. Specimens of each species are recorded by administrative divisions and localities, and notes on the habit, frequence, distribution and occurrence in forest types are included. Furthermore, where species have been matched by the author in the herbarium at Kew the number of the matching specimen is noted with an indication by the symbols A, B, or C of the degree of reliability of the determination. All recorded vernacular names have not been included as frequently they are very unreliable. The vernacular names shown have been checked and found to have fairly consistent usage.

49. The completeness of the catalogue varies with the locality and the type of plant. More ecological work has been undertaken in the Rejang Delta than elsewhere and consequently the flora is better known. It is also incidentally the richest. Furthermore, collecting was originally concentrated on the tree flora, though during the past five years collections have been made of herbs, lianes, parasites, epiphytes and ferns. It is considered that for tree and shrub species the catalogue is virtually complete. Visits to peat swamps in the past twelve months (1958-9) have failed to yield any important unrecorded species. It has been found also that the herbaceous and climbing elements of the flora are remarkably uniform. Though the

list is not as complete as that for the tree flora the same species tend to be found time and again. Even the epiphytic flora, which might have been expected to be the most variable, appears fairly constant in its distribution in peat swamps and in its occurrence in the forest types. Undoubtedly there are many species yet to be recorded in peat swamps but the most characteristic and abundant species have now been collected.

50. The names of some species included in the catalogue must be treated with a good deal of caution. The taxonomy of genera such as Eugenia, Garcinia and Quercus is in a somewhat chaotic state and accurate specific identifications for many species will not be obtainable until the families are revised. Where matching material has not been found the species is designated by the generic name followed by the number in brackets of what is considered to be the most representative specimen.

51. It is impossible at this stage to say how many species new to science have been collected. This can only be ascertained with certainty when the families are revised for Flora Malesiana. In those families that have been revised or are at present in the process of revision the most important discovery has been a new species of Litsea (L. palustris Kostermans (msc.)). This tree species is extremely abundant in the central areas of many swamps throughout Sarawak and Brunei; in the Rejang Delta it forms pure stands over many square miles with as many as 120 trees per acre. It is odd that it has never been collected previously. Presumably early collectors did not penetrate into the centre of the swamps. Knema uliginosa Sinclair (msc.) is a small tree with a localized distribution

in the Loba Kabang Protected Forest. It has more recently been found in the peat swamps of Johore. Mr. J. Sinclair also considers that Polyalthia (9059) is undescribed. It is known from only one ~~other~~ previous collection, p.b. 3919 by Beccari. Mr. E.J.H. Corner has examined all the collections of Ficus, and is describing three new species: F. callicarpides is a small root climber abundant on the buttresses of Shorea albida; F. spathulifolia and F. supperforata are stranglers or ground rooting epiphytes. In families that have not yet been revised there are a number of distinctive species which are unmatched in herbaria at Kew, Leiden, Singapore and Bogor and are therefore probably new to science. These include a Parishea (9802), a Xanthophyllum (2614), a Piper (9234) and a Cinnamomum (4751). Finally a single collection of a small tree from the Lundu swamps has proved to be of a new genus (Jarandersonia) in the Tiliaceae and has recently been described by Dr. A.J.G.H. Kostermans (28). It is not included in the catalogue.

52. Two hundred and forty-two tree species have been recorded, including 38 small trees of the understorey which rarely or never exceed twelve inches girth. Some of the latter might be considered as shrubs, but this term has been purposely avoided as few species have a fastigiate habit (except in the stunted forest in the centre of certain swamps in the Baram). The arboreal flora is somewhat greater than originally expected. Sewandano (49) estimated that the flora of the swamps of East Sumatra to be less than a hundred species. In one forest type alone in the peat swamps of Sarawak and Brunei as many as seventy-five species, twelve inches girth and over, are found to an acre.

Table 8. Representation of botanical families of Angiosperms and Gymnosperms.

Families	Total numbers of genera and species (in brackets) represented	Numbers of genera and species (in brackets) represented					
		Trees 12" girth	Trees 12" girth	Shrubs	Herbs	Climbers and Lianes	Epiphytes
Gymnosperms							
Coniferae	2 (2)	2 (2)				1 (1)	
Gnetaceae	1 (1)						
Angiosperms							
Dicotyledons							
Dilleniaceae	2 (2)	1 (1)				1 (1)	
Magnoliaceae	1 (1)	1 (1)					
Annonaceae	12 (17)	5 (9)	3 (3)			5 (5)	
Menispermaceae	2 (2)					1 (1)	1 (1)
Polygalaceae	2 (4)	2 (4)					
Hypericaceae	1 (2)	1 (2)					
Flacourtiaceae	2 (2)	1 (1)	1 (1)				
Guttiferae	3 (15)	3 (15)					
Ternstroemiaceae	2 (4)	2 (4)					
Dipterocarpaceae	7 (15)	7 (15)					
Malvaceae	2 (2)	2 (2)					
Sterculiaceae	2 (4)	2 (4)					
Tiliaceae	1 (4)	1 (2)	1 (2)				
Linaceae	2 (2)	2 (2)					
Rutaceae	2 (2)	1 (2)	1 (1)				
Simarubaceae	1 (1)		1 (1)				
Ochnaceae	3 (4)	2 (2)		1 (2)			
Burseraceae	2 (6)	2 (6)					
Meliaceae	3 (3)	2 (2)	1 (1)				
Olacaceae	4 (5)	4 (5)					
Ilicinaceae	1 (2)	1 (2)					
Celastraceae	3 (4)	3 (4)					
Rhamnaceae	1 (1)					1 (1)	
Ampelidaceae	3 (3)					3 (3)	
Sapindaceae	3 (4)	3 (3)	1 (1)				
Anacardiaceae	7 (12)	7 (12)					
Connaraceae	3 (3)		1 (1)			2 (2)	
Leguminosae	8 (8)	6 (6)	1 (1)			1 (1)	
Rosaceae	2 (3)	2 (3)					
Rhizophoraceae	2 (2)	2 (2)					
Myrtaceae	3 (16)	3 (15)	1 (1)				
Melastomaceae	4 (8)	2 (2)		1 (1)		1 (2)	1 (3)
Cucurbitaceae	1 (1)					1 (1)	
Araliaceae	2 (4)	1 (1)	1 (1)	1 (1)			1 (1)
Cornaceae	1 (1)	1 (1)					

Families	Total numbers of genera and species (in brackets) represented	Numbers of genera and species (in brackets) represented					
		Trees		Shrubs	Herbs	Climbers and Lianes	Epiphytes
		12" girth	12" girth				
Rubiaceae	18 (22)	6 (6)	5 (5)	1 (1)	1 (1)	5 (7)	2 (2)
Ericaceae	1 (1)			1 (1)			
Myrsinaceae	5 (11)	1 (1)	2 (3)	3 (4)		2 (3)	
Sapotaceae	4 (12)	4 (12)					
Ebenaceae	1 (4)	1 (4)					
Oleaceae	2 (4)	1 (3)				1 (1)	
Apocynaceae	5 (6)	2 (2)	1 (1)			2 (3)	
Asclepiadaceae	2 (6)						2 (6)
Loganiaceae	1 (2)			1 (2)			
Convolvulaceae	1 (2)					1 (2)	
Gesneriaceae	1 (1)					1 (1)	
Verbenaceae	3 (3)	1 (1)			1 (1)	1 (1)	
Nepenthaceae	1 (5)			1 (4)		1 (1)	
Piperaceae	1 (4)				1 (1)	1 (3)	
Myristicaceae	4 (7)	4 (5)	2 (2)				
Lauraceae	9 (18)	6 (14)	3 (4)				
Thymeliaceae	2 (4)	1 (3)				1 (1)	
Loranthaceae	3 (3)			1 (1)			3 (3)
Santalaceae	1 (2)			1 (1)			1 (1)
Euphorbiaceae	11 (17)	7 (12)	4 (4)		1 (1)		
Urticaceae							1 (2)
Moraceae	3 (27)	2 (3)		1 (1)		1 (18)	1 (5)
Casuarinaceae	1 (1)	1 (1)					
Fagaceae	2 (5)	2 (5)					
Monocotyledons							
Orchidaceae	12 (17)			3 (3)	3 (3)		11 (14)
Zingiberaceae	2 (2)			1 (1)	1 (1)		1 (1)
Dioscoreaceae	1 (1)				1 (1)	1 (1)	
Liliaceae	1 (1)			1 (1)			
Flagelleriaceae	2 (2)				1 (1)		
Palmae	7 (7)		1 (1)	3 (3)		3 (3)	
Pandanaceae	1 (4)			1 (3)		1 (1)	
Araceae	9 (9)				7 (7)	2 (2)	
Cyperaceae	2 (2)				2 (2)		

Representation of families.

53. The representation, by genera and species, of the families of phanerograms is shown in Table 8. If the arboreal species alone are considered it will be seen that most of the principal arboreal families that occur in lowland dipterocarp forest are to be found in peat swamp forest. Of the families that have not been recorded mention may be made of the Combretaceae, Lythraceae, Styracaceae, and Proteaceae. A comparison of the arboreal flora in peat swamp forest with that recorded by Wyatt-Smith (74) in two five acre plots in Malaya shows an obvious similarity in the relative numbers of genera and species recorded. It should be remembered, however, that the comparison is between the total arboreal flora in peat swamp forest and species exceeding twelve inches girth in two small plots. Nevertheless most of those families, i.e. Dipterocarpaceae, Anacardiaceae, Anonaceae, Euphorbiaceae, Guttiferae, Lauraceae, Leguminosae, Myrtaceae, Rubiaceae and Sapotaceae, that predominate in lowland dipterocarp forest also provide most species that occur in peat swamp forest. It would appear, therefore, that specialized adaptations, such as pneumatophores, kneed roots and, perhaps, stilt roots, for growing in peat swamps do not tend to be exclusive to or predominate in certain botanical families.

54. In the herbaceous vegetation there is an absence of the predominantly aquatic families and genera of dicotyledons, e.g. Nymphaceae, Limnanthemum, Jussiaea, and Ludwigia. A possible cause may be the extremely acidic and anaerobic conditions of peat swamp soils. It is hardly surprising to find an almost complete absence of the caciphyllous families such as Balsaminaceae (Impatiens),

Acanthaceae, Scrophulariaceae, Begoniaceae, and Gesneriaceae. Aeschynanthus hians, of the last mentioned family, is the only record. Monocotyledons, and in particular the Araceae and Cyperaceae, preponderate in the herbaceous flora.

55. The climbing flora is drawn from many families, of which particular mention may be made of the Anonaceae, Rubiaceae and Moraceae. Species of Capparidaceae, Malpighiaceae, Solanaceae and Acanthaceae have not been recorded, and the Convolvulaceae is only represented by two species, neither of which is common.

Floristic composition

56. Lists of the more important and characteristic peat swamp species are shown in Table 9. These include the more widely distributed and common species. For rarer and localized species reference should be made to the catalogue.

57. The arboreal flora has been subdivided into four canopy classes based on the average maximum girth attained by a species. This subdivision is somewhat arbitrary and does not presuppose that distinct canopy layers can be recognised or even exist. No consideration is taken here of the ecology of the species or their occurrence in the forest types. This will be discussed in later chapters. Furthermore, it should be remembered that the average maximum size class of a species varies very considerably in different forest types. For instance Dactylocladus stenostachys - the only tree species to occur in all forest types - is a massive dominant, with girths occasionally exceeding twelve feet, on the perimeter of the swamps, whereas in the stunted forest in the centre of certain

Table 9. Floristic composition (Angiosperms and Gymnosperms) of peat-swamp forests.

Note: Only the more abundant and widely distributed species are included.

Tree species

(i) Upper storey (60 ins. girth and over):

Alstonia spathulata
Anisoptera marginata
Artocarpus rigidus
Calophyllum retusum
Campnosperma coriacea
Casuarina sumatrana
Combretocarpus rotundatus
Copaifera palustris
Cratoxylon arborescens
Cratoxylon glaucum
Dacrydium beccarii var. subelatum
Dactylocladus stenostachys
Dillenia pulchella
Dipterocarpus coriaceus
Dryobalanops rappa
Durio carinatus
Dyera lowii
Ganua motleyana
Gonystylus bancanus
Gonystylus macrophyllus
Koompassia malaccensis
Litsea palustris
Lophopetalum multinervium
Melanorrhoea beccarii
Melanorrhoea tricolor
Mezzettia leptopoda venenosus ssp.
Parartocarpus venenosus ssp. forbesii
Parastemon urophyllum
Parishia sericea
Planchonella maingayii
Shorea albida
Shorea inaequilateralis
Shorea platycarpa
Shorea rugosa var. uliginosa
Shorea scabrida
Shorea teysmanniana
Swintonia glauca
Tetramerista glabra

(ii) Middle storey (24 - 60 ins. girth):

Abarema borneensis
Alangium havilandii
Alseodaphne insignis
Alseodaphne rigida
Amoora rubiginosa
Aromadendron nutans
Arthrophyllum rubiginosum
Bhesa paniculata
Blumeodendron subcaudatum
Blumeodendron tokbrai
Calophyllum fragrans
Calophyllum obliquinervum
Calophyllum sclerophyllum
Cotylelobium fuscum
Ctenolophon parvifolius
Dacryodes incurvata
Dacryodes macrocarpum var. macrocarpum
Dialium laurinum
Diospyros evenis
Diospyros maingayi
Diospyros pseudomalabarica
Elaeocarpus obtusifolius
Eugenia chrismanii
Eugenia havilandii
Eugenia incarnata
Eugenia nemestrina
Eugenia spicata

Ganua coriacea
Ganua pierrei
Gardenia pterocalyx
Garcinia havilandii
Garcinia vidna
Goniothalmus tapis
Gonystylus forbesii
Horsfieldia crassifolia
Jackia ornata
Kokoona ovatolanceolata
Litsea cylindrocarpa
Litsea gracilipes
Litsea grandis
Litsea nidularis
Longetia malayana
Macaranga caladifolia
Mussaendopsis beccariana
Nephelium melanomiscum
Palaquium cochlearifolium
Palaquium pseudocuneatum
Palaquium ridleyi
Palaquium walsurifolium
Parastemon veesteeghii
Parkia singularis
Platea excelsa
Polyalthia glauca
Pometia pinnata
Quercus wenzigianus
Santiria laevigata
Santiria rubiginosa var. rubiginosa
Santiria tomentosa
Sindora leiocarpa
Stemonurus scorpioides
Tristania grandifolia
Tristania maingayi
Tristania obovata
Vatica mangachapoi
Xerospermum muricatum
Xylopia coriifolia

(iii) Lower storey (12 - 24 ins. girth):

Antidesma coriaceum
Baccaurea bracteata
Canthium didymum
Carallia brachiata
Cryptocarya griffithiana
Cyathocalyx biovulatus
Cephalomapps aff. malloticarpa
Dillenia pulchella var.
Diospyros elliptifolia
Eugenia cerina
Garcinia rostrata
Garcinia tetranda
Glochidion lucidum
Gomphandra comosa
Gomphia hookerii
Goniothalmus malayanus
Gymnacanthera eugeniifolia var. griffithii
Ilex hypoglauca
Ilex sclerophylloides
Knema kunstleri
Litsea resinosa
Mezzettia umbellata
Nanclea parva
Neoscortechinia kingii
Pithecellobium oppositum
Polyalthia hypoleuca
Pygeum parviflorum
Quercus jaheri
Quercus sondaicus
Samadera indica
Stemonurus umbellatus
Sterculia rhoidifolia
Ternstroemia hosei
Ternstroemia magnifica
Tetractomia holttumii
Timonius peduncularis
Xanthophyllum amoenum
Xanthophyllum cf. citrifolium

(iv) Understorey (less than 12 ins. girth):

Antidesma phanerophlebium
Ardisia copelandii
Canthium umbellatum
Chisochetum brachyanthus
Cyrtostachys lacca
Dehassia sp. (9252)
Dipsepalum anomalum
Gaetnera borneensis
Ixora pyranthe
Polyalthia sp. (9059)
Tarenna fragrans

Shrubs

Daemonorops longipes
Dracaena cantleyi
Euthemis leucocarpa
Euthemis obtusifolius
Fagraea litoralis
Fagraea racemosa
Ficus deltoidea var. motleyana
Hanguana malayana
Iguanura sp. (12246)
Labisia punctata f. punctata
Labisia punctata f. pumila
Medinilla hasseltii
Nepenthes bicalcarata
Nepenthes gracilis
Nepenthes rafflesiana
Pandanus pentodon
Pandanus ridleyi
Pandanus brevifolius
Pinanga sp. (12332)
Schefflera subulata
Zalacca conferta

Herbs

Aglaonema simplex
Alocasia longiloba
Bromheadia finlaysoniana
Argostemma psychotrioides
Clerodendron fistulosum
Cryptocoryne pallidinervia
Cyrtosperma lasioides
Cystorchis variegata
Globba panicoides
Hanguana malayana
Homalomena rostrata
Piper muricatum
Podolosia stipitata
Schismatoglottis sp. (8364)
Thorachostachyum bancanum
Zeuxine violascens

Epiphytes

(i) Sun epiphytes:

Adenonces sumatrana
Bulbophyllum vaginatum
Dendrobium aff. merrillii
Dischidia hirsuta
Dischidia nummularia
Dischidia rafflesiana
Eria obliqua
Eria pannea
Eria pulchella
Ficus detoidea var. deltoidea
Grammatophyllum speciosum
Hya coronaria
Hydnophytum formicarium
Myrmecodia tuberosa

(ii) Shade epiphytes:

Appendicula pendula
Bulbophyllum beccarii
Dendrobium cumulatum
Dipodium pictum
Eulophia squalida
Liparis lacerata
Medinilla laxiflora
Pogonanthera pulverulenta
Pyenarrhena borneensis

Climbers

(i) Large climbers, frequently attaining crowns of upper canopy trees, including ground rooting epiphytic and strangling figs:

Calamus sp. (4788)
Erycibe impressa
Fibrauea chloroleuca
Ficus acamptophylla
Ficus consociata
Ficus crassiramea
Ficus spathulifolia
Ficus sundaica
Ficus sundaica var. beccariana
Ficus xylophylla
Grenacharia beccariana
Korthalsia rigida
Mitrella dielsii
Piper arborescens
Plectocomiopsis wrayi
Rourea mimosoides forma mimosoides
Tetrastigma sp.
Urcaria ovalifolia
Willughbeia glaucina
Zizyphus suluensis

(ii) Small climbers, usually confined to understorey:

Aeschynanthus hians
Ampelocissus thyrsiflora
Connarus semidecandrus
Epipremnopsis media
Flagellaria indica
Ficus callicarpides
Ficus villosa
Gnetum neglectum
Lecananthus erubescens
Lucinaea morinda
Linostoma longiflorum
Medinilla scandens
Nepenthes albomarginata
Nepenthes ampullaria
Pandanus sp. (14545)
Psychotria sarmentosa
Raphidophora lobbii

swamps in the Fourth Division it occurs abundantly as a small tree hardly exceeding twelve inches girth and frequently little more than a shrub.

58. In the upper storey species of Dipterocarpaceae predominate. Of the six species of Shorea commonly found in peat swamps Shorea albida forms remarkable pure stands (in the upper canopy) with 40 to 160 trees per acre and covering very extensive areas in the central zones of many swamps from the Sadong river in southern Sarawak to Badas in Brunei. Other important dominants are the timber producing species Gonystylus bancanus, Dactylocladus stenostachys, and Copaifera palustris. Litsea palustris, an associate of Shorea albida, occurs in almost pure forests in the centre of some of the larger swamps in the Rejang Delta. In Lawas District in north Sarawak, and in adjacent areas in North Borneo Shorea albida is absent and is replaced by a unique forest dominated by the conifer Dacrydium beccarii var. subelatum and Casuarina sumatrana. Little now remains of this forest after forty years of heavy exploitation.

59. The middle and lower storeys include many species of the Lauraceae, Euphorbiaceae, Guttiferae, Burseraceae, Ebenaceae, Fagaceae, and Annonaceae. Some of the more abundant species in the middle storey are Alangium havilandii, Blumeodendron tokbrai, Ctenolophon parvifolius, Diospyros evenis, Diospyros pseudomalabarica, Kokoona ovatolanceolata, Palaquium cochlearifolium, Parastemon vesterghii and Xylopia coriifolia. In the lower storey the most widely distributed species are Neoscortechinia kingii, Cyathocalyx biovulatus, Stemonurus umbellatus, Tetractomia holttumii and Cephalomappa malloticarpa.

60. In the understorey there are few species that rarely or never attain twelve inches girth, and most of these are rather rare or localized. Mention however may be made of Ixora pyranthe which is abundant in Shorea albida forest, and Tarenna fragrans in the peripheral zone. Shrubby dicotyledons are rare, those that do occur are largely confined to the more open forest in the centre of some swamps. Here may be found Ficus motleyana, Euthemis obtusifolius, Labisia pumila var. genuina and Medinilla hasseltii. Some species, such as the Nepenthes have a scandent or climbing habit, but they are more commonly found on or near to the swamp surface, and may be more correctly considered as shrubs. The stemless spiny palm Zalacca conferta and the large stemless pandan Pandanus andersonii (msc.) frequently form dense thickets; the former on shallow peat, and the latter in association with Shorea albida. Two other pandans are common: Pandanus brevifolius in the peripheral zone, and Pandanus ridleyi in stunted forest in the centre of some swamps in the Baram.

61. Herbaceous dicotyledons are practically absent. Argostemma psychotrioides is frequent and the interesting small myrmecophyte, Clerodendron fistulosum, has a wide distribution though is never common. Aroids and sedges predominate, of which the most abundant and widespread species is Thorachostachyum bancanum. Many aroids occur in damper localities where the water table is exposed or permanently near the surface. Here may be found Aglaonema simplex, Homalomena rostrata, Alocasia longiloba and Schismatoglottis sp. (8364) Near streams or in particularly damp spots in the swamps where the water table is permanently exposed the aquatic aroid Cryptocoryne pallidinervia abounds. Aroids are however almost entirely absent

from the drier central areas of swamps. The large herb, Hanguana malayana, also favours the damper localities and is frequently found in places where a hole has been torn in the swamp surface by a tree uprooted by wind. A smaller form of this species tends to occur in slightly drier habitats. The two small terrestrial orchids, Zeuxine violascens and Cystorchis variegata, with attractive variegated foliage, occur on leaf litter in deep shade.

62. A simple classification, such as is attempted here, for herbs, epiphytes and climbers may lead to complications. Some species such as many Ficus spp., Pycnarrhena borneensis, and Poikilospermum spp., start life as epiphytes and later, after their roots have reached the swamp surface, develop a climbing habit; whereas others, e.g. Randia sp. (7904) and Fagraea litoralis, are initially epiphytes and later become independent shrubs or small trees. Bulbophyllum beccarii, a conspicuous epiphyte on Shorea albida, is stated by Beccari (3) to start as a climber from the ground surface, but early stages in its development have not been seen by the author. The species has always been found as an epiphytic climber spiralling round the upper boles of trees. Another complication is that some crown epiphytes, e.g. Ficus deltoidea var. borneensis and Dischidia nummularia may be terrestrial in the more open forest in the centre of some swamps, where presumably the ecological conditions are not dissimilar to those found in the crowns of the upper canopy in dense forest.

63. Many of the commonest crown epiphytes are confined to the peripheral zone in swamps. They are particularly abundant in the crowns of Gonystylus bancanus and Dactylocladus stenostachys, both

of which have a soft fibrous bark. No attempt, however, has been made to determine host specialization. The most numerous group are the orchids, of which Bulbophyllum vaginatum, Dendrobium merrillii, Eria pannea and Eria aff. pulchella are particularly abundant. Crown epiphytes on Shorea albida are scarce. The Dischidia spp., Hydnophytum formicarium and Myrmecodia tuberosa are largely confined to stunted forest where conditions are similar to open heath forest in which these species also occur. The two most widely distributed and abundant shade epiphytes are Medinilla laxiflora and the orchid Liparis lacerata. Both tend to occur as epiphytes on small trees in dense forest at heights of from two to ten feet from the ground.

64. The liane and climber flora is not so conspicuous as that found in lowland dryland forest. The species are relatively few and do not appear to reach as large a size. In Shorea albida forest lianes are rare, and they are almost absent in the central forest types. Rattan palms, though not rare, are small in size and commercially of no value. Of the three species recorded two, Plectocomiopsis wrayi and Korthalsia rigida, are abundant; the latter frequently in association with Shorea albida. The commonest of the larger lianes is Uncaria ovalifolia, the sap of which is drunk by the natives to quench their thirst in the forest. This species also tends to form thickets in young secondary forest following exploitation. Other common lianes are Willughbeia glaucina, Fibraurea chloroleuca, and Mitrella dielsii.

65. Figs are particularly abundant in peat swamp forest; twenty-four species have been recorded. True strangling figs, that after killing the host then develop a trunk of their own, are

relatively rare. Ficus crassiramea is the most conspicuous example. This species is confined, however, to shallow peat near the coast. Many of the figs start as epiphytes but though adopting a strangling habit rarely, if ever, kill the host tree. They might be considered as partial stranglers, or, as is preferred, ground rooting epiphytes. These are especially abundant on Gonystylus bancanus and Dactylocladus stenostachys. The most common species are Ficus acamptophylla, Ficus consociata, Ficus spathulifolia, Ficus xylophylla and Ficus sundiaca. Some tend to be rather localized: Ficus xylophylla, for instance, is very abundant on Pulau Bruit in the Rejang Delta but rather rare elsewhere in swamps. Of the small root climbing figs Ficus callicarpides is abundant on buttresses of Shorea albida.

66. Of the small climbers, generally confined to the lower storey, though some may reach the crowns of middle storey trees, the most numerous are Lecananthus erubescens, Lucinaea morinda, Medinilla scandens, Aechynanthus hians, and the climbing aroid Raphidophora lobbii. Nepenthes ampullaria almost invariably has a climbing habit in peat swamps, though in heath forest the whorls of pitchers are not infrequently found embedded in the litter layer. Gnetum neglectum, a small twining climber which rarely attains a height of more than fifteen feet has been found throughout the Rejang Delta and Maludam Peninsular but is never common.

67. The myrmecophytes form an interesting group. They include two trees, Macaranga caladifolia and Macaranga puncticulata; the former is a primary forest species, whereas the latter had been only rarely recorded in primary forest, though it frequently forms almost pure dense stands in secondary swamp forest, especially along rail

lines and on shallow peat cleared for cultivation. Of the other myrmecophytes only the herb Clerodendron fistulosum occurs in dense forest; the remainder, which includes the epiphytic climbers Dischidia nummularia and Dischidia rafflesiana and the two conspicuous epiphytes Myrmecodia tuberosa and Hydnophytum formicarium, occur in open stunted forest.

68. Parasites are not common in peat swamps. Lepidaria oviceps, a very conspicuous species, is found as a crown parasite of upper storey trees, whereas Macrosolen beccarii occurs as a parasite of lower or middle storey trees in the shade. It can be quite abundant locally, for instance in the Naman Forest Reserve. The parasitic shrub Henslowia varians is found in open stunted forest.

69. A list of the common ferns of peat swamp forests is included in Table 10. Terrestrial ferns are limited in number. The most typical species are Vittaria elongata, Schizoloma coriaceum, and Syngramma lobbiana, all of which tend to occur on roots and pneumatophores above the water table. The stemless tree fern Cyathea glabra is locally abundant in Shorea albida forest. Schizaea malaccana, more usually a montane species, occurs in association with Lycopodium cernuum, which is so common on degraded soils. The interesting and rare Ophioglossum intermedium has only been recorded from one locality in the Rejang Delta. Nephrolepis biserrata is rare in primary forest but forms dense thickets in completely open secondary forest, especially where the slash has been burnt.

70. The epiphytic ferns are more difficult to classify into crown and shade epiphytes as they appear to be more tolerant than flowering plants of light and humidity conditions. Many of the

Table 10. Common ferns and fern allies of peat swamp forests.

Terrestrial ferns:

Asplenium longissimum
Cyathea glabra
Lindsaya scandens var. terrestris
Lycopodium cernum
Nephrolepis biserrata
Schizaea malaccana
Schizoloma coriaceum
Syngramma lobbiana
Vittaria elongata

Epiphytic ferns:

(i) Sun epiphytes:

Asplenium nidus
Asplenium phyllitidis
Crypsinus albidopaleatus
Drynaria involuta
Lecanopteris sinuosa
Photinopteris speciosa
Phymatodes crustacea
Platycerium coronarium

(ii) Shade epiphytes:

Asplenium glaucophyllum
Asplenium tenerum
Crypsinus albidopaleatus
Humata angustata
Humata parvula
Lycopodium phlegmaria var. divaricatum
Lycopodium pinifolium
Paragramma longifolia
Polypodium verrucosum
Pyrrosia longifolia
Selliguea heterocarpa
Vittaria ensiformis
Vittaria hirta

Climbing ferns:

Stenochlaena palustris
Teratophyllum ludens

common epiphytic ferns of gardens, rubber plantations, etc., such as Asplenium nidus, Asplenium phyllitidis, Pyrrosia longifolia and Paragramma longifolia are to be frequently found in peat swamp forest. Humata angustata and Humata parvula may be found as either crown or shade epiphytes and are occasionally even terrestrial in the central forest types. The most consistent shade epiphyte is Lycopodium phlegmaria var. divaricatum which occupies a similar habitat to Medinilla laxiflora and Liparis lacerata. Only two climbing ferns have been recorded: Stenochlaena palustris which clothes the lower stems of many trees on shallow peat near the coast, but becomes progressively rarer further inland; and Teratophyllum ludens which is confined to dense or moderately dense shade in the understorey.

Peat swamp endemics

71. A far greater knowledge of the flora of Borneo and of the ecology of the species is required before it can be stated with any authority which species are confined to peat swamp forest. There are probably very few. That there are similarities in the floras of heath and peat swamp forest is well known, and has been mentioned by Richards (45) and Browne (5 and 6). The author has recorded ninety-eight species which occur in both vegetation types and Mr. P.S. Ashton has recently added to the list. A note is included in the catalogue under each species where its occurrence in heath forest has been recorded. Dr. E.F.W.O. Brunig is at present engaged on an ecological study of heath forests and when this is in a more advanced state a comparison of the two floras will be possible. Some typical peat swamp species are also to be found in lowland dipterocarp forest.

A recent enumeration of a thirty acre block on a largely clay ridge in the Semengoh Forest Reserve near Kuching showed the presence of Neoscortechinia kingii, Shorea scabrida, Swintonia glauca, Mangifera havilandii, Parishea glauca, Koompassia malaccensis, Santiria tomentosa, Bhesa paniculata, Endospermum malaccense, Cratoxylon arborescens, Litsea grandis, Dialium laurinum, Sindora leiocarpa, Carallia brachiata, Mussaendopsis beccariana and Pometia pinnata. All these species occur in peat swamp forest and there are probably others in this area which have not yet been definitely identified. It is significant that all these species, without exception, occur and are largely confined to the peripheral zone, where the drainage is better and the peat soil probably more fertile. The species that occur in the forest types in the centre of the swamps are largely those that are also found on poor, frequently podzolic, soils found in heath forest.

Distribution of peat swamp species

72. The peat swamps form an almost continuous strip along the coast of Sarawak and Brunei from south western Sarawak to the Tutong river in Brunei. The only major breaks in their distribution occur between Bintulu and the Nyalau river, a distance of forty-five miles, and eight miles which separate the swamps in the Sibuti river from those in the Baram river. Conditions of development of peat swamps and the nature of the peat soils themselves are similar over the whole area. It can be expected, therefore, that the flora is relatively uniform. In comparison with the flora of other soil types, where marked discontinuities occur, this is generally so.

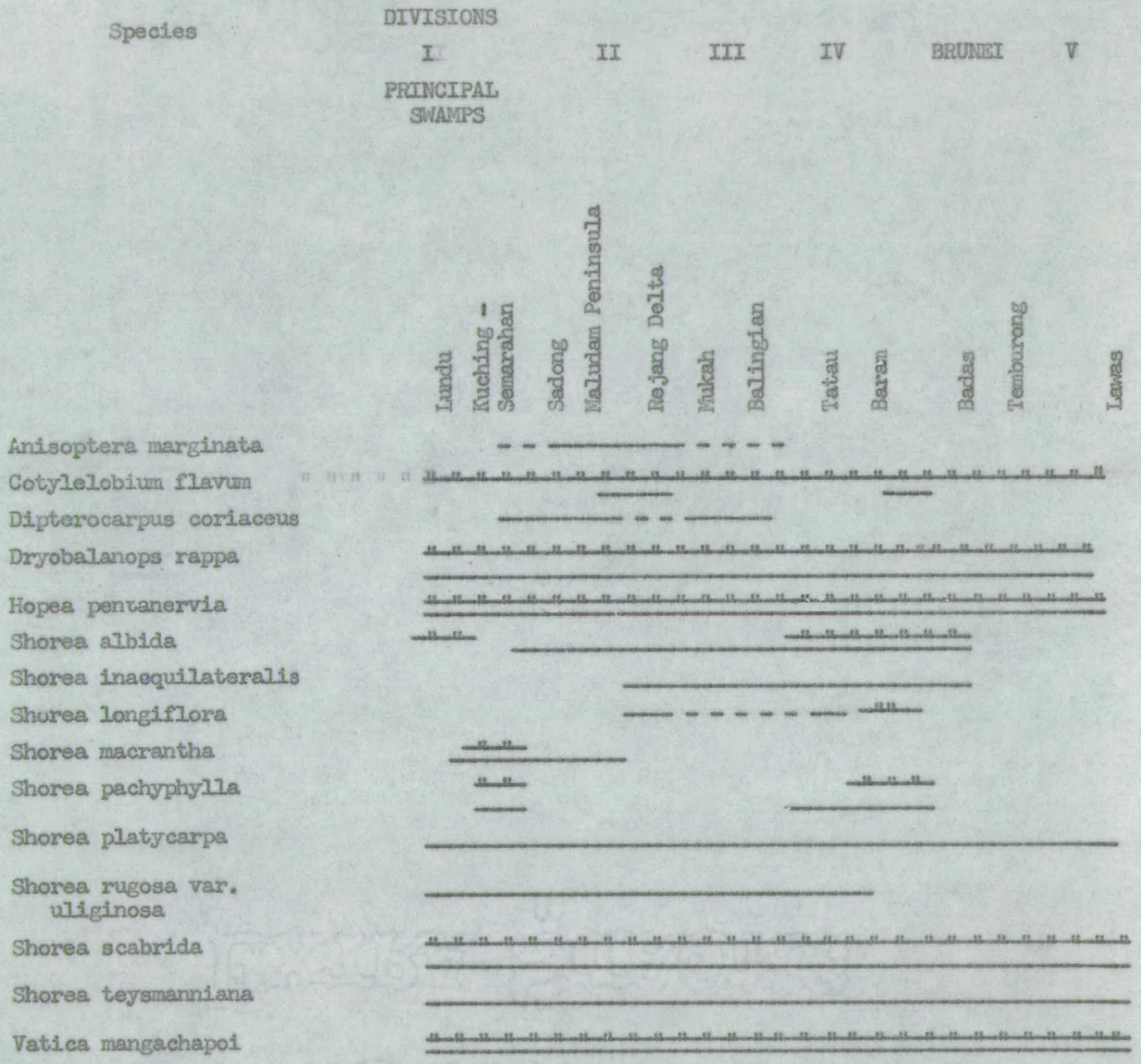
Nevertheless it has been found that the flora of the Rejang Delta is richer than that of swamps elsewhere in Sarawak or Brunei. Further collecting in less frequented areas will no doubt reveal a more widespread distribution of some species that are at present recorded from only the Rejang Delta. But there are in the Rejang Delta species such as Lophopetalum rigidum and Blumeodendron subcaudatum, which occur so frequently that if present elsewhere it is unlikely that they would have been overlooked. Moreover, in ecological sample plots it has been found that the species per acre tends to be consistently more numerous in the Rejang Delta than elsewhere. The following tree species are known in peat swamp forest only from the Rejang Delta: Anacalosa frutescens, Blumeodendron subcaudatum, Ellipanthus tomentosus spp. tomentosus, Parishea sp. (2697), Swintonia glauca, Lophopetalum rigidum, Castanopsis foxworthyi, Cephalomappa beccariana, Mangifera havilandii, Campnosperma squamatum, Linociera sp. (9402), Kibatalia sp. (9300), and Kibessia coriacea. In contrast there are few species apparently absent from the Rejang Delta yet recorded in other swamps. Neesia malayana has a localized distribution in Lawas swamps and has also been recorded from the Setapok Forest Reserve near Kuching. Tristania maingayi is abundant in the central forest types in the Baram and in the Maludam Peninsular, but has not been recorded in similar forest in the Rejang Delta. Ganua curtisii is known in swamp forest only in the Badas forests of Brunei, where it occurs abundantly in association with Shorea albida.

73. In general it has been found that upper storey species tend to have a more widespread distribution than smaller tree species of

the lower storey, and understorey trees are frequently very localized. Typical examples of the latter are Knema uliginosa in the Loba Kabang Protected Forest, and Kibatalia sp. (9300) and Lophopetalum rigidum which are confined to the apex of the Rejang Delta. An interesting exception to this generalisation is the distribution of the Dipterocarpaceae which is shown diagramatically in Table 11. Six species occur in peat swamp forest throughout the two territories. Cotylelobium flavum has a similar distribution in heath forests but in peat swamps it has only been recorded from the Rejang Delta and Brunei. Shorea macrantha and Shorea pachyphylla are also more frequently found in heath forest but both have a limited and localized distribution in heath and peat swamp forests. In peat swamps they are only found near the inland margins of the swamps. Dipterocarpus coriaceus, which is only known from localized areas in the Second Division and in the Sekai Forest Reserve in the Mukah river, is confined to peat swamps. It has not definitely been recorded from the Rejang Delta, but seedlings, probably of this species, have been found in the Naman Forest Reserve at the apex of the delta. The distribution of the gregarious species, Shorea albida, extends in peat swamps from the Sadong river to the Badas swamps of Brunei. It has also been recorded in heath forest near Lundu. Shorea inaequilateralis has a similar, though somewhat narrower, distribution.

74. There are many factors involved in determining the geographical distribution of peat swamp species. Unpublished pollen evidence indicates that many species, in particular Dactylocladus stenostachys, have been present in Borneo (probably in peat swamps) for millions of years. Recent changes in sea level during and

Table 11. Distribution of the species of Dipterocarpaceae in the peat swamps of Sarawak and Brunei.



Note: A straight line indicates known distribution of species in peat swamps forest, and a broken line probable distribution but no records yet. A crossed line indicates distribution of species in heath forest.

immediately after the Glacial Period with consequent erosion and deposition along the coasts may have been an important factor. Some species confined to peat swamps may have been eliminated from swamps in minor rivers yet retained a foothold in the Rejang river. After the stabilization of the sea level, some 5500 years ago, the spread of species may have been obstructed initially until the seaward development of peat swamps on alluvium had progressed sufficiently for the swamps to coalesce along the coast. There are, however, many other factors to be considered. Even if species were eliminated from coastal swamps, some would, no doubt, be preserved in heath forests and in small localized hill and montane peat swamps and thus be able to spread down again to the coast. Moreover some of the species, such as Swintonia glauca, Stemonurus scorpioides, Mangifera havilandii and Parishea sp. (2697), which in peat swamp forest have only been recorded in the Rejang Delta, may be considered more accurately as constituents of dry land forest, and only in the Rejang Delta have they become adapted to growing and regenerating in peat swamps. Further understanding of the distribution of the peat swamp flora is only likely to be achieved after greater knowledge has been gained of the Bornean flora as a whole. Later a comprehensive study of the peat swamp flora in the Malaysian region might yield some interesting information on the phytogeography of Malaysia.

Part 3

Results of ecological surveys; classification and description of forest types.

Bonn Challenges

Chapter 6

Results of Ecological Surveys

75. Summarized results of the ecological surveys undertaken in all the major areas of peat swamp forest in Sarawak and Brunei are included in this chapter. For complete summaries of species, recorded by three inch girth classes in the fifty-~~two~~ three half acre plots enumerated, reference should be made to Appendix 2.

Rejang Delta

76. The first ecological survey was undertaken in 1954 in the Loba Kabang Protected Forest, which lies at the apex of the Rejang Delta. The swamp covers an area of approximately 160 square miles and is bounded by the Rejang river and its deltaic branches. It is entirely under primary forest, with the exception of small areas on the fringe, where there is localized rice cultivation on recent alluvium; and the southernmost portion of the reserve where the swamp forest has been felled and replaced by rubber plantations.

77. A transect was cut from the River Igan for a distance of three and a half miles into the centre of the swamp. Details of a level survey and peat depths along this transect have been included in Chapter 4 and the profile of the swamp is shown on Figure 2. Six pairs of half acre plots (Nos. 1-12) were enumerated at half mile intervals, starting at one mile from the river bank. An additional pair (Nos. 17 and 18) was sited midway between the first and second pair of plots to examine in greater detail a transitional zone. Another pair of plots (Nos. 15 and 16) was enumerated near the

southern boundary of the reserve in a forest type not encountered along the transect. Furthermore, in order to compare coastal swamp forest with that further inland two plots (Nos. 13 and 14) were sited on Pulau Bruit, a large island at the mouth of the Rejang Delta. The location of the transect and sample plots is shown on Map 2.

78. Along the transect the forest changes in floristic composition and structure. On the perimeter and on Pulau Bruit the forest is many storied with an uneven canopy and dominated by a mixture of species. The aspect of the forest is not unlike lowland dipterocarp forest. In the central part of the transect (from Plots 17/18 to 7/8) the structure of the forest is similar to that previously mentioned, but a characteristic feature of the forest is the large dominants of Shorea albida. At the end of the transect, in the centre of the swamp, the forest is composed of numerous relatively small but tall trees with an even upper canopy, in which Shorea albida and Litsea palustris are almost the sole species. In Plots 15/16 Shorea albida forms a pure canopy at a height of approximately 160-190 feet.

79. The pattern of distribution of the most abundant and frequently represented species is to be clearly seen in the three histograms (Figs. 8-10). There are no precise floristic boundaries, yet the flora almost completely changes from the perimeter to the centre of the swamp. Three species only, Gonystylus bancanus, Copaifera palustris and Dactylocladus stenostachys, occur along the whole length of the transect. These three species are large dominants in Plots 1/2 but decrease in average size, though not necessarily in individuals, towards the centre of the swamp. With

these three exceptions the arboreal floras of the peripheral and central zones of the swamp are distinct. The long central portion of the transect might be considered as a transitional zone, with an overlapping of species, between the two extremes. An ill-defined floristic boundary occurs between Plots 1/2 and 17/18, coinciding with the first occurrence on the transect of Shorea albida; though the boundary is less marked in the middle and lower storeys. A second imprecise boundary occurs between Plots 7/8 and 9/10 where the dominance of Shorea albida and Litsea palustris becomes more apparent.

80. It was suspected that the pairs of plots were too far apart and too small in area to give a true pattern of the distribution of the species. A strip enumeration of the principal upper and middle storey species was therefore made along the length of the transect. The results, summarized in Table 12, generally confirm the previous results from sample plots. There are certain minor contradictions: Copaifera palustris and Dyera lowii have a narrower, and the two species of Melanorrhorea a wider, distribution than that recorded previously. But the overall pattern is similar.

81. The numbers of individuals per acre (pairs of plots) have been plotted on Figure 11. Near the margin of the swamp the numbers are relatively constant, ranging between 276 and 283, but towards the centre of the swamp there is a significant increase; 352 individuals being recorded in Plots 11/12. The pure Shorea albida forest in Plots 15/16 has only 220 individuals.

82. Corresponding to the increase in the number of individuals along the transect, there is a marked decrease in the number of species

Table 12. Distribution of principal tree species in acre plots (10 x 1 chains) along transect in Rejang Delta

SPECIES	Plots (10 x 1 chains)																																				
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350
Shores platycarpa	2	1																																	
Parastemon urophyllum		5			1																														
Shorea rugosa var. uliginosa			2	1		1		2	2																										
Mezzettia leptopoda	2		1	1	4	6	3	1	2	2																									
Durio carinatus	1		4	1		2		1		1			1																						
Shorea teysmanniana	1	8	2	2		5		10	2	2	3	1	1	1	1	1																			
Shorea scabrida			1			1		1			6		1							2															
Shorea inaequilateralis	4	7		10	9	5	6	7	3	5	5	15	7	9	7	1	2	5	8	8															
Dryobalanops rappa			3		1	3	5	1	4	2		1		1	6	5																			
Dyera lowii	2	3	3	2	10	5	8		6	5	20	14	26	8	9	9	8	18	16	5	10	9	4	10	6										
Copaifera palustris	3	4	8	18	8	7	6	6	11	14	6	4	2	1	3	6	7	5	5	8	8	8	5	10	6	6									
Gonystylus bancanus	2	1	9	16	7	14	11	17	10	21	4	10	4	8	5	2	8	7	2	3	7	4	6	5	6	7	5	7	5	3	3	5	3	3	10
Dactylocladus stenostachys			1	1	1	1	1	4		4	5	1		2	1	1	3	2	3	5	5	5	2	9	7	8	15	15	11	10	8	16	16	16	21
Melanorrhoea beccarii			3		1	1		2	1	2	3	1	3	4	4	4	7	9	1	2	1	3	2	2				1	1	1		3	1	2	1
Melanorrhoea tricolor			1		1	2	1		1	2	1		1	1	1	4	2		1	1	1		2	1				1							
Shorea albida								1	7	12	4	1	12	14	12	15	28	20	17	12	21	21	12	10	20	59	68	68	79	88	90	100	107	121	150
Swintonia glauca											3		3	3	4	6	4	3	7	1	5	7	3	3	6	4	5	2		1	1	3	4	1	
Combretocarpus rotundatus													2		3	2	5	8	5	1	3	6	1	4	6	9	9	7	7	10	6	10	6	3	4
Calophyllum retusum														1	3		2		1	1			2	2	2	4	5	4	3	2	5	6		2	1
Litsea palustris																	2	1	2	1	4	11	9	17	28	17	31	33	21	16	13	17	37	30	20
Calophyllum rhizophorum																							5	5	8	17	17	19	16	20	8	7	12	16	9
Calophyllum obliquinervum																										5	4	5	15	10	13	4	10	14	9
Cratoxylon glaucum																										1	7	4	5	2	4	1	3	1	3
Tristania obovata																												5	15	11	35	25	6	10	

(Fig. 12). In the first two pairs of plots (1/2 and 17/18) seventy-one and seventy-eight species were recorded respectively, but the numbers decrease to a final figure of twenty-two in Plots 11/12. The plots in the coastal swamps on Pulau Bruit have fewer species per acre (fifty-nine) than in similar forest further inland. The lowest number of species was recorded in the pure canopied Shorea albida forest in Plots 15/16, where only seventeen were found. Figure 13 gives some indication of the minimal areas for species along the transect; the numbers of species recorded in one chain square sub-plots have been plotted. The curves obtained are of interest for comparative purposes, but are inaccurate for precise minimal areas in the forest types, as linear plots are likely to give higher figures for a given area than plots arranged on progressive squares or circles. In the peripheral plots the minimal area has not been reached, though it is clear that the curves can be expected to flatten between one and one and a half acres. The minimal area decreases in relation to distance along the transect. The lowest figures are found in the central plots 11/12, and in the pure Shorea albida forest (Plots 15/16).

83. The histogram in Figure 14 shows the girth class structure of the forest in the plots. In the series of plots from 1/2 to 7/8 the structure is somewhat similar, but in the plots in the centre of the swamp there is a large increase in the girth classes between 24 and 48 inches, and an almost total absence of large trees. Shorea albida is not represented in Plots 17/18 and 3/4 by any tree less than 48 inches girth and most trees exceed 72 inches girth, whereas in the central plots this species is well represented in all girth classes, and its overall dominance in Plots 15/16 is clearly indicated.

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A clearer idea of the structure of the forest may perhaps be obtained by a consideration of basal areas and the ratio of basal area to number of trees. The data for all species and for Shorea albida independently are plotted on Figure 15. The maximum basal areas are recorded in Plots 5/6 and 15/16, where large trees of Shorea albida are especially numerous. It is of interest to note that the total basal area in the central plots exceeds that in the mixed forest in the peripheral plots despite the absence of large trees in the former. The ratio of the total basal area to number of trees for all species remains relatively constant in all plots, but there is a steep decline in the ratio for Shorea albida from the perimeter to the centre of the swamp. This is an index of a decrease in the average girth of the species. It is most marked in Shorea albida, but as may be seen in Figure 16 a decrease in average girth occurs in all the principal dominants in relation to distance along the transect. This is a feature which is common to all species: Lophopetalum rigidum and Cephalomappa malloticarpa, for example, are abundant in the lower storey (12-24 ins. girth) in Plots 7/8, whereas in Plots 11/12 they are of frequent occurrence in the understorey, but rarely exceed 12 inches girth.

Maludam Peninsula

84. The Maludam Peninsula, between the Batang Lupar and Saribas rivers (see Map 3), is the largest single peat swamp in Sarawak and Brunei and covers approximately 400 square miles. It is partially subdivided by streams that drain the central portion of the raised bog

itself, but the swamp is continuous from immediately behind the mangrove along the coast to the low hills forty miles inland. Three isolated small hills, formerly islands, occur in the swamp mass. The most important feature of this swamp is the enormous block of Shorea albida forest which originally covered approximately 105,200 acres. Some 25,000 acres were, however, destroyed by an insect epidemic in 1948 (see Chapter 16). The whole bog is largely undisturbed, except for a broken marginal fringe of cultivation, of negligible area, on recent alluvium.

85. A transect, three miles in length, was cut into the centre of the swamp between the Batang Lupar and Maludam rivers, and five half acre sample plots (Nos. 19-23) were enumerated at half mile intervals (see Map 3). A strip enumeration of the principal tree species was also undertaken along the length of the transect.

86. The representation in the sample plots of the most abundant upper, middle and lower storey species is shown in Table 13. Plots 19 and 20 are dominated by Gonystylus bancanus, Copaifera palustris, Shorea rugosa var. uliginosa and Shorea teysmanniana; Plot 21 is transitional, with large dominants of Shorea albida mixed with the aforementioned species, whereas Plot 22 is dominated solely by Shorea albida. The upper canopy in the central plot, No. 23, is composed of a mixture of species of which the most abundant are Dactylocladus stenostachys, Combretocarpus rotundatus, Litsea palustris and Shorea albida. In the middle and lower storeys there are sharp changes in the floristic composition coinciding with the complete dominance of Shorea albida (Plot 22). A middle storey is largely absent in Plot 22, and Tetractomia holttumii is particularly abundant in the lower

Table 13. Distribution of principal tree species in sample plots in the Maludam Peninsula.

SPECIES	SAMPLE PLOTS.				
Upper storey:	19	20	21	22	23
Shorea rugosa var. uliginosa	7	8			
Gonystylus bancanus	5	1	5		
Copaifera palustris	6		5		1
Dyera lowii		2	1		
Shorea teysmanniana		9	7		
Dactylocladus stenostachys			5	1	14
Shorea albida			6	34	8
Combretocarpus rotundatus			1	5	10
Litsea palustris			1	3	12
Middle storey:					
Alangium havilandii	2				
Palaquium pseudorostratum	1	4			
Diospyros pseudomalabarica	5	2	4		
Cyathoclyx biovulatus	3	1	3	1	
Diospyros evenis	2	10	8		
Ctenolophon parvifolius		1	1		
Blumeodendron tokbrai	5	3	7		
Nephelium melanomiscum		13	1		
Palaquium cochlearifolium				4	1
Tristania obovata					12
Tristania maingayi					31
Parastemon versteeghii				5	51
Lower storey:					
Gymnacanthera eugeniifolia	2				
Litsea gracilipes	1	1			
Neoscortechinia kingii	9	10	7		
Dillenia pulchella var.	7	27	1		
Stemonurus umbellatus	1	1	3		
Xanthophyllum amoenum		1	5	4	
Tetractomia holttumii		7	38	33	
Canthium didymum			1	1	2

storey. In Plot 23 Tristania spp. and Parastemon veesterghii are the principal associates. The general pattern of floristic distribution is similar to that found in the Rejang Delta, as may be seen from the results of the strip enumeration (Table 14). This enumeration was continued for a further distance of half a mile, and the reverse change in the floristic composition may be noted at 280 chains, where the Shorea albida is returning to overall dominance and species, such as Combretocarpus rotundatus and Tristania spp., whose distribution is confined to the central zone, are absent or poorly represented.

87. The number of species per unit area (Fig. 17) is generally lower than that found in the Rejang Delta, decreasing from forty-four in the peripheral plot (No. 19) to nineteen in Plot 23 in the centre of the swamp. Fourteen, the lowest number recorded on the transect was found in Plot 22, where the forest is entirely dominated by Shorea albida.

88. Variations in the structure of the forest correspond to those found in the Rejang Delta: a multi-storied mixed forest on the perimeter changes to an almost pure high forest of Shorea albida, and finally to a lower mixed forest with few trees exceeding sixty inches girth in the centre of the swamp. The numbers of individuals per half acre (Fig. 18) increase from 117 on the perimeter to 160 in the centre, with a minimum number of ninety-seven coinciding with the pure dominance of Shorea albida (Plot 22). Graphs of basal areas and ratios of basal areas to numbers of trees are included in Figure 19, and the girth class representation of trees in sample plots is shown in Figure 20. The progressive increase in the total basal area is caused by the occurrence of Shorea albida and reaches a maximum in

Table 14. Distribution of principal upper storey trees, greater than 12 ins. girth, in one acre (10 x 1 chains) plots along transect in the Maludam Peninsula

SPECIES	chains																											
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280
Mezzettia leptopoda		1			2	3	2																					
Shorea rugosa var. uliginosa	7	7	2	5	4	6		4	5	3		2	1	1			1											
Parastemon urophyllum	2	1	1	1		1	5	2		5	2		4	2	4	3	2											
Shorea platycarpa	3	2			5	1	2	7		10	5	4	8	1	4	3		2										
Shorea scabrida				1				1		1	2	2		2	2	4	2	1										
Shorea teysmanniana		4	1	1	4	3	6	10	9	9	6	5	16	7	3	2	3	2										
Dyera lowii	1	2		1		1	1		1		1		1	2	1		2			1								
Copaifera palustris	3	5	10	5	8	7	8	6	8	3	3	3	1	4	4	5	4	1					1					
Gonystylus bacamus	7	8	3	5	5	8	16	5	3	1	2		10	5	3	11	4	2	1	6	2					1		1
Dactylocladus stenostachys				1	3		3	2			1		1		3	6	10	7	2	2		5	17	25	37	23	11	6
Shorea albida																	3	13	28	65	68	84	70	41	49	66	63	58
Combretocarpus rotundatus																		1	5	9	9	4	4	9	6	14	7	
Litsea palustris																				2	1	3	15	19	18	11	20	10
Parastemon versteeghii																						2	10	17	22	15	5	3
Tristania spp. (2)																								12	8	1	2	

Plot 22. The total basal area of the central plot is again higher than the peripheral plots though only three trees exceed five foot girth. The ratio basal to number of trees for Shorea albida shows the typical pattern with a rapid decrease towards the centre of the swamp, though the total basal area for the species reaches a maximum in Plot 22.

Baram

89. Peat swamps in the Baram river cover approximately 845 square miles and extend for a distance of seventy-two miles from the mouth of the Baram itself. On the eastern side they are contiguous with the swamps in the Belait river in Brunei (see Map 4). The total swamp area is subdivided by tributaries of the Baram into numerous individual raised bogs, of which the largest covers approximately 200 square miles. Features of the Baram peat swamps are the extensive areas of forest dominated by Shorea albida, the distribution of which frequently spreads almost to the river banks, and the open stunted forest that covers large areas of the central swamp zones in the more upriver swamps, upstream from the mouth of the Bakong river. This forest type is only found in the Baram and in small contiguous areas in the Belait over the border. The peat swamps are virtually entirely undisturbed; exploitation of timber has occurred along the margins of some swamps, and this has recently increased in intensity, but the overall damage is as yet almost negligible. Details of three level surveys have been included in Chapter 4 and the swamp profiles are shown in Figure 3. The domed structure of the upriver bogs in the Baram has been found to be very pronounced.

90. Two contiguous sample plots (Nos. 24 and 25) were enumerated in the pure Shorea albida forest downriver at Sungei Dua, and sampling was undertaken along two transects further upriver to investigate in particular the ecology of the stunted forest. The location of the plots and transects is shown on Map 4, and the summarized results of the enumerations are included in Tables 15 and 16.

91. The structure of the forest and representation of the species in Plots 24 and 25 are generally similar to that in other plots dominated by a pure canopy of Shorea albida. The most abundant lower storey species in this locality is Xanthophyllum sp. (2614). Within a distance of half a mile from the river bank on Transect 1 the forest varies from a mixed forest with a few enormous dominants of Shorea albida on the perimeter (Plots 26 and 27) to a dense pure forest of Shorea albida and finally in the centre of the swamp to a very dense low forest with 280 trees to the half acre (Plot 29). In addition to Shorea albida the principal tree species in the upper and middle stories in Plots 26 and 27 are Gonystylus bancanus, Blumeodendron tokbrai, Polyalthia hypoleuca and Copaifera palustris, and in the lower storey Stemonurus umbellatus, Litsea resinosa, Alangium havilandii and Cyathocalyx biovulatus. In Plot 28 Gonstylus bancanus is abundant in the middle storey. The dense low forest in Plot 29 is largely composed of Dactylocladus stenostachys (82 trees), Parastemon veesterghii (67 trees), Tristania obovata and Tristania maingayi (46 trees) and Palaquium cochlearifolium (36 trees). These, it will be noted, are the same species as are dominant in the mixed forest in Plot 23 in the centre of the Maludam Peninsula.

92. The species and individuals per unit area are plotted on

Table 15. Distribution of principal tree species in sample plots in the Baram.

	S.P.'s 24 & 25			TRANSECT 1				TRANSECT 2			
			Total			Total					
SPECIES	24	25	24 & 25	26	27	26 & 27	28	29	30	31	3
Upper & middle storey trees:											
Blumeodendron tokbrai				8	4	12					
Polyalthia hypoleuca				4	6	10	2				
Copaifera palustris				1	3	4					
Gonystylus bancanus	1		1	3	2	5	28	4	5		
Shorea albida	27	16	43	4	5	9	44	23	4	15	
Dactylocladus stenostachys		1	1	4	1	5		82	1	10	3
Combretocarpus rotundatus	1	1	2	1	2	3	9	6	6	9	2
Dyera lowii	1	1	2				9				
Litsea palustris	4	3	7						1	21	
Cratoxylon glaucum									19		
Xanthophyllum sp. (2614)	22	12	34					1	13	1	
Parastemon versteeghii	1	3	4		2	2	11	67	6	33	
Palaquium cochlearifolium	1	1	2		1	1	9	36	11	54	
Diospyros evenis							2		36	16	
Tristania spp.								45	5	48	
Longetia malayana									5	11	
Xylopia coriifolia				1		1			5	10	
Lower storey:											
Litsea resinosa		1	1	2	5	7	2				
Hymnacanthera eugeniifolia				2	2	4					
Stemonurus umbellatus				6	3	9			6		
Alangium havilandii				6	1	7					
Xanthophyllum amoenum	1	3	4		3	3					
Ilex hypolauca	10	7	17	1	1	2	1				
Cyathocalyx biovulatus				3	3	6	3		1		
Canthium didymum				2	1	3			6	2	
Tetractomia holttumii	1		1	1		1			1		
Quercus sundaicus	2	8	10				2				
Sterculia rhoidifolia		1	1				1		4	2	
Ternstroemia hosii	1	1	2					3	1	1	

Table 16. Representation of species on transect at Lubok Pasir, Baram.

Plots (2 x 1 chains)

SPECIES	Chains 11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75
Cyathocalyx biovulatus	1	1	2																														
Copaifera palustris	1																																
Cratoxylon glaucum	5	7	9	8	3																												
Palaquium ridleyi	2		2	2	5	1	2	3																									
Melanorrhoea beccarii		1	1																														
Baccaurea bracteata		3				1		1																									
Mezzettia umbellata			1			1																											
Xanthophyllum aff. citrifolium	1	1				1	1																										
Stemonurus umbellatus	4	2	3		1	3		2																									
Canthium didymum	2	4	2	1	1	1	2	2		2																							
Xanthophyllum sp. (2614)	2	1	1	6	16	6	5	2																									
Diospyros evenis	5	5	9	16	17	14	9	15	11	5	8	3	1																				
Xylopia coriifolia		2	2	4		1	1	4	7	6	1																						
Sterculia rhoidifolia			1	1		2	1	1		2																							
Palaquium cochlearifolium	9	4	2	3	6		5	5	11	13	21	24	6	10	5	7																	
Shorea albida	4	1	1	2	2	2	4	10	8	10	1	11	5	3	4	3	1																
Longetia malayana	7	3	6	2		7	1		1	4	4	5	1			2				1												
Combretocarpus rotundatus	3	4	2	1		1	2		1	4	4	4	2	4	6	6	9	6	12	5	10	8	9	6	12	10	7	13	8	13	7	14	8
Dactylocladus stenostachys			1	1	1	3		4	2	5	2	3	12	12	8	14	14	14	10	17	16	13	12	15	8	9	12	24	22	22	12	8	
Parastemon versteeghii	2	2	1		4	5	2	4	9	9	22	4	2	2	3				1														
Garcinia rostrata					1	1	1		1							1																	
Eugenia sp.				1				1		2																							
Litsea palustris				1	2	3	3	1		7	13	7	4																				
Tristania spp. (2)	1	2	3	1					1	30	17	9	8																				

Figures 21 and 22. The pattern is similar to that found on the previous transects in the Rejang Delta and Maludam Peninsula: as the numbers of individuals increase from ninety to two hundred and eighty so the numbers of species decrease from forty on the perimeter to fourteen in the centre of the swamp. The basal areas and ratios basal area to number of trees are plotted on Figure 23. Total basal areas and basal areas of Shorea albida show an increase from the peripheral plot to Plot 28 and then a sharp decrease in the central plot. The ratios basal area to number of trees for Shorea albida show the typical sharp decline along the transect.

93. Three plots were enumerated on Transect 2 at Lubok Pasir. The vegetation of the extensive central zone of this swamp is a remarkable open almost savannah-like forest in which only two species generally exceed 12 inches girth and all species show a high degree of stunting. Plot 30, twenty chains from the river bank, was situated in a dense mixed forest similar in structure to Plot 23 (Maludam Peninsular) and Plots 9/10 and 11/12 (Rejang Delta); Diospyros evenis and Cratoxylon glaucum are the principal dominants. The structure and floristic composition of the forest in Plot 31, forty chains from the river bank, are similar to those found in Plot 29 on Transect 1; consisting of a very dense low canopied forest with few trees exceeding three foot girth. Immediately beyond this plot there is a sharp change to the open stunted forest in which only Combretocarpus rotundatus and Dactylocladus stenostachys exceed 12 inches girth. Some of the common associates of these species are found as small stunted trees or shrubs. The results of a strip enumeration along the transect, shown in Table 16, give an indication

of the distribution of the species. The sharp change in the composition of the forest at the forth-third chain may be noted.

Badas, Brunei

94. The Badas peat swamp is situated between a large loop in the Belait river and the littoral fringe along the coast (see Map 4). The greater part of the area, approximately 120 square miles, consists of Shorea albida forest, which in this locality comes unusually close to the coast. Despite the presence of a large oil field and a relatively dense population on the coastal fringe there has been little disturbance of the peat swamp itself. A light railway was constructed before the war across the centre of the bog but the forest on either side has been little damaged.

95. A transect was cut for a distance of five miles and this crossed the centre of the peat dome which lies towards the landward side of the bog. Ten sample plots were enumerated at half mile intervals.

96. Shorea albida dominates the forest along the whole length of the transect and the principal interest in the results lies in the pattern of distribution (Table 17) and the girth class representation (Fig. 24) of this species. In the region of the peripheral plot (No. 33), near the coast, enormous dominants of Shorea albida attain a larger size, particularly in height, than has been recorded elsewhere; trees of 200 feet in height are common, and individuals up to 220 feet have been recorded. In Plot 33 there are ten trees with girths ranging between 87 and 147 inches. For two and a half miles along the transect, as far as Plot 37, the average girth of Shorea albida

Table 17. Distribution of principal tree species in sample plots in the Badas area, Brunei.

Species	Sample Plots									
	33	34	35	36	37	38	39	40	41	42
Mezzettia umbellata	1									4
Stemonurus umbellatus	3	1								3
Polyalthia hypoleuca	13									
Cyathocalyx biovulatus	3									
Xanthophyllum amoenum	2			3						1
Ganua curtisii	48	35	56	20						
Diospyros evenis	7		3	3	1					
Dyera lowii	4	6	2	2	1					8
Calophyllum obliquinervum		2	6	2						4
Sterculia rhoidifolia	1		1	2	1		1			4
Palaquium cochlearifolium		1	1	10	25	5				2
Gonystylus bancanus	5	19	30	34	4					22
Combretocarpus rotundatus	3	4	3	8	10	10		20	10	4
Dactylocladus stenostachys	4	3	1	2	4	8	19	3	25	15
Shorea albida	10	27	30	59	95	92	86	30	38	18
Parastemon versteeghii	1	4		2		16	24	24	17	
Xanthophyllum sp. (2614)						1	1		1	
Eugenia sp. (2822)						1	3		2	
Litsea palustris						1		1	4	
Tristania obovata						7			6	
Garcinia rostrata								10	2	

decreases (see Fig. 24) and the numbers of individuals increases from five to ninety-five. For a further mile and a half (Plot 39) the representation of Shorea albida and the structure of the forest remain relatively constant. No tree greater than six foot girth was recorded in plots in this area. The overall dominance of Shorea albida becomes increasingly more pronounced along the first three miles of the transect, as far as Plot 39, where eighty-four of the 139 trees and 91.6 per cent of the total basal area are composed of this species. The very centre of the swamp (Plot 40) consists of low rather open forest with relatively few trees, none of which exceed sixty inches girth. Beyond the centre, the forest rapidly reverts to almost pure forest dominated by Shorea albida and after a mile to mixed forest with large Shorea albida dominants. The reverse change after Plot 40 can be clearly seen on Figures 23 to 26.

97. A corollary to the abundance and dominance of Shorea albida is the low representation of species (Fig. 25) throughout the length of the transect: on the perimeter twenty-one species were recorded, but in the central plots a minimum of five is reached; beyond the centre the numbers again increase. Correlated to this decrease in species there is an increase in the number of individuals (Fig. 26), except in Plot 40. The associated species of Shorea albida are generally the same as those found in other areas with the exception of Ganua curtisii. This species has only been recorded in peat swamps from the Badas area where it is the principal component of the middle and lower storeys in the first four plots along the transect, but is absent in the plots towards the centre of the swamp.

Figure 8

DISTRIBUTION OF PRINCIPAL UPPER STOREY SPECIES IN SAMPLE PLOTS IN THE REJANG DELTA

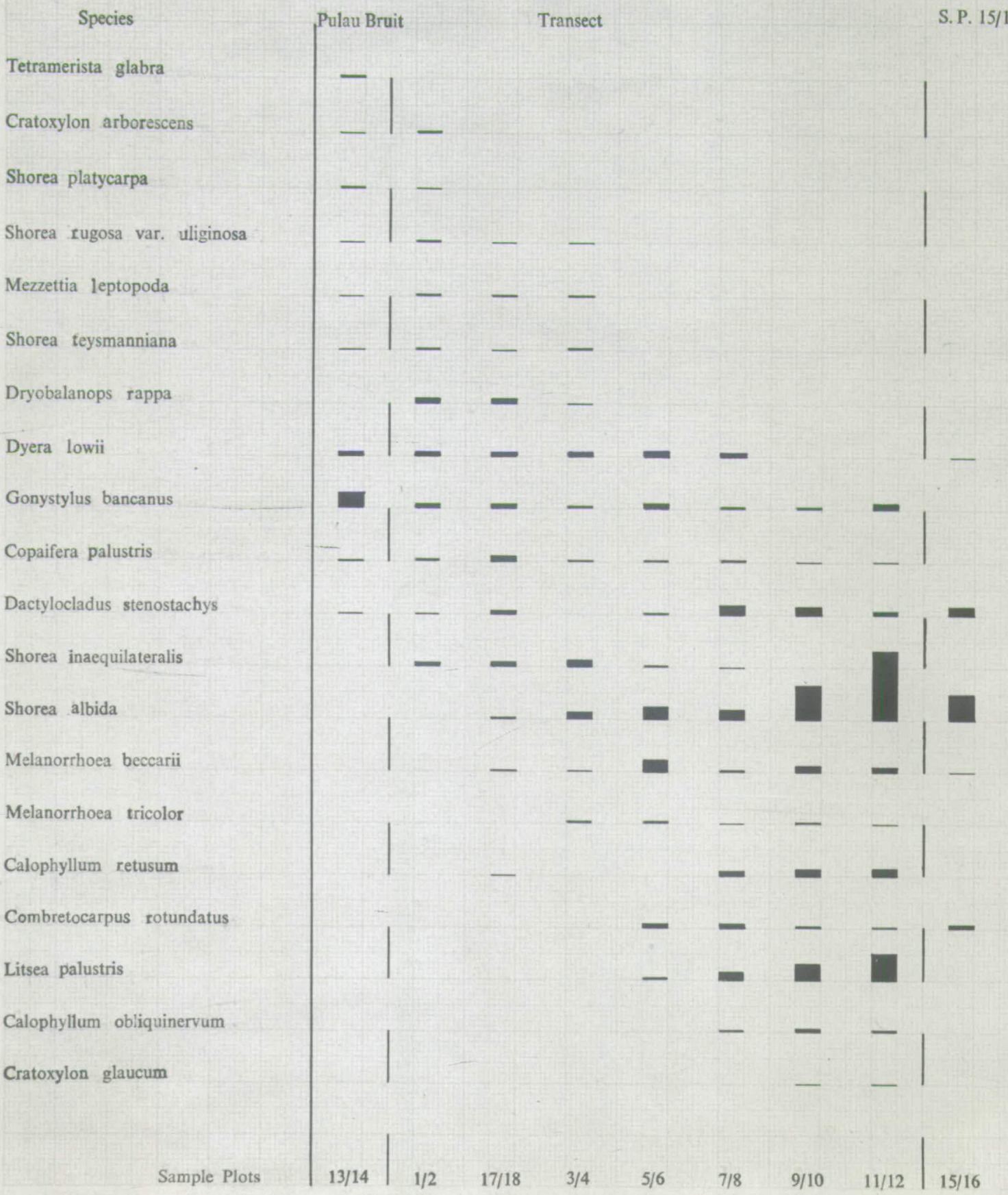


Figure 10

DISTRIBUTION OF PRINCIPAL MIDDLE AND LOWER STOREY SPECIES IN SAMPLE PLOTS IN THE REJANG DELTA

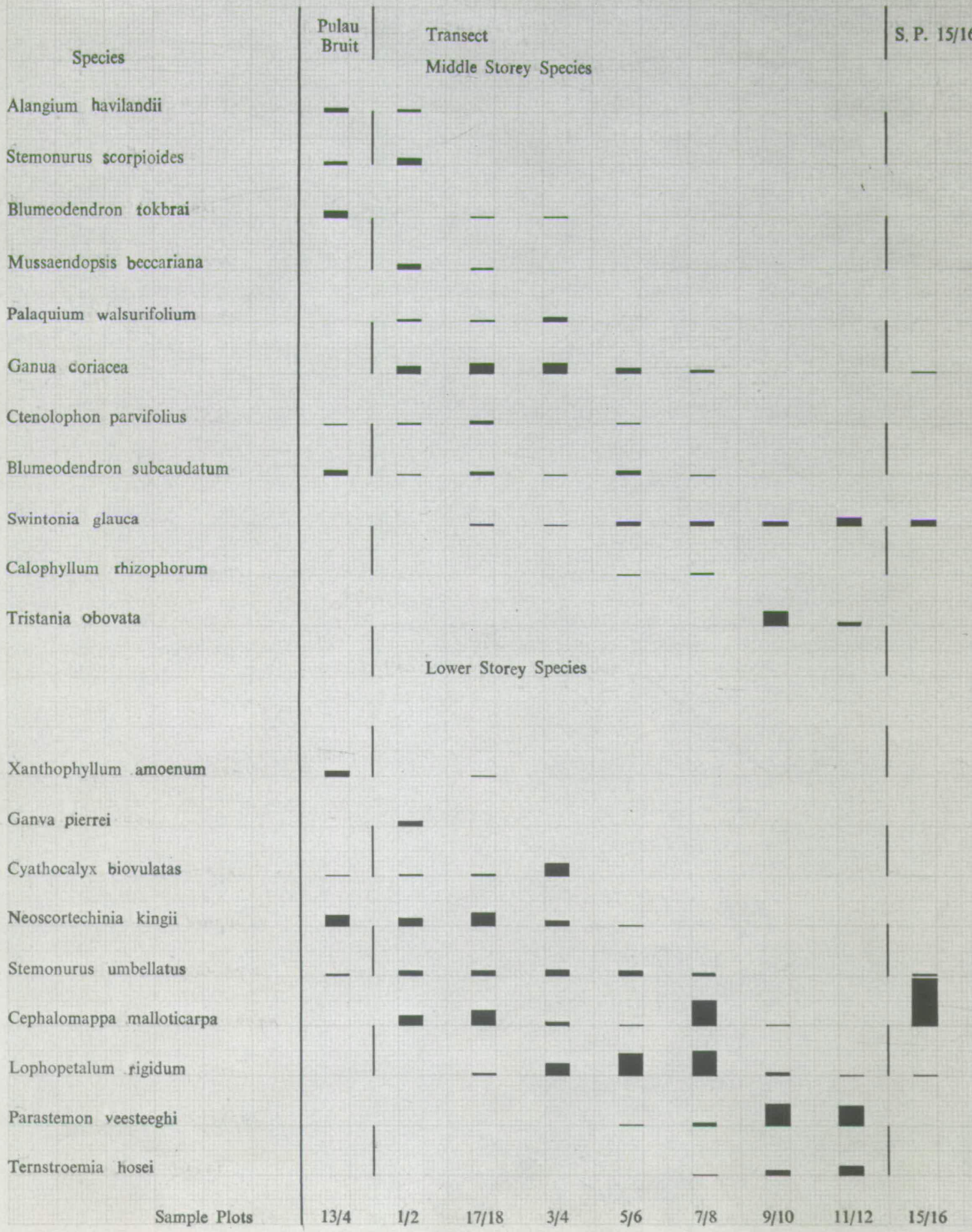


Figure II

Graph

SPECIES AND INDIVIDUALS PER ACRE IN SAMPLE PLOTS IN THE REJANG DELTA

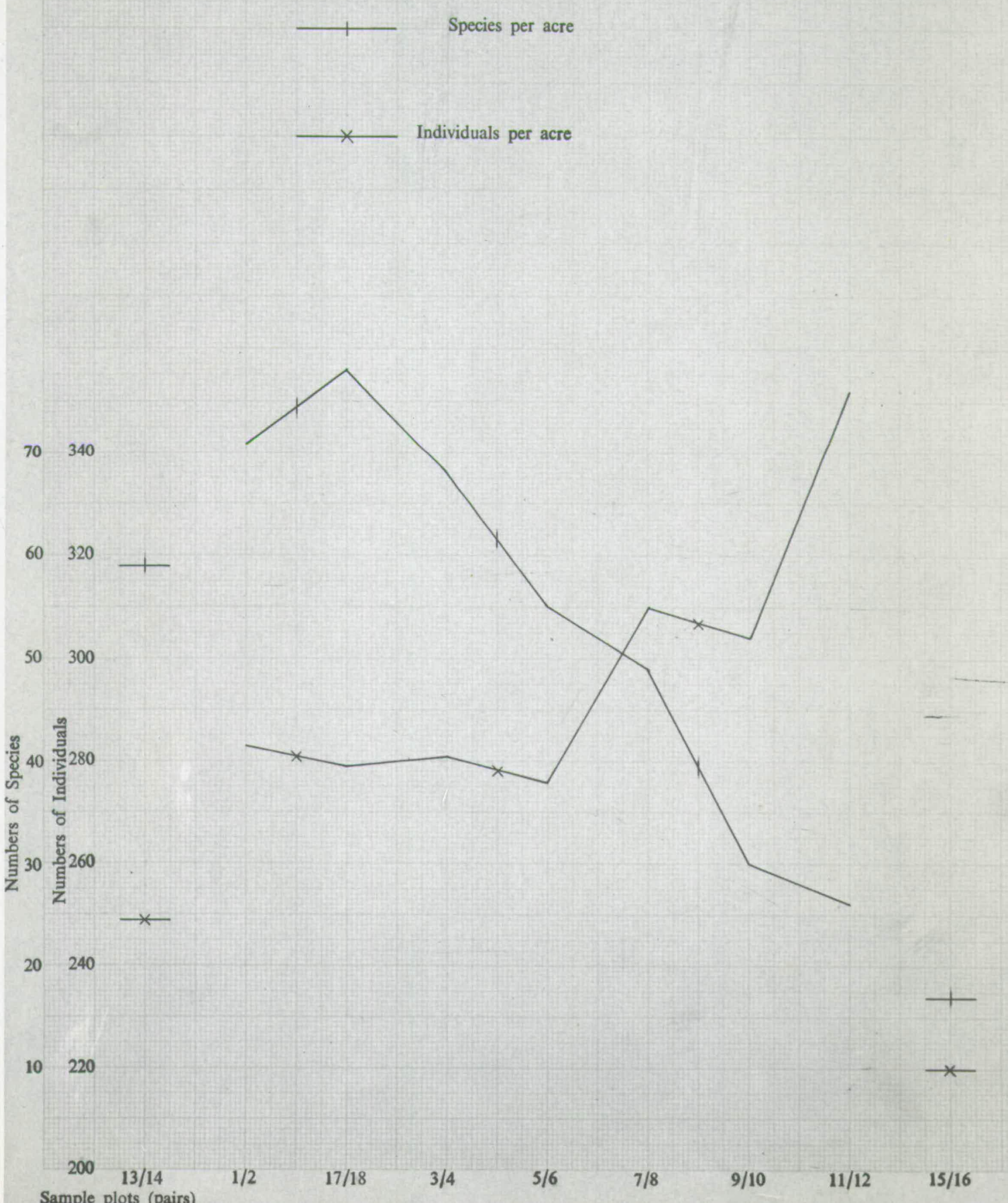


Figure 13

Graph

SPECIES PER UNIT AREA IN SAMPLE PLOTS IN THE REJANG DELTA

LEGEND

—⊙—	Sample Plots Nos. 1 & 2
—×—	" " " 3 & 4
—|—	" " " 5 & 6
—⊡—	" " " 7 & 8
—◇—	" " " 9 & 10
—H—	" " " 11 & 12
—S—	" " " 13 & 14
—Ŧ—	" " " 15 & 16
—+—	" " " 17 & 18

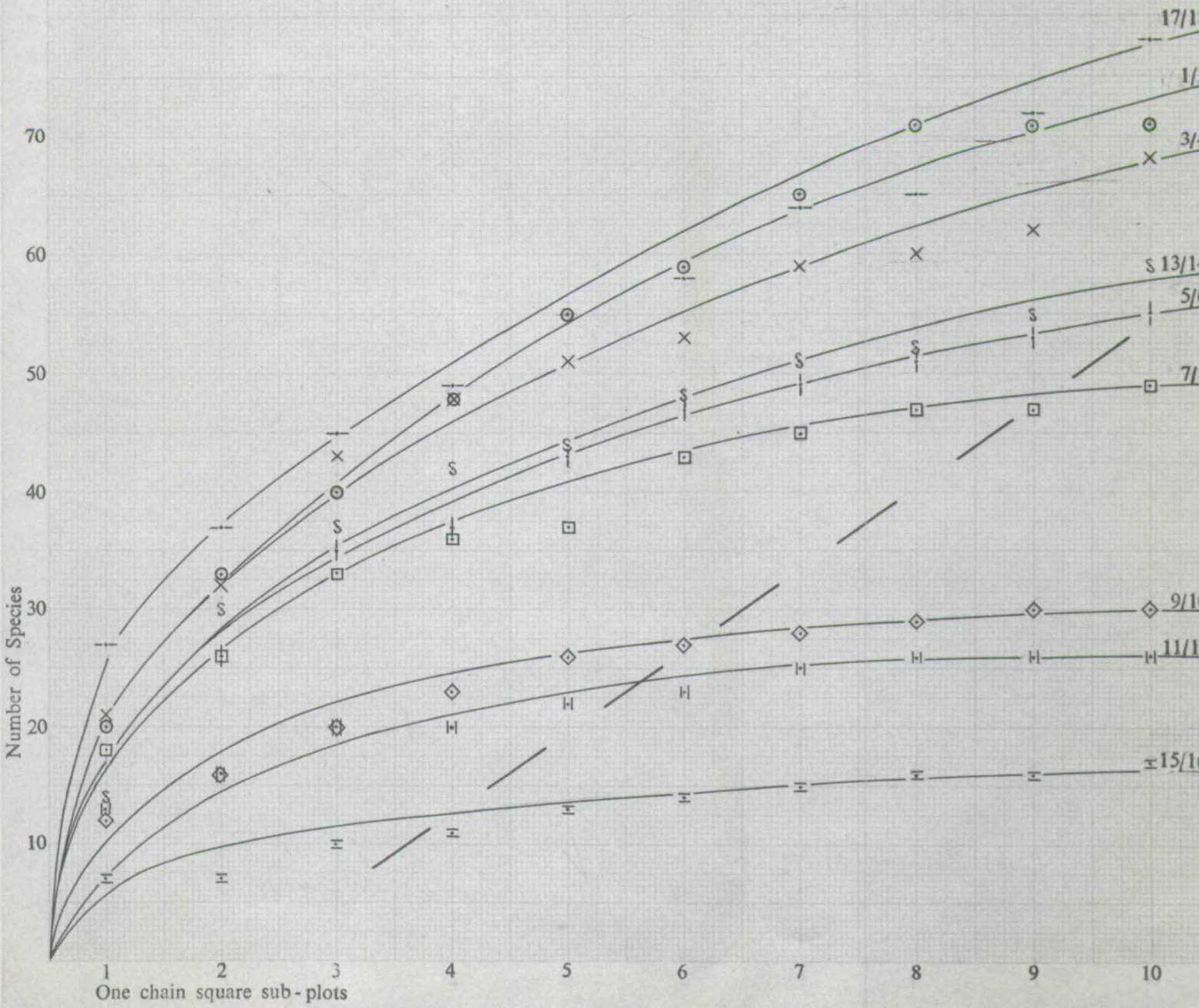


Figure 14

GIRTH CLASS REPRESENTATION OF SHOREA ALBIDA AND ALL SPECIES IN SAMPLE PLOTS IN THE REJANG DELTA

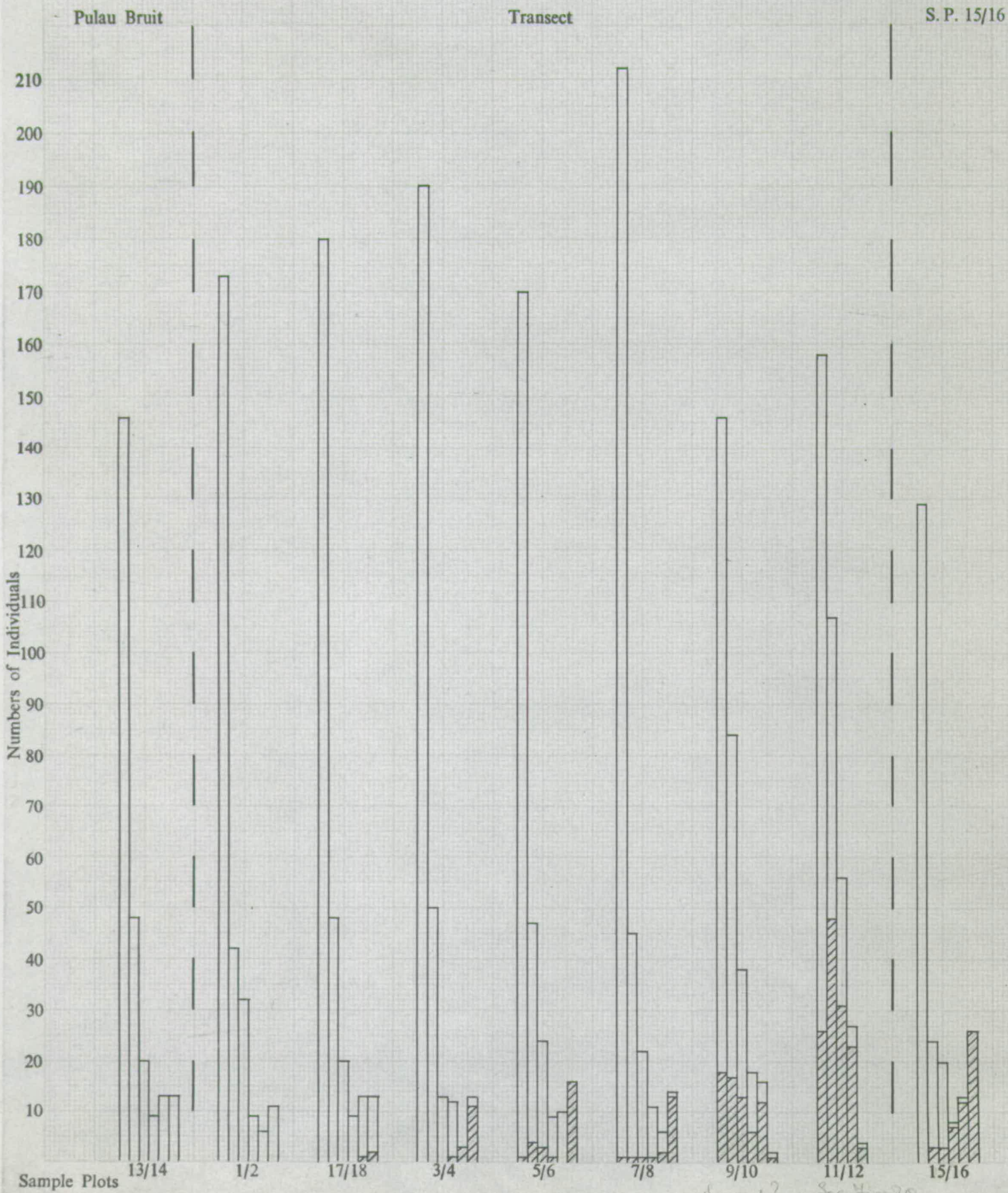
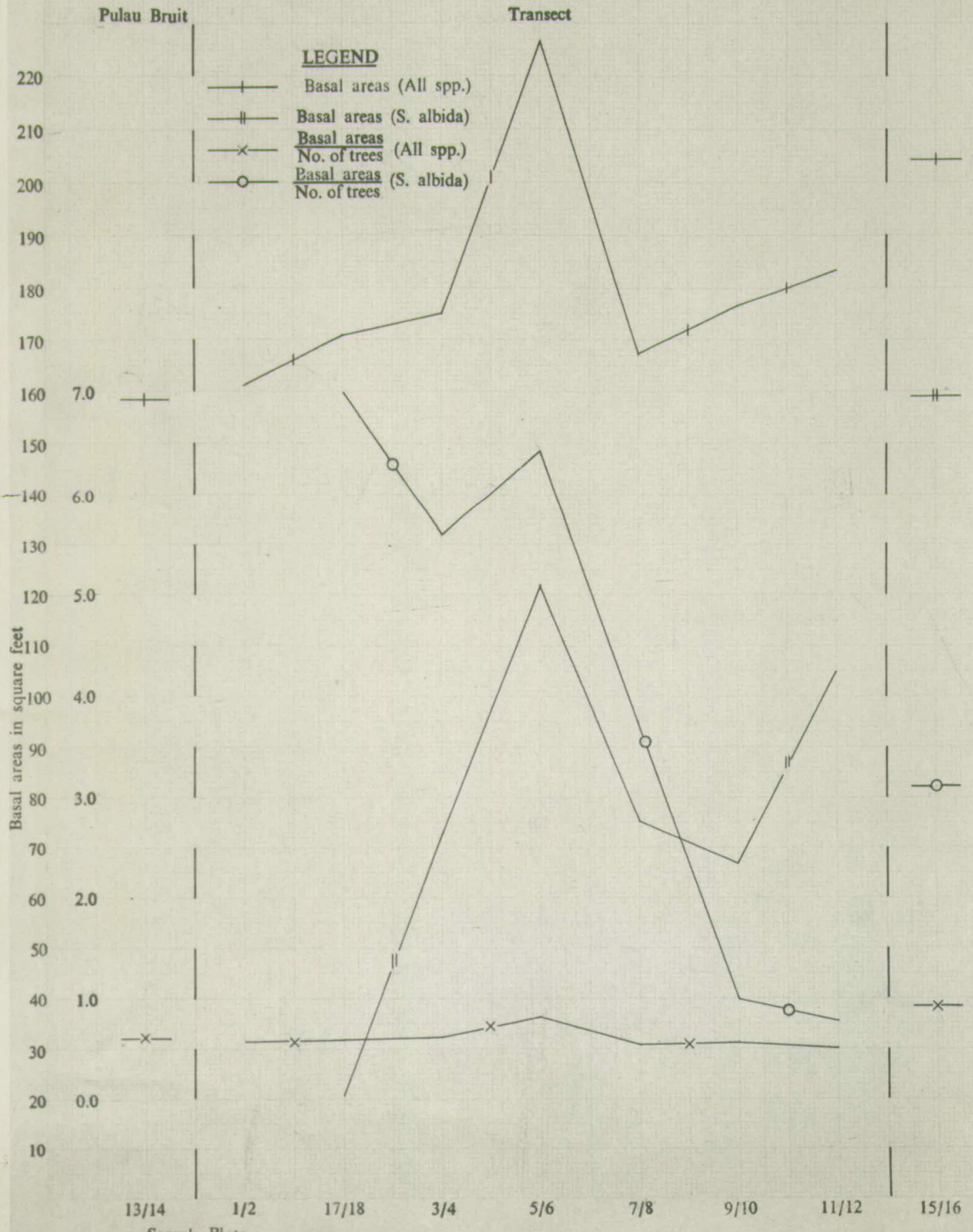


Figure 15

BASAL AREAS OF TREES IN SAMPLE PLOTS IN REJANG DELTA

Graph



Graph

AVERAGE GIRTHS OF PRINCIPAL DOMINANTS IN SAMPLE PLOTS
IN THE LOBA KABANG P. F.

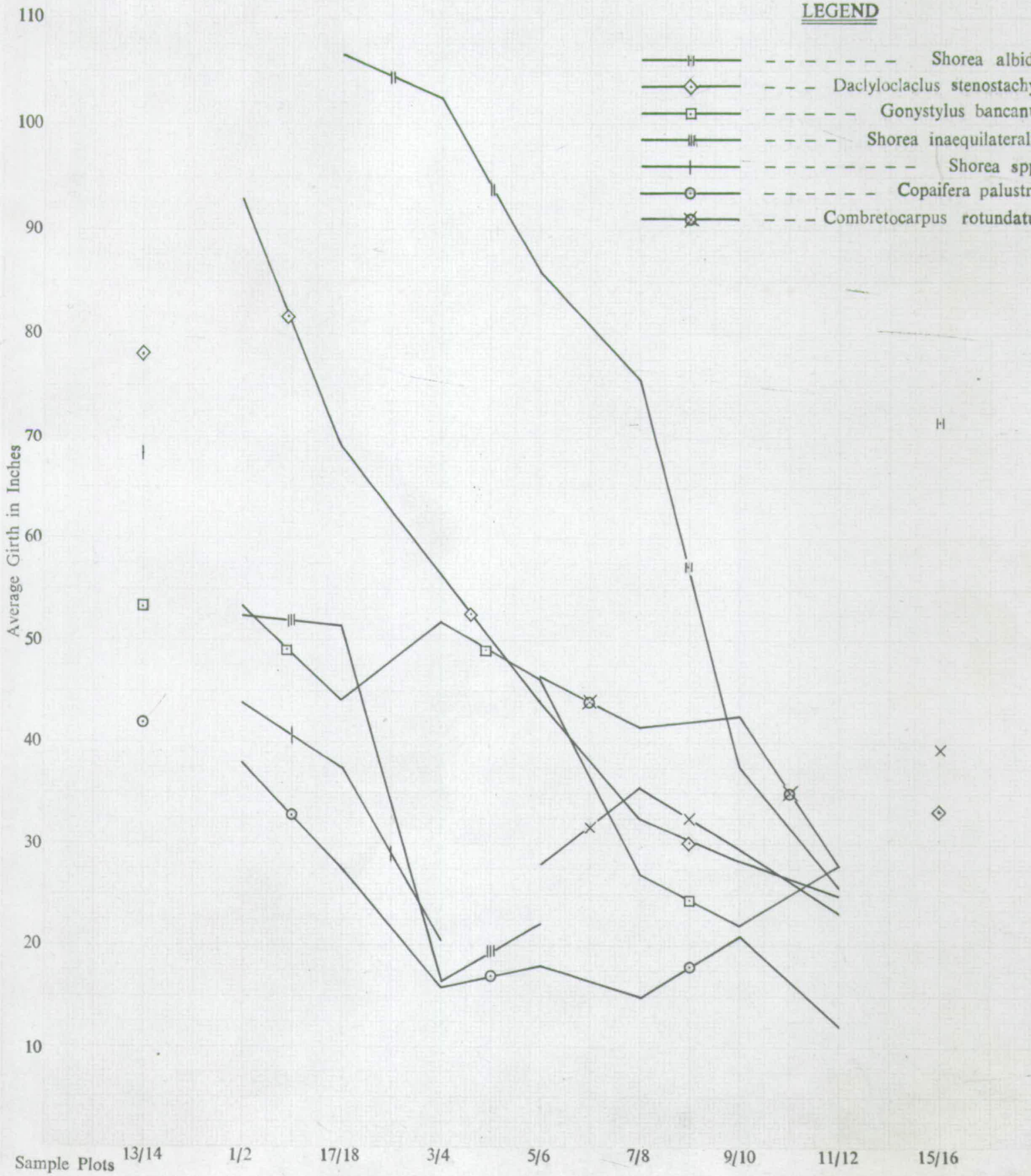


Figure 17

NUMBERS OF SPECIES AND INDIVIDUALS IN SAMPLE PLOTS
IN THE MALUDAM PENINSULA

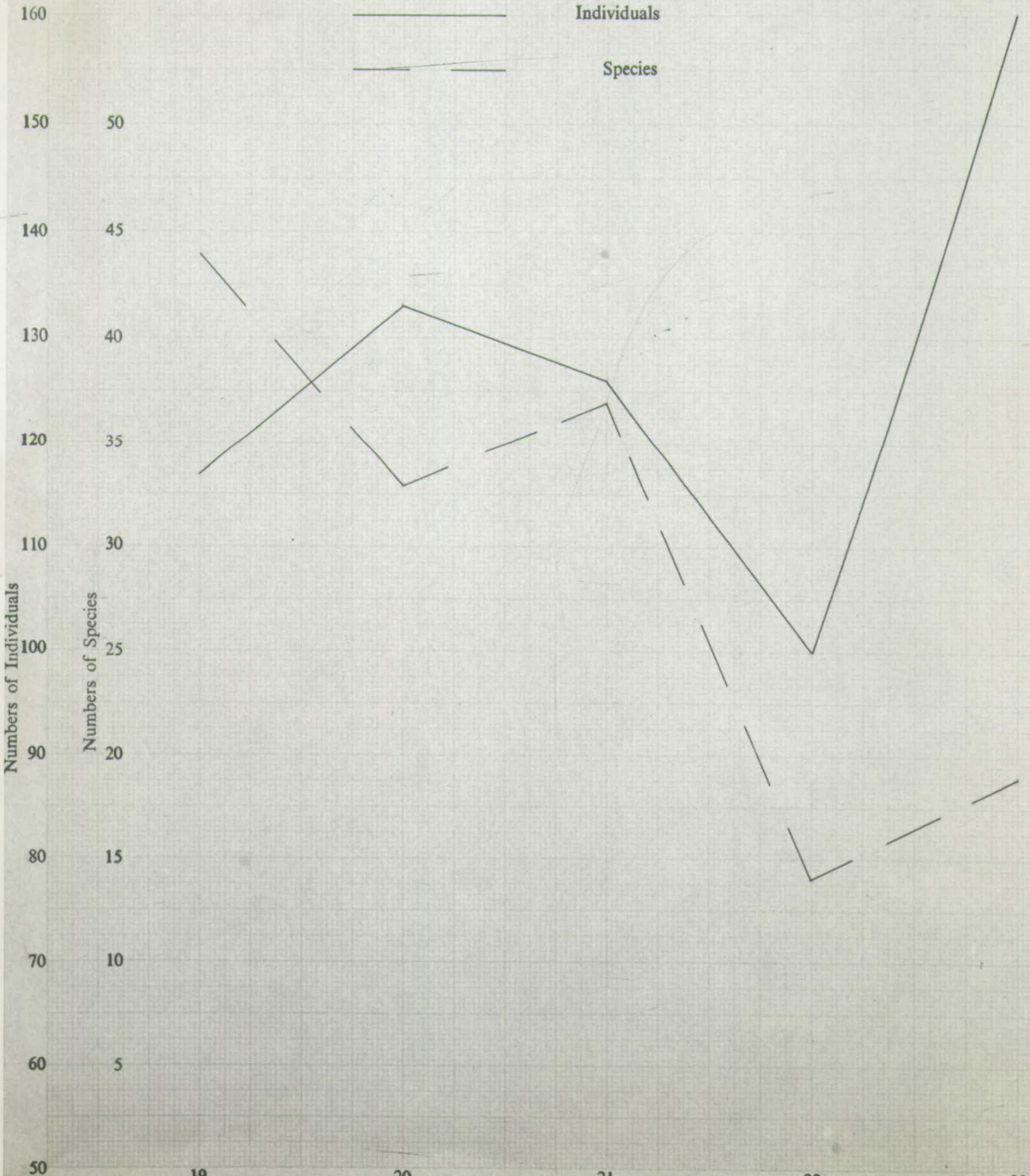
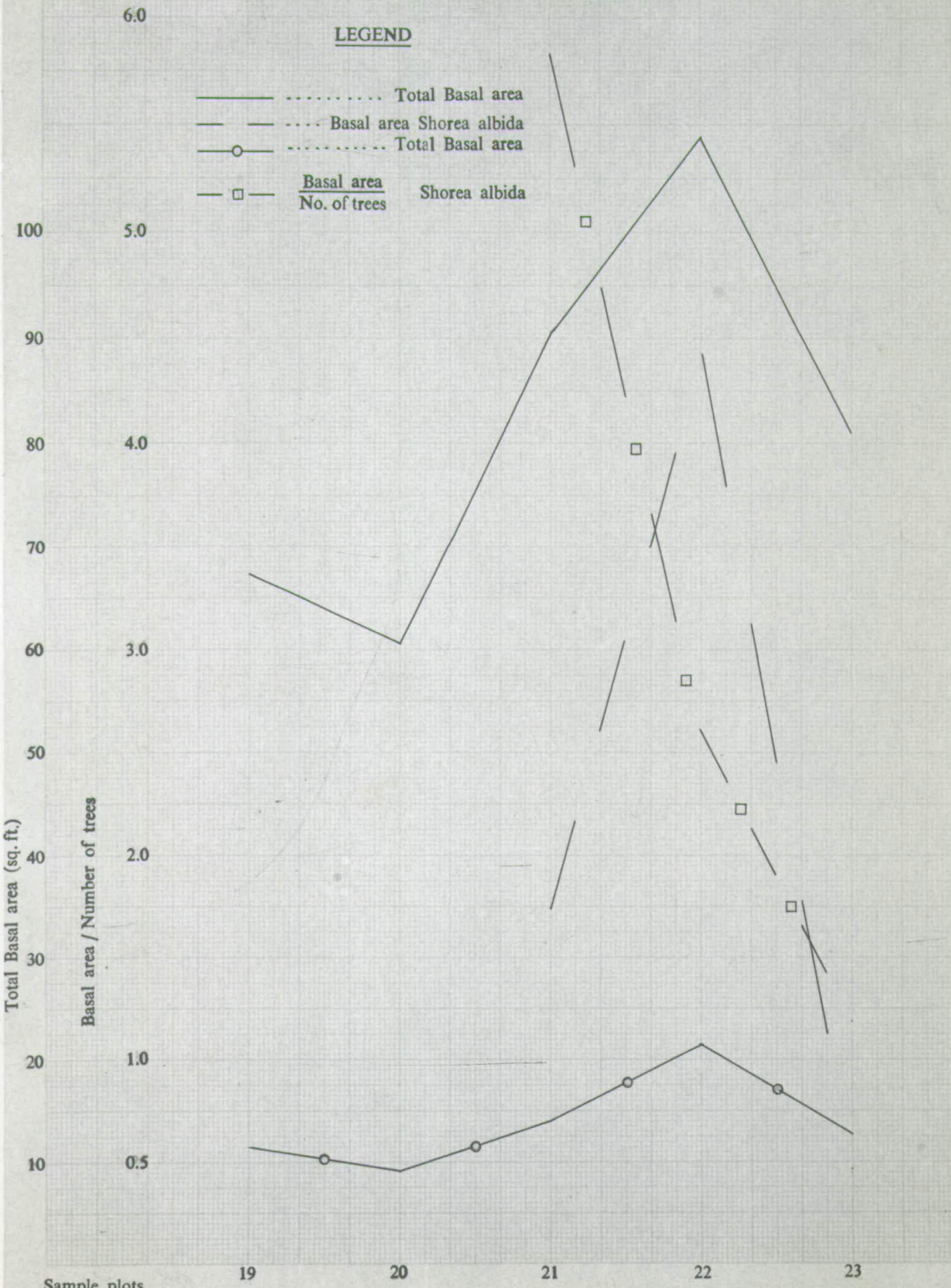


Figure 19

BASAL AREAS AND RATIO BASAL AREA: NUMBER OF TREES IN SAMPLE PLOTS IN THE MALUDAM PENINSULA



GIRTH CLASS REPRESENTATION OF SHOREA ALBIDA AND ALL SPECIES IN SAMPLE PLOTS IN THE MALUDAM PENINSULA

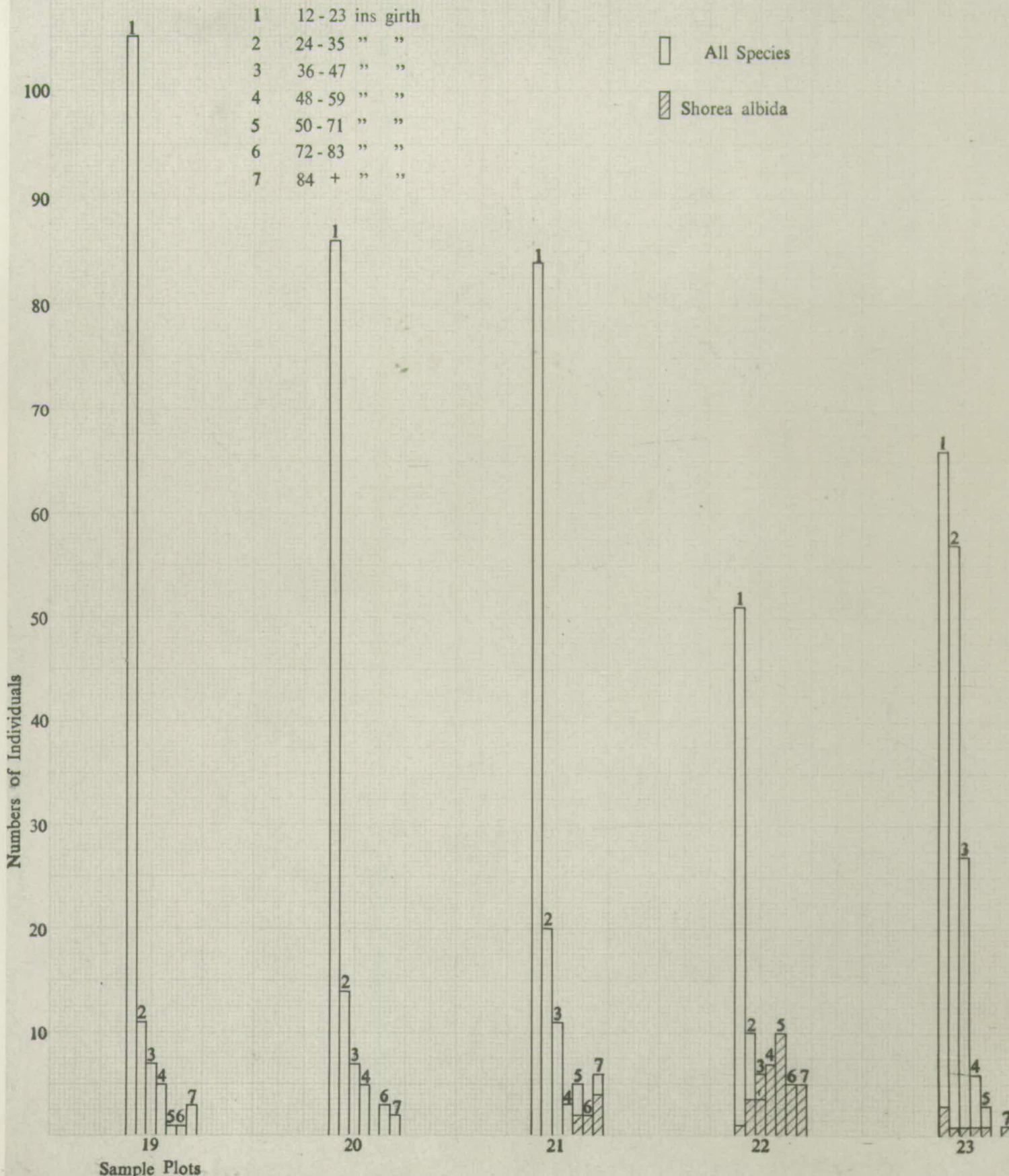
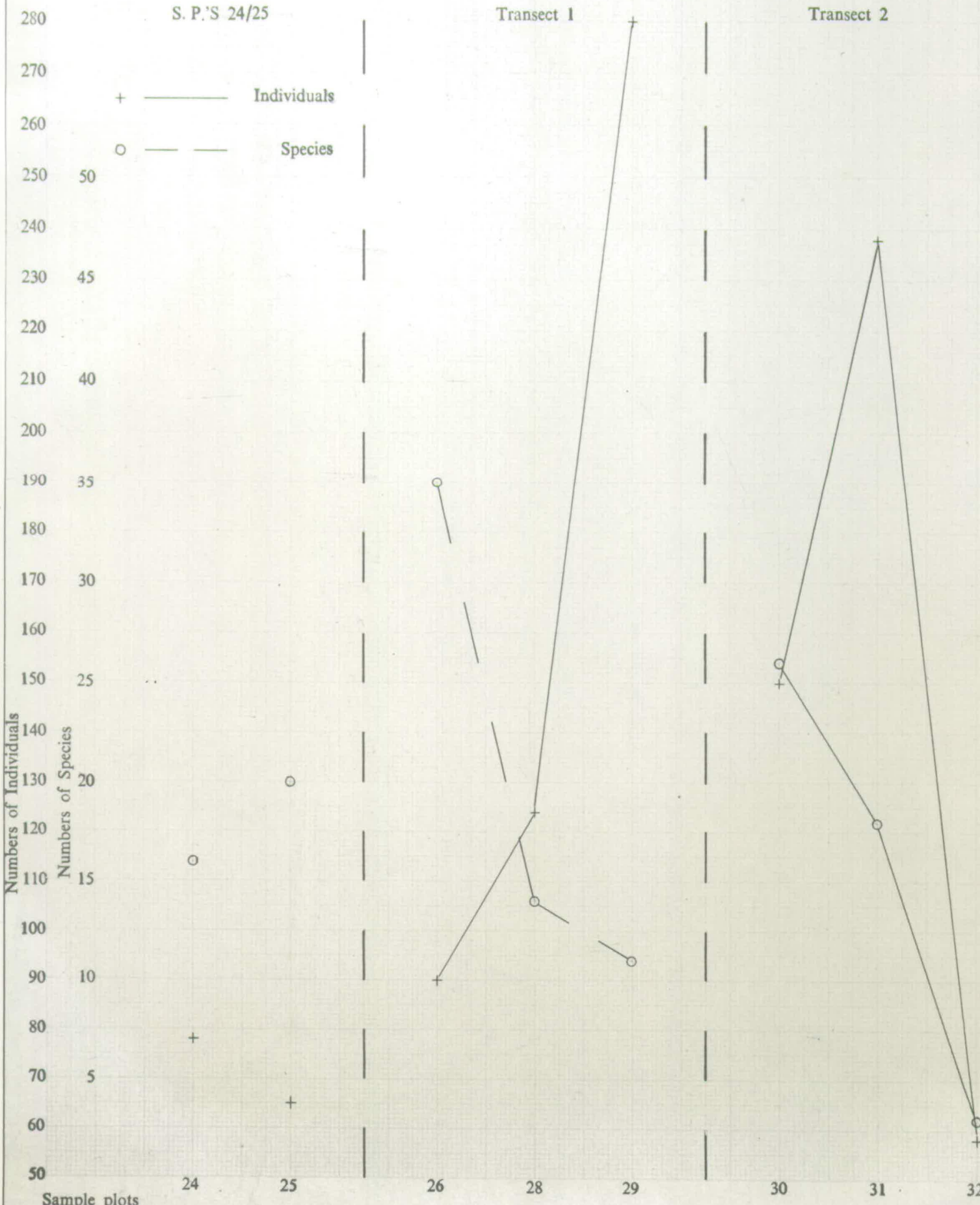


Figure 21

NUMBERS OF SPECIES AND INDIVIDUALS IN SAMPLE PLOTS IN THE BARAM



F 22A

Figure 22

GIRTH CLASS REPRESENTATION OF SHOREA ALBIDA AND ALL SPECIES IN SAMPLE PLOTS IN THE BARAM

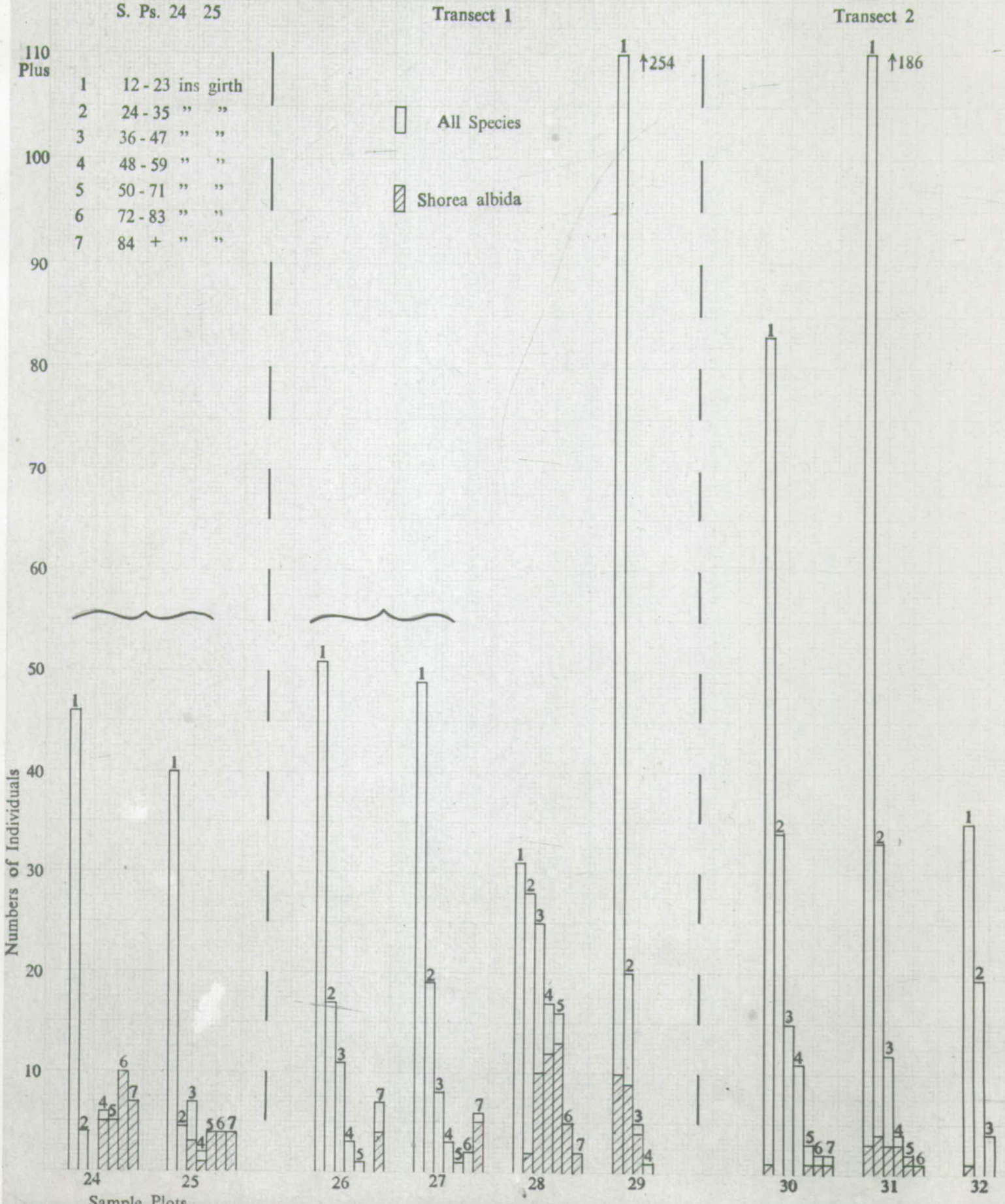


Figure 23

BASAL AREAS AND RATIO BASAL AREA: NUMBER OF TREES IN SAMPLE PLOTS IN THE BARAM

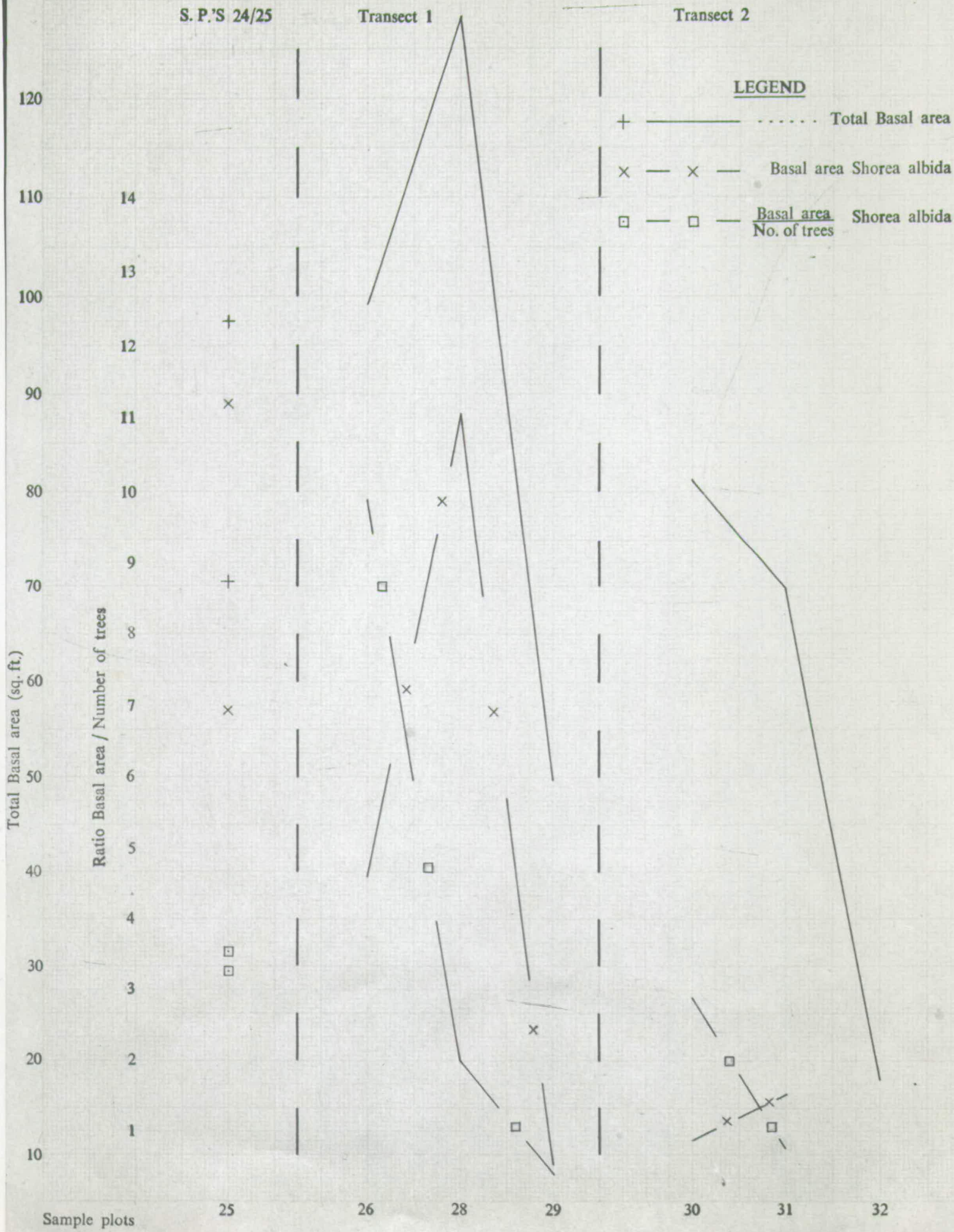
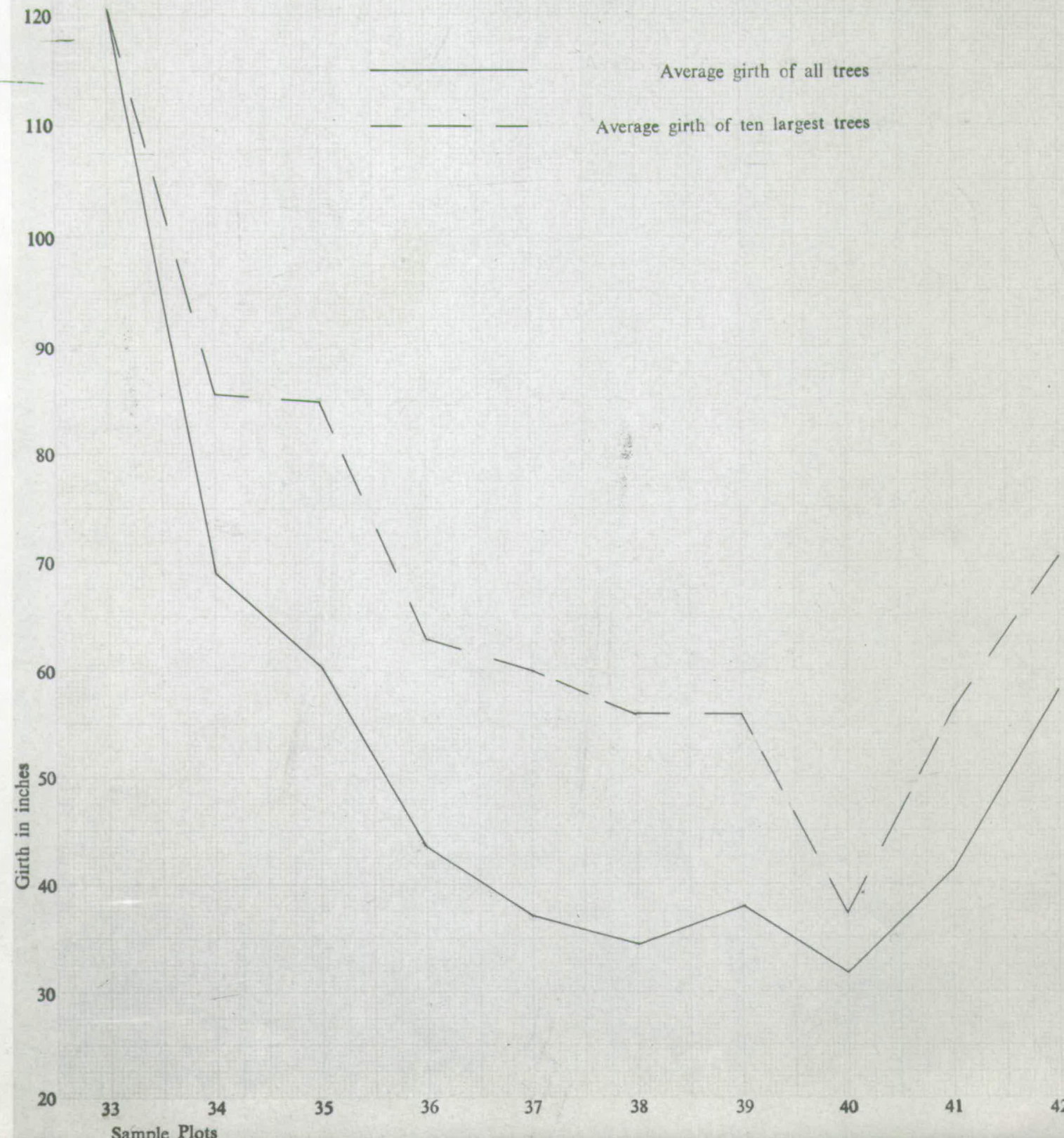


Figure 24

AVERAGE GIRTHS OF SHOREA ALBIDA IN SAMPLE PLOTS
IN THE BADAS AREA, BRUNEI



GIRTH CLASS REPRESENTATION OF SHOREA ALBIDA AND ALL SPECIES IN SAMPLE PLOTS IN BADAS FORESTS, BRUNEI

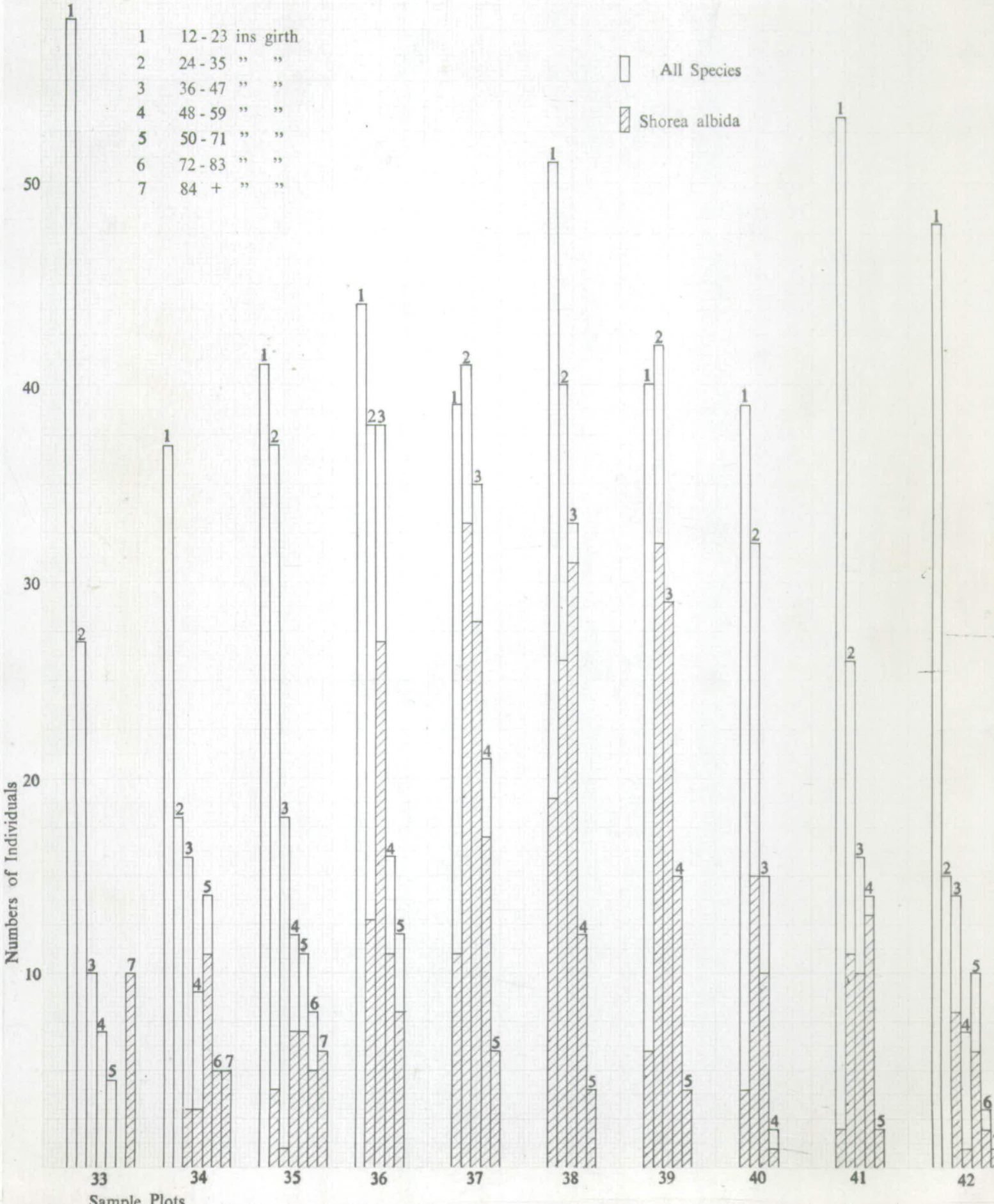


Figure 25

NUMBERS OF SPECIES AND INDIVIDUALS IN SAMPLE PLOTS
IN THE BADAS AREA, BRUNEI

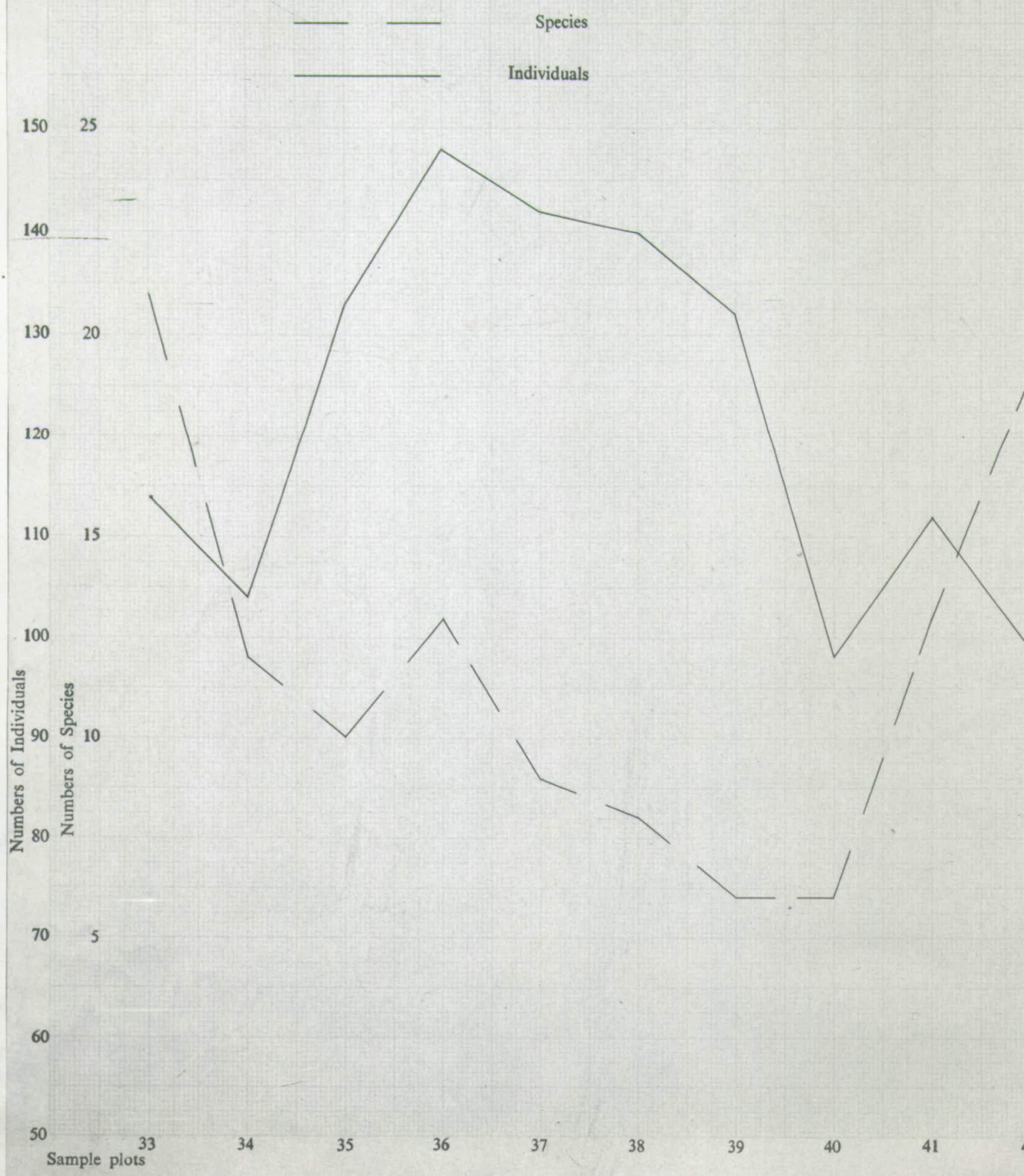
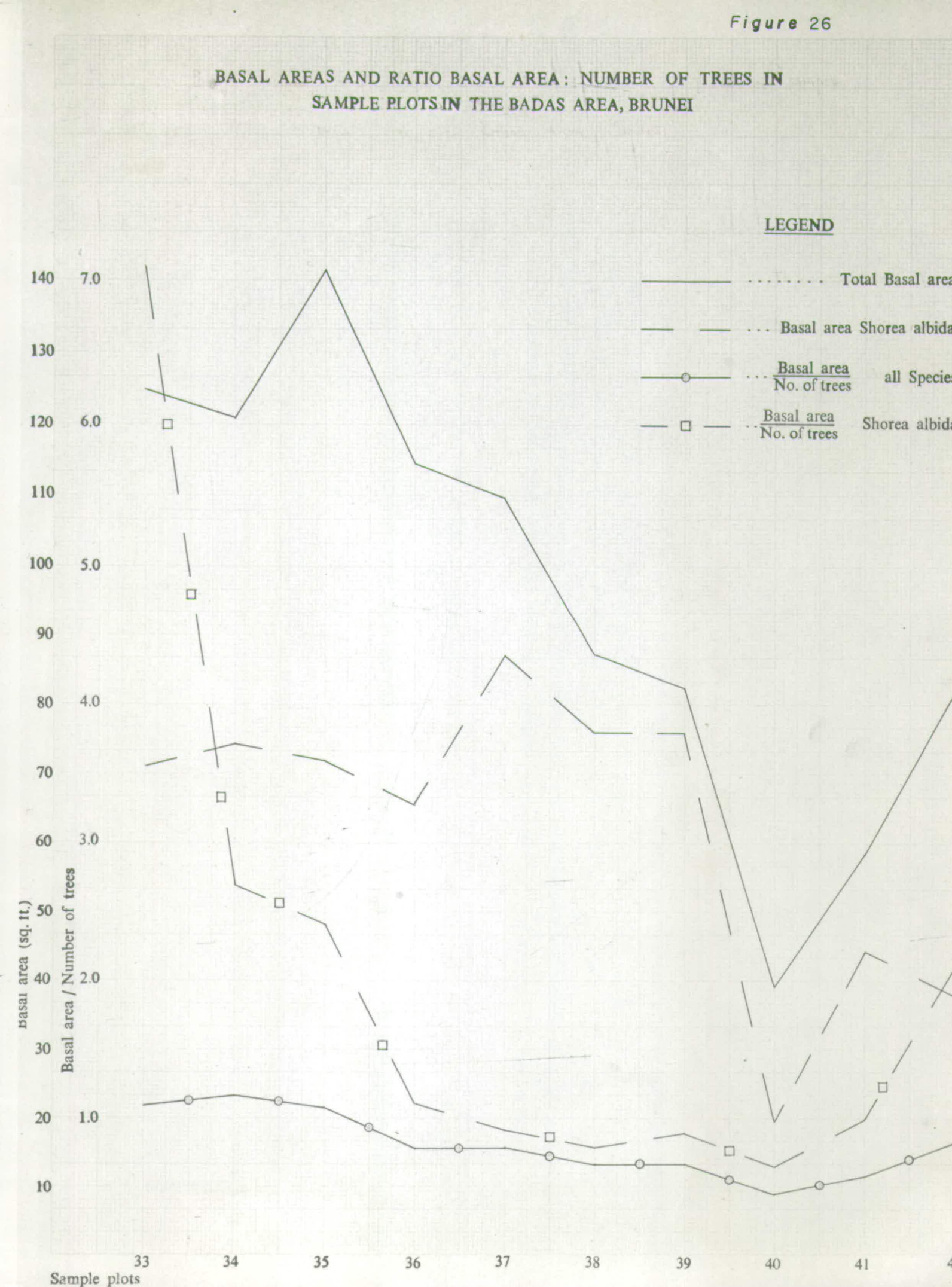


Figure 26

BASAL AREAS AND RATIO BASAL AREA : NUMBER OF TREES IN SAMPLE PLOTS IN THE BADAS AREA, BRUNEI



Chapter 7

Classification and comparison of the forest types

98. In the preceding chapter the results of a series of sample plots and transects, located in all the major areas of peat swamp in Sarawak and Brunei, indicate that the vegetation tends to follow a similar pattern from the perimeter to the centre of each swamp. Briefly this sequential pattern represents a change from an uneven canopied high forest, mesophytic and composed of a complex mixture of species (similar in structure and physiognomy to lowland dipterocarp forest) to a similar forest but dominated by scattered enormous trees of Shorea albida. This is followed by an even canopied high forest in which Shorea albida is the sole dominant which in turn is replaced by a dense even canopied forest, in which few trees exceed six foot girth, with a xerophytic and attenuated aspect. This, towards the centre of some of the Baram swamps, is succeeded by a very dense pole-like forest with a low canopy and in which few trees exceed three foot girth, and finally by an open almost savanna-like forest which shows a high degree of stunting and xeromorphism and in which only two species exceed twelve inches girth. Accompanying these changes in the structure of the forest the following features are generally evident:

(i) a complete or almost complete floristic change from the perimeter to the centre of a swamp, with an extended floristic 'overlap' in between;

(ii) a decrease in the number of species per unit area;

(iii) an increase in the number of individuals per unit area;

(iv) a decrease in the average girth of a species.

99. In each locality all the basic 'types', as described above, may not be present. For instance, the pure Shorea albida forest was absent on the transect in the Rejang Delta (though it was present elsewhere in the same swamp), and the mixed forest does not occur on the perimeter of the Baram or Badas transects. Nevertheless the sequence of the vegetation types is similar in all areas, and there is no transposition of types.

100. As a general thesis it may be stated that this pattern of vegetation is determined by the edaphic conditions consequent on the development of the raised bog formations, and that the vegetation from the perimeter to the centre in a swamp mirrors conditions of increasing infertility.

101. It is convenient to borrow, modify and adapt certain terms which are used for the classification of similar patterns of soil vegetation units in Africa (though not in swamps). A topographical sequence of soils was originally defined and named a catena by Milne (30). Morison et alia (33), in a comprehensive study of certain African soils, enlarged upon the term and used it for the classification of certain soil vegetation units which are found in a catenary sequence. They also introduced, among others, the terms phase and phase community to describe the soil and vegetation units respectively. As these terms have been modified it is advisable, before proceeding further, to define them as used here:

Swamp catena or simply catena: a group of soil vegetation types linked in their occurrence by physiographic and developmental conditions of individual peat swamps and repeated in the same relationship to each other wherever the same conditions occur.

Phase: a stage in the development of the peat swamps, characterized by a typical structure of the raised bogs and a particular sequence of vegetation types. Evidence for the phasic development of peat swamps is included in Chapter 14, where the Phases are described.

Phasic Community: a vegetation unit, or forest type, distinguished by the floristic composition, structure and physiognomy of the forest.

It will be realized that each peat swamp (or raised bog), bounded by dryland forest, rivers, deltaic channels or mangrove forest forms a single unit in the ecosystem. From the limited knowledge at present available it is not possible to define 'soil phases', coextensive with the phasic communities, though correlations between the distribution of the phasic communities and the structure of the raised bogs will be further discussed in Chapter 13.

102. For practical purposes the phasic communities have been designated 'associations', but this does not presuppose that they may be considered discrete communities in accordance with the plant sociological classification of Braun Blanquet or any other system of classification. It is doubtful, indeed, whether discrete plant communities can be defined. The catenary sequence of the vegetation may be perhaps more appropriately considered as a 'continuum' in which each species favours a range of distribution, repeated in each unit (individual bog) of the ecosystem. As the subsoil has probably little or no influence on the edaphic conditions at the surface of deep peat swamps soil changes tend to be very gradual across any one bog. No sharp vegetational or floristic boundaries can be expected and broad

transitional zones generally occur between the phasic communities. Nevertheless the forest over large areas, tens or even a hundred of square miles, in a single swamp may be relatively uniform. Two floristic boundaries may be clearly defined: between the mixed forest on the perimeter and forest dominated by Shorea albida, and between the latter and the open stunted forest in the centre of certain swamps in the Baram. The Shorea albida forest may be further subdivided into three phasic communities, and a sixth community is marginal to the open stunted forest. The six phasic communities are:

Phasic Community 1 - Gonystylus-Dactylocladus-Neoscortechinia Association.

Phasic Community 2 - Shorea albida-Gonystylus-Stemonurus Association.

Phasic Community 3 - Shorea albida Consociation.

Phasic Community 4 - Shorea albida-Litsea Parastemon Association.

Phasic Community 5 - Tristania-Parastemon-Palaquium Association.

Phasic Community 6 - Combretocarpus-Dactylocladus Association.

Comparison of data from Phasic Communities

103. Data from all sample plots (except for Nos. 40-42) are assembled in Tables 18-20 and Figures 27-30. The plots have been arranged in the catenary sequence, and the subdivisions of the phasic communities are shown.

104. In the tables the characteristic floristic 'drift' in the catena is clearly illustrated. Species of the upper storey have a more clearly defined range of distribution than species of the middle and lower storeys. Only one species, Dactylocladus stenostachys,

Table 18. Distribution in sample plots and phasic communities of most frequently represented species of the upper storey.

Species	Phasic communities: P.C.1							P.C.2												P.C.3								P.C.4													P.C.5	P.C.6
	Sample plots: 52	13	14	19	20	1	2	26	27	33	17	18	3	4	21	5	6	7	8	15	16	22	24	25	34	35	28	30	9	10	11	12	23	36	37	38	39	41	40	29	31	32
Lophopetalum multinervium	2	1																																							
Tetramerista crassifolia		1	5																																						
Parishia sericea	2					1	2																																		
Shorea platycarpa	4		4			1																																			
Cratoxylon arborescens			1			5	1																																		
Shorea rugosa var. uliginosa		1	1	7	8	4	1				1																														
Parastemon urophyllum		2	2				1	2	1																																
Shorea scabrida	1				3	1	3					1	1	2	2																										
Shorea teysmanniana	5	1	1		9	1	3		1		1	1	3		7																										
Dryobalanops rappa					9	9	2	2			4	5	2	1																											
Mezzettia leptopoda	3	1				2	2	1	2		2		3		2																										
Shorea inaequilateralis						2	7				5	5	8	5		2	2	1																						
Copaifera palustris			1	6		1	3	1	3		5	6	3		5	4	4	5	1											1	1		1								
Dyera lowii	2	2	8		2	5	5	2		4	3	5	5	11	1	1	13	1	8		1		1	1	6	2	9						2	1							
Gonystylus bancanus	1	17	13	5	1	2	6	3	2	5	4	9	6	1	5	7	4	3	3				1	1	19	30	28	5	5	1	10	3		34	4				4		
Dactylocladus stenostachys			1			1		4	1	4	4	4			5	1	3	12	7	10	9	1		1	3	1		1	9	7	3	6	14	2	4	8	19	25	3	82	10	31
Melanorrhoea beccarii									2			1	1			12	13	4			1							2	5	8	7	4									
Shorea albida								4	5	10		3	8	5	6	15	10	8	12	25	26	34	27	16	27	30	44	4	35	32	56	76	8	59	95	92	86	38	30	23	15	1
Combretocarpus rotundatus								1	2	3					1	4	5	5	5	5	4	5	1	1	4	3	9	6	2	4	2	2	10	8	10	10		10	20	6	9	26
Litsea palustris								1							1	4	1	8	8			3	4	3				1	22	10	25	23	12			1		4	1		21	
Calophyllum obliquinervum						1													5						2	6			4	3	5	1	1	2							
Cratoxylon glaucum																												19				2									
Tristania obovata																												5	9	20	1	6	12			7		6		46	48	
Tristania maingayi																																	31									

Table 19. Distribution in sample plots and phasic communities of the most frequently represented species of the middle storey.

Species	P.C.1							P.C.2												P.C.3																				P.C.4																		P.C.5		P.C.6	
	Sample plots																																																										
	52	13	14	19	20	1	2	26	27	33	17	18	3	4	21	5	6	7	8	15	16	22	24	25	34	35	28	30	9	10	11	12	23	36	37	38	39	41	40	29	31	32
Alangium havilandii	1	5	2	2		4	2	6	1																																																		
Litsea nidularis	1			6																																																				
Stemonurus scorpioides		4	2				11																																																
Campnosperma coriacea	1	1	1			1																												1				1		1															
Xylopia coriifolia		1				2		1					1															5										3			10														
Santiria rubiginosa	2			3		1	2	1			1																																													
Polyalthia hypoleuca	2			1			1	4	6	13	1	2																2																												
Amoora rubiginosa							1				1	1																																											
Alseodaphne insignis							3						3	1	4	4																																							
Santiria laevigata		4	1		5			2	1					1																																								
Quercus wenzigianus		1	6				3	3				1	1	1																																								
Palaquium walsurifolium	10					3	3				2		9	3																																								
Garcinia vidna	1			1			1			2		1	3	2		1																																						
Blumeodendron subcaudatum		6	2			2	2				3	5	1			7	2	1	1																																				
Alseodaphne rigida	1	2	3	2	1			1				1												1																															
Horsfieldia crassifolia			1	1	1	1						1		1																																									
Ctenolophon parvifolius	2	1	1		1	1	2				3	5			1	1	1																																					
Blumeodendron tokbrai	12	7	5	5	3			8	4			1	1		7																																						
Palaquium pseudorostratum			2	1	4	1						1	1	1		5	1																																				
Nephelium melanomiscum	3	1	1		13	1								1	1				2									1																									
Diospyros pseudomalabarica	11	1	1	5	2	3	2			2	2	2			4	1		1	1																																		
Palaquium pseudocuneatum		2	1			1			3						1																																						
Ganua coriacea	9				1	5	6	5	5		8	11	9	9		4	5	6			1							1																										
Aromadendron nutans						2	5		1		1	1	9			2	1						2																															
Palaquium ridleyi						1	1	2			1	1	2	3		2	2	2	1		1							2			1																						
Cyathocalyx biovulatus	2	1		3	1	2		3	3	3	1	3	12	15	3							1					3	1																										
Diospyros evenis	4	1	1	2	10	1	1			7			1	1	8	1							2			3	2	36						3	1				16												
Vatica mangachapoi					1	1			3			1	2	1	1	1								1	1																												
Polyalthia glauca											1	4	1	1		2	1																																				
Ganua curtisii									48																35	56							20																			
Swintonia glauca											3	3	2			2	6	7	3	6	8								4	5	8	11																			
Longetia malayana		1		1		1				1	1		1	1		5	1		1									5																								
Calophyllum retusum											1							5	6			5							11	3	7	8	1							11											
Parastemon versteeghii									2	1							1	6	1			5	1	3	4		11	6	23	20	19	22	51	2		16	24	17	24	67	33										

Table 20. Distribution in sample plots and phasic communities of the most frequently represented species of the lower storey.

Species	Phasic Communities: P.C.1							P.C.2												P.C.3								P.C.4														P.C.5	P.C.6
	Sample plots: 52	13	14	19	20	1	2	26	27	33	17	18	3	4	21	5	6	7	8	15	16	22	24	25	34	35	28	30	9	10	11	12	23	36	37	38	39	41	40	29	31	32
Adenanthera pavonina	1				1		1		1																																	
Xerospermum muricatum	9	1	1	1		1						1																															
Xanthophyllum cf citrifolium		3				1					1																															
Knema kunstleri		1	3	1								1																														
Litsea gracilipes		1		1	1						1																															
Litsea cylidrocarpa	5	4	1		4	5	1		1		1	1	1																													
Gymnacanthera engeniifolia	2	2	1	2		1	1	2	2		2	3																														
Neoscortechinia Kingii	11	7	14	9	10	4	11				14	12	6	5	7		1																									
Eugenia nemestima							2		1			1		3			3																										
Garcinia tetranda	6	1		1			2	1			2	1			2							1																				
Dillenia pulchella var.	4	8	6	7	27	1		1	1				2	1	1	1	1																									
Castanopsis foxworthyi													1	2				1	4																							
Eugenia chitismannii	2			5		3						1	1		1			1	1	1																						
Litsea resinosa	3			3				2	5	1	1				2								1			2																
Mezzettia umbellata								1	1	1		1		2		2	1										1															
Diospyros elliptica								1	1				1	2				1	1																							
Xanthophyllum amoenum	7	6	5		1				3	2		1			5							4	1	3			3															
Eugenia cerina				1	2				3			1	1	1				1																								
Stemonurus umbellatus		1	1	1	5	6	6	3	3	5	6	7	6	3	2	8	2	5	1	3					1			6													
Quercus jaheri					1	2					2	1	3	1	2	2		1	4																						
Sindora leiocarpa					2	2					1	2	2			1	1	1																							
Trigoniastrum hypoleucum												2				2	2	1																							
Lophopetalum rigidum											2	3	15	9		27	18	21	28	3								3	3	1	1										
Canthium didymum	1	1						2	1		2	2	1	1	1	1	2	3		1	4	1						6				2	2							2	
Cephalomappa malloticarpa						19					31		2	6			1	29	23	64	38								1	1											
Baccaurea bracteata			2														1						1					1													
Ilex hypoleuca					2			1	1														10	7			1														
Tetractomia holttumii	3				7			1							38							33	1					1												
Sterculia rhoidifolia										1			2			2		3	2	1				1		1	1	4	2			1		2	1		1			2	
Quercus sundaicus														3				2	1				2	8			2													
Eugenia sp. (2715)					4																								4	1	1	4								
Elaeocarpus obtusifolius						1								1				1						1					2		3		1						1	1
Androtium astylum																			2		1								1											
Arthrophyllum rubiginosum																1	1												2			1								1
Xanthophyllum sp. (2614)									1	1					1				1			2	22	12				13	1	3			3		1	1	1	1		1	1
Eugenia sp. (2822)								3															1	1											1	3	2				
Ternstroemia hosei																	1	1					1	1				1	4	6	11	9					1		3	1
Ilex sclerophylloides																																	3								
Palaquium cochlearifolium									1								1	3	3	2	2	4	1	1	1	1	9	11	6	1	1	3	1	10	25	5		1			36	54
Garcinia rostrata																							3	2	1				2								2	10			1

occurs in all phasic communities, though, whereas in Community 1 it occurs as a large tree (girth exceeding fourteen feet have been recorded), in Community 6 it barely reaches twelve inches girth and more frequently it is merely a small stunted tree or shrub. Campnosperma coriaceum is the only species known to have a discontinuous distribution in the catena. Near the coast it is very abundant in Community 1, especially on shallow peat, but it is absent from Communities 2 and 3, reappearing again in 4 and 5. The distribution of a species in the catena in different localities is relatively constant. There are however certain exceptions: Diospyros evenis is confined to Communities 1 and 2 in the Rejang Delta, but in the Baram and Badas swamps it occurs right through to Community 5. Longetia malayana is a similar exception. Few species are entirely confined to the intermediate phasic communities: Cephalomappa malloticarpa, Melanorrhoea beccarii, Quercus sundaicus and Lophopetalum rigidum (Rejang Delta only) are the most prominent examples, occurring in only Communities 2, 3 and 4, and being absent or very rare in Communities 1, 5 and 6.

105. The numbers of tree species, exceeding twelve inches girth, per half acre (Fig. 27) decrease from fifty-five in Communities 1 and 2 to a minimum of only three in Community 6. The number in the Shorea albida Consociation (P.C. 3) is generally less than in the succeeding community. The number of trees per sample plot (Fig. 28) is relatively constant in Communities 1 and 2, but there is a significant decrease in the Shorea albida Consociation, followed by a further increase in Community 4, reaching a maximum of approximately 260 individuals per half acre in the dense pole-like forest of Community 5.

106. The maximum basal areas (Fig. 29) are to be found in Communities 2 and 3, where large Shorea albida predominate in the canopy. It is of interest to note that the basal areas in Community 4 are consistently higher than in Community 1, despite the fact that in the former community trees rarely exceed six feet girth. This is an interesting ecological fact, considering the apparently less fertile conditions in Community 4, and also the xerophytic aspect of the forest.

107. The average girth of a species declines in the catena. This surely is an index of increasing infertility. Examples have been given in the previous chapter. The decrease is most pronounced for Shorea albida. The ratios, basal area to number of trees of this species, are shown in Figure 30. It will be noted that on the average the ratio in Community 3 is double or treble that in Community 4. Though when all species are considered (Fig. 31) the ratio is as high in Community 4 as it is in Community 1. The latter community is composed of a few large dominants and middle storey trees and numerous small understorey trees, whilst in Community 4 there are no large trees but a high proportion of trees in the twenty-four to forty-seven inch classes.

108. A summary of the principal features of the phasic communities is shown in Table 21, and more detailed descriptions follow in succeeding chapters.

109. The catenary sequence in the Baram swamps is a somewhat remarkable ecological phenomenon. Over a distance of only a few miles (in some localities less than a mile) changes occur in the structure and physiognomy of the forest corresponding to a change from typical tropical rain forest to the tundra fringe; equivalent

Table 21. Summary of principal features of phasic communities

Phasic Community Association	1. Gonystylus Dactylocladus Neoscortechinia Association.	2. Shorea albida Gonystylus Stemonurus Association.	3. Shorea albida Consociation	4. Shorea albida Litsea Association	5. Tristania Parastemon Palaquium Association	6. Combretocarpus Dactylocladus Association
Local name of community	Mixed Swamp Forest	Alan Forest	Alan Bunga Forest.	Padang Paya Forest.	-	Padang Keruntum Forest.
Principal tree species	Gonystylus bancanus, Dactylocladus stenostachys, Shorea spp.(4), Dyera lowii Copaifera palustris	Shorea albida, Gonystylus bancanus, Shorea inaequilateralis, Dyera lowii	Shorea albida, Combretocarpus rotundatus, Gonystylus bancanus, Dyera lowii	Shorea albida, Litsea palustris, Parastemon versteeghii, Combretocarpus rotundatus, Tristania obovata	Tristania spp. (2), Parastemon versteeghii, Palaquium cochlearifolium, Dactylocladus stenostachys	Combretocarpus rotundatus Dactylocladus stenostachys
Shrub and ground flora species	Abundant; Zalacca conferta, Thorachostachyum bancanum, aroids	Frequent; Thorachostachyum bancanum, Nepenthes bicalcarata	Variable; Nepenthes bicalcarata, Pandanus andersonii	Abundant; Nepenthes spp. (4), Ficus motleyana, Euthemis obtusifolius	Sparce; Thorachostachyum bancanum and Pandanus ridleyi	Abundant; Thorachostachyum bancanum, Pandanus ridleyi, Tetraria borneensis
Lianes	Abundant; Ficus spp. (stranglers), Uncaria ovalifolia	Frequent: Korthalsia rigida	Very rare	Very rare	Large lianes absent	Absent
Epiphytes	Sun and shade epiphytes abundant.	Sun and shade epiphytes frequent.	Sun epiphytes rare, shade epiphytes occasional: Bulbophyllum beccarii.	Rare, except near ground level	Rare	Sun epiphytes abundant, especially myrmecrophytes: Hoya spp., Dischidia spp.
Aspect of forest.	Mesophytic, uneven canopy, middle and lower storeys dense, typical rain forest.	Mesophytic; Uneven canopy; dominated by large Shorea albida; middle and lower storeys dense.	Pure even canopy, middle storey sparce, lower storey moderately dense.	Xerophytic; even canopy pole-like forest, all trees with small crowns and attenuated boles.	Very dense pole-like forest.	Markedly xerophytic, open forest, stunting apparent.

Table 21 cnd.

Height of canopy (ft.)	120 - 150	120 - 170	160 - 190	90 - 120	40 - 70	Canopy not closed largest trees 40-50 ft.
Av. number of species per half acre	46 (range 35-55)	42 (range 30-55)	14 (range 10-20)	22 (range 19-26) Badas 10	11 - 18	3
Av. number of trees per half acre	135(range 120-160)	131(range 120-155)	102(range 65-125)	153(range 135-185)	240-280	60
Av. total basal area of all species per half acre (sq. feet)	73	98	108	92	50-70	18
Shorea albida						
(i) No. of trees per half acre		8.0	28.6	54.1	15-25	
(ii) Average girth (ins. g.b.h.)		97.2	69.4	34.9	30.9	
(iii) Average basal area per half acre (sq. ft.)		46.3	78.5	49.3	0.4-1.1	

INDEPENDENCE BOND

to an altitudinal zonation at the equator of approximately 11,000 feet or a latitudinal change at sea level of approximately 65 degrees. Moreover it is clear that this sequential variation in the peat swamps is solely caused by the edaphic factor. The following features, in particular, in the catena may be noted.

(i) changes from a mixed uneven canopied forest to a dense even canopied forest dominated by a single species, to a mixed rather open even canopied forest and finally to an open forest;

(ii) the decrease in the average girth of species is compensated by a greater number of individuals per unit area and consequently the basal areas in dense even canopied forest are generally greater than in mixed uneven canopied high forest.

Figure 27

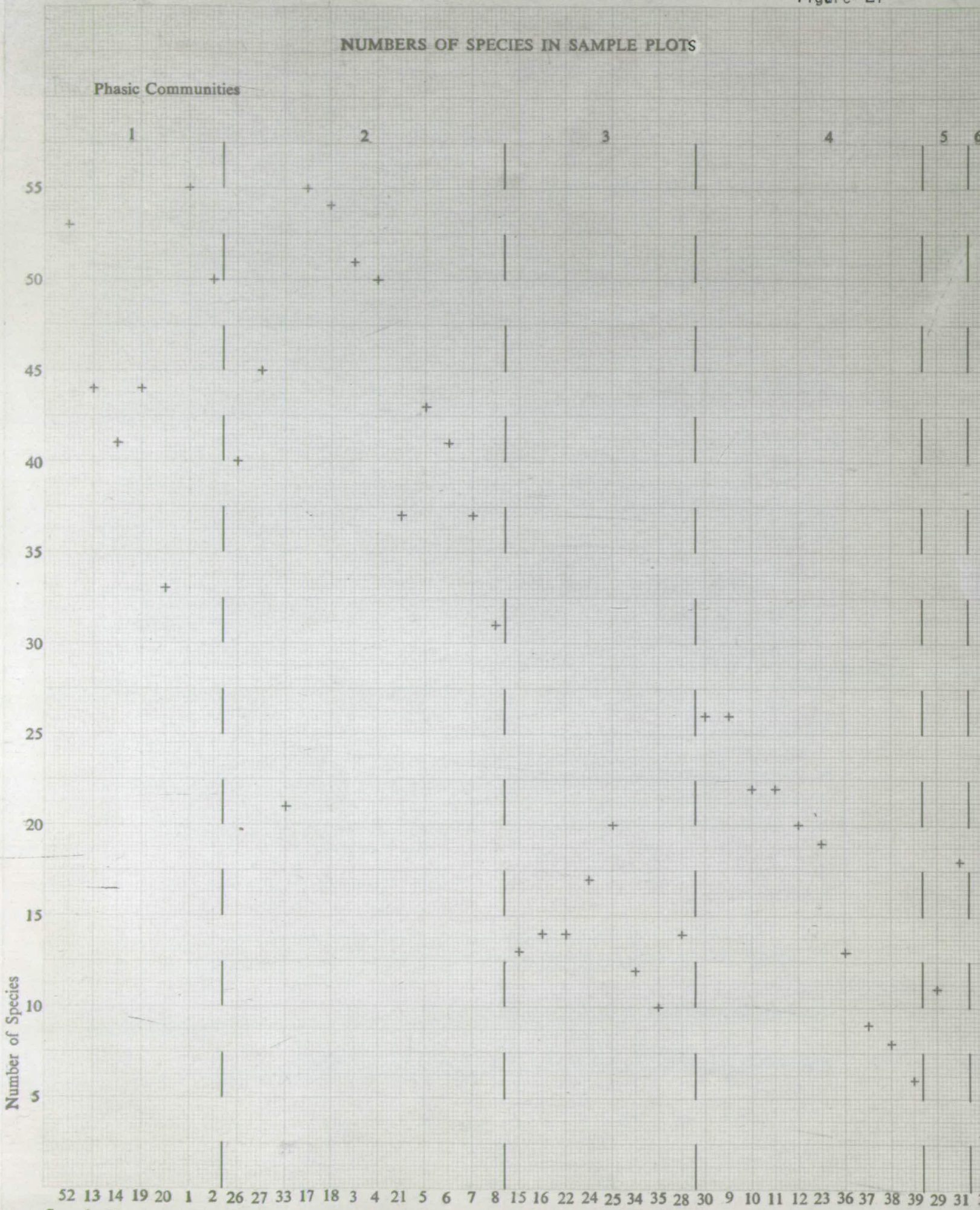

NUMBERS OF SPECIES IN SAMPLE PLOTS
Phasic Communities
1
2
3
4
5
6
55
50
45
40
35
30
25
20
15
10
5
Number of Species
52 13 14 19 20 1 2 26 27 33 17 18 3 4 21 5 6 7 8 15 16 22 24 25 34 35 28 30 9 10 11 12 23 36 37 38 39 29 31
Sample Plots

Figure 28

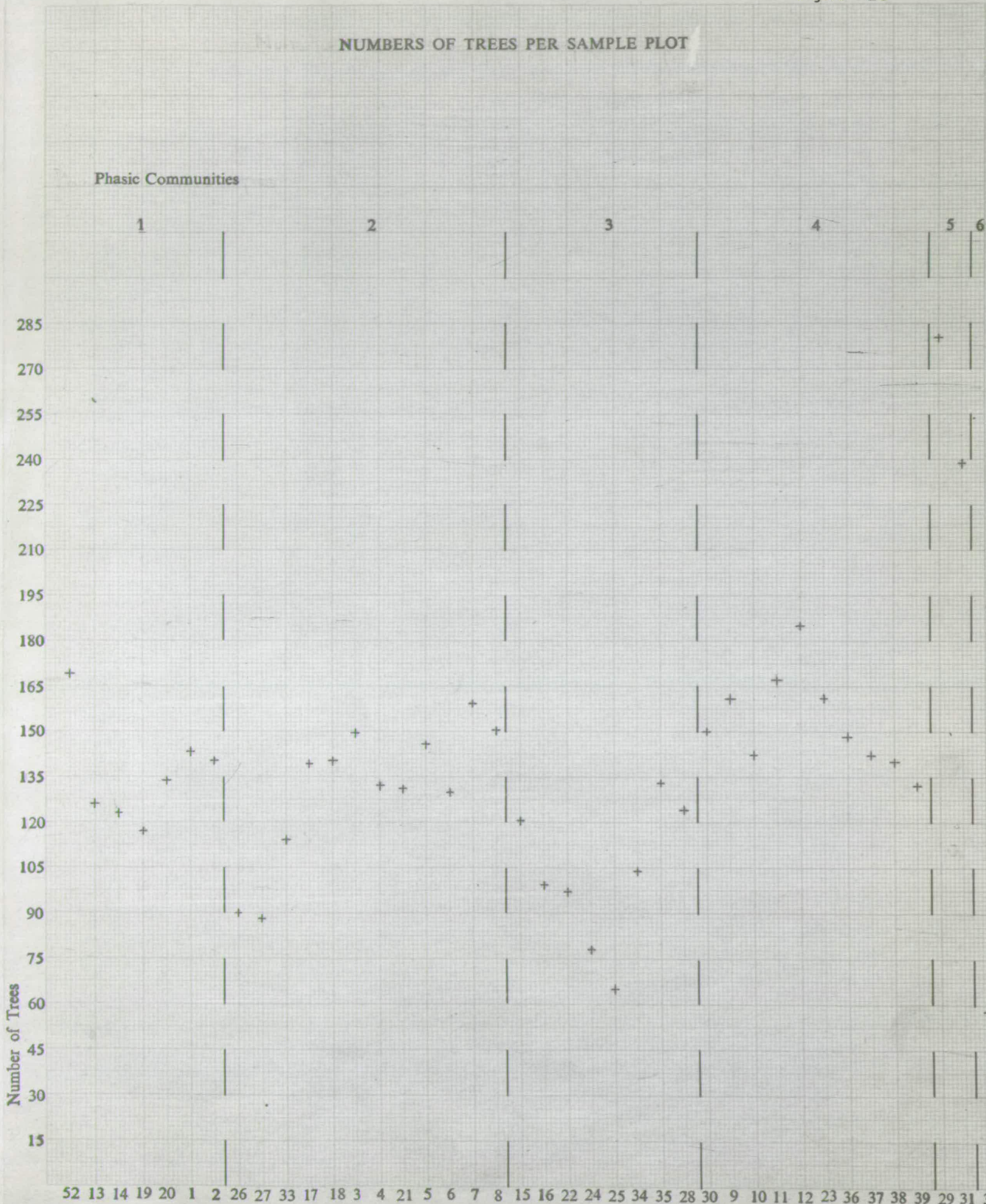

NUMBERS OF TREES PER SAMPLE PLOT
Phasic Communities
1
2
3
4
5
6
285
270
255
240
225
210
195
180
165
150
135
120
105
90
75
60
45
30
15
Number of Trees
52 13 14 19 20 1 2 26 27 33 17 18 3 4 21 5 6 7 8 15 16 22 24 25 34 35 28 30 9 10 11 12 23 36 37 38 39 29 31
Sample Plots

Figure 29

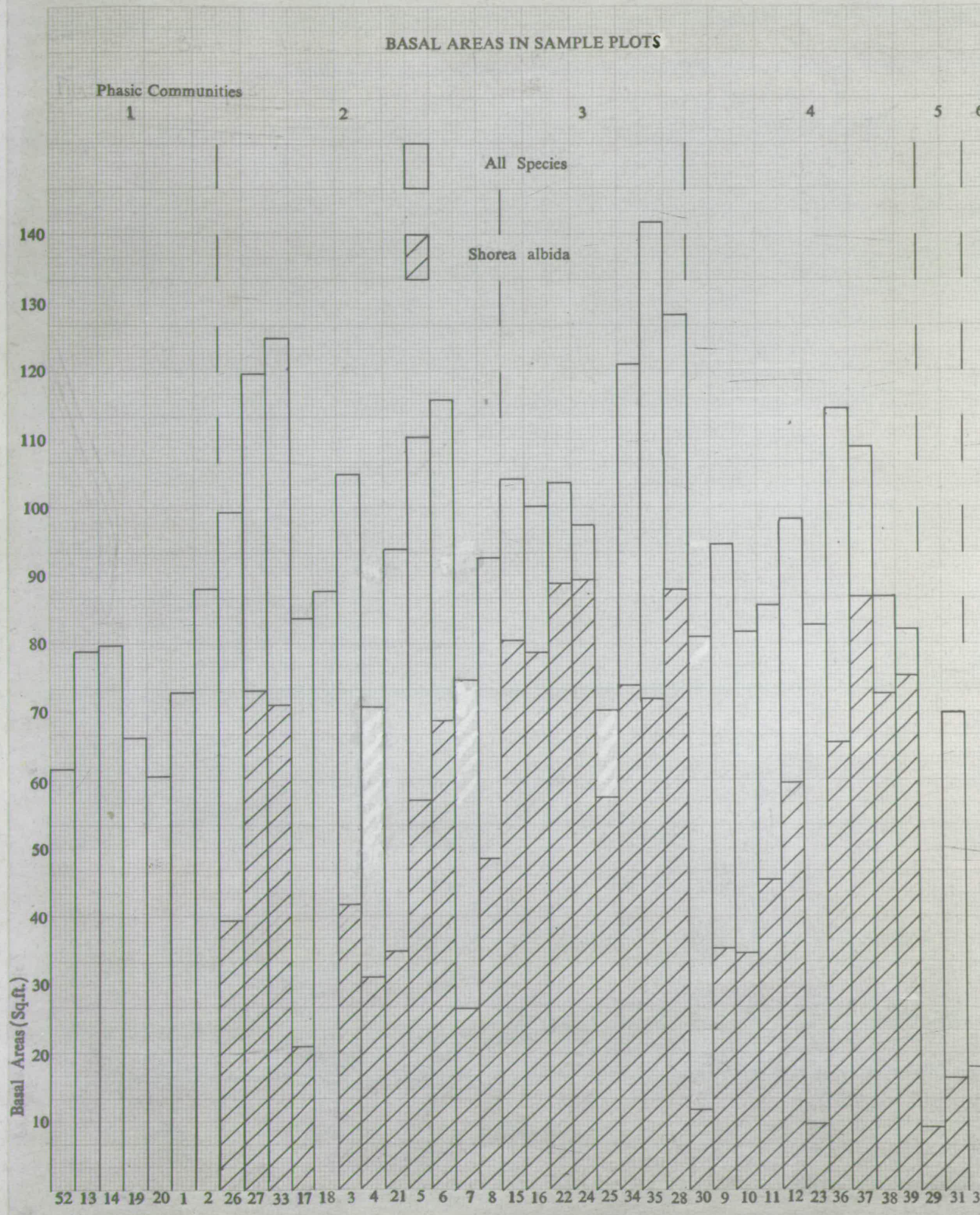

BASAL AREAS IN SAMPLE PLOTS
Phasic Communities
1
2
3
4
5
All Species
Shorea albida
140
130
120
110
100
90
80
70
60
50
40
30
20
10
Basal Areas (Sq.ft.)
52 13 14 19 20 1 2 26 27 33 17 18 3 4 21 5 6 7 8 15 16 22 24 25 34 35 28 30 9 10 11 12 23 36 37 38 39 29 31
Sample Plots

Figure 30

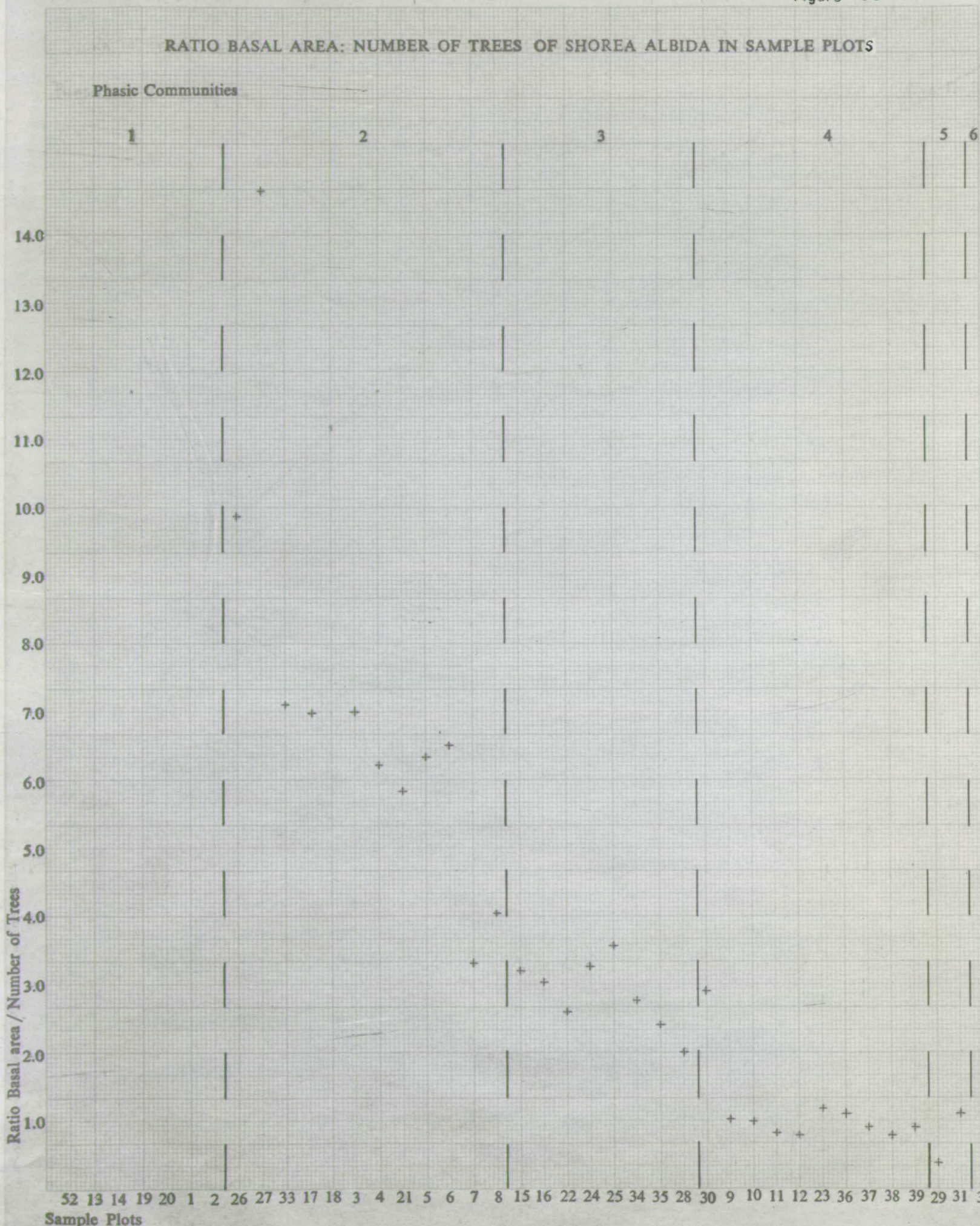
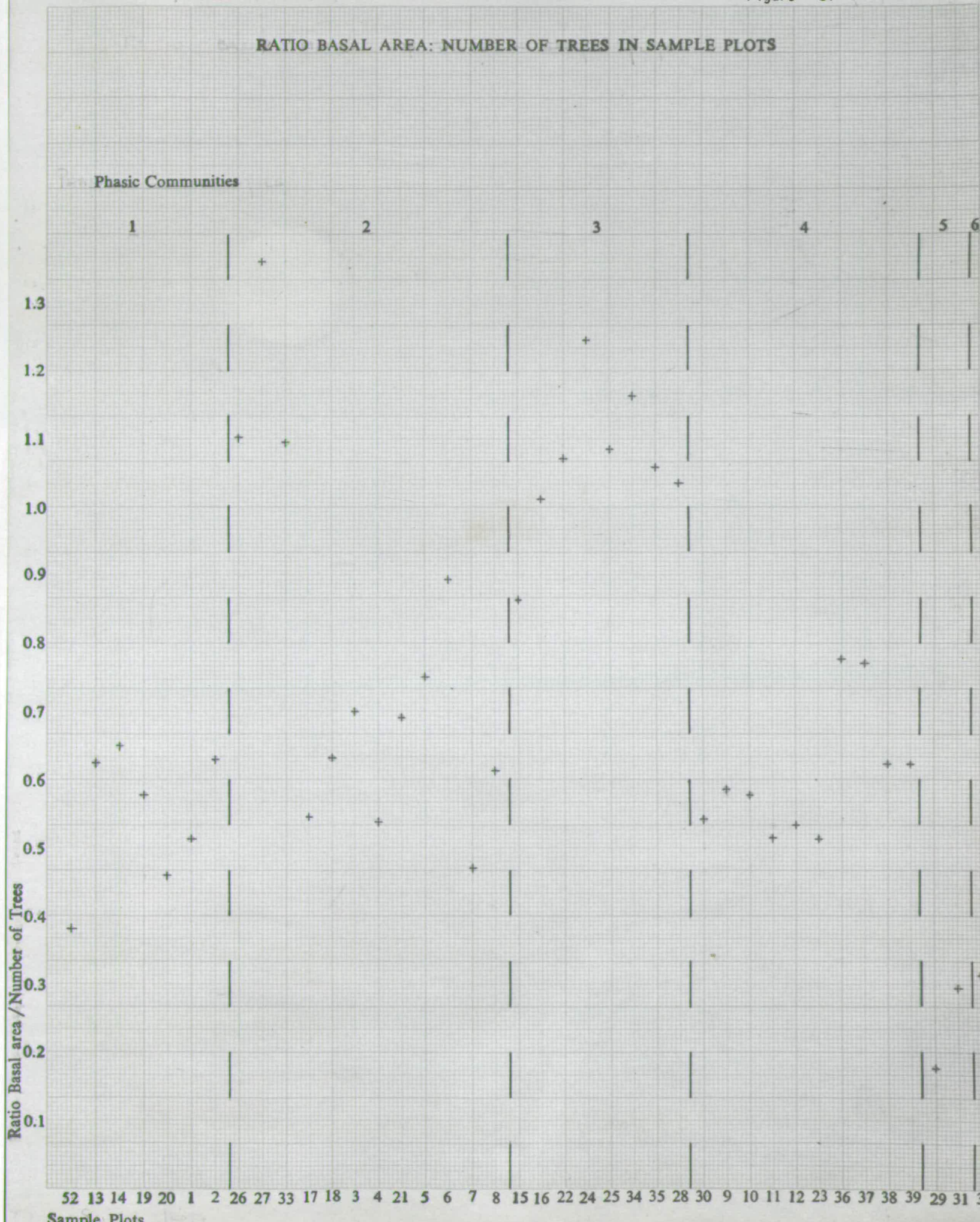

RATIO BASAL AREA: NUMBER OF TREES OF SHOREA ALBIDA IN SAMPLE PLOTS
Phasic Communities
1
2
3
4
5
6
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Ratio Basal area / Number of Trees
52 13 14 19 20 1 2 26 27 33 17 18 3 4 21 5 6 7 8 15 16 22 24 25 34 35 28 30 9 10 11 12 23 36 37 38 39 29 31
Sample Plots

Figure 31


RATIO BASAL AREA: NUMBER OF TREES IN SAMPLE PLOTS
Phasic Communities
1
2
3
4
5
6
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Ratio Basal area /Number of Trees
52 13 14 19 20 1 2 26 27 33 17 18 3 4 21 5 6 7 8 15 16 22 24 25 34 35 28 30 9 10 11 12 23 36 37 38 39 29 31
Sample Plots

Chapters 8 - 10

Description of Phasic Communities

Brief descriptions of the six phasic communities follow in Chapters 8-10. Only the more abundant and frequently represented species are mentioned; complete lists of species occurring in the communities have not been included. For the distribution of species in Sarawak and Brunei and their occurrence in the phasic communities reference should be made to the ecological classification in Appendix 3.

In describing the composition of the arboreal flora it is convenient to classify the trees into four storey classes based on the average maximum girth attained by a species, though this does not presuppose, as mentioned previously, the existence of defined strata. The storey classes are: upper storey sixty inches and over; middle storey twenty-five to fifty-nine inches; lower storey twelve to twenty-three inches; and understorey, trees that rarely attain twelve inches girth. This classification applies to Phasic Communities 1-3, but in Phasic Communities 4-6, upper storey trees are those that attain the canopy, though frequently they may be less than forty-eight inches girth.

Chapter 8

Phasic Community 1

(Gonystylus-Dactylocladus-Neoscortechinia Association)

110. The Gonystylus-Dactylocladus-Neoscortechinia Association, the first phasic community in the catena, locally known as Mixed Swamp forest, covers approximately 4,445 square miles in the peripheral zone of swamps, particularly in the Rejang Delta, and on bogs of relatively recent development along the coast. Its distribution tends to become increasingly more marginal on highly developed raised bogs further inland; in the middle reaches of the Baram river it is almost absent.

111. The peat soil is overlaid by a litter layer approximately a half to one inch in depth, beneath which there is usually an indistinct layer, of about six inches depth, of semi-decomposed vegetable matter in which feeding roots are very abundant. The peat beneath has a dark chocolate brown soupy matrix in which semidecomposed or, in the case of larger woody material almost undercomposed, branches, roots, logs, etc., are compacted. The surface level of the swamp is slightly irregular, varying by approximately twelve to eighteen inches. The higher levels are found near the base of larger trees, especially those species, for example Gonystylus bancanus, Copaifera palustris and Dactylocladus stenostachys, which have no buttressing of the stem. The deeper depressions may be below the permanent stilted water table, and after a spell of heavy rain the pools in these depressions coalesce and excess water drains off. The water table is relatively constant; recorded variations do not exceed nine inches and excess water drains off relatively rapidly. Small streams of tea-coloured water drain

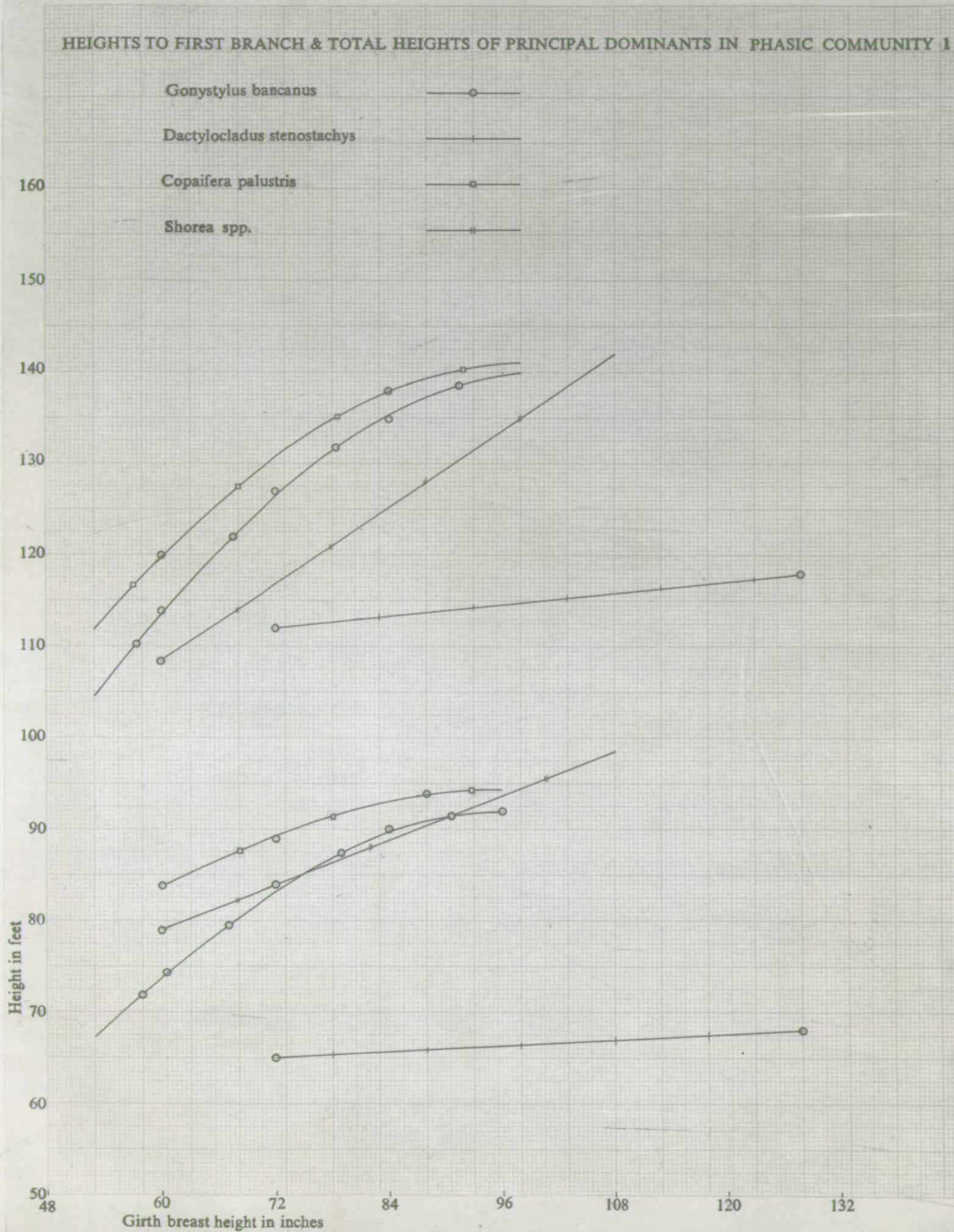
the bogs and these, in larger swamps, may be navigable by small boats for several miles. Level surveys indicate that surface levels in this community from the margins towards the centre of a swamp generally exceed three feet per mile and may on highly developed bogs exceed ten feet.

112. The structure and physiognomy of the forest in this community is generally typical of rain forest, though the average height of the dominants and the overall density are less and species per unit area fewer than found in lowland dipterocarp forest in Borneo. The forest is multi-storied with no marked discontinuity between the strata; the canopy is uneven and dense; trunks of trees tend to be straight and often sinuous; and leaves are largely mesophyllous, frequently with drip tips, especially in the lower storeys. Conditions at or near the swamp surface are shaded, damp and foetid. It is doubtful whether distinct stratification of the forest, such as described by Richards (44), exists. Proof of its presence would require a stratistical analysis of the structure of the forest. Some idea of the structure of the forest may be obtained from Profile Diagram 1 (Fig. 32). From this there are indications of three imprecise strata: a dominant strata between 100 and 140 feet, a middle storey between sixty and ninety feet, and a lower storey between twenty-five and forty-five feet. The total height of dominants averages between 120 and 140 feet. The occasional Shorea may exceed this, but in the preparation of volume tables for the principal dominants only one tree was recorded with a height in excess of 160 feet. The average total heights and heights to first branch of Gonystylus bancanus, Copaifera palustris, Dactylocladus stenostachys

Figure 32

Key to species on Profile Diagram 1 (Fig. 32)

1. Parastemon urophyllum
2. Sindora leiocarpa
3. Stemonurus umbellatus
4. Gonystylus bancanus
5. Ganua coriacea
6. Mangifera havilandii
7. Goniothalmus malayanus
8. Neoscortechinia kingii
9. Shorea inaequilateralis
10. Palaquium ridleyi
11. Cyathocalyx biovalatus
12. Eugenia aff. havilandii
13. Diospyros maingayi
14. Dyera lowii
15. Mezzettia leptopoda
16. Mussaendopsis beccariana
17. Palaquium walsurifolium
18. Diospyros elliptica
19. Quercus jaheri
20. Dryobalanops rappa
21. Samadera indica
22. Alseodaphne insignis
23. Stemonurus scorpioides
24. Blumeodendron tokbrai
25. Nephelium melanomiscum
26. Pometia pinnata
27. Ganua pierrei
28. Unidentified
29. Glochidion obscurum
30. Parishia sericea
31. Ctenolophon parvifolius
32. Alangium havilandii
33. Polyalthia glauca
34. Aromadendron nutans
35. Garcinia vidna
36. Blumeodendron subcaudaudatum
37. Trigoniostrum hypoleucum
38. Croton laevifolius
39. Quercus wenzigianus
40. Shorea rugosa var. uliginosa
41. Xanthophyllum amoenum
42. Dillenia pulchella
43. Santiria rubiginosa
44. Garcinia sp. (865)


HEIGHTS TO FIRST BRANCH & TOTAL HEIGHTS OF PRINCIPAL DOMINANTS IN PHASIC COMMUNITY 1
Gonystylus bancanus
Dactylocladus stenostachys
Copaifera palustris
Shorea spp.
160
150
140
130
120
110
100
90
80
70
60
50
Height in feet
48
60
72
84
96
108
120
132
Girth breast height in inches

and four species of Shorea (S. rugosa var. uliginosa, S. platycarpa, S. teysmanniana, and S. scarbrida) are shown in Figure 33. The data for the Shoreas has been grouped.

113. The principal trees of the upper storey in this community are Gonystylus bancanus, Dactylocladus stenostachys, Copaifera palustris and four species of Shorea. Enumeration surveys indicate that these species compose on the average at least seventy per cent of the trees exceeding seventy-two inches girth. Most of these species have a wide ecological distribution. Of those species that are characteristic of the community, i.e. generally confined to this community, mention may be made of Tetramerista glabra, Parishia sericea, Shorea platycarpa and Cratoxylon arborescens. The following is a list of the more widely distributed species:

Gonystylus bancanus	a	Melanorrhoea tricolor	lo
Dyera lowii	a	Alstonia spathulata	lo
Shorea rugosa var. uliginosa	f	Tetramerista glabra	r (lo)
Shorea teysmanniana	f	Dillenia pulchella	r
Shorea inaequilateralis	lf		
Dryobalanops rappa	lf	Koompassia excelsa	r
Dactylocladus stenostachys	o	Durio carinatus	r
Copaifera palustris	o	Parartocarpus forbesii	r
Cratoxylon arborescens	o	Anisoptera marginata	vr
Shorea platycarpa	o	Artocarpus rigidus	vr
Shorea scabrida	o		
Parastemon urophyllum	o		
Mezzettia leptopoda	o		

Photograph 7 . . The understorey of the Gonystylus Dactylocladus Neoscortechinia Association. In the centre of the photograph the understorey has been partially cleared along a trace. The tree to the left of the forest guard is an ebony (Diospyros ferrea var. buxifolia).

Photograph 8. A large Parishia sericea in the Gonystylus Dactylocladus Neoscortechinia Association. The large tree in the middle distance is a Dactylocladus stenostachys, o which a strangling fig is developing.

114. In the middle storey there are few species confined to this community. Two ebonies (Diospyros pseudomalabarica and D. evenis), Alangium havilandii, Blumeodendron tokbrai, and Ctenolophon parvifolius are the most abundant species. The more common species are:

Alangium havilandii	f	Aromadendron nutans	r
Diospyros pseudomalabarica	f	Palaquium pseudorostratum	r
Diospyros evenis	f	Amoora rubiginosa	r
Blumeodendron tokbrai	f	Xylopia coriifolia	r
		Kokoona ovatolanceolata	r
Palaquium walsurifolium	lf	Calophyllum retusum	r
Quercus wenzigianus	lf	Gonystylus forbesii	r
Ganua coriacea	lf	Polyalthia hypoleuca	r
Palaquium pseudocuneatum	o	Macaranga caladifolia	vr
Ctenolophon parvifolius	o	Calophyllum sclerophyllum	vr
Horsfieldia crassifolia	o		
Nephelium melanomisum	o		
Cyathocalyx biovulatus	o (lf)		
Campnosperma coriaceum	o (la)		
Santiria rubiginosa var. rubiginosa	o		
Santiria laevigata	o		
Stemonurus scorpioides	lo		

115. In the lower storey the most representative species, which is very widely distributed and abundant, is Neoscortechinia kingii. The commonest species are:

Neoscortechinia kingii	a (lva)	Garcinia tetranda	o
Dillenia pulchella var.	a		

Xanthophyllum amoenum	f (la)	Gymnacanthera eugeniifolia var. griffithii	o
Stemonurus umbellatus	o	Litsea resinosa	o
Eugenia chrismannii	o	Xanthophyllum aff. citrifolium	v
Litsea gracilipes	o	Adenanthera pavonina	v
Xerospermum muricatum	o	Canthium didymum	r

116. The understorey includes species that may be only a few feet in height, such as Antidesma phanerophlebium, Tarenna fragrans and Dehaasia sp. (4770), to those that may reach thirty feet, in height, though rarely attain twelve inches girth. No species is abundant in the understorey, which is very largely composed of saplings and poles of larger trees. A feature of understorey species is the localized occurrence of many: Luvunga motleyi is found in one or two areas in the Rejang Delta and has recently been recorded near Kuching; Knema ruliginosa is only known from the Loba Kabang Protected Forest, where it is abundant, Barringtonia gitingensis and Kibatalia sp. (9300) have only been recorded from swamps at the apex of the Rejang Delta. The more widespread species are:

Tarenna fragrans	f	Antidesma phanerophlebium	o
Knema kunstleri	f		
Cryptocarya griffithiana	o	Dehassia sp. (4770)	o
Chisocheton brachyanthus	o	Sarcotheca glauca	r
Elaeocarpus beccarii	o	Canthium umbellatum	r
Goniothalmus malayanus	o	Glochidion obscurum	r
Gaertnera borneensis	o		

117. The palmaceous flora of this community, and of the swamps as a whole, is not rich. Two species, Cyrtostachys lacca and Zalacca

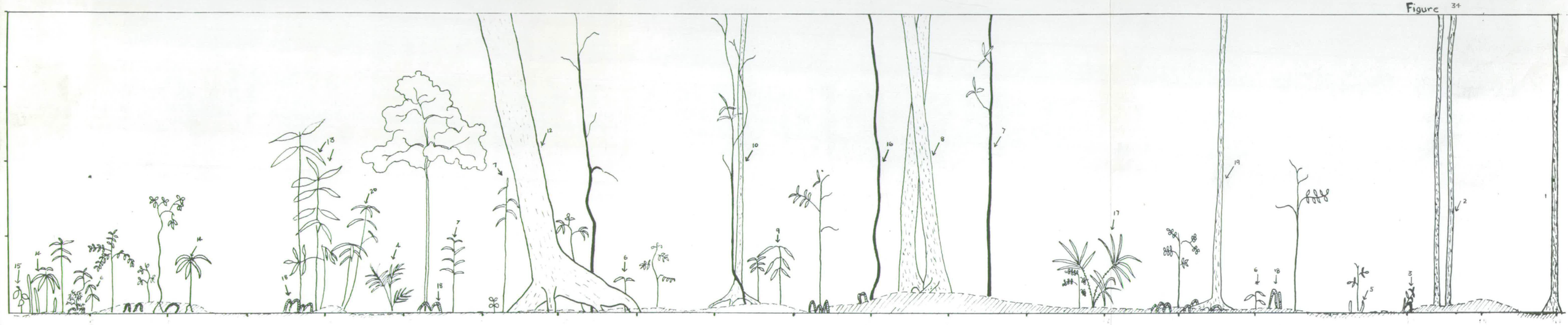
conferta are locally abundant, especially on shallow peat near the coast. The latter, a stemless palm with a formidable array of spines, frequently forms dense thickets that are a considerable obstacle in surveying and silvicultural work. Cyrtostachys lacca, an attractive thin-stemmed palm, may attain heights of twenty to thirty feet. Daemonorops longipes is less abundant and more localized.

118. The herbaceous vegetation is very largely composed of monocotyledons, including one sedge (Thorachostachyum bancanum) and many aroids. No grasses have been recorded, except the ubiquitous Paspalum conjugatum, an exotic coloniser in open disturbed forest. It has been noted that species of the herbaceous vegetation tend to have rather precise ecological requirements dependent on the degree of flooding of the habitat, which may be classified as follows:

(i) Swamp surface permanently or semi-permanently below the water table. The most characteristic species is the aquatic aroid Cryptocoryne pallidinervia. During particularly dry spells it may be found as a shrivelled plant on the surface of shallower pools. Homalomena rostrata, Hanguana malayana and Schismatoglottis sp. (8634) are also locally abundant in this habitat. A shorter form of Hanguana malayana is found in a slightly drier habitat.

(ii) Swamp surface subject to periodic inundation due to a rise in the water table, partially or wholly inundated during the wet season. The sedge Thorachostachyum bancanum is particularly abundant in this habitat, frequently forming almost a complete carpet on the surface. In the Rejang Delta a short stemless pandan, Pandanus brevifolius is found growing amidst the sedge. The aroids, Aglaonema simplex and

Figure 34



Key to species plotted on Profile Diagram 2 (Fig. 34)

1. Sindora leiocarpa
2. Polyalthia glauca
3. Argostemma psychotrioides
4. Thorachostachyum bancanum
5. Pneumatophores of Dactylocladus stenostachys
6. Seedlings of Gonystylus bancanus
7. Cephalomappa beccariana
8. Dactylocaldus stenostachys
9. Seedlings of Litsea resinosa
10. Quercus jaheri
11. Seedling of Pseudosindora palustris
12. Shorea teysmanniana
13. Knema kunstleri
14. Seedling of Garcinia tetranda
15. Seedling of Shorea inaequilateralis
16. Climbing fig on Dactylocladus stenostachys
17. Zalacca conferta
18. Pneumatophores of Gonystylus bancanus
19. Palaquium pseudorostratum
20. Actinodaphne sp.

Alocasia longiloba are frequent though of scattered occurrence. The two spiny aroids Cyrtosperma lasioides and Podolasia stipitata are rare; the former is more common in freshwater swamps.

(iii) Surface only occasionally or never inundated. The most striking feature of this habitat is the absence of herbaceous species. Seedlings of tree species may frequently be abundant, though on higher ground near the base of larger trees the swamp surface may be almost bare. The small scramblers, Aeschynanthus hians, and Pschyotria sarmentosa are occasional; Labisia pothoina and two small attractive orchids Zeuxine violascens and Cystorchris variegata var. purpurea have a wide distribution though are never common. The most characteristic components of the habitat are the terrestrial ferns Schizoloma coriaceum and Syngramma lobbiana; Asplenium longissimum and Asplenium tenerum have a more localized distribution.

119. A feature of Phasic Community 1 is the abundance of large kneed roots and pneumatophores. The most prominent of these belong to Dactylocladus stenostachys, Gonystylus bancanus, Copaifera palustris and Dyera lowii. Their average height above the swamp surface is approximately twelve inches, though the pointed pneumatophores of Dactylocladus stenostachys often exceed eighteen inches. The kneed roots appear to be frequently in small groups, and these groups form a small ecological niche (or synusium). Litter becomes lodged in the entwined groups and a specialized habitat is formed. Bryophytes are probably the first colonisers and in the developed habitat the ferns, Vittaria elongata, Syngramma labbiana and Schizoloma coriaceum, and the small herb, Argostemma psychotrioides, are the most typical species of the habitat. The small epiphytic orchid Appendicula aff. pendula

Photograph 9 . The surface of the swamp in the Gonystylus Dactylocladus Neoscortechinia Association, showing the tendency of the pneumatophores and knee roots to be grouped. The large knee root in the foreground belongs to Dyera lowii, and most of the remainder are of Gonystylus bancanus. The group in the centre is typical of the pneumatophore synusia and includes Argostemma psychotrioides and Syngramma lobbiana, growing on to accumulated litter.

Photograph 10 . A typical example of the pneumatophore synusia with Syngramma lobbiana and Vittaria elongata growing in a group of pneumatophores which has also been colonised by tree seedlings.

and Lecananthus erubescens are also of frequent occurrence, whereas Thorachostachyum bancanum frequently colonises the base. Tree seedlings may become established in the group and consequent of their growth the group may be broken up. Plates 6+7 show typical examples of this microhabitat. A typical profile of the swamp surface is shown in Figure 34.

120. Lianes and climbers are more abundant in this community than elsewhere in peat swamp forest, but they are less conspicuous and of smaller size than in lowland dipterocarp forest. The specialized rooting conditions probably limits the species representation. Of the climbing palms (rattans) there are only two species, Korthalsia rigida and Plectocomiopsis wrayi, that are of frequent occurrence. Neither of these reach large size. In consequence timber companies working in swamp forest have to obtain all their requirements for rafting from hill forest. Uncaria ovalifolia is the commonest and one of the largest lianes and is particuarly prominent in young secondary growth following exploitation. Richards (44) classifies climbers in rain forest by size and height they attain, and recognizes two groups: the large lianes which reach the crowns of the A and B storeys; and the smaller species, frequently herbaceous, growing in dense shade. It is proposed here to subdivide the first group into the larger lianes that generally reach the crowns of the dominants and the medium-sized lianes that are more frequently found in the crowns of middle storey trees. The principal representatives of the three groups are as follows:

(i) Large lianes:

Uncaria ovalifolia a Pyremidanthe prismatica o

Photographs 11 + 12 . Two photographs showing the surface of the swamp in the Gonystylus Dactylocladus Neoscortechinia Association. The water table is above the surface, though during a prolonged dry spell, it may be six inches lower. The numerous moss-covered pneumatophores will be noted. The seedling in the centre foreground of the upper photograph is Pseudosindora palustris, whereas the palm in the lower photograph is Daemonorops longipes.

Fibraurea chloroleuca	f	Mitrella dielsii	r
Korthalsia rigida	o	Willughbeia glaucina	r
Plectocomiopsis wrayi	o		

(ii) Medium-sized lianes:

Connarus semidecandrus	f	Lucinaea morinda	o
Rouea mimosoides	o	Urceola sp. (7909)	o
Erycibe sp. (9280)	o	Nepenthes ampullaria	o
Piper arborescens	o	Marumia nervosa	r
Tetrastigma sp. (9241)	o	Linostoma longiflorum	r

(iii) Small climbers confined to the lower storey:

Piper sp. (2811)	o	Rhaphidophora lobbii	o
Teratophyllum ludens	o	Stenochlaena palustris	o (la)
Gnetum neglectum	r		
Epipremnopsis media	o		

This generalized classification is not entirely satisfactory. Most species, in particular the smaller climbers in the understorey, tend to grow in a specialized habitat suited to their mode of rooting or climbing. Nepenthes ampullaria, for instance, the only pitcher plant that is commonly found in this community, frequently occurs as a terrestrial plant with the whorls of pitchers imbedded in the litter layer. It does, however, not infrequently adopt a climbing habit and may attain the crowns of middle storey trees.

121. The figs form an interesting group, which is largely confined to or more abundant in this community. Of the twenty-four species recorded in peat swamp forest only three (Ficus callicarpides, F. deltoidea var. motleyana, and F. deltoidea var. borneensis) occur frequently in other phasic communities. The group includes

stranglers, ground rooting epiphytes (see Chapter 4), epiphytes, large climbers and small root climbers. The ground rooting epiphytes are especially abundant, in particular on Gonystylus bancanus and Dactylocladus stenostachys. The more common species, arranged in accordance with their mode of habit are as follows:

(i) Stranglers: Ficus crassiramea - la (confined to shallow peat near the coast)
Ficus pellucido-punctata - lo (Rejang Delta)
Ficus sumatrana - r

(ii) Ground rooting epiphytes:
Ficus acamptophylla - o
Ficus consociata - lf
Ficus spathulifolia - lf
Ficus sundaica - f
Ficus sundaica var. beccariana - r
Ficus xylophylla - lf (Rejang Delta)
Ficus tristaniifolia - lf

(iii) Root climbers:
Ficus villosa - o
Ficus callicarpides - o

(iv) Epiphytes: Ficus deltoidea var. deltoidea - a
Ficus deltoidea var. borneensis - r
Ficus pisocarpa - r

No true tree fig has been recorded.

122. Epiphytic vegetation is abundant in this community though its floristic composition is certainly less rich than that found in lowland dipterocarp forest. Some of the common species occur both in hill and swamp forest. Epiphytes are largely confined to two distinct habitats: the crowns of the upper storey trees, occupied by the sun epiphytes; and within the understorey to a height of approximately twenty feet from the swamp surface where the shade epiphytes occur. The crowns of lower and middle storey trees and the upper boles of dominants are largely devoid of epiphytic vegetation.

123. Sun epiphytes are distributed along the branches of the crowns of the dominants. It has been noted that of the principal dominants, Gonystylus bancanus and Dactylocladus stenostachys have a much richer and denser epiphytic flora than the Shoreas or Copaifera palustris. It is probable that the soft fibrous bark of the former two species is more suitable for epiphytic growth than the smooth or brittle bark of the latter species. The sun epiphytes are largely composed of small orchids and ferns, of which the following are the more abundant species:

Dendrobium aff. merrillii	f	Vittaria hirta	o
Bulbophyllum vaginatum	lf	Humata angustata	r
Eria aff. obliqua	f	Lecanopteris sinuosa	r
Eria aff. pulchella	f		
Eria pannea	f	Phymatodes crustacea	r
Andenoncos sumatrana	o	Humata parvula	vr

124. The vertical distribution of shade epiphytes appears to be correlated with the moss on tree boles which rarely exceeds a height of twenty-five feet. It is probable that above this level there is

a rapid change in the humidity conditions. The shade epiphytes are less numerous than the sun epiphytes and show considerable variations in habitat, growth form and development. The following list of the principal species gives an indication of this diversity:

Medinilla laxiflora: on understorey trees at heights of from three to fifteen feet; ground rooting.

Medinilla sp. (9867): on rotting stumps above swamp surface.

Liparis lacerata: on understorey trees at heights from four to twenty feet.

Pycnarrheana borneensis: on understorey or lower storey trees at heights from six to twenty-five feet; ground rooting.

Poilkilospermum suavéolens and Poilkilospermum subtrinervium: on lower or middle storey trees at heights from ten to thirty feet, ground rooting, and subsequently adopting a climbing habit.

Crypsinus albidopaleatus: on rotting stumps, roots and pneumatophores above swamp surface to heights of three feet.

Lycopodium phlegmaria var. divaricatum: on understorey trees at heights of from two to fifteen feet.

125. The gap between the two epiphytic habitats is to some extent bridged by the nest ferns, Asplenium phyllitidis and Asplenium nidus, and the bracket ferns, Drynaria involuta and Drynaria quercifolia; these apparently can adapt themselves to a wide range of light and humidity conditions. The former group in particular may be found at heights ranging from a few feet above the swamp surface to the crowns of dominants. In addition the common ferns Paragramma longifolia, Pyrrosia longifolia and Vittaria ensiformis occur on boles of trees above the moss layer up to heights of approximately sixty feet.

Photograph 13 . The base of a spiny stemless palm, Zalacca conferta, which forms dense thickets in the Gonystylus Dactylocladus Neoscortechinia Association, especially on shallow peat near the coast and in disturbed forest.

Photograph 14. Typical epiphytic growth near the base of a large tree (Parastemon urophyllum) in the Gonystylus Dactylocladus Neoscortechinia Association. The pitcher plant at the base of the tree is Nepenthes ampullaria.

126. No saprophytic flowering plants have been recorded, and parasites are of rather rare occurrence. The very distinctive species, Lepidaria oviceps, and Dendropthoe falcata are occasionally found on the crowns of dominants. Macrosolen beccarii has a more localized distribution, and is unusual in being a shade parasite, occurring on the lower or understorey trees at heights from six to thirty feet. Myrmecophytes are an interesting group and include two trees, Macaranga caladifolia and M. puncticulata, a small herb, Clerodendron fistulosum, and two sun epiphytes, the ferns Lecanopteris sinuosa and Phymatodes crustacea.

127. The floristic composition of this community is not entirely uniform. Variations caused by the geographical distribution of the species have already been mentioned in a previous chapter. In addition ecological differences in coastal shallow peat swamps and deep peats further inland apparently limit the distribution of certain species, though basically the floristic composition and structure of the forest is similar. The most typical species of the coastal peat swamps are Alstonia spathulata, an enormous dominant, Campnosperma coriaceum, which in certain localities may form almost pure stands, and the palms Cyrtostachys lacca and Zalacca conferta. Other species include Lophopetulum multinervium, Planchonella maingayi, Xylopia fusca, Dacryodes incurvata, Litsea nidularis, Carallia brachiata and Dillenia pulchella. The most characteristic species of the inland form of this community is Melanorrhoea beccarii, which is abundant in peat swamps at the apex of the Rejang Delta. Melanorrhoea tricolor is also largely confined to inland swamps, though it does occur near the coast in the Tatau Protected Forest. Other typical species are

Dipterocarpus coriaceus, Shorea macrantha, Shorea pachyphylla, Swintonia glauca, Mussaendopsis beccariana, Mangifera havilandii and Barringtonia gitingensis. These species are either totally absent from or rare in coastal swamps. Shorea inaequilateralis has an interesting distribution. It is largely confined to well developed peat swamps where Shorea albida is present. It is in fact an associate of Shorea albida in Phasic Community 2 but also occurs in the peripheral Phasic Community 1 though it is almost totally absent from other communities in the catena.*

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* Since this chapter was completed an enumeration of one half acre plot (Plot 52) on shallow peat has been undertaken. The plot was located within a quarter of a mile of the coast near Bintulu. The depth of peat was three feet. The complete results are shown in Appendix 2, and the principal species recorded were Cyrtostachys lacca (111 trees), Camnosperma coriaceum (45 trees), Stemonurus scorpioides (48 trees), Sandoricum emarginatum (13 trees) and Cratoxylon arborescens (11 trees). Zalacca conferta was very abundant. The object of this enumeration was to obtain comparative data for the interpretation of the results of the pollen analysis (see Chapter 14). The transitional zone on shallow peat is provisionally considered as a sub-association in Phasic Community 1 and has been named the Campnosperma Cyrtostachys Zalacca association.

Chapter 9

Phasic Communities dominated by Shorea albida

128. Shorea albida, a gregarious species and a strong light demander, dominates Phasic Communities 2, 3 and 4, and is only found on moderately to well developed raised bogs, where it occupies the flat bog plain. It is in many ways a remarkable species that shows an ability to produce heavy stands of timber on extremely infertile deep peats.

Phasic Community 2. Shorea albida Gonystylus Stemonurus association.

129. This community is in many respects transitional between Communities 1 and 3, and yet must be considered separately as it covers very extensive areas, particularly in the Rejang Delta where Phasic Community 3 is almost absent. The transitional nature and ecological status of the community will be further discussed in Chapter 17.

130. The structure of the forest is similar to that in Phasic Community 1 (see Fig. 35) with the exception that the forest is dominated by enormous trees of Shorea albida. This is the most characteristic feature of the forest; large trees frequently exceed twelve feet girth and trees up to twenty feet girth have been recorded. Smaller trees less than seven feet girth are rare and poles and saplings virtually entirely absent. After a seed year seedlings may be abundant but they apparently do not survive. Large Shorea albida trees have the appearance of being moribund: they are usually stag-headed and wind-ravaged, from which they show a remarkable ability to recover; and stems are usually hollow, frequently only a thin outer

Figure 35

160
140
120
100
80
60
40
20
Feet
20
40
60
80
100
120
140
160
180
200
Feet

Key to species plotted on Profile Diagram 3. (Fig. 35)

1. Cyathocalyx biovalatus
2. Melanorrhoea beccarii
3. Palaquium pseudorostratum
4. Blumeodendron subaaudatum
5. Xanthophyllum amoenum
6. Actinodaphne aff. myriantha
7. Ganua pierrei
8. Quercus jaheri
9. Ganua coriacea
10. Stemonurus umbellatus
11. Palaquium cochlearifolium
12. Sterculia rhoidifolia
13. Sandoricum emarginatum
14. Litsea cylindrocarpa
15. Drypobalanops rappa.
16. Campnospermum squamatum
17. Neoscortechinia kingii
18. Garcinia sp (669)
19. Arthrophyllum rufosepalum
20. Nephelium melanomiscum
21. Quercus dasystachyus
22. Pseudosindora palustris
23. Palaquium walsurifolium
24. Longetia malayana
25. Mezzettia leptopoda
26. Gonystylus bancanus
27. Cephalomappa aff. beccariana
28. Sindora leiocarpa
29. Lophopetalum rigidum
30. Shorea inaequilateralis
31. Garcinia vidua
32. Eugenia sp (479)
33. Shorea albida
34. Diospyros maingayi
35. Eugenia sp.
36. Ficus sp. (ground rooting epiphyte)

Photograph 15 . An example of the recovery of Shorea albida following severe wind damage to the crown.

Photograph 16 . The collapse of a large tree of Shorea albida in the Shorea albida Gonystylus-Stemonurus Association in the Rejang Delta. The trees are frequently little more than a shell of timber and though very persistent may finally collapse under their own weight or be wind thrown.

shell of hard slow growing timber remains. The degree of defect may increase to such an extent that the stem is unable to support the crown and the tree will collapse under its own weight (Plate 9). On the outer perimeter of the community only two or three trees may be found per acre, but towards the inner margin where the community grades into the Shorea albida consociation up to eighteen trees per acre occur.

131. Large Shorea albida trees usually exceed 150 feet in height. Scattered beneath or between the Shorea albida typical dominants, such as Gonystylus bancanus and Dactylocladus stenostachys, of Phasic Community 1 form a sub-dominant canopy (see Profile Diagram in Fig. 35). The structure of the forest, with moderately dense middle and lower storeys, also resembles that in Phasic Community 1.

132. The floristic composition of the Community is largely similar to that in Phasic Community 1, excluding the species characteristic to the latter community. It is significant that other Shorea species, with the exception of Shorea inaequilateralis, generally do not occur in association with Shorea albida. In addition to Shorea albida the most characteristic species, which attain their greatest frequence in this community, are Shorea inaequilateralis, Stemonurus umbellatus, Canthium didymum and Sindora leiocarpa. The number of species per half acre remains high, averaging between forty and fifty-five per half acre. The absence of certain species of Phasic Community 1 is compensated by the occasional presence of species, such as Combretocarpus rotundatus, Litsea palustris, Swintonia glauca, Ternstroemia hosei, and Xanthophyllum sp. (2614), that are more typical of Communities 3 and 4. The principal understorey species

Photographs 17 + 18 . Two photographs taken from approximately the same position showing the base of a large Shorea albida before and after the removal of the litter layer. Note the numerous feeding roots ramifying over the lower buttresses of the tree. The photographs give some indication of the treacherous surface of the forest in forest dominated by Shorea albida.

are Knema kunstleri, Gaertnera borneensis, Ixora pyranthe, and Pithecellobium oppositum. It has been noted that in this community also many species of the understorey have a localized distribution. Disepalum anomalum and Bridelia ovata have only been recorded in the Baram swamps and Kibatalia sp. (9300), and Actinodaphne sp. (448) in the Rejang Delta.

133. The surface of the swamp is characterized by the large spreading buttresses and radiating roots of Shorea albida over which a litter layer collects that is largely devoid of herbs. Between the scattered Shorea albida trees the swamp surface and flora is similar to that occurring in Phasic Community 1. A large pitcher plant, Nepenthes bicalcarata, occurs frequently straggling over the swamp surface. Pandanus andersonii is often abundant.

134. The epiphytic and climbing flora is similar to that in Phasic Community 1, but in so far as it has been studied it would appear to be less abundant and the floristic composition more limited.

Phasic Community 3. Shorea albida consociation.

135. The Shorea albida consociation is the most uniform of the swamp communities. In Sarawak it covers approximately 411 square miles, mostly in the swamps of the Second and Fourth divisions and also occurs in the Badas area of Brunei, but its distribution in the Rejang Delta is very limited. On the Maludam Peninsula alone there are approximately 190 square miles of forest dominated by Shorea albida of which about 38 square miles have been destroyed (see Chapter 16). Towards the centre of swamps it merges into Phasic Community 4, and towards the perimeter into Phasic Community 2, but

Photographs 19 + 20. Two photographs of small trees of Shorea albida where the litter layer has been partially or wholly removed exposing the root and buttress system. The stilt roots may be noted, also the tall knee roots, some over 3 ft. high, of other species growing within the roots system of Shorea albida.

Photograph 21 . A young Shorea albida showing the early development of the buttresses. The stilt roots enlarge vertically to form the typical buttresses of the mature trees.

Photograph 22. Cross section of the root system of a large Shorea albida in the Shorea albida Consoc.

Photograph 23 . This photograph was taken from a De Haviland Rapide and shows the dense even canopy of the Shorea albida Consociation in the vicinity of the Pagalayan Canal in the Baram. The direction of the canal is indicated by the slight break in the canopy running diagonally across the photograph. Note the larger gaps in the canopy, probably caused by lightning damage.

Photograph 24 . Taken from an R.A.F. Valetta over the Maludam Peninsular in the Second Division. In the foreground the canopy is composed entirely of Shorea albida whereas in the middle distance the forest with a slightly lower canopy is of the Gonystylus-Dactylocladus-Neoscortechinia Association in the vicinity of the Sungei Maludam. In the background the line where the Shorea albida occurs again can be made out and in the far distance, approximately twelve miles away, the Saribas river is just visible.

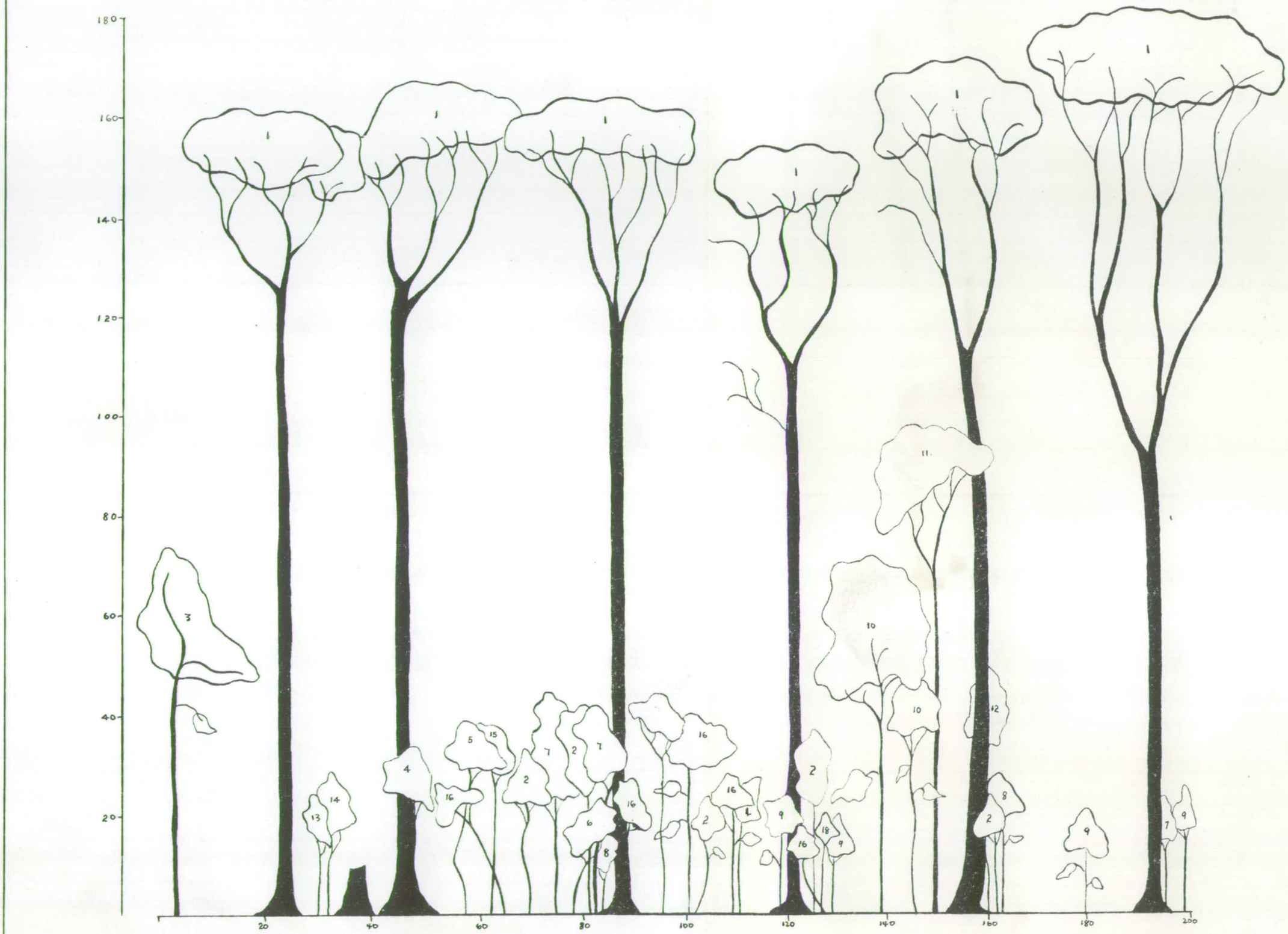
over tens of square miles the forest may be uniform.

136. The forest is dominated by a pure even canopy of Shorea albida which varies in height between 150 and 190 feet, and in some localities (e.g. Badas, Brunei) may exceed 200 feet. Lengths of clear bole usually exceed one hundred feet, and branching is acute with small rather light crowns. The general structure of the forest may be seen in Profile Diagram 3 (Fig. 36), ~~and Fig. 36A shows the average total heights, and heights to first branch of trees measured in the preparation of volume tables.~~ Small Shorea albida trees apparently grow very rapidly into the canopy without heavy branching, and initially a tree is little more than a bunch of leaves on the top of an attenuated pole. Girths range between three and ten feet and the average number of trees per acre is between fifty and seventy. Occasional gaps in the canopy, probably caused by lightning damage, are of frequent occurrence. Wind damage is also of local importance (see Chapter 15). There is a general absence of a middle storey, as may be seen in the Profile Diagram and Plate 27, but the lower storey is moderately dense and is frequently largely composed of a single species.

137. Numbers of trees and species per unit area are invariably low. Species per half acre vary between ten and twenty, usually less than fifteen, and individuals over twelve inches girth rarely exceed one hundred.

138. The floristic composition is relatively uniform. In the sparse middle storey Gonystylus bancanus is locally abundant, and Combretocarpus rotundatus and Dactylocladus stenostachys are usually present. There is a tendency towards single species dominance in

Figure 36



Key to species plotted on Profile Diagram 4 (Fig. 36)

1. Shorea albida
2. Xanthophyllum sp. nov. (2614)
3. Gonystylus forbesii
4. Mecaranga caladifolia
5. Baccaurea bracteata
6. Litsea gracilipes
7. Stemonurus umbellatus
8. Timonius peduncularis
9. Ilex hypoglauca
10. Xanthophyllum aff. citrifolium
11. Parastemon versteeghii
12. Gonystylus bancanus
13. Tetractomia holttumii
14. Palaquium cochlearifolium
15. Garcinia eugeniifolia
16. Eugenia sp (9274)
17. Eugenia sp (2822)
18. Eugenia sp. (479)

the lower storey: Cephalomappa malloticarpa in the Rejang Delta; Tetractomia holttumii in the Maludam Peninsula and parts of the Baram; Xanthophyllum sp. (2614) locally in the Baram; and Ganua curtisii in the Badas swamps. Other widely distributed trees of the lower storey include Palaquium cochlearifolium, Parastemon vegrsteeghii, Sterculia rhoidifolia, and Canthium didymum. The understorey is moderately dense and is largely composed of small trees of the aforementioned species. Ixora pyranthe is also abundant, and Quercus sundaicus, Elaeocarpus mastersii, Ardisia copelandii and Pithecellobium oppositum also frequently occur.

139. Shorea albida has large spreading buttresses and radiating roots, which ramify over the buttresses forming an irregular 'platform' of roots, on which litter collects, above the surface of the swamp (see Plates 17 and 18). Walking through Shorea albida forest is often treacherous owing to the instability of this platform. Herbaceous vegetation is sparse. In the immediate vicinity of Shorea albida trees the surface is usually bare, but where the platform is lower Pandanus andersonii is often abundant, sometimes forming a dense shrub layer. Nepenthes bicalcarata is widely distributed, and another pitcher plant, Nepenthes rafflesiana, is occasionally found. Thorachostachyum bancanum and, to a lesser extent, Hanguana malayana occur where the surface of the swamp is exposed, also Euthemis obtusifolius on the litter layer above the water table. Two terrestrial ferns, Lindsaya scandens var. terrestris and Cyathea glaba, are largely confined to this community.

140. Large lianes are exceptionally rare, and only very occasionally attain the height of the main canopy. An unidentified

Photograph 25 . Two trees of Shorea albida in the Shorea albida Consociation. The base of the stems are heavily covered in mosses. Note the apparent rather low buttresses of the trees hidden by the litter layer and also the stems of a moderately dense understorey.

Photograph 26 . The surface of the swamp in the Shorea albida Gonystylus Stemonurus Association. The apparent surface is very uneven, and the water table may be exposed in places. The small tree in the centre is Cyathocalyx biovalatus.

27

Photograph 27 . The Shorea albida Consociation. This photograph was taken in the same vicinity as the profile diagram was drawn. The height of the canopy is between 170 and 190 ft. Note the small crowns of Shorea albida with rather light foliage, and the almost complete absence of a middle storey.

Photograph 28 . This photograph was taken in a gap in the canopy, probably caused by lightning, in the Shorea albida Consociation. In certain localities a spiny stemless pandan (Pandanus pentodon) forms dense thickets.

Calamus is the most abundant species. Lianes and climbers common in Phasic Community 1 are almost entirely absent. Two well distributed species, Myxopyrum ellipticum and Erycibe sp. (4117), are found as medium-sized climbers to a height of approximately one hundred feet.

141. Epiphytic vegetation is also scarce in this community. The most typical species is Bulbophyllum beccarii which spirals round the upper stems of Shorea albida. Two small epiphytic ferns, Humata parvula and Humata augustata, are occasionally found as sun epiphytes in the crowns of Shorea albida, but most of the upper canopy is usually devoid of epiphytes. Asplenium nidus occurs on middle and lower storey trees, and the small myrmecophyte Hoya mitrata is an epiphyte near the swamp surface, and has been only recorded in this community.

Phasic Community 4. Shorea albida Litsea Parastemon association.

142. The Shorea albida Litsea Parastemon association occupies approximately 274 square miles in the centre of larger swamps in all localities. Ecological conditions are most infertile: the swamp is virtually stagnant, recorded fluctuations in the water table exceed seven inches and the mineral content (especially Phosphorus) of the peat soils is probably less than in peripheral communities. The community is locally known as padang paya, or as padang alan where Shorea albida is dominant and padang medang where Litsea palustris predominates in the canopy. Outstanding features of this community, very obvious in the field, are the pole-like sinuous nature of all trees, the paucity of the canopy, that permits light to filter through to the swamp surface, and the predominantly xerophytic aspect of the

vegetation.

143. Profile Diagram 4 (Fig. 37) gives some indication of the structure of the forest, though the density of the crowns appears greater than is in fact the case. The number of trees per acre ranges between 250 and 370 and all girth classes up to sixty-six inches may be represented, with relatively large numbers in the twenty-four to thirty-five and thirty-six to forty-seven inch classes. Trees with girths exceeding seventy-two inches are rare. There is a pure even upper canopy between 100 and 120 feet. This is very largely composed of Shorea albida and there may be between 70 and 180 stems per acre of this species. In certain swamps in the Rejang Delta and in adjacent areas further east Litsea palustris is almost the sole dominant.

144. Crown diameters of all trees are small, those in the upper storey rarely exceed twenty-five feet and may be less than fifteen feet. Branching of upper storey species is acute, and the scanty foliage is restricted to the terminal branches. The ratio length of stem to depth of crown is usually greater than 8:1 and may exceed 15:1. The length of clear bole of Shorea albida frequently exceeds eighty feet. Something of the extreme slenderness of the stems may be gathered from the accompanying graph (Fig. 38) where heights of trees, greater than twelve inches girth, recorded during the preparation of the profile diagram have been plotted against their girths at breast height. Shorea albida trees attain the main canopy height of 112 feet when they are only thirty-four inches girth. Tenuousity of stem is most marked in Shorea albida, but is to be found to a lesser degree in all species. Ratios, girth to height, for Shorea albida at

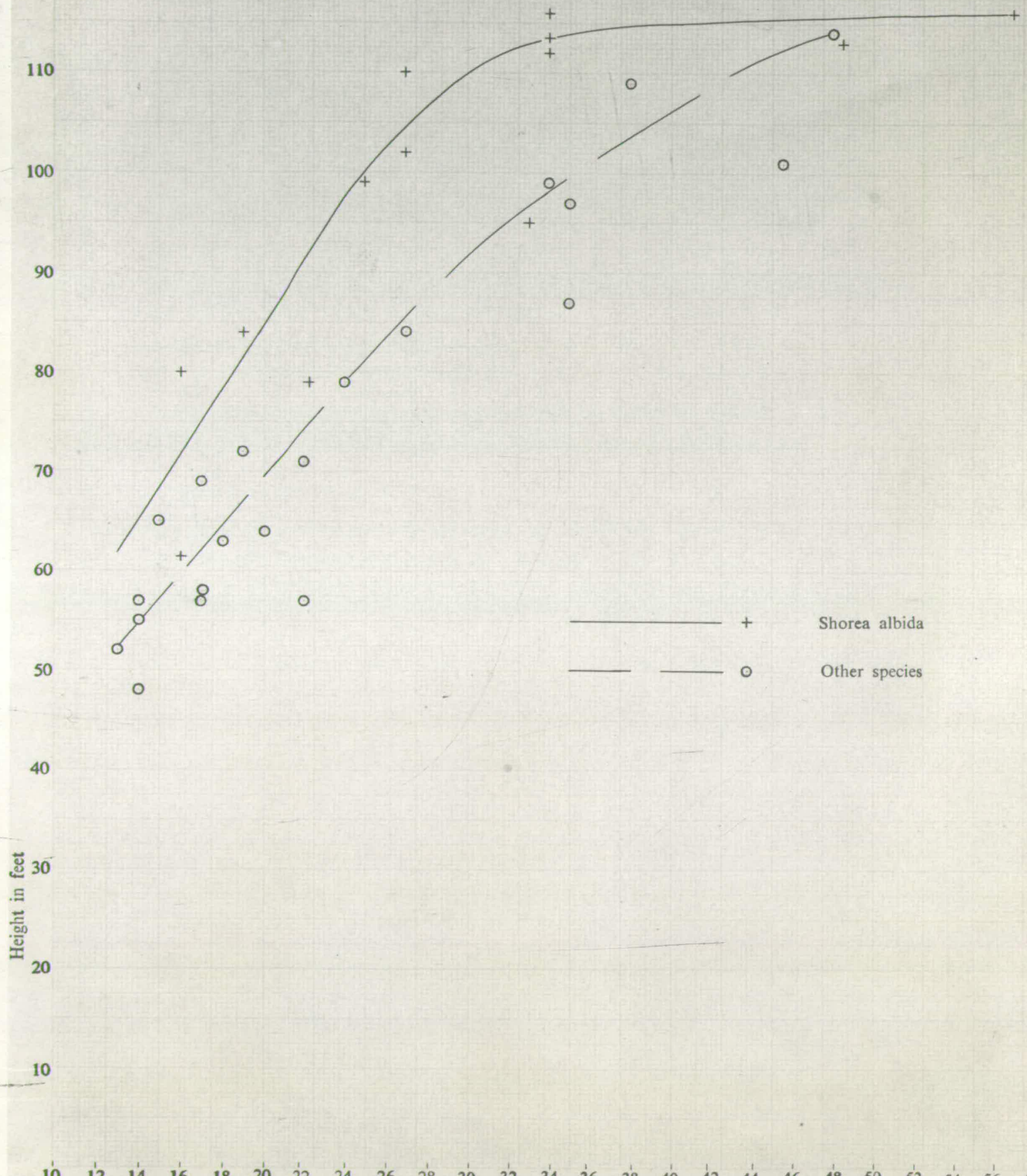
Fingure 37

Key to species plotted on Profile Diagram 5 (Fig. 37)

1. Shorea albida
2. Timonius peduncularis
3. Gonystylus bancanus
4. Lopopetalum rigidum
5. Palaquium cochlearifolium
6. Litsea palustris
7. Tristania obovata
8. Ternstroemia hosei
9. Calophyllum retusum.
10. Parastemon versteeghii
11. Garcinia rostrata
12. Arthrophyllum rufosepalum
13. Antidesma coriaceum
14. Melanorrhoea beccarii
15. Melanorrhoea tricolor
16. Sterculia rhoidifolia
17. Dactylocladus stenostachys

Figure 38

GIRTH HEIGHT RELATIONSHIP OF TREES IN PROFILE DIAGRAM 5



eighteen and thirty-three inches girth are 1:56 and 1:41 respectively; the equivalent ratios for other species (grouped) are 1:47 and 1:35. Below the main canopy no stratification of the forest is evident except, perhaps, a rather dense understorey between ten and twenty feet. The number of species per acre is generally higher in the Rejang Delta, where the average is approximately twenty-five, than in other swamps; less than ten species per acre occur in the Badas swamps of Brunei.

145. The floristic composition of this community is very uniform though the frequence of occurrence of species varies widely. In addition to Shorea albida and Litsea palustris only Cratoxylon glaucum and Calophyllum obliquinervum consistently attain the upper canopy. Common subdominant species are Gonystylus bancanus, Dactylocladus stenostachys, Combretocarpus rotundatus, Tristania obovata and Parastemon versteeghii. In the slightly lower forest, towards the centre of certain swamps in the Second and Fourth divisions, these species form a mixed upper canopy with the two principal dominants. Parastemon versteeghii is one of the most characteristic species of this community occurring abundantly in all localities. Typical species of the lower storey are Palaquium cochlearifolium, Ternstroemia hosei, Garcinia rostrata, Xanthophyllum sp. (2614) and Sterculia rhoidifolia. The understorey is very largely composed of saplings and small trees of the species already mentioned. Quercus sundaicus is the most widespread and abundant of the species that rarely attains twelve inches girth, others include Ardisia sp. (9826), Rapanea aff. philippensis and Pithecellobium oppositum.

146. The surface structure of the swamp shows a development of

Photographs 29 + 30 . Pole forest. Two photographs taken from a height of about 30 ft. which give some idea of the slender pole-like appearance of the Shorea albida Litsea Parastemon Association. The paucity of trees forming a middle storey and the almost total absence of climbers may be noted.

Photograph 31 . The Shorea albida-Litsea-Parastemon Association. The density of the understorey and the light penetrating from the canopy may be noted. The sapling on the forest guard's right is a Cotylelobium flavum, a Dipterocarp species more commonly found in heath forest.

Photograph 32 . This photograph should be compared with the previous one. Here the understorey has been cut to reveal the base of the trees. The outside trees are Shorea albida and the centre trees in the foreground are Litsea palustris. Buttresses are almost entirely hidden by the false platform of roots and litter layer. For comparison see the profile diagram of the surface of the swamp.

Photograph 33 . The visible swamp surface in the Shorea albida-Litsea-Parastemon Association. The water table is exposed on the left, but elsewhere is covered by the root system and litter layer.

Photograph 34. The canopy in the Shorea albida-Litsea-Parastemon Association. In this locality (in the Lassa Protected Forest) Litsea palustris was almost the sole dominant.

34

the 'platform' of radiating roots above the water table as described previously in Phasic Community 3. Here the platform is almost continuous, denser and more stable. A cross section of the surface rooting system of the larger trees and of the platform is shown in Figure 39. The broken broad line indicates the visible surface of the swamp or the surface of the platform, whereas the continuous line indicates the water table level. During the wet season the water table probably rises by about twelve inches and may cover the lowest parts of the platform but the greater part of the system of radiating roots will not be inundated. A first impression of the root and buttress system of trees in this community is that buttressing is not pronounced. However, a closer examination, as may be seen in the diagram, shows that the buttresses are hidden by a litter layer overlying the system of feeding roots, and that many species, including Shorea albida, are virtually stilt rooted. The pneumatophores and kneed roots of species, such as Gonystylus bancanus, Dactylocladus stenostachys and Dyera lowii, which have no buttresses, frequently exceed two feet in height, and are partially or completely hidden beneath the platform. The platform itself consists of a dense mass of feeding roots in a compacted humus which may be continuous or discontinuous to the main surface level of the swamp beneath. Overlying the humus is a litter layer a half to two inches in depth on which seedlings and a specialized ground flora are found.

147. Herbs and terrestrial ferns are extremely rare. The principal components of the ground flora are small prostrate shrubs, often with a scrambling habit, of which the most frequent species are Labisia pumila var. genuina, Ficus motleyana, Euthemis obtusifolius,

Figure 39

SCALE 1 INCH = 5 FEET

Key to species plotted on Profile Diagram 6 (Fig. 39)

1. Shorea albida
2. Swintonia glauca
3. Pneumatophore of Dactylocladus stenostachys
4. Seedlings of Glochidion lucidum
5. Seedling of Androtium astylum
6. Ficus deltoidea var. motleyana
7. Xanthophyllum sp nov. (2614)
8. Parastemon versteeghii
9. Ardisia sp (9826)
10. Antidesma coriaceum
11. Cephalomappa beccariana
12. Euthemis obtusifolius
13. Litsea palustris
14. Lophopetalum rigidum
15. Seedlings of Palaquium cochlearifolium
16. Ilex hypoglauca
17. Timonius peduncularis
18. Pneumatophores of Gonystylus bancanus

and Medinilla hasseltii. Pitcher plants are common; the most abundant species is Nepenthes gracilis, but N. bicalcarata and N. rafflesiana are also of frequent occurrence. In small localized places where the water table is permanently or semi-permanently exposed Hanguana malayana, Pandanus andersonii, and Thorachostachyum bancanum may be found.

148. Climbers and epiphytes are extremely sparse, and lianes virtually absent. Nepenthes gracilis and Euthemis obtusifolius occur as low climbers or climbing shrubs on the higher parts of buttresses and Flagellaria indica is frequent on understorey trees. Ficus deltoidea var. deltoidea, Dischidia nemerosa and Humata parvula, which occur as sun epiphytes in the previously described communities, are occasionally found as epiphytes on understorey trees and even on the surface of the platform itself. Asplenium nidus and Drynaria involuta occur as epiphytes in the understorey, but rarely at higher levels.

Chapter 10

Phasic Communities 5 and 6

149. Phasic Communities 5 and 6 occur only in the middle reaches of the Baram and in small adjacent areas over the border in Brunei. They are found in the centres of highly developed raised bogs, and represent the last known phase in the catena (see Chapter 14).

Phasic Community 5. Tristania Palaquium/Parastemon association.

150. This community has a limited distribution occurring only as a narrow though well defined zone between Communities 4 and 6, and is indeed transitional between these two communities, but is clearly separated from them on the structure of the forest, and boundaries between the three communities are often precise. In area it is the most limited of the communities, covering only approximately fifteen square miles.

151. The community consists of a dense low pole forest, not dissimilar in structure to that found in young secondary rain forest, with between five and six hundred stems, greater than twelve inches girth, per acre; seventy to ninety per cent of which are less than twenty-four inches girth. The canopy height varies between fifty and seventy feet with the occasional emergent exceeding this. Crowns are small and constricted, and, though the foliage is sparse, owing to the density of the forest the understorey is more heavily shaded than in Community 4. An indication of the density is to be seen in Profile Diagram 5 (Fig. 40).

152. The floristic composition of the community is very limited.

Figure 40

Key to species plotted on Profile Diagram 7. (Fig. 40)

1. Tristania maingayi
2. Parastemon versteeghii
3. Litsea palustris
4. Palaquium cochlearifolium
5. Palaquium ridleyi
6. Xylopia coriifolia
7. Ilex sclerophylloides
8. Xanthophyllum sp. nov. (2614)
9. Diospyros evenis
10. Dactylocladus stenostachys
11. Arthrophyllum rufosepalum
12. Canthium didymum
13. Ternstroemia hosei
14. Stemonurus umbellatus
15. Garcinia rostrata
16. Longetia malayana

In the two plots enumerated only eleven and eighteen species were recorded. The most abundant species are two Tristanias (T. obovata and T. maingayi), Palaquium cochlearifolium and Parastemon versteeghii, all of which are common beneath the main canopy in Community 4. Other abundant tree species include Dactylocladus stenostachys, Shorea albida, Litsea palustris, Combretocarpus rotundatus, and Longetia malayana.

153. Despite the density of the forest the understorey is rather sparse and open and one can move without difficulty through it. To determine the composition of the understorey a five chain milliacre transect was enumerated at Lubok Pasir. The results are shown in Table 22. This indicates that the understorey is largely composed of saplings and poles of species already recorded in the half acre sample plots. Species, which rarely attain twelve inches girth, abundant in the understorey, include Ilex sclerophylloides, Garcinia rostrata, Palaquium ridleyi, and Eugenia sp. (2822). A short stemmed pandan, Pandanus ridleyi, is common throughout the community.

154. On every fifth milliacre plot along the transect everything less than twenty-four inches high was enumerated to determine the composition of the ground flora and the distribution of seedlings. The results are included in Table 23. The ground flora is sparse, and herbs, with the exception of Thorachostachyum bancanum, rare. Three pitchers plants are occasional, but are much less luxuriant than found in Community 4. Lianes, climbers and epiphytes are almost entirely absent.

155. The surface of the swamp is level and the 'platform' of radiating roots is not noticeable, though the top six inches consists

Table 22. Results of milliacre transect in Phasic Community 5 at Lubok Pasir, Baram.

Trees and shrubs, 2 ft. high and over.

Number of plots = 50

	HEIGHT CLASSES								GIRTH CLASSES													
	2'	3'	4'	5'	6'	7'	8'	9'	1"	2"	3"	4"	5"	6"	7"	8"	9"	10"	11"	12"+	Total	Freq
Parastemon versteeghii	5	2	1	6	6	4	5	6	10	16	6	6	3		2	1	2	5	4	3	93	39
Ternstroemia hosei	1				4			1		2	1	1	2	3	1					3	19	13
Litsea palustris	1	1		4		3	1	5	1	3	1				1	3	2	1	3	8	38	25
Garcinia rostrata	2	1	2	2	3	3	3	2	2	3	3	2		1							29	21
Palaquium cochlearifolium	2		1	2			2			2	6	1	4	1					1	4	26	20
Palaquium ridleyi				1						2	3	1	1	1							9	8
Ilex sclerophyllo-ides	7	5	1	9	6	5	1	3		1		1							1		40	26
Eugenia sp. (2822)	1			3	2	4		2	1		1		1	1	1						17	13
Tristania maingayi											1	1	1	3		1	1	1		2	11	9
Tristania obovata										1	1		2	1						1	6	6
Shorea albida				1																2	3	3
Sterculia rhoidifolia				1									1								2	2
Combretocarpus rotundatus																				4	4	1
Xanthophyllum sp. (2614)	1																				1	
Xylopia coriifolia			1	1						1											3	3
Diospyros evenis	2		1	1					2	1			1							1	9	7
Myrsine sp.(2)	7	1	1																		9	4
Canthium didymum								1		2				1							4	4
Myrsine sp (1)				1		1		1													3	2
Elaeocarpus obtusifolius	1								1												2	2
Dactylocladus stenostachys	1												1							1	2	2
Longetia malayana				1					1	1								1			4	4
Stemonurus umbellatus										1											1	1
Arthrophyllum rufosepalum						1															1	1
Ixora pyranthe			2	2		1															5	5
Pandanus ridleyi			1	10	10	6	7	3		3											40	21
Baccaurea bracteata																						
Unidentified																						
Totals	30	10	11	45	31	28	19	24	14	34	32	13	17	12	5	5	5	8	9	29	381	

Table 23. Results of milliacre transect in Phasic Community 5 at Lubok Pasir, Baram.

Trees, shrubs and ground flora, less than 2 ft. high.

No. of plots = 10

(i) Trees and shrubs

	0 - 1'	1 - 2'	Freq.
Parastemon versteeghii	49	2	9
Ternstroemia hosei	10	5	6
Litsea palustris	169	3	10
Garcinia rostrata	40		7
Palaquium cochlearifolium		4	2
Palaquium ridleyi	19		2
Ilex sclerophylloides	57	6	9
Eugenia sp. (2822)	1	2	2
Tristania sp. (2)	95		7
Sterculia rhoidifolia	4		3
Combretocarpus rotundatus	2		2
Diospyros evenis	3		2
Myrsine sp. (2)	14	11	7
Myrsine sp. (1)	1		1
Elaeocarpus obtusifolius	8	1	7
Dactylocladus stenostachys	1		1
Ixora pyranthe	1		1
Pandanus ridleyi	2	3	2
Unidentified	34		
Totals	511	38	

(ii) Ground flora and climbers

	0 - 1'	1 - 2'	Freq.
Thorachostachyum bancanum	25		7
Nepenthes gracilis	4		3
Nepenthes bicalcarata	2		2
Nepenthes rafflesiana	1	2	2
Bromheadia finlaysoniana		2	1
Flagellaria indica	3	1	3
Totals	35	5	

of a stiff humus ~~mass~~ held together by a mass of small rootlets. The water table was found at a depth of twelve inches.

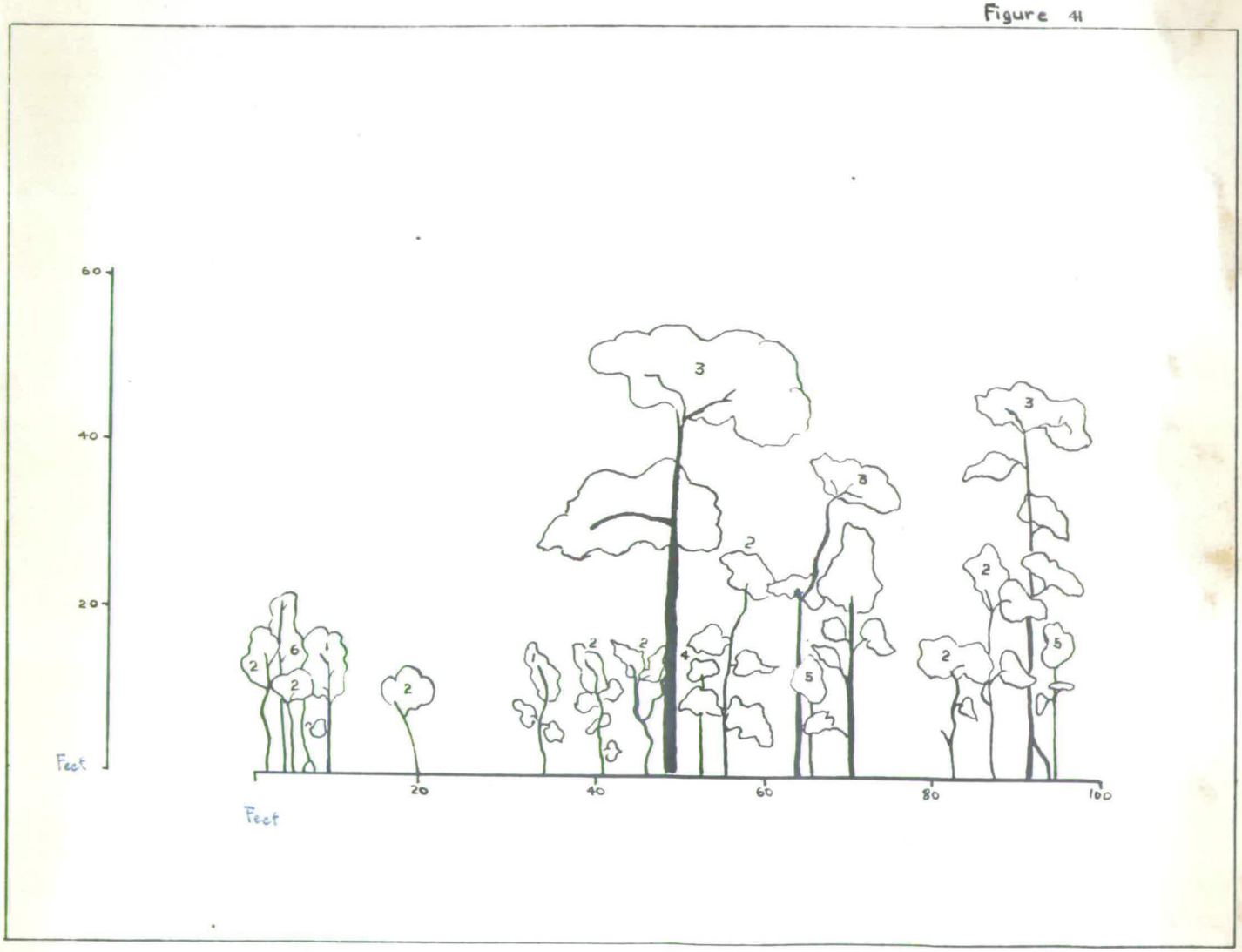
Phasic Community 6. Combretocarpus Dactycladus association.

156. This community, quite atypical of lowland tropical rain forest, occupies the central zone of swamps in the middle reaches of the Baram upstream from the Bakong river to the upriver limit of the peat swamps, and covers approximately sixty-one square miles. It is the final known phase in the catena. Certain structural resemblances and floristic affinities to temperate raised bogs cause this community to be of particular ecological interest and significance.

157. The aspect of the vegetation is quite different from that in the previously described communities, being open and almost savannah-like with scattered stunted trees and a moderately dense though patchy shrub layer (see Profile Diagram 6, Fig. 41). The whole vegetation, from trees to ground flora, has the appearance of being stunted. Foliage of most species tends to be a uniform pale greenish yellow chlorotic colour, and leaves are markedly sclerophyllous and generally of a smaller size than found in other communities. Probably due to insolation the bark of trees is a uniform pale greyish brown.

158. Combretocarpus rotundatus is the principal tree species. Girths may occasionally exceed thirty-six inches but heights are rarely greater than forty feet. There are obvious signs of stunting; die back and regrowth of the crown from adventitious shoots are of frequent occurrence. After the death of the crown or a branch a complete callus over the joint with the main stem rarely forms and the main stem

Figure 41



Key to species plotted on Profile Diagram 8 (Fig. 41)

1. Parastemon versteeghii
2. Dactylocladus stenostachys
3. Combretocarpus rotundatus
4. Tristania obovata
5. Litsea palustris
6. Garcinia rostrata

is frequently hollow, providing an ideal habitat for epiphytes. Dactylocladus stenostachys is abundant as a small stunted tree, rarely exceeding thirty inches girth, though in the centre of the community it barely attains eighteen inches and occurs more often as a shrub six to ten feet in height, frequently flowering profusely.

159. The results of a transect, similar to that undertaken in Phasic Community 5, are shown in Table 24. A scattered shrub layer up to eight feet in height is largely composed of small stunted trees of Litsea palustris, Garcinia rostrata, Dactylocladus stenostachys and Parastemon versteeghii, with numerous Ilex sclerophylloides rarely exceeding five feet in height. These species, with the exception of Dactylocladus stenostachys, show a marked tendency to vegetative regeneration and not infrequently up to ten sucker or adventitious shoots are found on the same plant.

160. The peat near the surface is very different from that found in other communities and more resembles Temperate peats. A litter layer covers a tough fibrous reddish brown peat, which when the moisture is removed becomes a pale greyish brown. The swamp surface varies in height by about eighteen inches, being highest near the base of larger trees. At slightly lower levels the water table is probably exposed for the greater part of the year.

161. The distribution of the ground flora has the appearance of being zoned in relation to the degree and frequence of inundation by the water table. A preliminary description of the zones follows, though it is realized that a more thorough investigation is required.

Zone A: Surface permanently or almost permanently inundated. Litter layer covered in a green algal scum. Thread-like pneumato-

Table 24. Results of milliacre transect in Phasic Community 6 at Lubok Pasir, Baram.

Number of plots = 50

Species Trees and shrubs :-	2'	3'	4'	5'	6'	7'	8'	9'	Girth classes (ins.)	Total	Freq.
Combretocarpus rotundatus									18"	1	1
Dactylocladus stenostachys	9	6	2	2	2	2	1		13"-2,16",30"	28	18
Garcinia rostrata	52	46	20	8	1				4"	128	38
Parastemon versteeghii	7	3	4	4	3	2			6", 11"	25	22
Tristania maingayi	1								4"	2	2
Ilex hypoglauca	28	6	2							36	20
Litsea palustris	8	6	10	7	6	1		1		39	23
Myrsine sp (2)	5		1	1						7	4
Myrsine sp (1)	14	3	2	1						20	13
Elaeocarpus obtusifolius				1						1	1
Palaquium ridleyi	2	1								3	2
" cochlearifolium		1								1	1
Eugenia sp. (2822)	1									1	1
TOTALS	127	72	41	24	12	5	1	1	9	292	

Number of plots = 10

Seedlings Trees and shrubs :-	0-1'	1-2"	Freq.
Combretocarpus rotundatus	80		9
Dactylocladus stenostachys	28		4
Garcinia rostrata	61	6	8
Parastemon versteeghii	8	1	5
Ilex hypoglauca	13	12	7
Litsea palustris	6		4
Myrsine sp. (1)		5	3
Canthium umbellatus		1	1
Palaquium cochlearifolum		1	1
TOTALS	196	26	

Climbers:

Henslowia varians	5

Epiphytes:

Dischidia nemerosa	13
Hoya coronaria	3
Epiphytic orchids	9
Lecanopteris sinuosa	1

Herbs (height classes not recorded:

		Freq.
Pandanus ridleyi	97	10
Thorachostachyum bancanum	329	8
Flagellaria indica	168	9
Bromheadia finlaysoniana	71	7
Nepenthes gracilis	105	8
Nepenthes rafflesiana	30	7
Nepenthes bicalcarata	6	5
Lycopodium cernuum	3	1
Unid. ground orchid	37	3
Euthemis obtusifolius	63	10
TOTAL	909	

phores of Combretocarpus rotundatus floating on the surface; generally devoid of other vegetation.

Zone B: Surface, periodically inundated, frequently forming an ill-defined rim around Zone A. The most typical species is Sphagnum junghuhnianum, which is usually quite luxuriant. This is the only locality in peat swamps where sphagnum moss occurs. Stunted forms of Thorachostachyum bancanum and Pandanus ridleyi are abundant, and short pointed pneumatophores of Dactylocladus stenostachys protrude through the surface. The common ground orchid, Bromheadia finlaysoniana and Nepenthes gracilis are of frequent occurrence. During the wet season two unidentified Utricularias make an appearance.

Zone C: A slightly drier zone, characterized by small hummocks or minor peat hags only a few inches high, frequently in the vicinity of pneumatophores of Dactylocladus stenostachys. Typical species of this zone, often growing on the hummocks are Thorachostachyum bancanum, Pandanus ridleyi, Bromheadia finlaysoniana, Flagellaria indica and Nepenthes rafflesiana.

Zone D: The highest and consequently the driest zone. There is generally little ground vegetation. The surface is covered in a desiccated and brittle leaf litter layer, light grey in colour. Lycopodium cernuum is the most typical species of the zone. Small stunted plants of Pandanus ridleyi and Euthemis obtusifolius also occur, and Nepenthes bicalcarata is found at the base of large trees and frequently adopts a climbing habit.

Regeneration of trees and shrubs is most abundant in Zones B and C.

Photograph 35. Sphagnum junghuhnianum and Nepenthes bicalcarata in the Combretocarpus Dactylocladus Association.

Photograph 36. The centre of the Combretocarpus Dactylocladus Association, showing the abundance of the sedge Tetraria borneensis.

Photographs 37 + 38 . Two photographs in stunted forest (Combretocarpus-Dactylocladus Association). The very open nature of the forest may be noted, also the stunted appearance of many of the trees. In the second photograph the medium-sized tree on the right, a Combretocarpus rotundatus, showed clear signs of die back and regrowth on at least six occasions.

Photograph 39 . The base of a Combretocarpus rotundatus in the Combretocarpus-Dactylocladus Association. The sedge is Thorachostachyum bancanum, and the small pointed pneumatophores belong to Dactylocladus stenostachys.

Photograph 40 . The surface of the swamp in the Combretocarpus-Dactylocladus Association. Nepenthes bicalcarata is abundant but the pitchers in this forest type are usually much smaller than found elsewhere in the swamps.

Photograph 41 . This photograph was taken from an angle of about 45° and shows the surface of the swamp in the Combretocarpus-Dactylocladus Association. On the left is a small peat hag with Nepenthes gracilis on its margins, and on the right a pool with standing water. The floating thread-like structures are pneumatophores of Combretocarpus rotundatus which arise from roots deeper in the peat.

Photograph 42. This photograph gives some idea of the density of the forest in Phasic Community 5, the Tristania-Parastemon-Palaquium Association. Pandanus ridleyi is the shrub in the foreground.

162. The epiphytic vegetation is characterized by the large number of myrmecophytes, some of which occur elsewhere in the swamps as sun epiphytes in the crowns of canopy trees. Abundant species are Hydnophytum formicarium, Myrmecodia tuberosa, Dischidia nummularia and Hoya coronaria. The myrmecophyllous ferns, Lecanopteris sinuosa and Phymatodes crustacea also occur though less frequently. Epiphytic orchids are occasional, and include such common species as the pigeon orchid (Dendrobium crumenatum), and small unidentified Bulbophyllum spp.

163. Lianes are entirely absent. Nepenthes rafflesiana and Nepenthes bicalcarata both tend to adopt a climbing habit in this community. It is noticeable that the pitchers of all species of Nepenthes are much reduced in size. Flagellaria indica occurs as a small climber in the shrub layer.

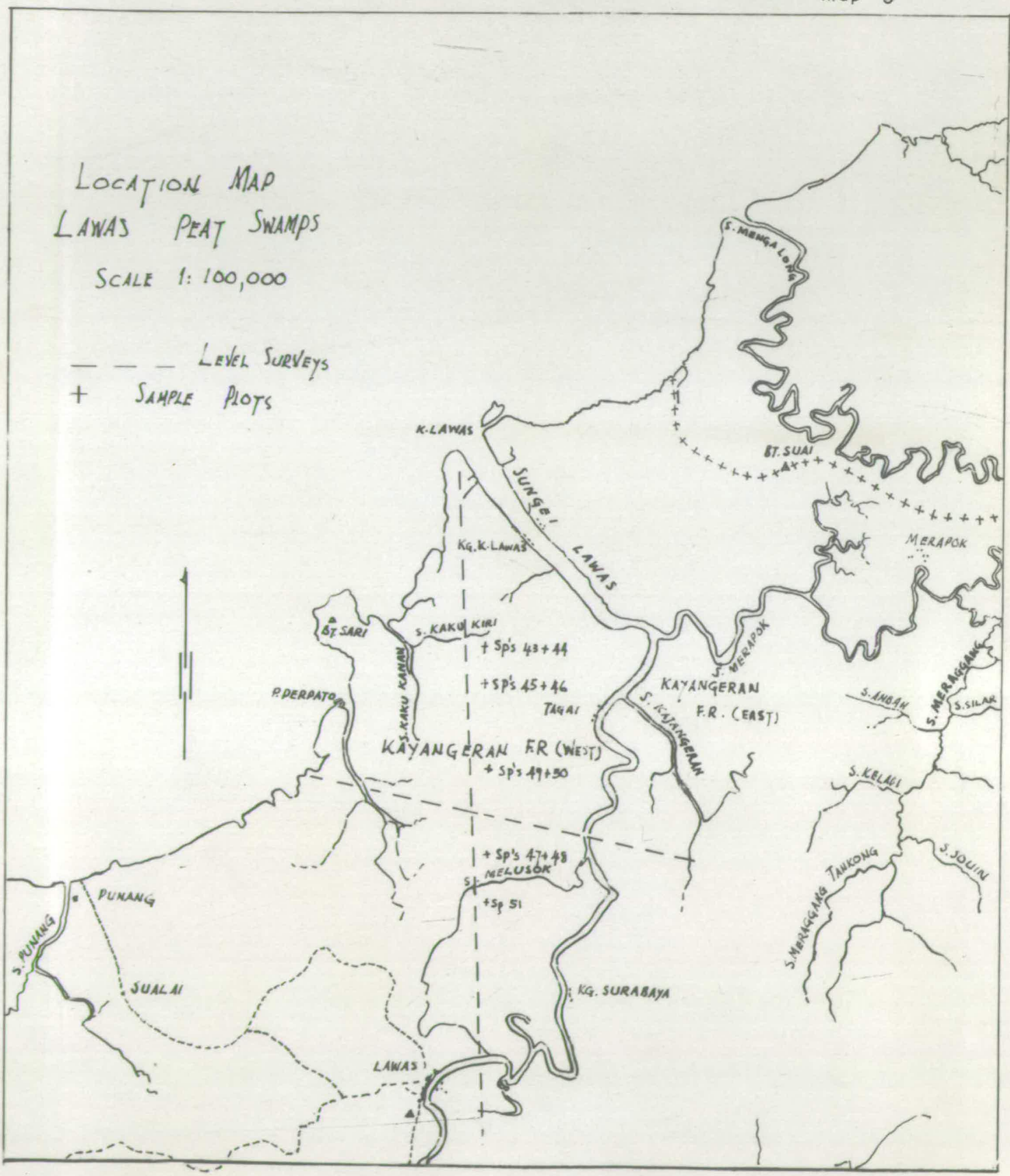
164. A feature of this community is the frequence of the flowering of the species. On the three occasions (twice in November, and once in June) when the community has been visited Dactylocladus stenostachys, Litsea palustris and Parastemon versteeghii have been found in full flower; fertile individuals of Combretocarpus rotundatus, Ternstroemia hosei and Ilex sclerophylloides were also noted. It has been observed that the flowering of the epiphytes and Nepenthes spp. is also widespread and frequent.

Chapter 11

Lawas Peat Swamp Forests

165. The eastern distribution of Shorea albida ceases at the Tutong river in Brunei and this species has not been recorded in the limited areas of peat swamps in the Fifth Division or in the Tembrurong District of Brunei. In the Lawas District the phasic communities dominated by Shorea albida are apparently replaced by unique forest types in which the conifer Dacrydium beccarii var. subelatum and Casuarina sumatrana are the principal dominants. As far as is known these species only occur in coastal peat swamps in this locality and in the immediately adjacent areas in the Colony of North Borneo. It is to be regretted that after forty years of exploitation little now remains of the interesting and unique Dacrydium forest.

166. The Dacrydium Casuarina forests in Sarawak are almost entirely confined to the Kayangeran Forest Reserve immediately north of Lawas (see Map 4). Two seismic surveys bisected the Kayangeran Forest Reserve (West) and the results of level surveys prove that the swamps are raised bog formations with a maximum height above mean sea level of 17.06 feet in the centre of the dome. Furthermore, these surveys indicate that the centre of the swamps has the characteristic bog plain. Peat depths were measured by Mr. B.E. Smythies; the maximum depth was twenty feet in the centre of the swamp and the average depth was approximately eighteen feet. Samples for pollen analysis were collected by Mr. J. Muller and the author from the centre of the swamp approximately one mile west of the Tagai sawmill. The depth of peat in this location was ten feet. A sample from the


LOCATION MAP
LAWAS PEAT SWAMPS
SCALE 1: 100,000
— — — LEVEL SURVEYS
+ SAMPLE PLOTS
S. MENGALONG
K. LAWAS
BT. SUAI
SUNGEI LAWAS
KG. K. LAWAS
MERAPOK
BT. SARI
S. KAKU KIRI
+ Sp's 43+44
+ Sp's 45+46
TAGAI
S. KAKU KANAN
P. PERPATOH
KAYANGERAN F.R. (WEST)
+ Sp's 49+50
S. MERAPOK
KAYANGERAN F.R. (EAST)
S. KAYANGERAN
S. ANGAH
S. MERAGGANG
S. SILAR
S. KELALI
+ Sp's 47+48
MELUSOK
+ Sp 51
S. JOUIN
S. MERAGGANG TAHKONG
PUNANG
S. PUNANG
SUALAI
KG. SURABAYA
LAWAS

Photograph 43 . This photograph was taken in a clearing in the Dacrydium-Casuarina Association. The tree in the centre with a feathery crown is a Dacrydium elatum and those with small rounded crowns are Casuarina sumatrana. The appearance of this forest type is not dissimilar to that of the Shorea albida Litsea Parastemon Association.

Photograph 44 . An attractive palm (Cyrtostachys lacca) in the Dacrydium-Casuarina Association. This species is rather rare in this forest type, but is abundant on shallow peat near the coast.

Photograph 45 . The understorey of the Dacrydium – Casuarina Association. The two trees in the left centre are Casuarina sumatrana, and that with the scaly bark is a Dacrydium elatum. The tall pandan is the same species (Pandanus pentodon) as that which occurs in the Shorea albida Consociation.

Photograph 45A . Two common pitcher plants in peat swamp forest, Nepenthes ampullaria, and Nepenthes bicalcarata.

base of the peat was forwarded for an age determination, using the radio carbon method, to the Department of Scientific and Industrial Research, Division of Nuclear Science, New Zealand, and was found to be 1830 ± 120 years old (1950 ± 70 years corrected for industrial effect), as reported by Wilford (73). The average rate of accumulation was therefore ~~0.0051~~ 0.513 feet per hundred years (see Chapter 14).

167. The composition of the forest has been examined by means of sample plots situated in five acre preservation plots, as it is now impossible to examine the catena by transects. This can only be interpolated by studying the probable former distribution of the forest types; by examining the structure of the swamps; and by a comparison of the floristic composition and structure of the forest in the remaining areas with the results obtained from elsewhere in Sarawak and Brunei.

168. Four pairs of half acre plots (Nos. 43-50) and one single plot (No. 51) were enumerated, and the complete results in three inch girth classes are included in Appendix 2. The location of the plots is shown on Map 5, and a summary of the more frequent and abundant species is included in Table 25. The plots are arranged in this table in accordance with the inferred catena. Owing to the limited areas remaining of the Casuarina Dacrydium forest it would serve little purpose to assign association rank to the communities, but the following forest types may be recognized:

Phasic Community I (Sample Plots 43 and 44)

Gonystylus-Casuarina Type (Sample Plots 45-48)

Dacrydium-Casuarina Type (Sample Plots 49-50)

Dacrydium-Campnosperma Type (Sample Plot 51)

Table 25. Distribution of species in sample plots in the Lawas District.

SPECIES	SAMPLE PLOTS 43	44	Total 43 & 44	45	46	Total 45 & 46	47	48	Total 47 & 48	49	50	Total 49 & 50	51
Upper storey													
Parastemon urophyllum	1	2	3										
Sandoricum emarginatum					2	2							
Mezzettia leptopoda	2	1	3	1	1	2							
Shorea platycarpa	2	3	5		1	1		1	1				
Parishia sericea				2	2	4	1	2	3				
Copaifera palustris	6	2	8	4	1	5	3	2	5				
Dyera lowii	15	15	30	13	6	19	32	26	58		1	1	1
Gonystylus bancanus	12	13	25	38	21	59	3	8	11		1	1	1
Dactylocladus stenostachys	2	2	4	2		2	9	10	19	7	10	17	8
Shorea scabrida					1	1	1		1	1	1	2	
Combretocarpus rotundatus	2									1		1	7
Casuarina sumatrana				7	11	18	21	13	34	9	27	36	
Litsea palustris										7	5	12	
Dacrydium elatum							1		1	32	62	94	113
Campnosperma coriaceum				1	1	2							32
Middle storey													
Ctenolophon parvifolius	8	4	12										
Polyalthia glauca	21	7	28										
Blumeodendron tokbrai	4	5	9		3	3							
Horsfieldia crassifolia		1	1		1	1							
Aromadendron nutans				6	1	7							
Palaquium leiocarpum				2	4	6							
Polyalthia hypoleuca	7	5	12	1	1	2		3	3				
Nephelium melanomiscum		2	2	4	5	9	2	4	6				
Palaquium pseudorostratum	4	3	7	3	3	6	4	6	10				
Gonystylus forbesii										2	4	6	
Tristania grandifolia		2	2	1	3	4	4	6	10	1	1	2	
Parastemon versteeghii	1		1		1	1				3		3	1
Palaquium cochlearifolium	2	2	4				1		1	5	9	14	8
Diospyros evenis		4	4	2	1	3	1	1	2	3	1	4	9

SPECIES	43	44	Total 43 & 44	45	46	Total 45 & 46	47	48	Total 47 & 48	49	50	Total 49 & 50	51
Lower storey													
Adenanthera pavoniana	1	1	2										
Alseodaphne rigida	2	1	2	2		2							
Glochidion lucidum		1	1		1	1							
Santiria laevigata	1		1	1		1	1		1				
Neoscortechinia kingii	8	11	19	2	1	3	1		1				
Tetractomia holttumii				2	2	4	1		1				
Antidesma coriaceum	1		1				6	2	8				
Knema kunstleri				3	1	4	1	1	2				
Canthium didymum	1	1	2							1	1	2	
Xanthophyllum amoenum	4	2	6	4	7	11	3	5	8	2		2	
Stemonurus umbellatus	4	3	7	2	1	3	8	1	9	5	3	8	
Hopea pentanervia				3	2	5	4	9	13	2	1	3	
Sterculia rhoidifolia	1	6	7	4	2	6	2		2				2
Litsea cylindrocarpa	1	1	2	1		1				1		1	1
Dillenia pulchella var.	4	6	10	2	1	3					2	2	1
Baccaurea bracteata	7	6	13	2	5	7	3	1	4		3	3	1

169. Phasic Community 1 needs no description, as the composition and structure of the forest is similar to that described previously. The number of species recorded is on the average less than in this association elsewhere in Sarawak. The important dominants Shorea rugosa var. uliginosa, Shorea inaequilateralis are absent from the Lawas swamps and Shorea teysmanniana is relatively rare. Dyera lowii is especially abundant; its regeneration may have been encouraged by Jelutong tappers.

170. In the Gonystylus-Casuarina Type the principal dominants are Gonystylus bancanus, Casuarina sumatrana and Dyera lowii; and the floristic composition is generally similar to Phasic Community 2. The large dominants of Casuarina sumatrana may exceed 130 feet in height and develop extensive stilt roots at the base which is a feature of the habit of the species in swamps. Trees of Gonystylus bancanus rarely exceed forty-eight inches girth. Tristania grandifolia, rare to very rare in peat swamp forest elsewhere, is very prominent in the Lawas swamps and is most frequent in this forest type.

171. In structure and aspect the Dacrydium Casuarina Type bears a close resemblance to Phasic Community 4. The remnants of this type occur in the centre of the swamps, and forty years ago the type probably extended over the whole of the bog plain. The tall slender trees of Dacrydium beccarii var. subelatum and Casuarina sumatrana form an even canopy at a height of approximately 110 feet. The forest has the same pole-like aspect as found in the Shorea albida Litsea Parastemon association, and light, penetrating through the sparse upper canopy, filters through to the swamp surface, where the radiating roots of Dacrydium and Casuarina form a platform above the water table.

The litter layer is largely composed of the needle-like leaves of the two principal dominants. The girth class representation (Fig. 42) shows a high preponderance of trees in the 36 to 59 inch classes, and few trees exceeding 72 inches girth. The most abundant associates in the upper and middle storeys are Litsea palustris, Dactylocladus stenostachys and Palaquium cochlearifolium, three typical species of Phasic Community 4. But the understorey includes Stemonurus umbellatus, Hopea pentanervia and Dillenia pulchella var. which are more commonly found in Phasic Community 2. Typical ground flora species are Nepenthes bicalcarata, Nepenthes gracilis, Euthemis obtusifolius and Ficus motleyana. Pandanus andersonii and the stemless tree fern Cyathea glabra are also locally abundant.

172. 172. The Dacrydium Campnosperma Type now occurs only in one very localized area, and it is suspected that it was never very extensive. The small remnant was probably unexploited as the trees are generally not of merchantable size. In structure, with a large proportion of the trees in the 12 to 35 inch girth classes, the Type resembles Phasic Community 5, but it occurs near the margin of the bog and it is possible that it does not represent the final stage in the catena. The even canopy, at a height of sixty to eighty feet, is very largely composed of Dacrydium beccarii var. subelatum and Campnosperma coriaceum. Casuarina sumatrana is completely absent. Other important upper storey species are Combretocarpus rotundatus and Dactylocladus stenostachys.

173. The numbers of species and individuals in the sample plots (average of each pair of plots) has been plotted on Figure 42A. The species decrease from forty-one in Phasic Community 1 to seventeen in

the Dacrydium Campnosperma Type. There is no increase in the numbers of individuals except in Plot 51.

174. There has been a certain amount of speculation on the unique occurrence of Dacrydium and Casuarina in the Lawas peat swamps. Browne's (5) hypothesis that these species are growing on small islands of dryland Kerangas soil in the centre of the swamp is quite untenable. The level surveys and measurements of peat depths show conclusively that the whole area is covered in deep peat. A thorough search, both by Dames (18) and the author, has failed to locate the low ridge which Browne mentions. It may be tentatively concluded that the forest types represent a catena, basically similar to that previously described, in which Casuarina and Dacrydium take the place of Shorea albida. The final results of the pollen analysis should indicate whether the catena in fact represents an ecological succession (see Chapter 14).

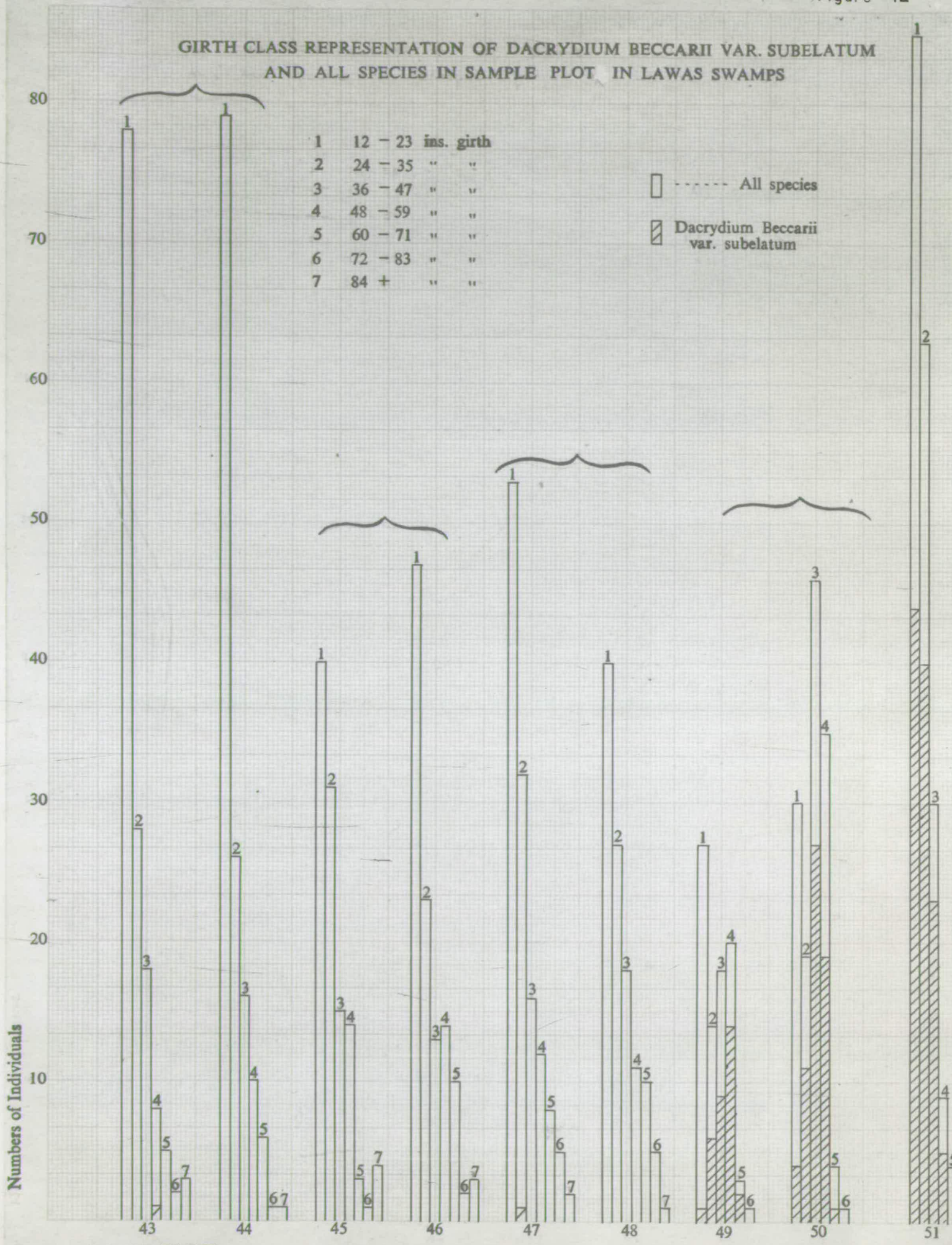
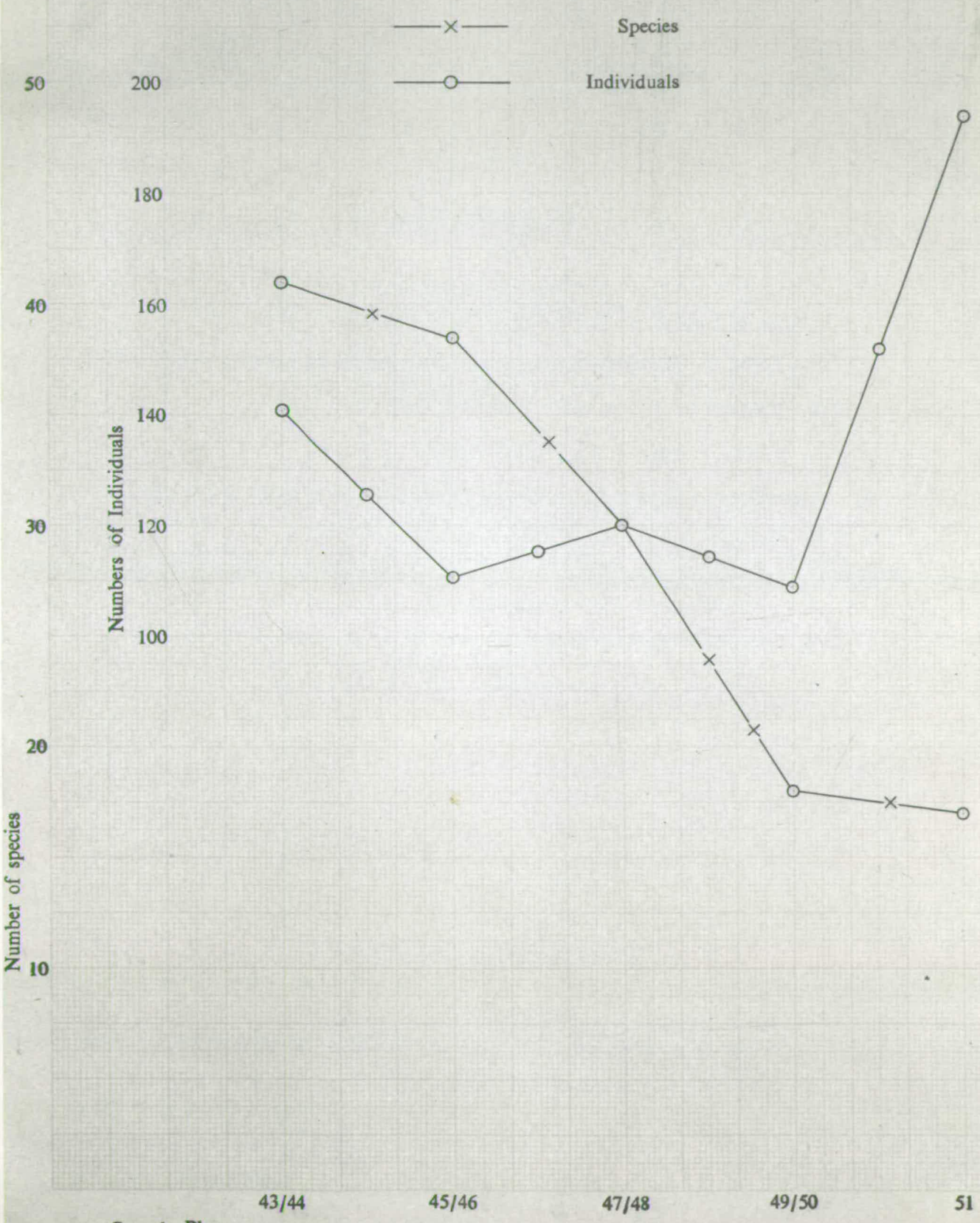

GIRTH CLASS REPRESENTATION OF DACRYDIUM BECCARII VAR. SUBELATUM AND ALL SPECIES IN SAMPLE PLOT IN LAWAS SWAMPS
1 12 – 23 ins. girth
2 24 – 35 " "
3 36 – 47 " "
4 48 – 59 " "
5 60 – 71 " "
6 72 – 83 " "
7 84 + " "
All species
Dacrydium Beccarii var. subelatum
Numbers of Individuals
80
70
60
50
40
30
20
10
43
44
45
46
47
48
49
50
51
SAMPLE PLOTS

Figure 42 A

NUMBERS OF SPECIES AND INDIVIDUALS IN SAMPLE PLOTS
IN LAWAS DISTRICT



Chapter 12

Interpretation of Phasic Communities from Aerial Photographs

175. Complete aerial photographic coverage, on a scale of 1:25,000, of coastal and deltaic peat swamps in Sarawak and Brunei is available. The Forest Department Sarawak has made extensive use of these aerial photographs in mapping forest types. Mr. B.E. Smythies, as previously mentioned, was the first to recognize their value, and he prepared maps of the Rejang Delta on which three basic types were recognized. The Land Use Maps of the territory were also prepared from aerial photographs. Brunig (9) in his preliminary classification of forest types of Sarawak from aerial photographs identified Meranti Bunga Forest (Phasic Community 3), in addition to the three basic types used on the Land Use Map, but Phasic Communities 5 and 6 were omitted. Moreover, he distinguished certain variations in Phasic Community 1. In this chapter only the general interpretation of the communities will be considered, though it is realized that certain variations within the communities can be recognized.

176. The principal features used in the interpretation of the phasic communities for aerial photographs are:

(i) Height and evenness of the canopy (a stereoscope is essential).

(ii) Texture and tone of the dominant crowns.

(iii) Density and homogeneity of canopy.

It is fortunate that Shorea albida may be identified without difficulty; the pale toned crowns of this gregarious species are an outstanding feature on aerial photographs of peat swamp forest.

No other species, except Alstonia spathulata and Campnosperma coriaceum, can be identified with certainty. Owing to the small scale of the photographs it is quite impracticable and frequently impossible, to measure crown size.

177. Brief descriptions, illustrated by plates, of the principal features of the phasic communities used in their interpretation from aerial photographs are included in the following paragraphs. Maps 2-4 have been prepared from aerial photographic interpretation, using the Land Use Map as a basis, with ground checks in localized areas.

178. Phasic Community 1 (Gonystylus Dactylocladus Neoscortechinia association) - Plates 25 and 26.

Canopy uneven, single emergents or groups of dominants; crowns very variable in size and texture, and usually lighter in tone than the denser middle and lower storeys visible beneath. Species cannot be identified, except the large white crowns of Alstonia spathulata near the coast, and occasional small gregarious stands of Campnosperma coriaceum.

179. Phasic Community 2 (Shorea albida-Gonystylus-Stemonurus association) - Plates 26, 27, 28 and 30.

Canopy uneven, large conspicuous emergent crowns of Shorea albida, light in tone, single or in groups; other dominants rare and darker in tone, middle storey crowns dense. Density and size of Shorea albida crowns very variable, but where crowns do not form a continuous canopy this community should be interpreted.

180. Phasic Community 3 (Shorea albida consociation) - Plates 27, 28 and 30.

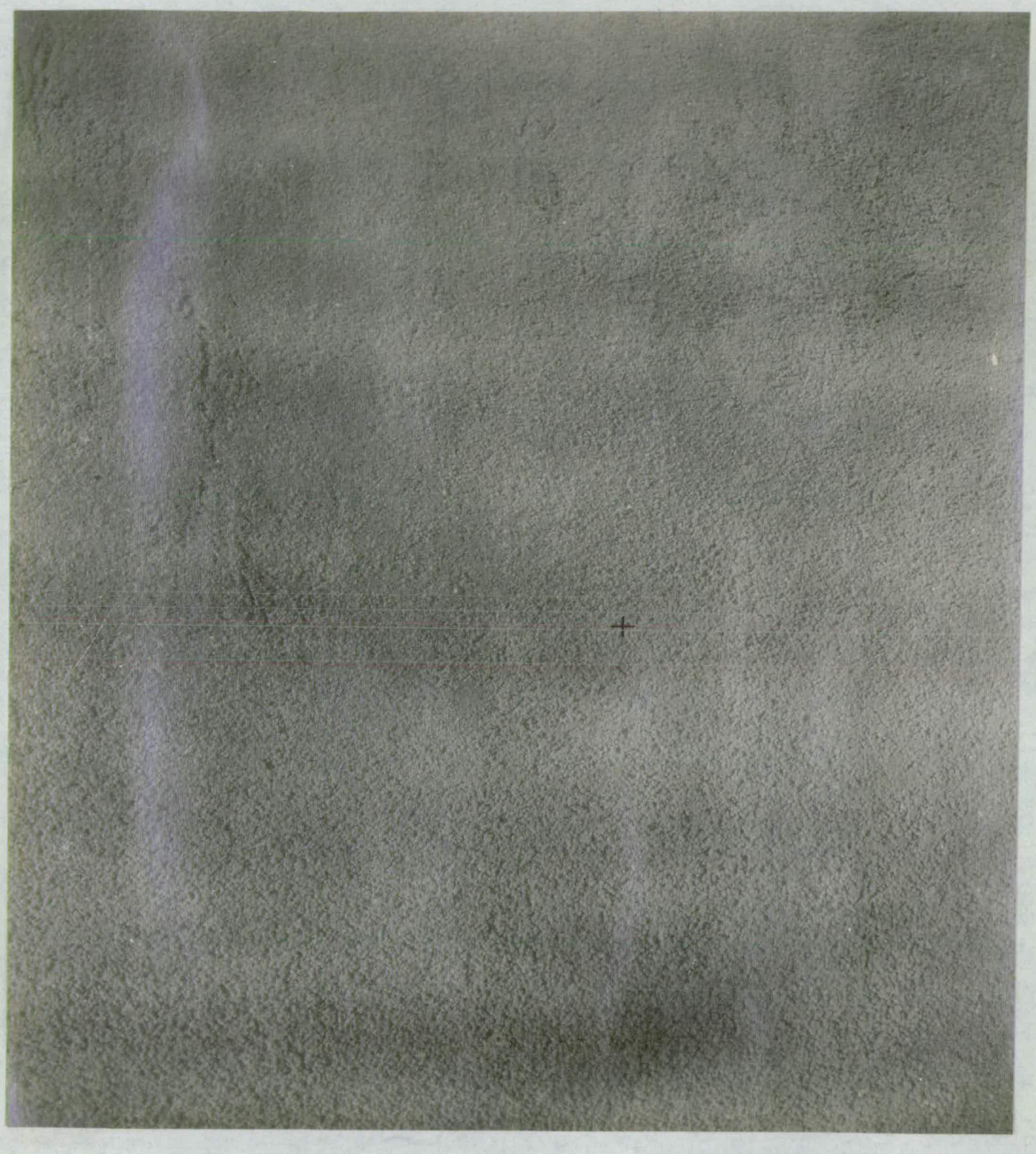
Canopy even and higher than in adjacent forest types, entirely

Photograph 46 , Lassa, Rejang Delta. Phasic Community 1, showing mangrove and the transitional zone at the top of the photograph. The very light patches indicate recent cultivation on shallow peat.

Photograph 47, Rejang Delta. Phasic Communities 1 and 2, the large white crowns of Shorea albida may be clearly identified.

Photograph 48 , Baram. Phasic Communities 1, 2 and 3. The individual crowns of Shorea albida in P.C. 2 may be distinguished, whereas in P.C. 3 they form a solid mass, broken only by distinct holes in the canopy, probably caused by lightning damage.

Photograph 49 , Maludam Peninsula. Phasic Communities 1, 2 and 3.



Photograph 50 , Rejang Delta. Phasic Community 4. Individual crowns can be barely distinguished. The lighter toned crowns indicate Shorea albida, and the darker smaller crowns Litsea palustris.

composed of dense light toned crowns of Shorea albida. Size of crowns variable, but on good quality photographs individual crowns can be differentiated; conspicuous breaks in the canopy, usually round or oval in shape, showing as small darker toned patches.

181. Phasic Community 4 (Shorea albida-Litsea-Parastemon association) - Plate 29.

Canopy even and very dense, individual crowns frequently indistinguishable, though on better quality photographs they can be differentiated as little more than pinpoints. Variable in tone; pale tone with even texture indicates Shorea albida, darker tone with feathery texture Litsea palustris. Wind damage is locally of frequent occurrence.

182. Phasic Community 5 (Tristania-Palaquium-Parastemon association) - Plates 30 and 31.

Canopy even and very dense, with a rapid decrease in height from the previous community; occasional emergents may be present. Tone conspicuously darker than forest dominated by Shorea albida.

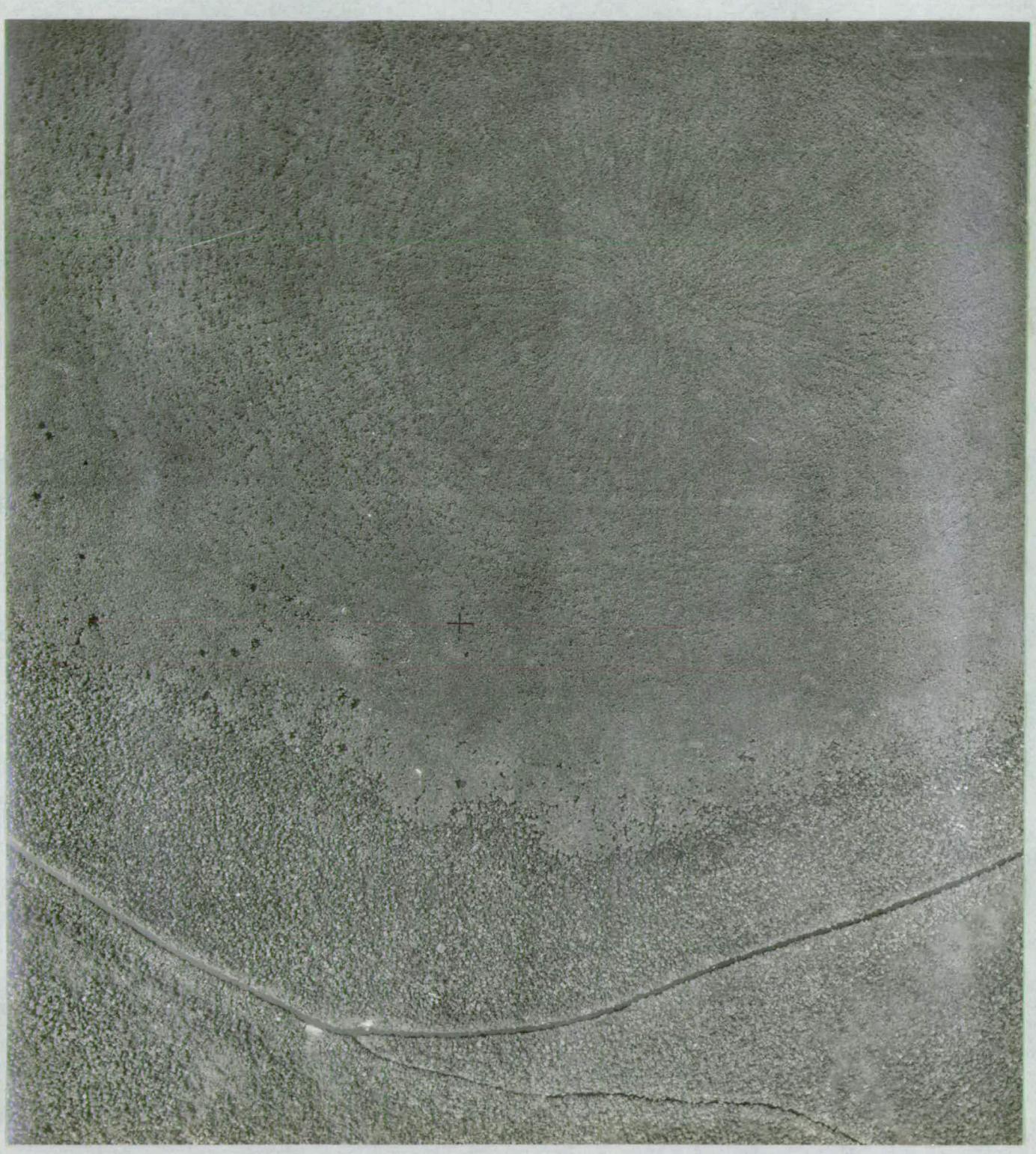
183. Phasic Community 6 (Combretocarpus-Dactylocladus association) - Plates 30 and 31.

Canopy open with scattered small dark toned trees; density decreasing towards centre of swamps, and concentric zonation of vegetation often present. Swamp surface reflects the light giving a lighter toned background.

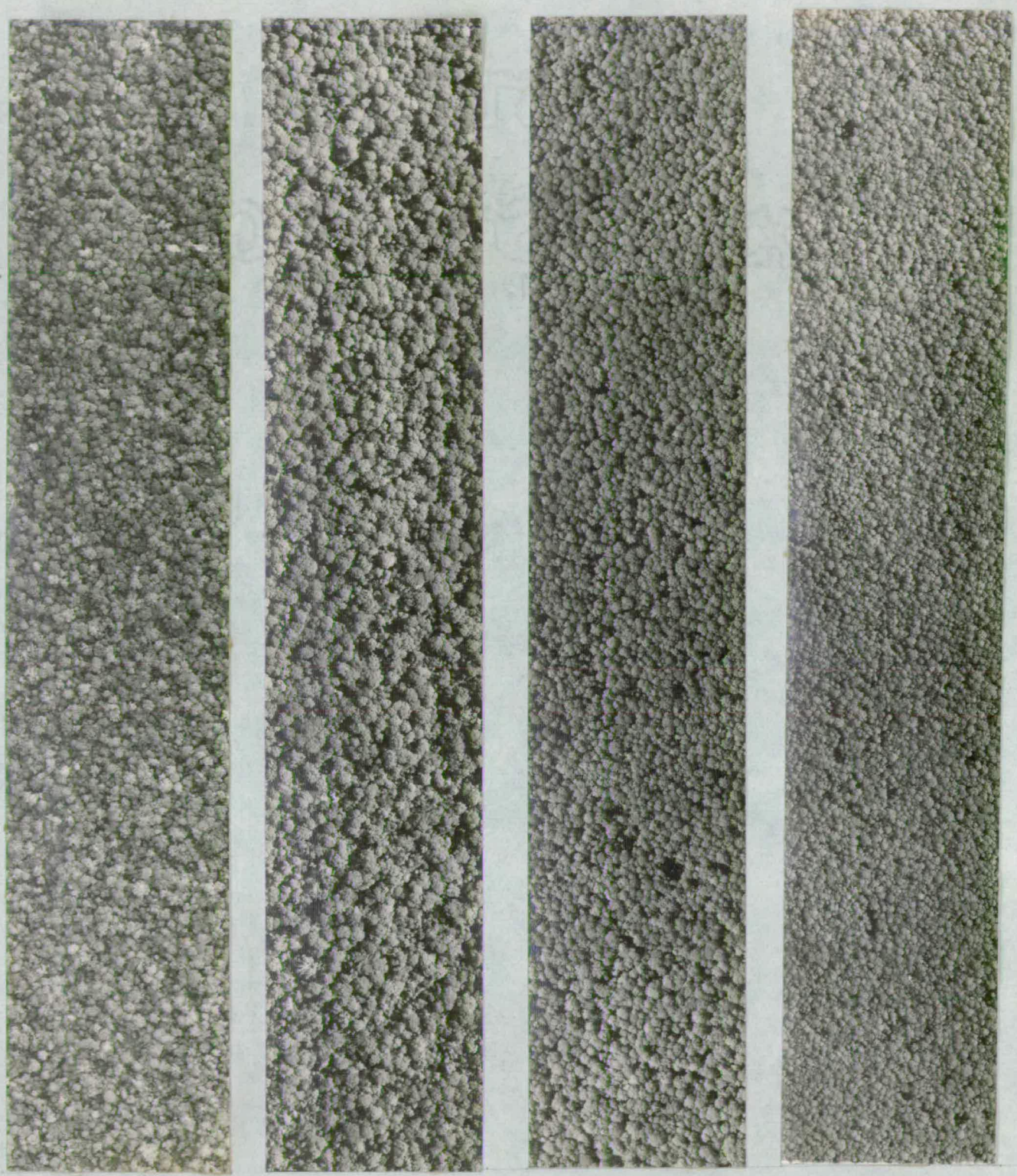
184. Plates 30 and 31 are of ecological interest in that they show similarities between these highly developed tropical raised bogs and Temperate raised bogs. Aerial photographs of Irish and Swedish bogs have a remarkably similar appearance. The concentric zonation

Photograph 51 , Baram. Phasic Communities 1 to 6, the complete series. P.C. 5 can be seen as a broad band of dense dark toned crowns between P.C. 4 and the very open forest in P.C. 6.

Photograph 52 , Baram. The zonation of the vegetation in Phasic Community 6 may be clearly seen here. The transect at Lubok Pasir ran into the centre of the swamp at the bottom right hand corner of the photograph.



Photograph 53 , Baram. A swamp that has not yet been investigated. Concentic zonation of vegetation in Shorea albida forest; in the centre a distinct radial zonation may be noted.



Photograph 54 . Four strips of aerial photographs at a scale of 1/12,500 that show differences in the canopy structure, particularly in crown size, in Phasic Communities 1 - 4. Number 1 was taken in the vicinity of Sample Plots 13 and 14, Nos. 3 - 4 over the Loba Kabang Protected Forest, where the transect in the Rejang Delta was located.

of vegetation is a conspicuous feature. Plate 32 illustrates an exceptional raised bog in the Baram that has not yet been examined. Here the concentric zonation is replaced in the centre of the bog by a distinct radial zonation. An unusual feature of this swamp is that the clearly zoned groups of trees are very largely composed of Shorea albida. It is suspected that the central radial zonation is caused by a slight depression in the bog plain.

185. The strips of aerial photographs on Plate 33 illustrate the principal differences in the canopy, especially in size of the crowns, in Phasic Communities 1 to 4. These photographs, on a scale of 1:12,500, were taken over the Loba Kabang Protected Forest and Pulau Bruit in the Rejang Delta, in the same localities as the first ecological survey was undertaken.

Part 4

Development of raised bog formations, and the hydrosere.

Chapter 13

Observations on the factors influencing the distribution of species and phasic communities

186. It seems apparent, as has already been mentioned, that the phasic communities mirror conditions of increasing infertility in the swamps. To determine more precisely the relationship between the distribution of species and edaphic factors further ecological surveys, especailly those of an autecological nature, are required. Nevertheless it is possible from the results of this study to point out certain primary factors and discuss their relative importance, and so indicate the lines along which further investigations may be made.

187. In Chapter 4 it was shown that the doming of the surface of bogs tends to become more pronounced with distance from the coast, and that coastal bogs have a more or less true lens-shaped structure whereas inland bogs are generally distinguished by a level or almost level bog plain in the centre. Moreover the distribution of phasic communities, as shown on Maps 2-4, indicates that the more advanced communities (Nos. 3-6) are of more frequent occurrence on inland than coastal swamps. A closer examination of the relationship between the surface structure and the distribution of the communities may be made by comparison of the gradients of the swamp surface. In Table 26 the gradients, expressed by the rise in feet, for each half mile across the surveyed swamps in the Rejang Delta are shown. The

Table 26. Gradients expressed in feet rise per half mile on surface of surveyed swamps in the Rejang Delta.

Survey No.	Distance 0 - ½	½ - 1	1 - 1½	1½ - 2	2 - 2½	2½ - 3	3 - 3½	3½ - 4	4 - 4½
1	3.10	3.17	3.63	2.17					
2	9.41	2.01	0.30						
3	5.89	2.15	2.54	1.68	0.87				
4	5.22	2.64	0.69	1.90	2.03	0.00	0.04	0.47	
5	8.3	1.9	1.4	0.6	0.5	0.5	0.6	0.2	0.2
6	15.13	7.37	2.72	1.02	0.77	2.12	3.00		

Survey No.	Location of surveys
1	Pulau Bruit (Sungei Semup)
2	Pulau Bruit (Kuala Paloh)
3	Daro Forest Reserve
4	Loba Kabang P.F. (Sungei Sawei)
5	Loba Kabang P.F. (Rantau Panjang)
6	Naman Forest Reserve

Table 27. Mean gradients of swamp surface in phasic communities in the Rejang Delta.

	Phasic communities. 1	2	4
Pulau Bruit (Sungei Semup)	0.00109		
Pulau Bruit (Kuala Paloh)	0.00204		
Daro Forest Reserve	0.00129	0.00058	
Loba Kabang P.F. (Sungei Sawei)	0.00150	0.00036	0.00016
Loba Kabang P.F. (Rantau Panjang)	0.00192	0.00026	0.00005
Naman Forest Reserve	0.00424	0.00048	

relatively steep gradient, especially in the Naman Forest Reserve, and the flat bog plain in the centre of the swamps are clearly indicated. Table 27 shows the mean gradients, expressed in decimals, of the swamp surface in the phasic communities. The gradient in Phasic Community 1 is three to seven times greater than that in Phasic Community 2, and Phasic Community 4 occupies the stagnant bog plain where the gradient is less than a foot per mile. Since the drainage of the swamps is probably very largely at the surface the gradients may be taken as an index of the drainage conditions. It is highly probable that the oxygen content of the surface peat soil is greater in the peripheral zone, in Phasic Community 1, and the conditions become increasingly more anaerobic towards the centre. The water table is a closely interrelated factor and reference may be made to Chapter 4 and Figure 7. The height of the water table is relatively stable in Phasic Community 1, where excess water drains off rapidly after periods of heavy rain, whereas in the centre of the swamp, in Phasic Community 4, variations up to 7.8 inches have been recorded, and greater variations can be expected. During periods of dry weather the water table drops, thus maintaining the water table in the peripheral communities, and the vegetation may be subject to drought, but during wet periods the higher stagnant water table probably causes conditions of physiological drought. Hence, perhaps, the development of radiating surface roots above the water table.

188. Initially it was considered that depth of peat might be correlated to the distribution of the communities. This view was supported by certain participants at the Kandy Symposium (58). Due to the convex structure of the bogs greater depths of peat tend to be

found towards the centre of swamps, and the deepest peats occur on the more inland swamps. But in individual swamps this pattern is highly modified by irregularities of the original ground surface below the peat. It is clear from the peat profiles in the Rejang Delta (Fig. 2) that there is no correlation between peat depth and the distribution of communities. The most notable example in support of this is the profile in the Naman Forest Reserve. Here, between twenty and one hundred chains from the river bank, the deepest peat recorded (over fifty feet) in the course of this study was found, yet the forest is entirely composed of Phasic Community 1. A further example is the profile in the Loba Kabang Protected Forest (Rantau Panjang), where Phasic Community 4 is found over some of the shallowest peat recorded on this survey.

189. Due to the convex nature of the bogs and the almost complete absence of flooding, replenishment of plant nutrients in the centre of swamps must largely come from the atmosphere. It was originally considered that the high rainfall and surface drainage was liable to cause severe leaching, and this combined with the loss of minerals in the peat itself, might be an important factor in determining the distribution of species. Samples collected have been inadequate to give proof of this hypothesis. In the Loba Kabang Protected Forest only the Phosphorus content was significantly lower in the samples from the centre of the swamp. It is noteworthy, however, that the mineral content of the samples from the highly developed raised bog in the Baram is much lower (loss on ignition 98 - 100 per cent) than in the Rejang samples. Moreover the centre of the bog is much poorer in Phosphorus and Potassium. The relatively

sharp transitions between Phasic Communities 4 and 5, and 5 and 6 require more detailed investigation. It seems unlikely that the structure of the bog, with consequent variations in drainage and water table, is an adequate explanation for the occurrence of these communities. Availability of plant nutrients may be an important factor. The most interesting feature of the analyses of the samples from the Baram was the greater mineral content in the top six inches. In the samples collected up to the thirty-fourth chain along the transect the top sample of the three taken in each locality was situated on the 'platform' of radiating roots above the water table. It is evident that as the feeding roots are most abundant in this layer the nutrient cycle probably by-passes the stagnant water table beneath, and a high proportion of the plant nutrients are carried up on top of the accumulating peat.

190. After a study of the structure of the bogs in the Rejang Delta had been completed, and the probable ecological importance of the surface drainage of the swamps realised, a brief investigation was made to determine the occurrence in three phasic communities (Nos. 1, 2 and 4) of morphological features characteristic of adaptations to anaerobic conditions. Pneumatophores and kneed roots are obvious adaptations, but the occurrence of stilt roots and buttresses was also enumerated, as the physiological function of these may possibly be related to anaerobic conditions. The results are shown in Table 28. The most significant feature of the results is that species without any apparent adaptations are generally confined to Phasic Community 1. The most prominent examples are Cratoxylon arborescens, Dillenia pulchella, Blumeodendron subcaudatum, and

Table 28. Adpatations of species to anaerobic conditions in Sample Plots Nos. 1 and 12

Sample Plot 1 (P.C. 1) SPECIES	Buttresses		Stilt Roots			Pneumatophores			No adaptations
	54"+	24-54"	54"+	24-54"	0-24"	pointed	kneed	Roots above surface	
Alangium havilandii			2	2					
Anisoptera marginata		1							
Aromadendron nutans							2		
Blumeodendron subcandatum									2
Buchanania arborescens									1
Campnosperma coriacea		1					1		
Campnosperma squamatum		1						1	
Cephalomappa malloticarpa							19		
Cratoxylon arborescens									5
Ctenolophon parvifolius		1						1	
Cyathocalyx biovulatus		1					2		
Dactylocladus stenostachys						1			
Dillenia pulchella var.					1				
Diospyros evenis	1							1	
Diospyros maingayi		1		1				1	
Diospyros pseudomalabarica		1			1		3		
Dryobalanops rappa.		2		3	4			2	
Durio carinatus							1		
Dyera lowii							5		
Eugenia chrismannii			1	1	1				
Ganua coriacea							5		
Ganua pierrei									7
Goniothalmus malayanus					2				
Gonystylus bancanus							2		
Gymnacanthera eugeniifolia					1				
Horsfieldia crassifolia		1							
Kayea sp. (509)		1						2	1
Kokoona ovato-lanceolata	1							1	
Litsea cylindrocarpa		1		1				3	3
Longetia malayana		1							
Mangifera havilandii								1	2
Mussaendopsis beccariana	1	1		2	1			2	1
Mezzettia leptopoda							2		
Neoscortechinia kingii									4
Nephelium melanomiscum		1						1	
Palaquium pseudocuneatum			1						
Palaquium pseudorostratum					1				
Palaquium ridleyi		1						1	
Palaquium walsurifolium			1	2					
Parishia sericea	1								
Pseudosindora palustris							1		
Quercus jaheri				1					
Quercus wenzigianus			1	1	1				
Samadera indica									1
Santiria rubiginosa		1							
Shorea inaequilateralis	2							1	
Shorea platycarpa	1							1	
Shorea scabrida		1							
Shorea teysmanniana									1

Table 28 (ctd.)

	Buttresses		Stilt Roots			Pneumatophores			No
	54"+	24-54"	54"+	24-54"	0-24"	point-ed	kneed	Roots above surface	adaptations
Shorea rugosa var. uliginosa	1	2			1			1	
Sindora leiocarpa									2
Stemonurus umbellatus									5
Vatica mangachapoi								1	
Xanthophyllum aff. citrifolium					1				
Xylopia coriifolia			2						
Totals	8	20	8	14	15	1	43	18	35

Sample Plot 12 (P.C. 4) SPECIES	Buttresses 54"+	24-54"	Stilt Roots 54"+	24-54"	Pneumatophores 0-24"	Pointed	Kneed	No adaptations
Arthrophyllum rubiginosum							1	
Calophyllum retusum		2		2	4			
Calophyllum obliquinervum							1	
Combretocarpus rotundatus				1	1			
Cratoxylon glaucum		1		1				
Dactylocladus stenostachys			1	1		6		
Eugenia sp. (2715)	1	3						
Gonystylus bancanus							3	
Litsea palustris	3	7		6	6			
Lophopetalum rigidum				1				
Melanorrhoea beccarii	2	2						
Palaquium cochlearifolium		3						
Parastemon versteeghii	8	7		2	5			
Shorea albida	15	23	1	22	15			
Sterculia rhoidifolia					1			
Swintonia glauca		2		4	4			
Ternstroemia hosei		4		2	3			
Ternstroemia magnifica					2			
Tristania obovata	1	1		1	3			
Totals	30	55	2	43	44	6	5	-

Sindŕa leiocarpa. Species with prominent pneumatophores or kneed roots, such as Gonystylus bancanus, Dactylocladus stenostachys, Dyera lowii and Copaifera palustris, generally have a wider distribution across the swamps. There are certain anomalies, especially in middle and lower storey species: Stemonurus scorpioides has prominent small pneumatophores yet is confined to Phasic Community 1, whereas the related species Stemonurus umbellatus, with no apparent adaptations, is abundant in Phasic Communities 1 to 3. True stilt rooted species, that is, with stilt roots arising at heights above two feet from the swamp surface and frequently without a central root, are largely confined to Phasic Community 1. Alangium havilandii, Myristica lowiana, Palaquium walsurifolium, Quercus wenzigianus, Platea excelsa and Blumeodendron tokbrai are typical examples.

191. The results so far indicate that the surface structure of the bogs has a considerable influence on the distribution of species. This is particularly apparent in the initial formation of the bog plain, but this factor is inadequate to explain the development of Phasic Communities 5 and 6. It is suggested that a more intensive analysis of the edaphic factor in these two communities, and a further attempt should be made to obtain samples from various depths in the swamps to determine the distribution of nutrients in the profile.

Chapter 14

Development of raised bog formations and succession of forest types

192. In the previous chapter it has been shown that there is a loose correlation between the distribution of the phasic communities and the structure of the raised bogs, and that the apparently younger communities (Phasic Communities 1 and 2) generally occur near the coast, whilst the more advanced communities are to be found inland on raised bogs which usually have a greater depth of peat and a more highly developed structure. It is evident that an explanation for the distribution of the phasic communities based on the development of the raised bogs and the increasing infertility at the centre of the bogs can be framed. But it must be admitted that the evidence is circumstantial and without further data the explanation must remain hypothetical. It was therefore decided to attempt, with the collaboration of the Brunei Shell Petroleum Company Limited, a pollen analysis of a single core from the centre of a highly developed raised bog.

Pollen analysis

193. This section was undertaken jointly with Mr. J. Muller, Palynologist, Brunei Shell Petroleum Company Limited, who was responsible for all the laboratory work.

194. It was known from the pioneer work of Polak (38) that pollen is well preserved in peat swamps of Malaysia, and this was confirmed by Van Veen (60A) who collected surface samples in Brunei.

There are, however, certain basic problems that affect the interpretation of the results which should be mentioned at the outset. A thorough knowledge of the flora and the composition of the vegetation communities is a prerequisite, and, though certain fundamental knowledge has been gained during the course of this study, considerable gaps still remain. Moreover, no attempt has been made to study the floral biology of peat swamp species and there is a general dearth of information on this subject for the tropical rain forest as a whole. It is suspected that most species are insect pollinated, but there is little data on frequence of flowering, pollen production, pollen mechanisms, and dispersion of pollen. Erosion and redeposition of pollen is another aspect which requires further investigation. This may occur on shallow peats or possibly even by the surface drainage of well developed bogs.

195. Initially it was necessary to build up a representative collection of comparative material. Most of this was obtained from botanical specimens collected during the course of this study or from fresh material in the field. But for a number of species material was obtained from herbaria at the Royal Botanic Gardens, Kew, and the Botanic Gardens, Singapore. In a few instances it was necessary to substitute material from a species of the same genus not found in peat swamp forest.

Location

196. The site selected for the bore was in the centre of the swamp opposite Marudi, on a bearing of 215° and a distance of 132 chains from the banks of the Baram at Lobok Pasir (see Map 4). The

forest was entirely composed of Phasic Community 6 for a distance of approximately one mile in all directions.

Field technique

197. Some difficulty was initially experienced in obtaining samples. In 1955-6 attempts were made using Dachnowski and Hiller peat samplers, but these proved a failure in tropical peats, being incapable of dealing with the virtually undecomposed or semidecomposed woody material found at all levels. The flange on the container was frequently buckled or even broken. Furthermore, when the container was opened it immediately filled with the soupy matrix which, apart from providing an inadequate sample, often drained away or became contaminated on the withdrawal of the sampler. However, with the assistance of Dr. G.E. Wilford of the Geological Survey Department a final attempt was made in 1958 using a Swedish Kjellman piston soil sampler. This heavy instrument, though cumbersome and difficult to handle in peat swamps, produced excellent results. Occasionally it was found impossible or impracticable to drive the sampler through well preserved woody material and a further bore had to be attempted elsewhere in the locality. Moreover the sample was liable to contain an overabundance of woody material and little pollen. But there can be little doubt that the centre of each sample was virtually undecontaminated. A series of twenty-seven samples was obtained at half metre intervals from the surface to a depth of thirteen metres. The clay subsoil was reached at ten metres. A further set of samples was taken for chemical analysis (see Chapter 4), and sufficient additional bulk material at five, ten and twelve metres was collected by Dr. Wilford

for radio carbon dating. Surface samples were collected from phasic communities in the Baram for comparison with the samples from the bore.

Laboratory technique

198. The core samples were carefully opened in the laboratory and the undisturbed central column of the core was utilized for preparation only. If the sample was large, a representative smaller sample was taken by random selection of a number of smaller pieces, otherwise the complete undisturbed sample was prepared. The samples were first boiled for a few minutes in 5 per cent KOH and the resulting disintegrated mass was washed with water by repeated decanting until the water remained fairly clear. The sample was then sieved and the coarse residue retained for examination on larger plant remains. The fine residue was centrifuged and then subjected to standard acetolysis-treatment. Most samples yielded a rich crop of pollen, but a few of the very fibrous ones had to be sieved again on a finer sieve. One sample only failed to yield sufficient pollen. Preservation of pollen was excellent throughout.

Peat lithology

199. Lithology and peat stratification has been studied in the field and in the laboratory. The results have been summarized in the columns for peat lithology and humification degree on the chart (Fig. 45). In the field details of texture, colour and macroscopically visible plant remains have been noted. In the laboratory the smaller plant remains were studied with low and high magnification after chemical treatment of the samples. pH and mineral content have also

been determined. The most important components of the peat are remains of wood, bark, roots and rootlets, cuticles and leaf mosses. A few very typical but as yet unidentified tissue fragments were noted. The degree of humification has been estimated by a combination of observations on texture while fresh, appearance of tissue fragments microscopically and by a rough colorimetric test. For this, the colour of the alcohol extract of the prepared residue was compared as very striking differences appeared after some time.

On the basis of these observations, the column studied could be roughly subdivided into four stratigraphic units.

A. The basal clay and transition to peat from 13-11.5 m. The clay is very humic at the bottom and semidecayed plant fragments, possibly derived from Nipa are frequent. Microscopically the large amount of pyrite inside the plant tissue fragments is conspicuous, which suggests a brackish influence in the depositional environment. The clay very probably represents a mangrove sediment. The transition to the overlying peat from 12-11 m. is gradual.

B. From 11.5-5.5 m. a rather compact strongly humified wood peat of a typical crumbling, granular structure occurs. Minor variations between the amounts of wood and bark remains, and the occurrence of cuticles and rootlets are indicated as far as possible on the column for peat lithology. The sample at 9.5 m. consisted almost entirely of wood, but this may have been accidental as remains of very large logs are found scattered throughout the profile.

C. At 5 m. the character of the peat changes markedly. From 2-5 m.

few wood remains are found, the peat has a very high water content, is sloppy and less humified and is very difficult to collect in. Root fragments of monocotyledonous type both large and very small make up the bulk of the peat. It is possible that Pandanus roots occur as its pollen is well represented at these levels. Other peculiar tissue fragments are also found which do not occur either below or above. At 4 m. and from 3-2 m. a large amount of leaf moss remains are found. They occur in a perfect state of preservation and complete archegonia are conspicuously frequent.

D. From 2-0 m. the peat is heavily compacted, fibrous and highly humified. Small pieces of wood occur, but roots, rootlets and cuticles are the main constituents.

Recognition of pollen and spores

200. The samples were subjected to standard acetolysis treatment. With the aid of the reference collection it proved possible to identify with reasonable certainty about 75 per cent of the pollen and spores occurring in samples. Many of the unidentified types, moreover, were generally scarce and probably of little importance for ecological interpretation. The certainty of identification varies, of course, for the different species, genera and families involved. Specific identification was occasionally possible, but more often only the genus was recognizable. Due to a lack of a comprehensive reference collection uncertain determinations had to be indicated by adding 'type' to the species or genus of the pollen. Finally it must be stated that the accuracy of the determinations depends to some degree on the assumption that little extraneous pollen is represented. The evidence

available indicates that this assumption is largely valid.

Results

201. Most samples were rich in pollen, which was in an excellent state of preservation. Very little extraneous pollen was found. This is in all probability due to the large area covered by the peat swamp; to the dense forest which clothes the swamp (except in Phasic Community 6); and to the general absence of strong winds. These factors are a direct contrast to conditions frequently prevailing in peat bogs of the Temperate Zone. Over-representation of localised vegetation, caused by pollen and intact flowers dropping in situ, is more to be expected. As the peat accumulates at a rate of approximately one foot per hundred years (see para. 213), a single sample may represent the peat accumulation beneath a single tree. An attempt has been made to minimize errors of over-representation by taking a well mixed sample from each small core sample.

202. The pollen content of different species varied very considerably. Certain species, such as Dactylocladus stenostachys, Gonystylus bancanus and, in mangrove, Rhizophora spp., were very well represented; whereas other species, for example Dyera lowii and Neoscortechinia kingii, which in the catena are no less abundant, were very poorly represented. There was also a complete or almost complete absence of pollen of the families Lauraceae, Leguminosae, Anonaceae, Myristicaceae and Sapindaceae. Herbarium material of the Lauraceae produced very little pollen on acetolysis, and it is suspected that some of the other families may be poor pollen producers. The possibility, however, that the pollen of these families is not durable in

peat swamps cannot be dismissed. The problem requires further investigation.

203. It has proved impossible to differentiate the pollen of species in certain genera which may be represented by two or more species with marked differences in their ecology and distribution. The genera Palaquium, Calophyllum and Quercus and Eugenia are the most prominent examples. The last mentioned genus has also to be grouped with Tristania. Dipterocarpaceae pollen was also a problem; Dryobalanops rappa could be identified and a Shorea albida 'type' (perhaps including at least one other Shorea), but the remainder are grouped under Dipterocarpaceae varia.

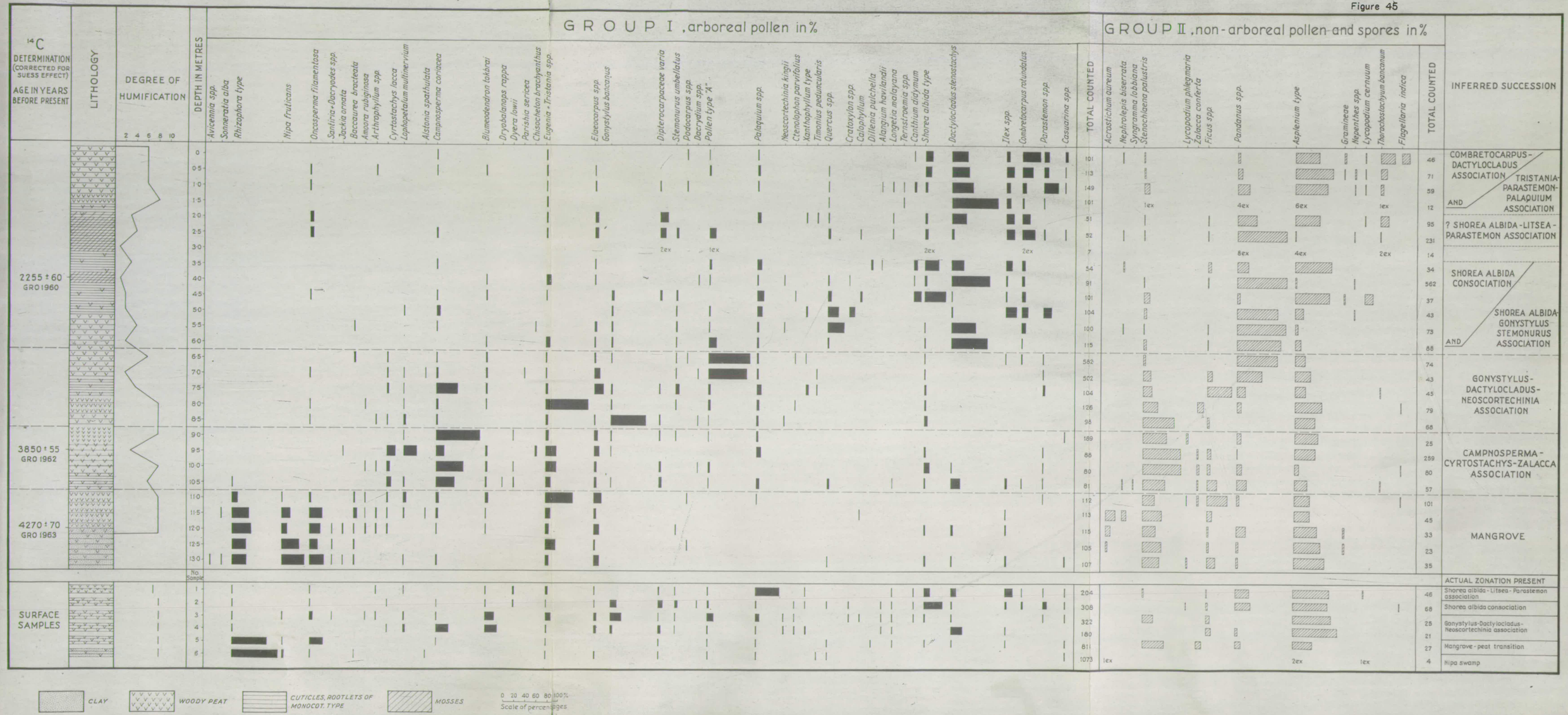
204. In the preparation of the pollen diagram (Fig. 45) all positively identified pollen types have been included; unidentified pollen and spore types which are of small percentage in any sample have been excluded. The diagram has been divided into two groups: Group I shows the arboreal flora down to understorey species, and Group II the shrubs, herbs, epiphytes, climbers and ferns. Percentages were calculated separately for each group. The columns from left to right on the diagram represent the following:

(1) Carbon 14 determination. Age has been given in years before the present (1959) corrected for a suess-effect of 230 years (see para. 213).

(2) Peat lithology in simplified style, showing approximate quantitative relations between clay, woody peat, fibrous peat (cuticles and rootlets) and remains of mosses.

(3) Degree of humification on a convential scale.

(4) Depth in metres below surface.


14C DETERMINATION (CORRECTED FOR SUESS EFFECT) AGE IN YEARS BEFORE PRESENT
LITHOLOGY
DEGREE OF HUMIFICATION
2 4 6 8 10
DEPTH IN METRES
GROUP I, arboreal pollen in %
Avicennia spp.
Sonneratia alba
Rhizophora type
Nipa fruticans
Oncosperma filamentosa
Santiria-Dacryodes spp.
Jackia ornata
Baccaurea bracteata
Amoora rubiginosa
Arthrophyllum spp.
Cyrtostachys lacca
Lophopetalum multinervium
Alstonia spathulata
Campnosperma coriacea
Blumeodendron tokbrai
Dryobalanops rappa
Dyera lowii
Parishia sericea
Chisocheton brachyanthus
Eugenia - Tristania spp.
Elaeocarpus spp.
Gonystylus bancanus
Dipterocarpaceae varia
Stemonurus umbellatus
Podocarpus spp.
Dacrydium spp.
Pollen type "A"
Palaquium spp.
Neoscortechinia kingii
Ctenolophon parvifolius
Xanthophyllum type
Timonius pedunculatus
Quercus spp.
Cratoxylon spp.
Calophyllum
Dillenia pulchella
Alangium havilandii
Longetia malayana
Terminalia spp.
Canthium didymum
Shorea albida type
Dactylocladus stenostachys
Ilex spp.
Combretocarpus rotundatus
Parastemon spp.
Casuarina spp.
TOTAL COUNTED
GROUP II, non-arboreal pollen and spores in %
Acrostichum aureum
Nephrolepis biserrata
Syngramma lobbiana
Stenochlaena palustris
Lycopodium phlegmaria
Zalacca conferta
Ficus spp.
Pandanus spp.
Aspleniym type
Gramineae
Nepenthes spp.
Lycopodium cernuum
Therachostachyum bancanum
Flagellaria indica
TOTAL COUNTED
INFERRED SUCCESSION
2255 ± 60 GRO 1960
3850 ± 55 GRO 1962
4270 ± 70 GRO 1963
No Sample
SURFACE SAMPLES
COMBRETOCARPUS-DACTYLOCLADUS ASSOCIATION AND TRISTANIA-PARASTEMON-PALAQUIUM ASSOCIATION
? SHOREA ALBIDA-LITSEA-PARASTEMON ASSOCIATION
SHOREA ALBIDA CONSOCIATION AND SHOREA ALBIDA-GONYSTYLUS-STEMONURUS ASSOCIATION
GONYSTYLUS-DACTYLOCLADUS-NEOSCORTECHINIA ASSOCIATION
CAMPNOSPERMA-CYRTOSTACHYS-ZALACCA ASSOCIATION
MANGROVE
ACTUAL ZONATION PRESENT
Shorea albida - Litsea - Parastemon association
Shorea albida consociation
Gonystylus-Dactylocladus-Neoscortechinia association
Mangrove - peat transition
Nipa swamp
CLAY
WOODY PEAT
CUTICLES, ROOTLETS OF MONOCOT. TYPE
MOSSES
0 20 40 60 80 100%
Scale of percentages

DISTRIBUTION OF ARBOREAL SPECIES IN THE CATENA

SAMPLE PLOTS	Santiria + Dacryodes spp.	Jackia ornata	Baccaurea bracteata	Amoora rubiginosa	Arthrophyllum spp.	Cyrtostachys lacca	Lophopetalum multinervium	Alstonia spathulata	Campnosperma coriacea	Blumeodendron tokbrai	Dryobalanops rappa	Dyera lawii	Parishia sericea	Chisocheton brachyanthus	Eugenia + tristania spp.	Elaeocarpus spp.	Gonystylus bancanus	Dipterocarpaceae varia	Stemonurus umbellatus	Podocarpus spp.	Dacrydium spp.	Longetia sp.?	Palaquium spp.	Neoscortechinia kingii	Ctenolophon parvifolius	Xanthophyllum type	Timonius pedunculatis	Quercus spp.	Cratoxylon spp.	Calophyllum	Dillenia pulchella	Alangium havilandii	Longetia malayana	Ternstroemia spp.	Canthium didymum	Shorea albida type	Dactylocladus stenostachys	Ilex spp.	Combretocarpus rotundatus	Parastemon spp.	Casuarina spp.	PHASIC COMMUNITIES
32															8								54			1			48						2	15	10		9	33		VI Combretocarpus-Dactylocladus Assoc.
31					1										50	1							36			1			46					3		23	82		6	67		V Tristania-Parastemon-Palaquium Assoc.
29									1						46	1	4						54			1			48				1	1	2	15	10		9	33		
40															8								10						6							30	3		20	24		
41									1						8											1			6							38	25	1	10	17		
39															3														7							86	19			24		
38															8								5													92	8		10	16		
37												1					4						25													95	4		10			IV Shorea albida-Litsea-Parastemon Assoc.
36									1								34						10			3			12	2				2	59	2		8	2		
23															50	1							1						6	1			2	2	8	14	3	10	51		
12					1										10		3						3						1	8				11		76	6		2	22		
11															3	3	10						2						20	12				11		56	3		2	19		
10															23		1						1			3			9	6				8		32	7		4	20		
9					2										13	2	5						6			1			5	15				6		35	9		2	23		
30			1												12		5						13		1	13			19				5	1	6	4	1	1	6	6		
28												9					28						9					2							44			9	11		
35												2					30						1							6					30	1		3			
34												6					19	1					1		1					2					27	3		4	4		III Shorea albida Consoc.
25												1			1	1	1	1					1			12	1	8					1		16	1		1	3		
24		1										1					1																		27		1	1	1		
22																							4			6								1	34	1		5	5		
16												1			1			3					3											4	26	9		4			
15															2			1					2											1	25	10		5			
8												8					3		5				3			1		8		13		1	1		12	7		5	1		
7												1			1	1	3	1	2				5							5					3	8	12		5	6		
6		1		1								13			3		4	2	8				4	1	1							1	1	2	10	3	1	5	1		
5				1								1			1		7	4	2				7		1			2		1		5		1	15	1		4			
21									7			1			4		5	3	3				1	7	1	6					1			1	6	5		1			
4	1										1	11			6	1	1	8	6				7	5		7				1		1		1	5						II Shorea albida-Gonystylus Stemonurus Assoc.
3									1		2	5			4		6	11	7				12	6		4					2	1		1	8						
18				1					1		5	5			5		9	5	6				3	12	5	4		4		1					2	3	4					
17	4			1							4	3			4		4	5	5				3	14	3	1		2		1			1		2		4					
33												4					5		3				1			2						1			10	4		3	1		
27	1								4						8	1	2	3	3				4			3					1	1		1	5	1		2	2		
26	4								8		2	2			6	2	3		6				2								1	6		2	4	4		1	2		
2	2		1								2	5	2		5	1	6	16	6				4	11	2			5	1			2		1					1		
1	1								1		9	5	1		3		2	9	5				6	4	1	1		4	5	1	1	4	1			1					
20									3		9	2			13		1	12	1				4	10	1	1					27										I Gonystylus-Dactylocladus-Neoscortechinia Assoc.
19	15	2							5						8		5	7	1				1	9							7	2	1				2				
14	2			10			1	5			8				3		13	5	1				3	14	1	5		6	1		6	2				1			2		
13	4			11	1		1	7			2				1		17	1					2	7	1	9		1			8	5			1				2		
52					2		1	12			2	2					1	5						11	2							1	1		1						
53		1		111			45								8		1	1	48							2			11			1	2				2		4		Campnosperma-Cyrtostachys-Zalacca Assoc.

(5) Percentages in which all positively identified pollen or spore types are found. In one sample, at three metres, pollen was virtually absent, whereas in others grains belonging to Group II were too few to indicate as a percentage. In such cases the number of grains found is stated. The pollen and spore types have been arranged in a stratigraphical order.

(6) The inferred succession. This is discussed in the following paragraphs.

Beneath the peat profile the results of the pollen analysis of the surface samples are plotted in the same manner as above.

Interpretation of results

205. It is abundantly clear from the pollen diagram that the peat has originated over former mangrove and that a succession, with similarities to the catena, previously described, has occurred. Floristic boundaries in the peat above the mangrove are indistinct, but from a knowledge of the surface vegetation of the swamps approximate boundaries have been drawn.

206. The mangrove pollen, especially Rhizophora spp., Nipa fruticans and Oncosperma filamentosa, is particularly abundant and occurs between 13 and 11 m., above which there is a precise boundary. The lithology shows the clay level at 11.5 metres, so the initial formation of peat probably occurs in old mangrove forest in which the typical mangrove species provide a proportion of the debris. Most of the non-mangrove pollen, especially the Eugenia or Tristania and Gonystylus pollen, is probably extraneous in this zone, being brought

in by tidal action. The fern Acrostichum aureum is a typical mangrove species and Asplenium spp. are common epiphytes in this forest type.

207. From 10.5 to 9 m., proceeding upwards, the abundance of Campnosperma coriaceum and Cyrtostachys lacca pollen clearly indicates the previous occurrence of the Campnosperma Cyrtostachys Zalacca association, a transitional zone between the mangrove and true peat swamp. The presence of Zalacca conferta and Lophopetalum multinervium is further confirmation of this association which, though not investigated in detail during this study, has been briefly described in Chapter 8.

208. Above 9 m. the pollen is almost entirely confined to true peat swamp species; the little obvious extraneous pollen of Group I species belongs to conifers and Casuarina spp. An indication surely that few Angiosperms are wind pollinated in tropical rain forest. In considering the inferred succession above 9 m. it is of interest to compare the pollen diagram with the recorded distribution of species in the catena which is shown on Figure 46. Species have been arranged in the same order as in the pollen diagram, and the sample plots follow the catenary sequence previously shown in Chapter 7, starting with sample Plot 58 and the Phasic Community 1 plots at the bottom of the diagram. It is apparent that there is a general similarity between the pattern of the two diagrams, and this is most pronounced at the beginning and end of each diagram. It is significant that close correlations are found in Combretocarpus rotundatus, Dactylocladus stenostachys, Stemonurus umbellatus, Ctenolophon parvifolius and Lophopetalum multinervium. The first two of these are monospecific, and the others are the sole representative of the genera recorded in

the Baram peat swamps. The distribution in the profile of the important swamp species, Gonystylus bancanus, is largely as may be expected. Though the Shorea albida type may include at least one other species of Shorea, the abundance of this pollen in the upper half of the diagram is in accordance with its distribution in the catena. The abundance of pollen of Longetia sp. (?) at 6.5 and 7.0 metres is at present a complete enigma. It has not yet been possible to identify this pollen with any certainty despite the evidence from the surface samples that shows it still occurs in peat swamps. The principal anomalies between the two diagrams are Alangium havilandii, and Dillenia pulchella, which in the pollen diagram are completely misplaced, though it must be admitted that the pollen representation of both species is very low. There is little of significance in the distribution of the pollen of species or genera that are grouped, i.e. Calophyllum, Eugenia and Tristania, Palaquium, etc., except that it generally conforms with the wide distribution of the genera or groups in the catena.

209. The evidence of the non-arboreal pollen and spores in Group II generally confirms the interpretation of the arboreal pollen. Stenochlaena palustris is very abundant as a climber on shallow peat and becomes increasingly more rare in the catena. The distribution of the spores of this species confirms this. The spores of Syngramma lobbiana and pollen of Zalacca conferta are largely confined to the zones between 6.5 and 10.5 metres, as may be expected. The frequent occurrence of undifferentiated Ficus pollen is of interest as, considering the floral mechanism of figs, it is hardly to be expected. It is most abundant in the inferred transitional zone, where Ficus

crassiramea is a common and very prominent strangler, and in Phasic Community 1 where figs are particularly numerous. The abundance of pollen of Pandanus in the upper middle half of the diagram and generally correlated with the Shorea albida type pollen indicates the presence of Pandanus andersonii, a species that frequently forms thickets, especially in the Baram swamps, in the Shorea albida consociation. No grasses have been recorded in primary peat swamp forest. The Graminae pollen is, therefore, probably extraneous.

210. The most obvious floristic boundaries have been indicated, but above 6.5 metres only the inferred succession is shown. It must be admitted that the inferred succession in this zone is controversial, and requires further pollen results for elucidation.

211. The surface samples taken for comparison with the samples from the bore have been arranged in accordance with the catenary sequence (to Phasic Community 4). Rhizophora pollen is surprisingly found in all samples and was represented by over forty per cent of the pollen content in the mangrove - peat transition even though the lithology of the sample was woody peat with no clay content. Most of the surface samples were collected from near the coast so the Rhizophora pollen is probably extraneous. In other respects there is a general correlation between the representation of the pollen in the two diagrams.

212. The structure and lithology of surface peat requires more study before any conclusions can be drawn from the results of this analysis. The abundance of particles of mosses in the samples between 1.5 and 4.0 metres is unexplained. It has been noted, however, that mosses are particularly abundant on the base of trees

in Phasic Communities 3 and 4, and this is in the approximate zone of these communities in the inferred succession. But the surface samples from these communities do not support this interpretation.

Radiocarbon age determinations

213. The peat samples for radiocarbon dating were analysed by Professor H.L. de Vries, Physical Laboratory, University of Groningan, Holland, and the results have already been reported by Wilford (73). These indicate that the peat has accumulated at an average rate of almost one foot per 100 years during the past 4,500 years. The present coast is thirty miles to the north and northwest, thus the Baram delta must have moved seawards at an average rate of about thirty feet per year during the last 4,500 years. Wilford (l.c.) records that this is comparable to the rate of growth of the Limbang flood plain. The rates of accumulation of the peat are shown in the following table:

Depth of sample	14 C determination	Rate of accumulation
5 metres	2255 ± 60 years	0.7271 ft. per hundred years
10 "	3850 ± 55 "	0.8521 ft. " " "
12 "	4270 ± 70 "	0.9221 ft. " " "

Rate of accumulation: 5 to 0 m. = 0.7271 ft. per hundred years
" " " : 10 to 5 m. = 1.0285 ft. " " "
" " " : 12 to 10 m. = 1.5624 ft. " " "

The most significant feature about these results is the decreasing rates of accumulation towards the surface. For the structure of a

raised bog to change from an almost true lens to the characteristic flat centred (inverted plate) structure typical of highly developed bogs one must presuppose either an increase of accumulation on the perimeter or a decrease in the centre. The rate of accumulation in the early stages of development is approximately twice that in the final stage. From these results it may be presumed that the rate of accumulation decreases in each succeeding phasic community in the catena, hence the gradual extension of the bog plain towards the perimeter of the swamp.

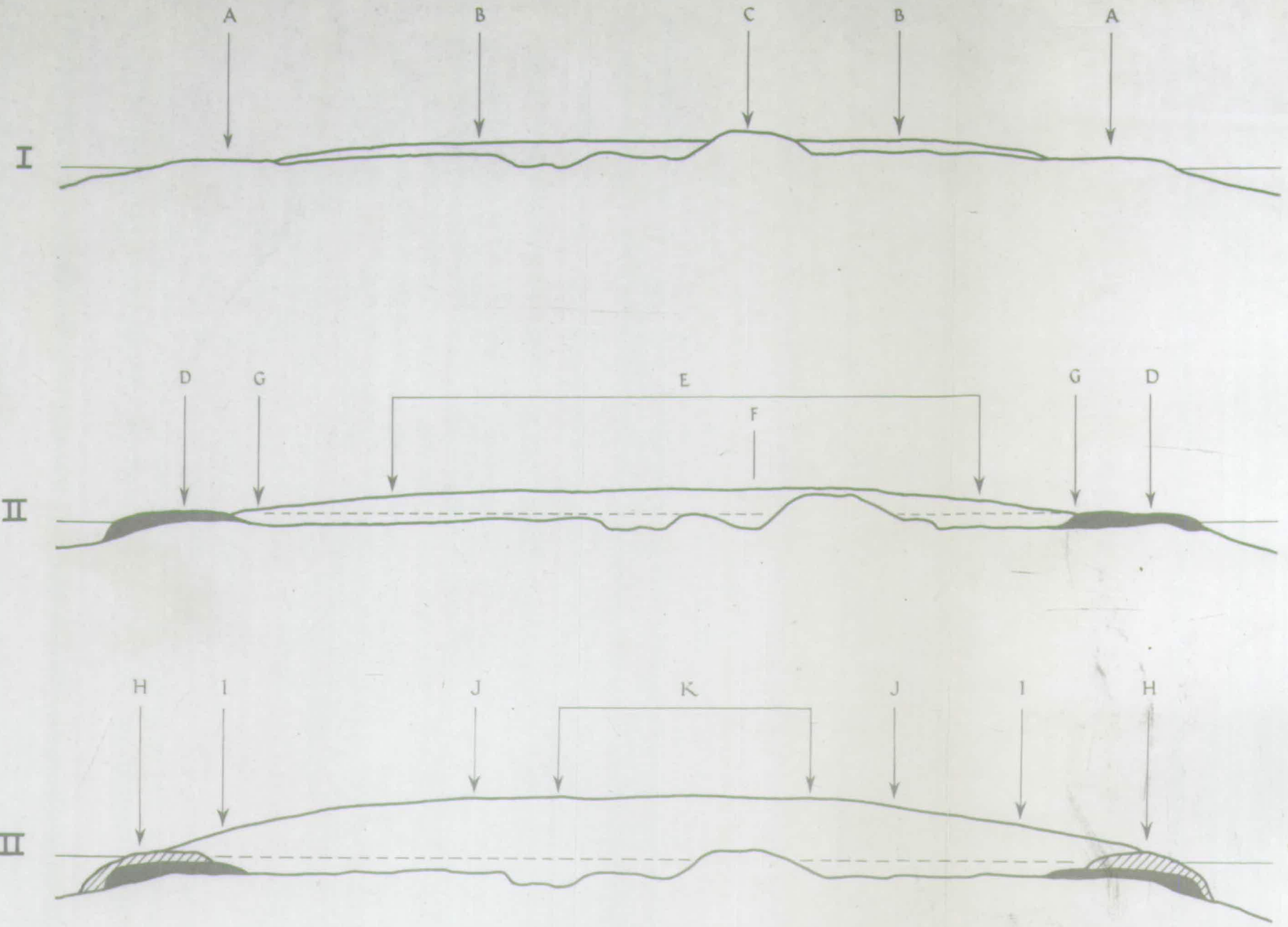
Development of raised bogs

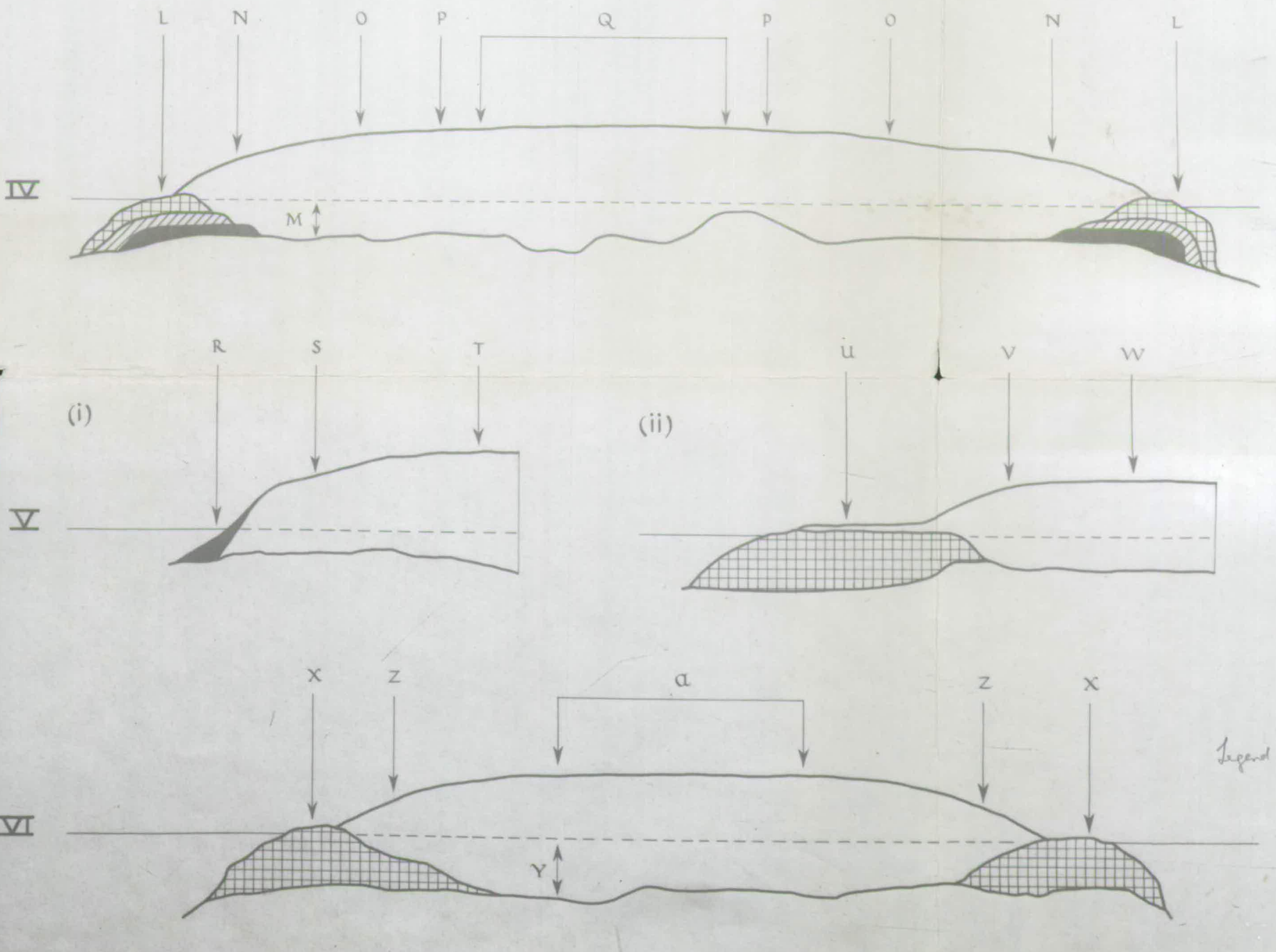
214. From the results of the pollen analysis of a single core it may be concluded that the phasic communities bear a relationship to each other in time as well as in space; and that the catena in fact represents an ecological succession in the development of the raised bogs. It is now possible to describe in greater detail the development of the raised bogs and the series of Phases. It is realized, however, that in fact the process is continuous and the Phases represent only convenient divisions. The Phases are shown diagramatically in Figure 47, and are briefly described below.

Phase 1. Alluvium transported by the rivers is deposited at or within the mouths of the rivers, in bays, or along the coastline itself where the erosive action of sea currents is at a minimum. The alluvial deposits, where not permanently inundated, are colonised by mangrove ('A on Diagram). As a result of further deposition and the seaward progression of the mangrove, combined with the build up of plant debris (conspicuous in the more inland mangrove communities)

Figure 47

DEVELOPMENT OF RAISED BOG FORMATIONS





and the action of crabs, the surface becomes progressively less inundated and the mangrove is replaced by a transitional phase (B) on shallow peat; the first layers of which probably consist to a large extent of semidecomposed mangrove debris. The relatively flat surface and the heavy clay soil provide conditions of impeded drainage. The transitional phase is characterized by the Campnosperma Cyrtostachys Zalacca association. The original subsoil surface may not have been perfectly level: mangrove channels would cause depressions, and small islands of higher land (C) would remain clothed in dry land forest. Such isolated hillocks are still conspicuous near the landward margins of the swamps (see Profile Diagram 4, Fig. 2).

Phase II. Consequent of the further seaward progression of the coastline there is a 'backing up' of tidal rivers and the mean river level rises. The latter is clearly indicated by the seismic level surveys shown in Figure 4. This will cause a further deposition of alluvium (D) along the river banks on the margins of the swamps which, if the tidal influence is still saline, will remain under mangrove forest, probably dominated by Nipa fruticans. The peat swamp, separated from the mangrove by a narrow transitional zone, develops the characteristic shallow convex shape and is dominated by Phasic Community 1 (E). The accumulation of peat will obliterate minor undulations (F) so forming the characteristic irregularities in subsoil levels. The variations in peat depth have no apparent influence on the development of the bog or the distribution of the vegetation.

Phase III. In this phase (III on Diagram) the rate of accumulation in the centre decreases and the bog develops the characteristic structure with a flattening at the centre to form the bog plain (K),

which is usually occupied by one of the phasic communities dominated by Shorea albida. Phasic Community 2 usually occurs on the margin of the bog plain (J), and Phasic Community 1 on the steeper gradient of the peripheral zone (I). An additional rise in the mean river level will result in further alluvial deposits on the margins of the swamps, where, provided there is no saline influence, riparian vegetation will replace the mangrove fringe.

Phase IV. This final phase (IV on Diagram) is only found in the Baram and Belait rivers. The accumulation of peat continues at a decreased rate in the centre of the bog and the bog plain extends laterally. Consequently the margins of the bog are relatively steep and the distribution of Phasic Communities 1, 2, 3 and 4 (N, O, P) becomes very constricted, whereas Phasic Community 6 (Q) covers the central bog plain, with a narrow zone of Phasic Community 5 separating it from Phasic Community 4. Phasic Community 1 may be absent or occupy only a very narrow zone near the river bank.

215. Diagrams V (i) and (ii) on Figure 47 indicate the effects of river erosion on the swamp margins. Meanders are a prominent feature of most of the large rivers, especially of the Baram, Oya, Mukah and Balingian rivers, which drain through the coastal plain. There is no evidence to show that rivers cut right through the peat bogs but within certain limits the rivers meander and erode the margins of the bogs, not infrequently causing the formation of oxbow lakes. Severe erosion on the margins may cut through the levee and expose the peat itself (R). Examples of this are to be seen in the Baram between Marudi and the coast. When the river changes course again the surface will tend (if allowed) to revert to peat swamp

forest. Occasionally the silt may lie over peat and a succession, from the surface, of peat - clay or silt - peat may occur. Examples of this have been recorded by the seismic surveyors, and by the Consulting Engineers (71) at Kuala Tinjar. In Diagram V (ii) the silting up of a meander succeeded by the redevelopment of peat on the surface (U) is illustrated. An example of this is shown in the Profile Diagram 3 (Fig. 3) from Tanjong Jabei in the Baram. If the meander becomes completely detached from the river before it has been silted up a hydrosere in the oxbow lake may develop. This has not been studied, though examples are known from the Baram and Oya rivers. The erosion of peat by the sea is a rather rare phenomenon, as, generally owing to the continuous deposition of alluvium, the mangrove and peat swamps are ~~generally~~ progressing seaward. The mangrove or littoral fringe and even peat swamp forest may, however, be eroded when a change of sea currents occur. An example of this erosion (see Plate 34) has been observed on the west coast of Pulau Bruit (Rejang Delta). The peat swamp had been eroded for a distance inland of approximately half a mile, and the depth of peat was seven feet.

216. This general theory on the development of the raised bogs gives an explanation for the cause of the typical biconvex shape of the bogs, as mentioned by Richards (44). The upper surface results from the accumulation of peat, and the convex lower surface, below river level (though not necessarily below sea level) originates from the build up of alluvium on the swamp margins, consequent of the rise in river level, with the original subsoil at a lower level in the centre of the bog. In Diagram IV the difference between the subsoil

Photographs 55+56. Sea erosion of peat swamp forest on the western side of Pulau Bruit. Note the surface rooting of the trees, especially that of a Dactylocladus stenostachys in the left foreground.

level and the mean river level is shown (M) and this will approximately equal the rise in the river level above mean sea level. Where, however, subsidence has occurred, as in the Rejang Delta, the subsoil level may be below mean sea level and the difference between the subsoil level and the mean river level will be much greater ('Y' in Diagram VI). Removal of the peat in such areas may result in inundation by saline water. This has occurred on Pulau Bruit where shallow peat has been cultivated. An interesting and perhaps significant consequence of this subsidence is the fact that the height of the surface above sea or river levels in the centre of the bogs is less in the Rejang Delta than in the Baram, and the water table is therefore less stilted. This may be a possible explanation for the complete absence of Phasic Communities 5 and 6 in the Rejang Delta; the succession has never proceeded beyond Phasic Community 4. There can be little doubt that the peat swamps towards the apex of the Rejang Delta are as old as the Marudi swamps. In fact the deepest peats recorded have been in the former locality.

Causal factors influencing the development of peat

217. Mention has already been made in Chapter 1 of conflicting opinions about the causal factors of peat formation in the humid tropics. In this study the early conditions of peat formation and the transitional zone from mangrove have not been investigated in detail. This, it is felt, must form the subject of a separate detailed ecological study, in which tidal measurements, chemical analyses of soils and ground water in different zones, and an investigation of biological activity in the soils are included.

Here, the ecology of peat swamps after their initial formation has been considered. Nevertheless certain results from this study are relevant when considering conditions under which peat initially develops on the north coast of Borneo.

218. A stiff clay, almost certainly of mangrove origin, was found below the peat in all bores in the Rejang Delta. In the Report (70) on the Maludam Peninsula it is stated "the soil on the river banks is clay and clay underlies the peat deposits in the interior." This clearly refutes the opinion of Kostermans (27) that peat will only develop on infertile poorly drained sands, and supports the view of Bramao (58) that reducing conditions of waterlogged soils are important and peat soils have a clay horizon that holds the water table. A subsoil of sand has been recorded in localized areas in the Pagalayan Canal area (Fig. 3) and in a recent bore (results not included in this study) in the centre of the Lawas peat swamps. But these are exceptions and there is little evidence from Sarawak and Brunei to support the hypothesis of Wyatt-Smith (58) that peat swamp forest in Malaysia is always associated in an estuarine area with a sandbank which has appeared on the seaward side of the land thereby damming up a large surface of water. There is some evidence of this in localized areas and coastal sandbars or mudbars are a prominent feature at the mouths of many rivers, especially between the Matu and Belait rivers. But along this stretch the coastline has the appearance of being relatively stable. Indeed there is perhaps more evidence at present of erosion than accretion. The development of peat swamps in lagoons in Sarawak is probably of very limited occurrence. Areas where peat swamp is clearly developing at present,

or would develop if cultivation had not intervened, are associated with the rapid seaward progression of mangrove, notably in Brunei Bay within the Rejang Delta and on Nonok and Maludam peninsulas. It is significant that these areas are either in bays or to the leeward of projecting land masses and thus protected from the scouring effects of the predominant northeast-southwest currents of the China Sea. The occurrence of a highly developed raised bog close to the coast at Seria in Brunei (see Map 4) would indicate that the littoral fringe in which the oil field is situated at one time formed a long spit or sand bar out at sea causing the formation of a bay, which was rapidly filled with alluvium from the Baram and Belait rivers. There is no comparable swamp near the coast in Sarawak or Brunei.

219. The initial formation of peat overlying clay requires further investigation. It is a controversial problem that was discussed at some length at the Kandy Symposium (58). Richards (244) supports the view of Mohr (31) that in the lowland humid tropics in addition to waterlogged conditions a deficiency of bases is necessary. In Sarawak and Brunei the fact that the alluvium has originated from generally infertile and acidic soils from the Interior of Borneo tends to support this hypothesis. The clay soils of mangrove origin may, however, be relatively rich in bases (perhaps unavailable to plants). Mohr and van Baren (31A) mention the possible occurrence of an impediment or poison in the soil flora which might not exert a similar effect in the micro-flora. From the results of this study it is suggested that the high Sulphur content associated with cat clays may be toxic to microbiological activity and provide conditions for the development of peat. It is significant perhaps that the initial formation of peat is relatively fast (see para. 213).

Part 5

Climatic and insect damage in peat swamp forest.

Chapter 15

Observations on Climatic Damage in Peat Swamp Forest

220. A study of climatic damage in the peat swamp forests of Sarawak has certain advantages: the structure of the forest is markedly variable in different forest types, thus enabling a comparison of the effects of climatic damage; and the topography is perfectly flat (infinitesimal gradients of the raised bog formations can be ignored), so factors caused by variations in topography are minimised.

Wind Damage

221. Climatic damage in peat swamp forest was initially interpreted from aerial photographs (scale 1:25,000) of the Rejang Delta. Extensive areas of apparent wind damage were noted in the centres of some of the larger peat swamps, where the forest is of the Shorea albida Litsea Parastemon association, and especially where Litsea palustris is the principal dominant. In some localities the interpretation was confirmed by reports from forest survey parties. The most extensive areas of wind damage occur in the Loba Kabang and Oya-Mukah protected forests, and in the Narub Forest Reserve. In each of these localities the damage covers hundreds of acres. Plates 35-37 show typical examples of wind damage. Perhaps the most remarkable of these is Plate 35 which shows damage in the Narub Forest Reserve. Here the destroyed forest, which is entirely composed of the Shorea albida-Litsea-Parastemon association, covers approximately 250 acres, and the distance from the focal point to the

Photograph 57, Rejang Delta. Wind damage in Phasic Community 4, probably caused by a line squall. The distance from the focal point to the limit of damage is over a mile.

Photograph 58 , Rejang Delta. Severe winds damage in Phasic Communities 3 and 4.

Photograph 59 , Rejang Delta. Old wind damage in Phasic Communities 2 and 4. The regrowth has also been partially damaged.

extreme limit of damage is just under a mile and a half. A notable feature, to be seen in other areas also, though to a lesser extent, is the blast-like nature of the damage, resembling the surface pattern of the effects of a shrapnel shell. The principal damage is confined to an arc of about 30 degrees, but there is also evidence of lateral and back blast, indicating that the wind though having a strong horizontal direction may also have been rotating. Plate 36 shows another extensive area of wind damage within the same reserve, but here the Shorea albida consociation has been struck, on more than one occasion. Plate 37 is of interest in showing an area of forest, probably formerly of the Shorea albida consociation, which has been severely damaged many years previously and pole sized regrowth has been subsequently struck again.

222. Severe wind damage, on the scale found in the Third division of Sarawak, is generally absent from peat swamps in other localities in Sarawak and Brunei, though limited damage, usually a single swathe through the forest, is to be found in all areas.

223. Dr. I.E.M. Watts (formerly of the Malayan Meteorological Service, now Government Meteorologist, Hong Kong), examined Plate 35 and considers that the damage is most likely to have been caused by line-squalls, which occur in movements of the boundary separating two air streams or in the onset of a sea breeze, though local thunderstorms may produce isolated convectional storms of a similar nature. The 'Sumatras' which strike the south-west coast of Malaya are of the former type. A characteristic of these, which accords with squalls noted on the Bornean coast, is the down currents, of small horizontal extent and short duration, which would not necessarily show on upper-

wind observations, while the strength of the squall wind could be accounted for by convergence as the down-draft impinges on the ground (the canopy of the forest).

224. Recording instruments in Sarawak and Brunei are too few and far between to obtain accurate information on localized squalls along the coast. But squalls are of relatively frequent occurrence and occasionally do considerable damage especially along rail line extraction routes in peat swamp forest. On two occasions the author has been caught in squalls in the Shorea albida Litsea Parastemon association. The experience is somewhat frightening; the small crowns of the canopy trees on long attenuated stems whip and twist in the wind and one expects at any moment the forest to break above one's head. On such occasions the local people not unnaturally clear out of the forest as quickly as they can. An interesting record of the localized nature of a squall was reported by Urquhart (60) in the Baram District of Sarawak: "A whirlwind on a very narrow front struck one end of Penghulu Gau's longhouse at Long Ikang on 18th September. The wind got under the end six doors (apartments) and liftem them off their foundations, depositing them in a crumpled heap on the ground."

225. In the Shorea albida Litsea Parastemon association wind damage usually lays the forest flat, frequently uprooting the trees; most, if not all, of which are surface rooting. This form of damage has been encountered on three occasions. An example of the damage is to be seen in Plate 38. A second type of damage results in the crowns of trees - mostly Shorea albida - being snapped off, often at a height of from ten to thirty feet from the ground. Shorea albida, and indeed most species in this forest type, has an unusual ability to

Photograph 60 . Typical wind damage in the Shorea albida Litsea Parastemon Association.

Photograph 61 . A wind thrown Shorea albida, somewhat unusually torn up by the roots and leaving a cavity in the swamp over which a temporary bridge has been constructed.

recover by sucker shoots, frequently developing in the process double or triple stems. In an area of wind damaged forest in the Loba Kabang Protected Forest an enumeration of a two chain square plot was undertaken to determine the composition and origin of the regeneration. The results are included in Table 28A. Fifty-five per cent of the stems originated from vegetative regeneration, and many other stems were probably also of coppice origin though it was impossible to ascertain this with any certainty. The principal species in the regrowth are Quercus sundaicus (a small light-demanding tree that comes away very fast when the canopy is opened), Litsea palustris, Elaeocarpus obtusifolius and Combretocarpus rotundatus, which throws off numerous sucker shoots even from the stem of the fallen tree.

226. Severe wind damage in the Shorea albida consociation may kill some trees and severely damage the crowns of others. Evidence of this is frequently encountered in the forest. In a complete enumeration of all trees of Shorea albida in an eighteen acre block in the Maludam Peninsula 128 of a total of 1006 trees enumerated showed obvious signs of previous wind damage; 43.5 per cent of the trees of greater girth than 72 inches was damaged, and 82.1 per cent of those larger than 108 inches. It is probable that this damage occurred at least sixty years ago and most of the smaller trees in the block have originated from regeneration following the holocaust. Large trees that show signs of damage and regrowth of the crown are likely to be very defective.

227. Less frequently damage in the Shorea albida consociation may take the form of wind throw, with one, two or more trees uprooted in a swathe. In one locality in the Baram damage of this nature was

Table 28A. The results of an enumeration of regrowth in wind damaged forest in the Rejang Delta. Area 0.2 acres.

Species	Girth classes (inches) 12	15	18	21	24	27	30	33	36	39	42 and over	Total
Quercus sundaicus	6(5)	11(7)	5(4)	5(3)	1(1)							28(20)
Copaifera palustris		1(1)										1(1)
Dyera lowii	2				1							3
Elaeocarpus obtusifolius	2(2)	3(2)	2(2)	2			1					10(6)
Shorea albida											1(101")	1
Combretocarpus rotundatus	4(4)	1(1)	1(1)		3(3)		1(1)					10(10)
Cephalomappa malloticarpa	2	3	2		1(1)							8(1)
Litsea palustris	4(3)	2	5(2)		3(2)	1	1					16(7)
Cratoxylon glaucum			1(1)			2(1)						3(2)
Nephelium melanomiscum		1										1
Payena obscura	2(2)	1										3(2)
Ternstroemia hosei	1(1)	2										3(1)
Swintonia spicifera											1(51")	1
Eugenia sp.	4(1)	1(1)										5(2)
Pygeum parviflorum	1											1
Total	28(18)	26(12)	16(10)	7(3)	9(7)	3(1)	3(1)				2	94(52)

Note: Figures in brackets indicate vegetative regeneration.

examined. Seven large trees have been windthrown in an approximate line, 8.6 chains in length and averaging about 50 feet in breadth, with an area of approximately 0.5 acres. It was apparent that the damage occurred on two separate occasions: the first about five years previously, when three trees were thrown, and the second about three years later. In falling the trees had almost completely destroyed the understorey, and in the recent area of damage the gap was open with direct light penetrating to the swamp surface. This gap was of interest as there was an abundance of regeneration of Shorea albida in the seedling and sapling stages. A milliacre survey of the regeneration was made down the centre of the swathe and the results are shown in Table 29. The total regeneration was estimated to be about 3000 stems, and it had the appearance of being very vigorous, especially that in the more open part of the swathe. Here the regeneration of species other than Shorea albida was largely vegetative, with which the Shorea albida saplings were competing successfully. An interesting feature of the regeneration was the occurrence of seedlings on the trunks of the fallen trees, indicating that part of the regeneration at least originated from a seed year after the damage occurred.

228. Wind damage in the Gonystylus-Dactylocladus-Neoscortechinia association is relatively rare. The forest is more typical of tropical rain forest with an uneven canopy and a dense storied structure which is relatively wind resistant. However, even in this forest areas of wind damage are known: one area is situated in the Naman Forest Reserve, and a second on the right bank of Igan river in the Rejang Delta. Dense sapling and pole stage regeneration

following logging is also liable to severe wind damage. Heavy exploitation of swamp forest began ten years ago so the regeneration is only now reaching a stage when it is liable to wind damage. None has yet been recorded. However in the Lawas District where Dacrydium forest has been worked for forty years severe wind damage, which destroyed large areas of the regrowth, occurred in 1957.

Table 29. Summary of regeneration of Shorea albida recorded in milliacre survey of wind damaged forest. Area approximately 0.5 acres.

Chain No.	Regeneration in height classes (inches)							No. of plots regenerated	
	0-11	12-23	24-35	36-47	48-59	60+	Total		
1	14	5					19	2	Recent wind-throw
2	67	12	3				82	9	
3	27	22					49	8	
4	11	4					15	4	
5	24	5	1				30	7	
6	4	8	3	2			17	5	Old wind-throw
7	5	46	29	17	33	28	158	10	
8	42	83	16	4	6	3	154	10	
9	100	61	34	7	1		203	6	
Total	294	246	86	30	40	31	727		

Lightning Damage

229. Many of the characteristic cavities in the canopy of the Shorea albida consociation are attributed to lightning damage.

Typical examples are to be seen on Plates, 27, 28, 30 and 39. On Plate 39 there is also some evidence of wind damage. The cavities are usually approximately circular in outline and the largest have a diameter of about four chains, though smaller gaps may be less than one chain in diameter. Areas of the gaps may exceed one and a half acres. On clear photographs, when examined through a stereoscope, the gaunt leafless stems may occasionally be seen in the cavities. The cavities may also be very clearly viewed from a low flying aircraft.

230. A preliminary investigation of lightning damage was undertaken in 1955 in the extensive Shorea albida forests in the Baram river. Five gaps were found; two of which could not be detected on the 1948 aerial photographs and were therefore less than seven years old. The approximate age of the dead patches could also be estimated by the state of decomposition of the dead trees. The surveyed areas of the two recent patches were 1.58 and 0.5 acres, in which fifty-seven and thirty-seven trees had been killed. Details of the dead trees are shown in Table 30.

Table 30. Dead trees in two dead patches of Shorea albida in the Baram swamps.

	Girths of dead trees in twelve inch classes							
Species	12	24	36	48	60	72	84 & over	Total
Patch 1 (area 1.58 acres)								
Shorea albida			3	5	8	13	23	52
Gonystylus bancanus	1	2	1					4
Parastemon versteeghii	1							1
								57
Patch 2 (area 0.5 acres)								
Shorea albida			3	6	11	8	9	37

Photograph 62, Brunei. Lightning damage in Phasic Communities 2 and 3. There are also indications of wind damage.

Photograph 63 . A photograph taken from a low flying De Haviland Rapide showing a typical gap in the canopy probably caused by lightning.

Photograph 64 . Lightning damage in the Shorea albida Consociation on the margin of a logging area. Twenty three Shorea albida trees had been killed here.

There was some evidence to show that some trees of the understorey towards the centre of the patches had been killed also though as most had fallen it is uncertain whether mortality occurred at the same time as that of the canopy trees.

231. The three older patches of dead forest were between 0.4 and 0.6 acres in size. Here the dead canopy trees had fallen and the stumps were in an advanced state of decomposition. The understorey in these patches was moderately dense and the presence of climbers, normally rare in the Shorea albida consociation, was particularly noted. Regeneration of Shorea albida in the patches is very variable. In the three older patches there was a little regeneration in the seedling stage. However, in the more recent patches regeneration of seedlings and saplings was abundant and appeared vigorous. The regeneration was counted on three transects across the large patch and the results are included in Table 31. It is probable that Shorea albida seeded two or three years previously.

232. In 1957-8 the nature and extent of the damage was more carefully investigated in the Saribas Forest Reserve and in the Triso Protected Forest on the Maludam Peninsula. Four patches (three of recent origin) were located and the position of all dead and damaged trees was carefully surveyed. Damaged trees were classified as follows:

Heavily damaged: half or more than half of crown killed.

Moderately damaged: less than half of crown, but at least one large branch, killed.

Slightly damaged: a small branch or part of a large branch killed.

Table 31. Summary of regeneration of Shorea albida in plots (0.005 acres) on three transects in Patch 1 (1.58 acres) in the Baram.

Transect No.	Plot No.	Height classes of regeneration 0-12"	12-24"	24-36"	36-48"	48" plus	Total
1	1		8	7	1		16
	2	7	4	7	1		19
	3		12	6			18
	4		1	3			4
	5			1			1
	6		5	6	2		13
	7	2		1			3
		9	30	31	4		74
2	1	1	1				2
	2	1					1
	3	2	6	4	1		13
	4	2	5				7
	5	2	6	1	1		10
	6	3	15				18
	7	3	4	6	8		21
	8	1	10	3	1		15
		15	47	14	11		87
3	1	5	4				9
	2	4	14	7	1		26
	3	2	9	6	1		18
	4		3	4	2		9
	5			4			4
	6				1	1	2
	7		5	6	3		14
	8		2				2
		11	37	27	8	1	84

Details of all killed and damaged trees are included in Appendix 4, and the plotted position of the trees is shown in Figures 48-51.

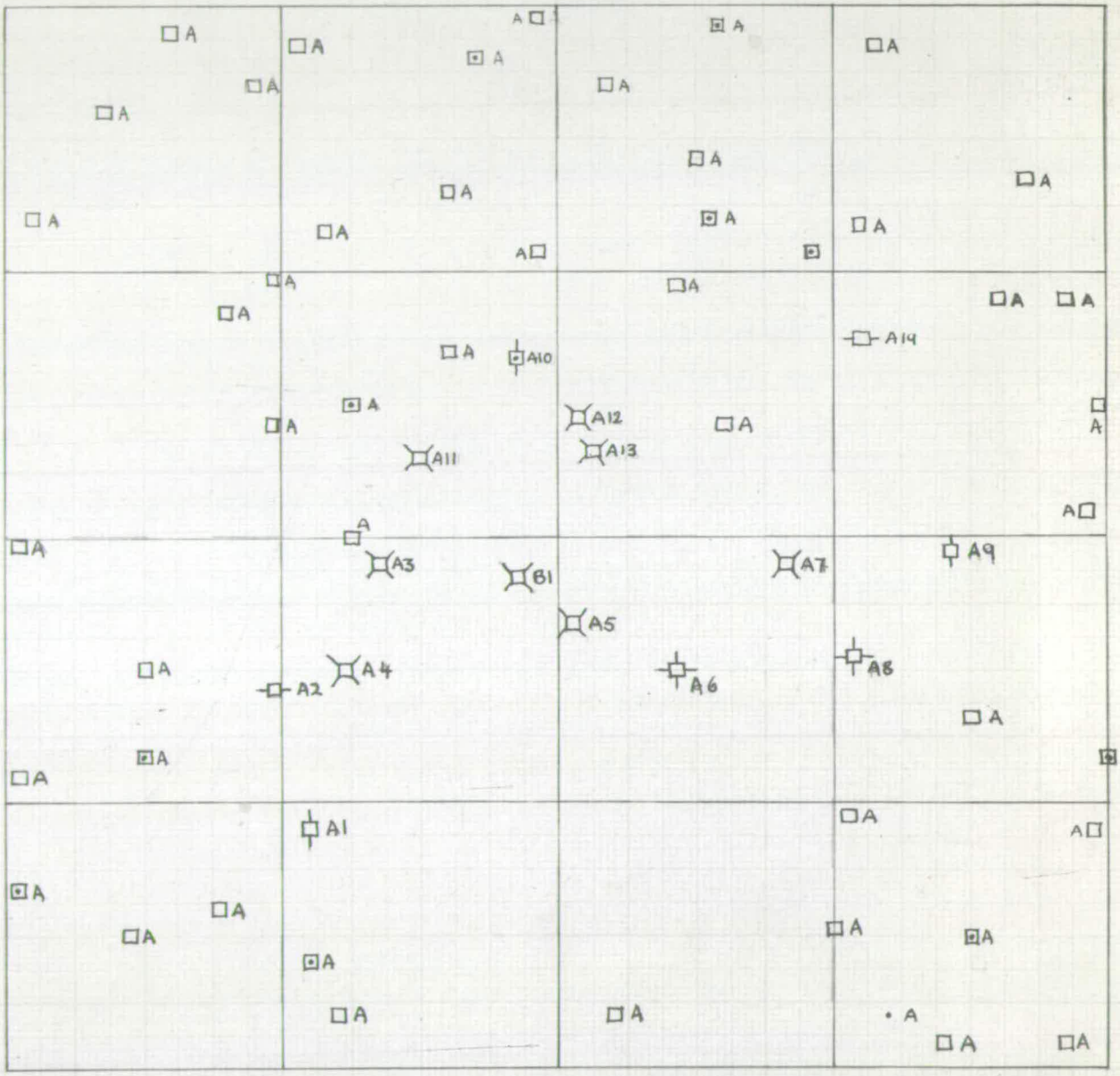
Patch 1 (Fig. 48). This patch is situated in the Shorea albida consociation in the Saribas Forest Reserve and was relatively small in size, totalling approximately 0.4 acres. It is estimated that the damage occurred about five years previously. Seven Shorea albida, and one large Dactylocladus stenostachys, had been killed. Six Shorea albida on the perimeter had been severely damaged. The damaged branches were almost invariably those bordering on the patch itself.

Patches 2-4 are located in the Triso Protected Forest. Patch 2 (Fig. 49) was in the Shorea albida consociation and the mortality was of recent origin; the branches and many twigs of all killed trees in the canopy were still intact. The extent of the damage covered approximately 1.2 acres and was roughly oval in shape. Forty-eight trees, including thirty Shorea albida, had been killed and a further fifty-four damaged, of which eighteen were heavily damaged. These are summarized by species in Table 32. A zonation of damage was apparent, and this is indicated on Figure 49. The central zone was off-centre and the focal point was a large Shorea albida (No. A 32 on Figure). This showed a split down the length of the stem but no obvious signs of charring. In the central zone the canopy trees had been almost invariably killed, as well as many of the understorey trees of all species. In the intermediate zone many of the canopy trees were killed or severely damaged but few of the understorey trees, whereas in the peripheral zone few trees had been killed, but branches of canopy trees have been moderately or slightly damaged.

LIGHTNING DAMAGE IN THE SHOREA ALBIDA CONSOCIATION IN THE SARIBAS FOREST RESERVE

LEGEND

	Dead	Damage to crowns Heavy	Moderate	Light
Trees 48 + ins girth	⊠	⊞	⊡	⊟
Trees 24-47 " "	⊠	⊞	⊡	⊟



Scale: 1 Chain = 4 cms.

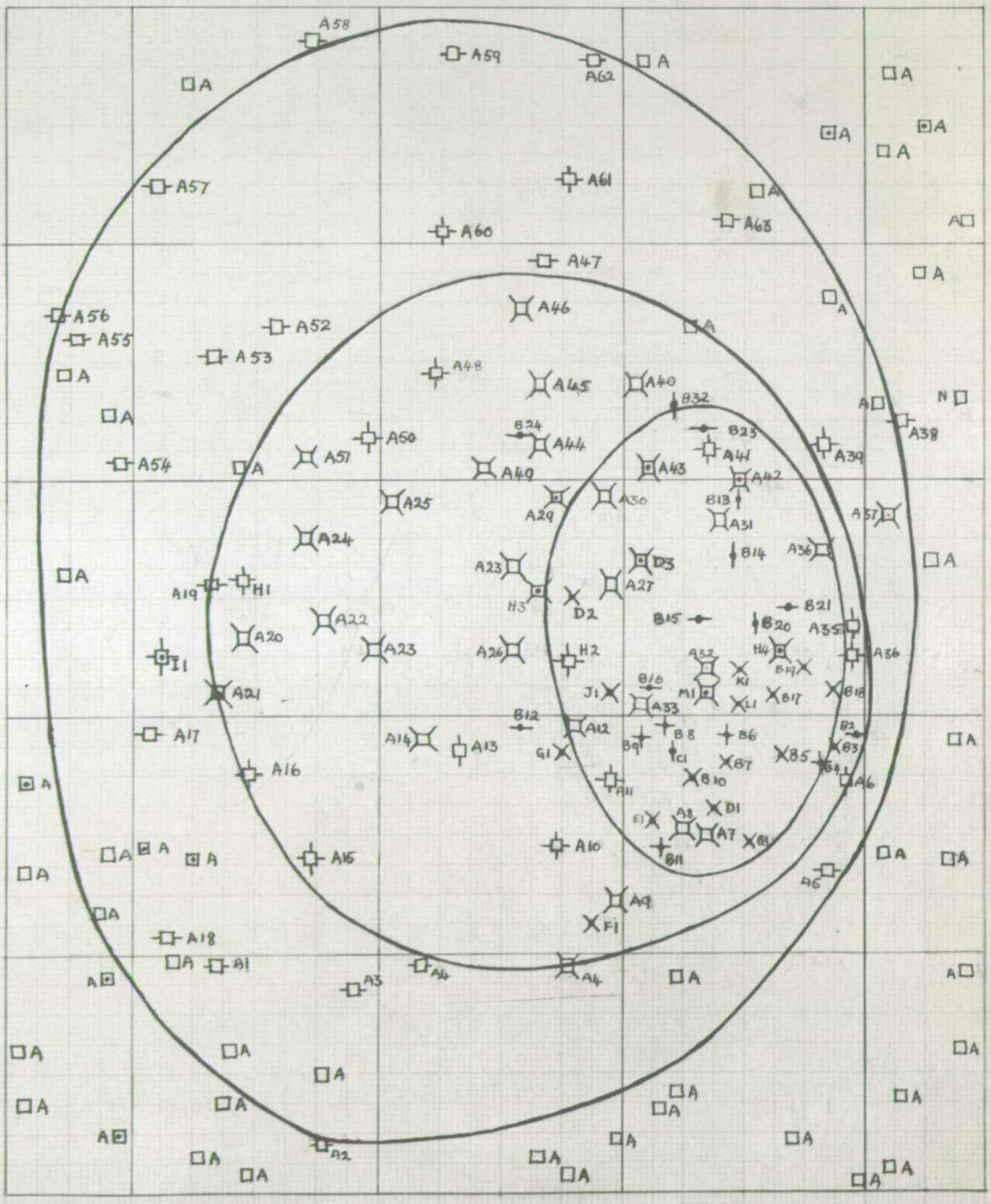
Figure 49

LIGHTNING DAMAGE IN THE SHOREA ALBIDA CONSOCIATION IN THE MALUDAM PENINSULA

LEGEND

	Dead	Damage to crowns: Heavy	Moderate	Light
Trees 48 + ins girth	✕	✛	⊕	⊕
Trees 24–47 " "	✕	✛	⊕	⊕
Trees 12–23 " "	✕	+	|	–

21	22	23	24	25
20	19	18	17	16
11	12	13	14	15
10	9	8	7	6
1	2	3	4	5



Scale: 1 Chain = 4 cms.

Table 32. Summary of damage in Patch 2 (Triso P.F.).

Species	Trees killed	Trees heavily damaged	Trees moderately damaged	Trees slightly damaged	Total
Trees of girths 48 ins. plus					
Shorea albida	24	10	5	19	58
Trees of girths 24-47 ins.					
Shorea albida	6				6
Garcinia tetranda	1				1
Palaquium pseudorostratum	2	2			4
Dactylocladus stenostachys		1			1
Palaquium cochlearifolium	1				1
Trees of girths 12-24 ins.					
Tetractomia holttumii	8	5	4	7	24
Dillenia pulchella var.			1		1
Canthium didymum	1				1
Ilex sclero-phylloides	1				1
Diospyros evenis	1				1
Cyathocalyx biovulatus	1				1
Xanthophyllum sp. (2014)	1				1
Gonystylus bancanus	1				1
Total	48	18	10	26	102

233. Patches 3 and 4 are of particular interest as the damage here had not occurred in the Shorea albida consociation but in the Shorea albida Litsea Parastemon association (Patch 3) and the Gonystylus Dactylocladus Neoscortechinia association (Patch 4).

Patch 3 (Fig. 50). The forest had the typical structure of the forest type, with a dense closed canopy composed of numerous relatively small trees. Consequently, though the area is small (approximately 0.4 acres), the numbers of trees killed and damaged are relatively large. The damage was of very recent origin and many of the killed trees still retained their foliage, which facilitated the identification of species. A summary of the trees killed and damaged is included in Table 33. Twenty-nine trees, with girths exceeding twelve inches, of eleven species had been killed, and a further nineteen trees of the understorey including seedlings of Timonius peduncularis and seven unidentified seedlings. The total number of trees and shrubs killed or damaged amounted to one hundred and eight. In this patch also there was a zonation of damage, but this was less distinct than in Patch 2. A feature of the central zone was the large number of lower storey trees and understorey species killed and damaged. These are not plotted on Figure 50 but are included in the summary. Trees on the perimeter of the Patch showed the typical damage to branches of canopy trees which projected towards the centre of the damage.

Table 33. Summary of damage in Patch 3 (Triso P.F.).

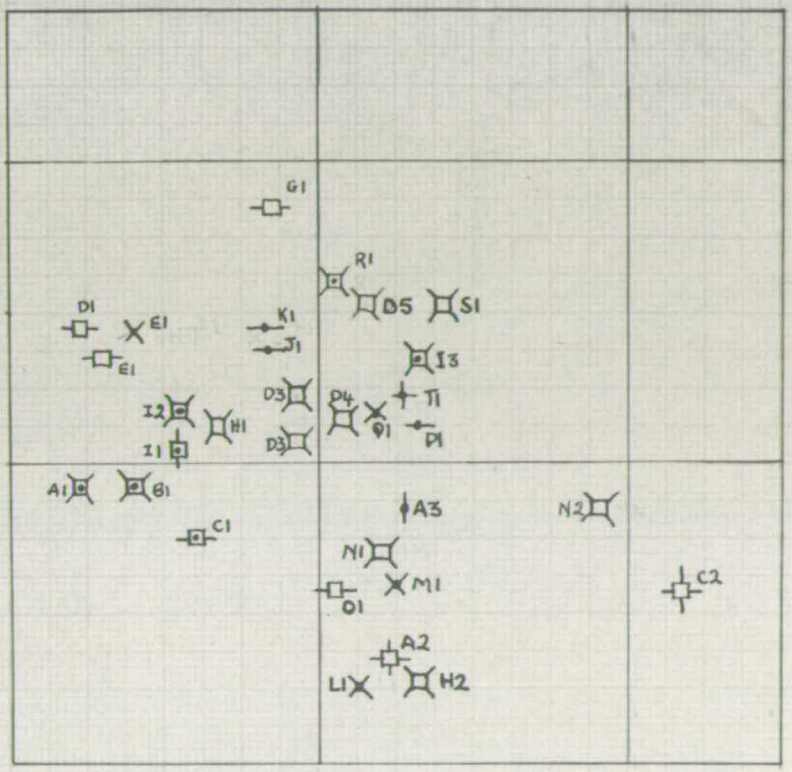
Species	Killed	Heavily damaged	Moderately damaged	Slightly damaged	Total	Symbol on diagram
(i) Trees of girths 48 ins. and over						
Shorea albida	3	2		7	12	A
Dactylocladus stenostachys	2		1		3	B
Litsea palustris		1		2	3	C
Total	5	3	1	9	18	
(ii) Trees of girths 24-47 ins.						
Shorea albida	5	1	1	2	9	A
Dactylocladus stenostachys	6				6	B
Litsea palustris	3		1	3	7	C
Longetia malayana				1	1	D
Tristania obovata	2		1	2	5	G
Tristania maingayi		2	1		3	H
Total	16	3	4	8	31	
(iii) Trees of girths 12-23 ins.						
Shorea albida				1	1	A
Dactylocladus stenostachys	2				2	B
Longetia malayana	2	1			3	D
Xanthophyllum sp. nov.	1	1	1	1	4	E
Parastemon versteeghii	1		1	3	5	F
Tristania obovata	4				4	H
Myrsine sp.	1				1	I
Eugenia sp.	1				1	J

Species	Killed	Heavily damaged	Moderately damaged	Slightly damaged	Total	Symbol on diagram
Palaquium cochlearifolium		1		1	2	K
Pseudosindora palustris	1	1			2	L
Combretocarpus rotundatus						M
Total	13	4	2	6	25	
(iv) Trees of understorey - 10 ft. high - 11 ins. girth						Not plotted on diagram
Quercus sundaicus	1				1	
Timonius peduncularis		4			4	
Palaquium cochlearifolium	1	1			2	
Parastemon versteeghii	1				1	
Baccaurea bracteata	1	1			2	
Longetia malayana	2				2	
Canthium umbellosa	1				1	
Tetractomia holttumii	2				2	
Bhesa paniculata	2				2	
Unidentified	1				1	
Total	12	6			18	
Grand total of trees	46	16	7	23	92	

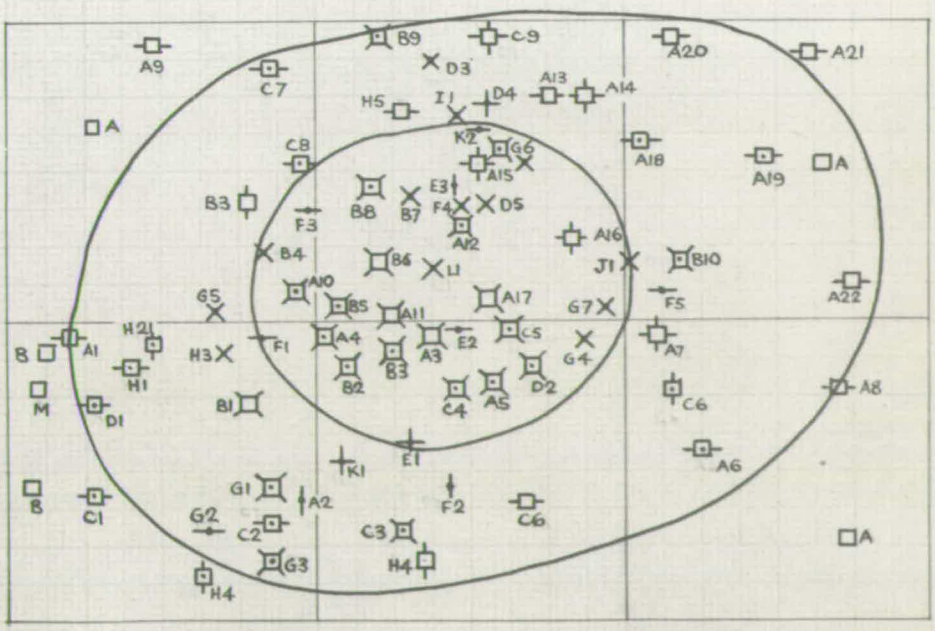
Species	Killed	Heavily damaged	Moderately damaged	Slightly damaged	Total	Symbol on diagram
(v) Saplings, seedlings and shrubs						Not plotted on diagram
Timonius peduncularis	5	1			6	
Eugenia sp.	1				1	
Ixora pyrantha		2			2	
Unidentified	7				7	
Total	13	3			16	

234. Patch 4 (Fig. 51). The destruction and damage had occurred in forest of uneven canopy and dense middle and lower storeys, typical of the Gonystylus Dactylodadus Neoscortechinia association. Eighteen trees had been killed including individuals of eleven species. Zonation of damage is indistinct, and the principal damage had occurred in the vicinity of two emergents, Shorea rugosa var. uliginosa (127 ins. girth - N1) and Garcinia motleyana (75 ins. girth - H1). A third large emergent, Shorea rugosa var. uliginosa (127 ins. girth - N2), was also killed. This tree stood apart from the main area of damage, but its crown leaned towards the other two dead trees. Damage to middle and understorey trees is not so severe as in other patches and a complete cavity in the canopy had not been made, though as a result of the death of the dominants much more light than normal is filtering through to the swamp surface. A summary of the damage in this patch is included in Table 34.

(I) LIGHTNING DAMAGE IN THE GONYSTYLUS DACTYLOCLADUS NEOSCORTECHINIA ASSOCIATION IN THE MALUDAM PENINSULA



(II) LIGHTNING DAMAGE IN THE SHOREA ALBIDA LITSEA PARASTEMON ASSOCIATION IN THE MALUDAM PENINSULA



Scale: 1 Chain = 4 cms.

Table 34. Summary of damage in Patch 4 (Triso P.F.).

Species	Killed	Heavily damaged	Moderately damaged	Slightly damaged	Total	Symbol on diagram
(i) Trees of girths 48 ins. and over						
Shorea rugosa var. uliginosa	2				2	N
Gonystylus bancanus	2			1	3	D
Jackia ornata				1	1	E
Ganua motleyana	2	1			3	H
Dillenia pulchella		1			1	A
Diospyros pseudo-malabarica	1				1	S
Total	7	2		2	11	
(ii) Trees of girths 24-47 ins.						
Dillenia pulchella	1				1	A
Knema kunstleri	1				1	B
Diospyros evenis				1	1	C
Santiria laevigata				1	1	G
Gonystylus bancanus	2				2	D
Eugenia sp.	2		1		3	I
Shorea platycarpa	1				1	R
Total	7		1	2	10	

Species	Killed	Heavily damaged	Moderately damaged	Slightly damaged	Total	Symbol on diagram
(iii) Trees of girths 12-23 ins.						
Xerospermum muricatum	1				1	F
Xanthophyllum amoenum				1	1	J
Alangium havilandii				1	1	K
Litsea resinosa	1				1	L
Litsea sp.		1			1	T
Blumeodendron tokbrai	1				1	M
Ardisia sp.				1	1	O
Dillenia pulchella			1		1	A
Neoscortechinia kingii				1	1	P
Polyalthia hypoleuca	1				1	Q
Total	4	1	1	4	10	
Grand total	18	3	2	8	31	

235. In each patch the dead trees were examined for some of the more usual damage associated with lightning, such as shattering or splitting of the trunk, scarring of the bark, etc. A tree or trees near the focal point of damage may show a longitudinal splitting of the bark, though frequently it is not continuous, and it is uncertain whether this is a primary or secondary effect. During the course of surveys and ecological work in peat swamps numerous patches of damage have been encountered and the damage in each patch is very similar. On only one occasion - recently in the Saribas Forest Reserve - has

the more typical damage been found. One large Shorea albida tree near the focal point of damage had been shattered and the trunk split and splayed open.

236. To summarize, the principal characteristics of damage attributed to lightning in peat swamp forest are as follows:

(i) The damage is most severe in the Shorea albida consociation, where the canopy is pure and even, but it also occurs less noticeably throughout the swamps.

(ii) Groups of trees, up to about one hundred in number may be killed, where the canopy is even, but in forest with an uneven canopy damage is largely confined to emergents and a few of the middle storey species.

(iii) The intensity of damage radiates from a focal point, which is usually at or near the centre of the group. Here upper, middle, lower storey trees, and even understorey trees or shrubs, may be killed or damaged. The damage decreases towards the periphery of the group where only the upper canopy trees are affected, and on the margin itself individual branches protruding towards the centre of damage are liable to be killed. These branches may or may not be touching branches of other trees more seriously damaged. Beyond the margin the occasional tree may also be slightly damaged.

237. Since observing and studying the effects of lightning damage in peat swamp forest a search has been made for similar damage in other forest types. It is in fact particularly noticeable in mangrove forest, especially in the pure stands of Rhizophora, where conditions

Photograph 65. Looking up into a gap caused by lightning. The tree on the left is a Dactylocladus stenostachys, the remainder of the large trees are Shorea albida. Note the small trees in the foreground that have also been killed.

Photograph 66. Typical lightning damage in the Shorea albida Consoc. Damage to the trees on the margins of the patch tends to be confined to branches facing the focal point of the damage.

are not dissimilar to those in Shorea albida forest: the canopy is pure and even and the forest is growing on a relatively level surface which is subject to inundation. During a visit to the Matang Mangrove Reserve in Malaya in 1958 extensive group damage was noted. F.S. Walker (62) confirmed that this was caused by lightning and stated that allowance was made for lightning damage when calculating yields in Rhizophora compartments. Typical lightning damage has also been observed in heath forest in the Berakas Forest Reserve (Brunei). Two large Agathis dammara and one Dactylocladus stenostachys were killed. In lowland dipterocarp forest damage is less evident, being masked by the dense storied structure of the forest. As in the Gonystylus Dactylocladus Neoscortechinia association only the emergents and a few of the middle storey species are liable to be killed. Nevertheless the typical damage has been recorded on a number of occasions, and is particularly evident on ridges in the Andulau Forest Reserve (Brunei). An interesting example has recently been observed on the top of a jagged limestone hill at Bau. Here a large Shorea coriacea was at the centre of the group, but this was in fact rooted in a crevice twenty feet below most of the surrounding trees. During a brief visit to Ceylon in 1958 group lightning damage was noted in pure Dipterocarpus zeylanicus forest in the Inikada Forest Reserve. Five large trees were killed and three others on the perimeter had damaged branches.

238. Group mortality of trees by lightning in the Temperate Zone is not generally recognised and is still considered as an interesting though perhaps rare phenomenon to be reported as a freak occurrence. No doubt damage of this nature occurs less frequently for no other

reason than the less frequent occurrence of lightning storms. Peace (37) reported an interesting case of lightning damage in the New Forest. About half a dozen trees of sixty-five-year-old Douglas fir, several small beech and one small oak had been killed. Moroever branches of surrounding trees were affected and these were invariably on that side of the tree nearest the dead trees - a feature also noted in peat swamps. An examination of the dead branches showed that the cambium had been killed and where the trees had taken a period to wither and die the effect had been similar to that of girdling. More recently Murray (35) has recorded severe lightning damage in Scotland. About 100 trees of forty-five-year-old Japanese larch were killed in a group covering approximately three-quarters of an acre. Typical lightning seer occurred on only two trees which stood in the centre of the group. Girdling effect on surrounding branches or on the stem at point of juncture of a dead branch was noted on surrounding trees. A possible explanation given is that lightning struck only a few trees in the group, travelled down their stems and crossed to other trees by means of touching branches. Observations in peat swamps do not confirm this hypothesis; frequently killed branches are some distance from neighbouring trees. In America Wadsworth (61) considers that one-third of the total mortality in Ponderosa pine forests in Western Arizona is caused by lightning, though surprisingly he makes no mention of group damage. There is also a number of reports of group damage from the Continent, especially from Germany, where Müller deals with the problem in some detail. The phenomenon has also been recently observed in New Zealand, where the N.Z. Forest Department (36) briefly reported the investigation of group damage

in Pinus radiata plantations. Twenty groups each about a quarter to half an acre in area, have been investigated and the damage attributed to lightning. Similar damage has also been noted in farm shelter belts in New Zealand.

239. In Malaya Sharples (51) and Weir (68) investigated group lightning damage in coconut and rubber plantations. Death was much more frequent in coconut palms as a result of the killing of the meristematic tissue in the apical bud. According to these investigators mature rubber is relatively resistant to lightning damage; though many are struck mortalities are few. Furtado (22) closely observed the effects of three lightning strikes on trees in the vicinity of the Botanic Gardens, Singapore, and concluded that bark and wood structure of species influences the liability to damage.

240. From observations in peat swamp forests and from a study of the literature it is concluded that the severity of damage in any locality is dependent on a number of factors:

(i) The frequence and intensity of lightning storms. Thunderstorms are of frequent occurrence in the humid tropics. Watts (63) states that in Penang thunder is heard on an average of 204 days per year and he mentions that over most of England there are only 10-15 days of thunder each year. In 1959 at Kuching Airport thunder was heard on 163 days and thunderstorms occurred on 104 days (30A).

(ii) The structure of the forest. Forest with a pure even canopy, especially when it is composed of a single species, is liable to greater damage than a mixed forest with an uneven canopy.

(iii) The topography of the ground. More severe damage is likely to occur on a flat or gently undulating surface, or on ridges.

(iv) The species of trees. Certain species are probably inheritantly resistant to lightning damage by reason of their bark and wood structure or for other unknown reasons, and/or have greater ability to recover from lightning damage.

241. It is probable that the relatively severe damage in peat swamp forest, and especially in the Shorea albida consociation, is because these factors are at an optimum, as they are also in Rhizophora forest in the mangroves. Another factor that requires further investigation is the nature of the ground surface and the height of the water table.

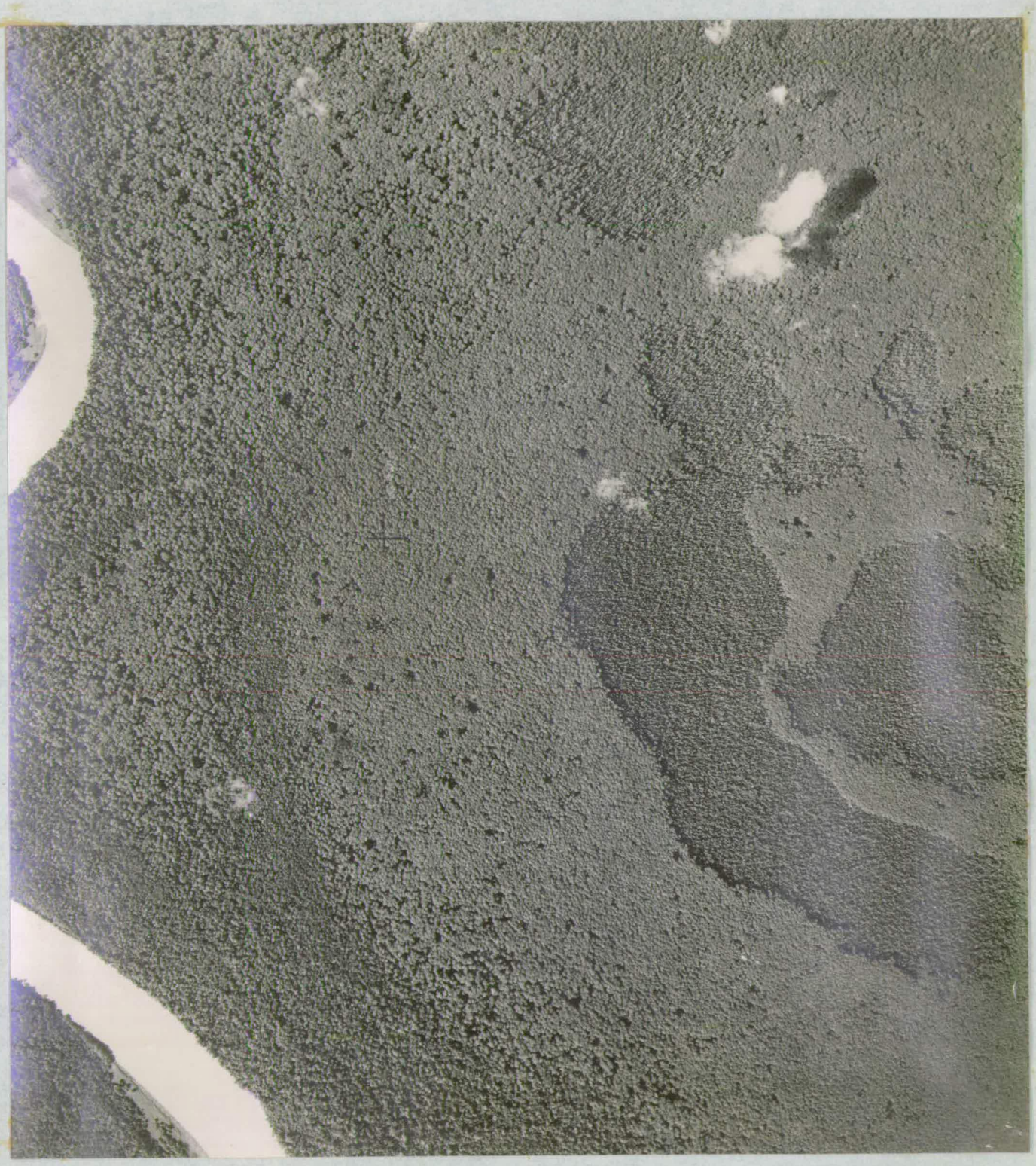
242. Observations on lightning damage have only been considered here. Further elucidation of the problem might come from a study of the purely physical aspects of lightning discharges. It is indeed possible that laboratory experiments with models representing forests of different structures and on different topography might assist in solving certain aspects of group damage.

Chapter 16

The destruction of Shorea albida forest by an unidentified insect

243. The first report of damage in Shorea albida forest was made in 1953 by Mr. J.H. Nelson-Smith after a reconnaissance flight over the lower reaches of the Baram river in northern Sarawak. Large areas downriver from the Bakong river were noted where heavy defoliation of Shorea albida had occurred. Subsequent examination of aerial photographs (sorties flown 1948) confirmed this report and it was possible to plot the location and extent of the damage. The margins of the damage in each locality are remarkably precise and from the air the flat canopy of the pure Shorea albida forest resembles a moth-eaten carpet (see Plates 42 and 43). Further reconnaissance flights indicated that the damage had not occurred simultaneously; in some areas the dead trees had completely disappeared (subsequent ground inspection proved their former existence) and different stages from recent defoliation to complete absence of stems were noted. Moreover, recent damage, not visible on the 1948 photographs, was plotted.

244. In 1958 further aerial photographic sorties were flown over part of the lower Baram and Brunei, and these provide evidence of the increase in damage during the previous ten years. Four new patches of damage, totalling 637 acres, have occurred in the forest downriver from the Puran river. These patches, though quite distinct from each other, are closely grouped and lie on a line running approximately south west by north east. A further area of 395 acres



Photograph 67 , Baram. Destruction of Shorea albida forest by an unidentified insect. The very sharp margins of the damage may be clearly noted, also the small areas of lightning damage.

Photographs 68 + 69 . Two photographs taken from a De Haviland Rapide at a height of about 2000 ft. near the Bakong river in the Baram showing the decimation of Shorea albida forest by the unidentified caterpillar 'ulat bulu'. The destruction here has probably occurred within the last ten years as the majority of the killed trees are still standing. The very clear cut margins of the damage may be noted. A bird's eye view of this forest is not dissimilar to that of the appearance of a moth-eaten carpet.

on approximately the same axis occurs on the true right bank of the Baram and two further smaller patches, totalling 154 acres (not shown on Fig. 52), are to be found in the Ulu Panderuan in Brunei, a few miles to the east. In this last locality it is probable that defoliation occurred in 1958 as the texture of the canopy as seen on the aerial photographs flown that year appears disturbed in the precise areas where dead patches of forest are to be found on the 1958 photographs. In the middle reaches of the Baram, and in its tributary the Bakong, four new areas of damage, totalling approximately 600 acres, have been noted on recent (1958) aerial photographs. These occur near Loagan Bunut, in the Beluru Protected Forest and upstream from Kuala Nyabor. It is probable that additional patches of damage are yet to be discovered in areas not covered by recent aerial photographic sorties.

245. In 1955 two of the areas of the damaged forest were examined on the ground. A trace was cut into the forest downriver from the Puran river and three half acre sample plots were enumerated. Two were sited in patches of dead forest and the third in a narrow intervening strip of undamaged Shorea albida forest. The location of the trace and sample plots is shown in Figure 52 and the aerial photograph illustrated on Place 42 covers part of the same area. The results of the enumeration are summarized in Table 35. The surviving remnant of high forest (Plot 1) has the typical structure and floristic composition of the Shorea albida consociation, and is similar to plots enumerated elsewhere; the middle storey is largely absent, but there is a moderately dense understorey with seventy-nine trees, in the 12-24 inch class, to the half acre. In the patch of

Figure 52

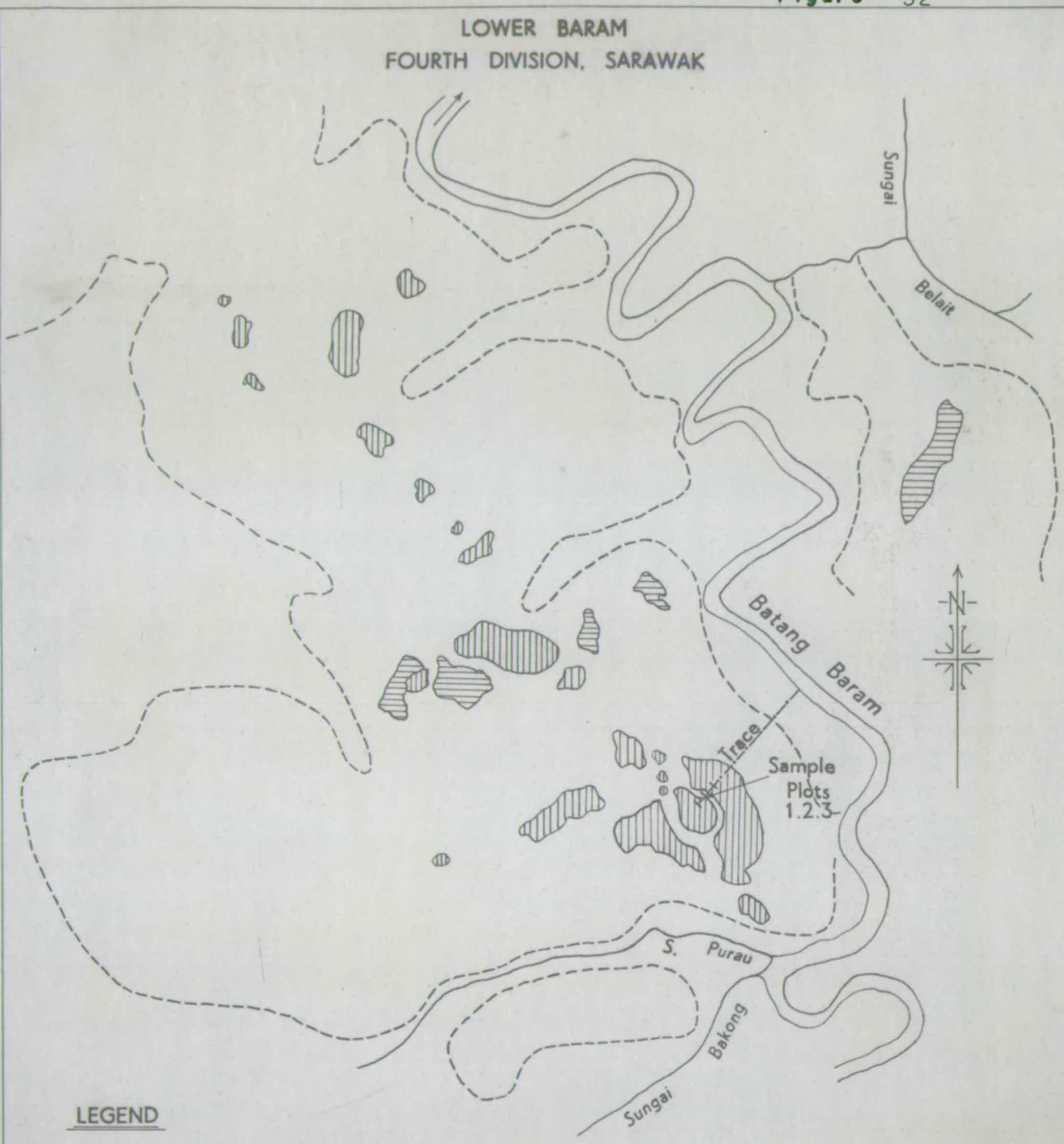

LOWER BARAM
FOURTH DIVISION, SARAWAK
Sungai
Belait
Batang Baram
Trace
Sample Plots 1.2.3
S. Purau
Sungai Bakong
LEGEND
Perimeter of Shorea Albida Forest
Areas of dead Shorea Albida Forest, 1948
Areas of dead Shorea Albida Forest, 1958
Scale 2 Miles to an Inch

Table 35. Summary of trees in twelve inch girth classes recorded in Plots 1, 2 and 3 in the Baram, Sarawak.

Species	Girth classes 12			24			36			48			60			72			84 and over			Total		
	Plots 1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Shorea albida							8			6			9			7			5			35		
Gonystylus bancanus	6	4	4	7	12		5	4	5		2											18	22	9
Copaifera palustris	7	5	10	1		5			1														5	16
Palaquium cochlearifolium	6	5	9	1	1	2																7	6	11
Diospyros evenis	7	6	8	3	4	6	1	1	16													11	11	30
Dyera lowii	2	6	2		3	1					1											2	10	3
Dactylocladus stenostachys	2	2	1		1	1																2	3	2
Combretocarpus rotundatus				5			4	3	3		2						1					9	6	3
Buchanania arborescens	1																					1		
Polyalthia hypoleuca	3	2	1			1																3	2	2
Ganua coriacea	5	5																				5	5	
Canthium didymum	9	13	2	1																		10	13	2
Sterculia rhoidifolia	2	1	5																			2	1	5
Eugenia nemestima	1	1	1	1	3	2			1													2	4	4
Eugenia sp (2615)		4	1	1																		1	4	1
Eugenia sp. (4153)	3	2				1																3	2	1
Eugenia chrismannii	1																					1		
Tetractomia holttumii	9	54	11	1	7	3																10	61	14
Ilex hypoglauca	3	9	11																			3	9	11
Nephelium melanomiscum	2	2	7			3			1													2	2	11
Xanthophyllum amoenum	1	1																				1	1	
Cyathoclyx biovulatus	1	1																				1	1	
Calophyllum rhizophorum				1																		1		
Mezzettia umbellata	2			1																		3		
Stemonurus umbellatus	5	2																				5	2	
Shorea inaequilateralis	1	1	2																			1	1	2
Xanthophyllum sp. (2614)				1		2																1		2
Quercus sundaica		22			1																		23	
Palaquium ridleyi					1																		1	
Macaranga puncticulata		1																					1	
Garcinia sp (2828)		1																					1	
Vatica mangachapoi		1																					1	
Hopea pentanervia		1																					1	
Tristania grandifolia		2	1																				2	1
Linociera sp. (3282)		1																					1	
Santiria griffithii		1				1																	1	1
Litsea cylindrocarpa		1			1																		2	
Dryobalanops rappa		1																					1	
Cratoxylon arborescens		1																					1	
Parastemon versteeghii		1				2																	1	2
Xylopia coriifolia						1				1		1												2
Litsea insignis			1			1																		2
Horsfieldia crassifolia						1																		1
Amoora rubiginosa			1																					1
Xerospermum muricatum			1																					1
Goniothalmus malayanus			1			1																		2
Cratoxylon glaucum						1																		1
Garcinia rostrata		1	1																				1	1
Garcinia vidna		1																					1	
Eugenia sp.				1															1					
Totals	79	162	81	25	34	35	18	8	27	6	5	1	9			7	1	5	149	210	144			

dead Shorea albida forest nearest to the Baram (Plot 2) it was estimated that the Shorea albida trees had been killed ten to fifteen years previously. All the killed trees had fallen and only the rotting stumps and timber remain. No regeneration of the species was noted. The understorey is particularly dense with 161 trees in the 12-24 inch class. Tetractomia holttumii and Quercus sundaicus were very abundant. The understorey merges into an uneven canopy in which Gonystylus bancanus is the principal dominant. The floristic composition is similar to that in undamaged forest (except for the absence of Shorea albida), though some species which do not normally exceed twelve inches girth in the latter were recorded. In the second patch (Plot 3) it was estimated that the Shorea albida had been dead for at least twenty-five years and perhaps over thirty years. Only the remains of old stumps, in an advanced state of decay, can be found. Once again young trees and regeneration of Shorea albida were absent. Competition among the middle and understorey trees has eliminated many of the smaller stems and there is a greater number of trees in the 36-48 and 48-60 inch classes; Diospyros evenis is the most abundant dominant. The canopy height varies between eighty and one hundred feet, and is at least sixty feet below the height of the surrounding Shorea albida canopy.

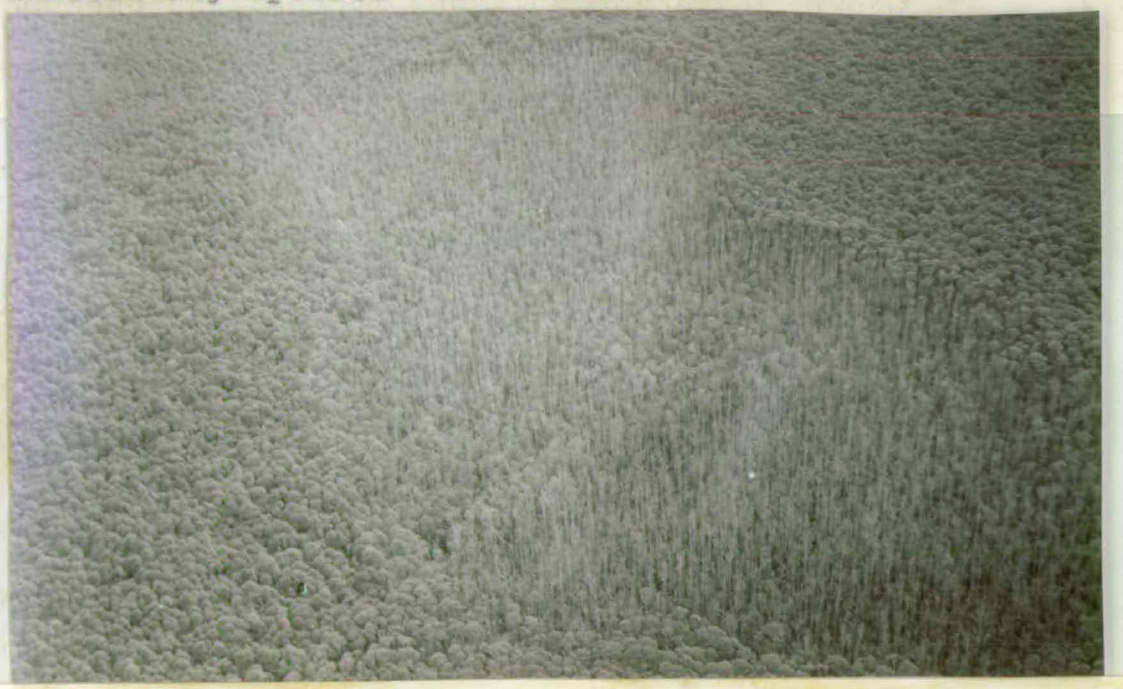
246. Further extensive damage has recently occurred in the Badas peat swamps, which cover ninety square miles behind the oil field at Seria in Brunei. Near the river Belait one small area of damage of forty acres can be seen on the 1948 photographs, whereas the 1954 photographs show a large lozenge-shaped area of damage of 680 acres (Plate 44), and photographs taken in 1958 indicate the presence of

Photograph 70 , Badas, Brunei. Recent destruction of Shorea albida forest. The damage probably occurred in 1953 - 4, and may be seen as a long sausage shaped area on the edge of Phasic Community 4.

two further smaller areas, 95 and 170 acres, near the permanent rail line across the swamp. On a number of occasions the damaged areas have been examined from the air, including a close inspection by helicopter (Plate 45). The stark gaunt stems of the dead Shorea albida are extremely prominent and the areas of dead forest can be easily picked out from a distance of ten miles. The largest area of damage was visited by the author in 1954 when one of the transects cut during an ecological survey of the Badas swamps impinged on the margin of dead forest. It was obvious that the Shorea albida had only recently been killed. The canopy was completely defoliated but the branch system and even smaller twigs were intact (see Plate 45). There was an absence of recent fallen foliage of Shorea albida but the surface of the swamp was covered in what appeared to be decaying frass. No damage to other species was noted, nor were there any apparent signs of revival of the Shorea albida trees, which are particularly dense here. The damaged area is composed of the Shorea albida Litsea Parastemon association and enumerations showed 160-190 trees of Shorea albida to the acre.

247. The most extensive and remarkable area of damage has occurred in the Maludam Peninsula near the western limit of distribution of Shorea albida, about 270 miles from the nearest damaged forest in the Baram. The species covers an area of approximately 190 square miles and is the largest single block of the species. 25,000 acres, a little more than one-fifth of the total area of forest, was destroyed during a period of not longer than six months in 1948. It so happened that the destruction of the forest coincided with a series of aerial photographic sorties over parts of the area, so the time of the attack

Photograph 71 . Recent decimation of Shorea albida in the Shorea albida Litsea Parastemon Association in the Badas area of Brunei. This photograph was taken in 1954 and the damage probably occurred within the previous eighteen months. The crowns of the killed trees were still intact and only the smaller twigs had fallen. The understorey species were unaffected.



Photograph 72 . Recent destruction of Shorea albida by an unidentified insect in the Badas area of Brunei. This photograph was taken from a helicopter of the Brunei Shell Petroleum Company in 1956 and the forest was probably killed two or three years previously.

Photographs 73 + 74 . Two photographs of the extensive damage in Shorea albida forest between the Batang Lupar and the Saribas. The damage occurred in 1948 and this photograph was taken in 1958. At least 75 per cent of the stems of the killed trees have fallen. The generally feathery appearance of the forest is caused by the understorey species. A few Shorea albida have recovered, or escaped the insects' depredations.

and the extent of the damage can be accurately checked. In the earliest photographs, flown 1947, the canopy is still intact, whereas in the area covered by the 1948 photographs it is clear that defoliation is occurring; the texture of the canopy being speckled as opposed to the pure even canopy of undamaged Shorea albida forest, the appearance of which is an almost unbroken white mass. On the 1949 photographs the crowns are completely defoliated; the bare individual crowns giving a feathery appearance to the canopy when the photographs are viewed through a stereoscope. From these sorties the area of the damage can be clearly delimited and subsequent sorties in 1952 and 1954 show no further developments. The area of destroyed forest extends for eighteen miles and virtually the entire Shorea albida forest between the Saribas and the Sungei Tissak has been killed from Bukit Bunga at the upriver margins of the peat swamp to Sungei Sila, a small tributary of the Saribas. The former forest was mainly of the Shorea albida consociation, though the central areas were probably of the Shorea albida Litsea Parastemon association and the damage also extended into the Shorea albida Gonystylus Stemonurus association towards the margin of the swamp. It is estimated that the average number of Shorea albida trees per acre was about sixty, which means that approximately 1,542,000 trees have been killed (see Plate 46).

248. The destroyed forest has been flown over and visited on foot on a number of occasions. The characteristics of the damage are similar to those found in the Baram, though it would appear that there have been more survivors in the damaged zone in the Maludam Peninsula, especially towards the northern limits of the damage. Two half acre plots were enumerated and summaries are included in

Table 36; Plot 1 in the Shorea albida Gonystylus Stemonurus association and Plot 2 in the Shorea albida consociation. Twenty and forty-seven Shorea albida trees had been killed in the two plots respectively. No damage to other species was recorded. Seedling regeneration of Shorea albida was found in Plot 2. This probably originated from a tree a short distance outside the plot that had survived, and which fruited in 1954. In Plot 1 medium size trees of Gonystylus bancanus are dominant. This species is sub-dominant in the canopy of the undamaged forest. The middle storey, which is composed of a large number of species, is moderately dense. In Plot 2 the structure and floristic composition of the forest is similar to that found in Plot 3 in the Baram, with a large number (99) of trees in the 12-24 inch girth class. Tetractomia holttumi is again the most abundant species.

249. Initially the cause of the damage in northern Sarawak and Brunei was quite unknown. Indeed, there are still doubts on this point. The possibility that it may have been caused by pollution of the swamps originating from oil seepage or gas escapes was investigated. This hypothesis appeared attractive as the Brunei Shell Petroleum Company operate a concentrated oilfield on the littoral fringe three miles from the damage in the Badas area. Furthermore, exploratory wells, which proved to be dry, had been drilled along the banks of the lower Baram, and there are three well-known gas escapes or minor mud volcanoes on the margins of the peat swamps further upstream along the banks of the Bakong river, a tributary of the Baram. If, however, this had been the causal factor it is likely that evidence of pollution would have been found on the

Table 36. Summary of trees in twelve inch girth classes recorded in Plots 1 and 2 in the Maludam Peninsula, Sarawak.

Species	Girth classes (inches) 12		24		36		48		Totals	
	Plots 1	2	1	2	1	2	1	2	1	2
Gonystylus bancanus	6	2	17	4	7	2	5	2	35	10
Litsea palustris	2				1				3	
Copaifera palustris	1	11	1	2			1		3	13
Tetractomia holttumii	10	46	1						11	46
Polyalthia hypoleuca	1								1	
Campnosperma coriacea	1								1	
Litsea resinosa	2								2	
Palaquium pseudocuneatum		1				1				2
Neoscortechinia kingii	3	4							3	4
Polyalthia glauca	2								2	
Ganua coriacea	7	4	2						9	4
Knema kunstleri	1	1							1	1
Eugenia nemestima	2		2		1				5	
Quercus dasystachyus	4								4	
Canthium umbellatum	2								2	
Quercus jaheri	2								2	
Garcinia tetranda			1						1	
Samadera indica	1								1	
Gymnacanthera eugeniifolia	1								1	
Eugenia havilandii	3		1						4	
Santiria griffithii	1	1							1	1
Cephalomappa malloticarpa	2	9	2						4	9
Tetractomia parviflora	1								1	
Quercus sundaica	1								1	
Pygeum parviflorum	3								3	
Macaranga caladifolia	1								1	
Gonystylus forbesii	1								1	

Species	Girth classes 12		24		36		48		Totals	
	Plots 1	2	1	2	1	2	1	2	1	2
Aromadendron nutans		6								6
Dactylocladus stenostachys		4		2			1	1	1	7
Palaquium ridleyi		1								1
Canthium didymum		3								3
Pithecellobium oppositum		2								2
Dyera lowii		1								1
Cyathocalyx biovulatus		1								1
Xanthophyllum amoenum		1								1
Totals	62	99	27	8	9	3	7	3	105	113

swamp surface and that the degree of damage would have tended to follow the natural drainage of the swamps. Moreover, severe pollution of the soil would almost certainly affect more than one species. It is considered more probable, therefore, that the cause of the damage is biological or pathological.

250. There is little doubt as to the causal factor in the Maludam Peninsula. News of a plague of caterpillars, locally known as ulat bulu (hairy caterpillar) filtered through to the Forest Department, but when a forest officer made an investigation the infestation was over and he found neither the caterpillar nor the damage. The local people, however, and in particular the Ibans, who live along the banks of the Batang Lupar and Saribas and visit the Shorea albida forest in search of dammar and other minor forest produce, vividly recall the plague and tell lurid tales, sometimes no doubt exaggerated, of the infestation. The caterpillars were described as being one to one and a half inches in length, the thickness of a pencil, with black bodies and covered in reddish brown non-poisonous and non-irritant hairs. At the height of the infestation there were millions of larvae and according to at least one report, towards the end of the outbreak they completely covered the ground. The wife of the District Officer, Betong, on the southern bank of the Saribas, remembers caterpillars swarming into her garden. They were greedily devoured by her hens, which subsequently died. Apparently the outbreak originated towards the southern end of the peninsula and spread northwards finally petering out near Sungei Sila, a small tributary of the Saribas. It managed to cross the Sungei Trusan but was contained between the Saribas and

Tissak rivers, though the insects apparently tried to cross the latter. The infestation was at its height during the rice harvesting season, in March and April. Thousands of larvae were also found floating down the main rivers. There is no definite evidence that it attacked other species, though the Ibans reported that it also defoliated trees of other Shorea species, none of which grow in association with the pure stands of Shorea albida though some species are found as scattered trees in the Shorea albida Gonystylus Stemonurus association. Only one defoliation was noted and this was apparently sufficient to cause mortality.

251. The damage has been attributed by the Entomologist, F.R.I., Malaya, to Hymantrids (tussock moths) or related Hypsidae, though of course confirmation of this must wait the collection of the insect. Arrangements have been made for the Entomologist to visit Sarawak when an attack is found in progress. A discussion at this stage on the insect and the infestation must be largely speculative, but there are certain factors that deserve comment. Each infestation is remarkably localized, with the destruction radiating from one point then suddenly ceasing. Presumably climatic conditions - perhaps a short dry spell - control the depradations of the insect. There is no sign of damage older than perhaps fifty years and it is therefore probable that the insect has only recently become a serious menace. It is indeed possible that it may not be indigenous. Perhaps its former host was another Shorea species from elsewhere in Borneo or in another part of Malaysia. Certainly the infestation has increased at a very rapid rate during the past ten years, even if the exceptional damage in the Maludam Peninsula is discounted. Explosive outbreaks

of infestation of this nature are extremely rare in primary tropical rain forest. Their absence is ascribed by Elton (19A) to the usual complexity of the forest with a large number of species and no single dominant. The exception in this case is perhaps not the outbreaks but the gregarious stands of a single species. It may be noted that on two occasions during the past seven years the author has observed limited and localized outbreaks of defoliation by insects in tropical peat swamp forests. In 1953 heavy defoliation of species of Sapotaceae, especially of Palaquium walsurifolium, occurred in certain localities of the Rejang Delta. The large caterpillars responsible were eagerly collected by local Ibans to supplement their diet. In 1958 almost complete defoliation of Dactylocladus stenostachys occurred in the Naman Forest Reserve and the Rejang Delta. Mr. A.D. Parsons, a local forest officer, attempted without success to breed out the insect.

Part 6

Regeneration and silviculture of peat swamp forests.

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Part 6

Regeneration and Silviculture of Peat Swamp Forests.

Introduction.

252. Regeneration and silviculture of peat swamp forests can be most conveniently discussed in two separate chapters : the first on the silviculture of Phasic Community 1, or, to use the local term, Mixed Swamp Forest, and the second chapter on the silviculture of forest dominated by Shorea albida. Phasic Communities 5 and 6 are of no economic importance. The results of the ecological survey are the basis for the discussion on silviculture, though it is admitted that far more information is required on the regrowth following exploitation before silvicultural prescriptions can be in anyway finalised. For this purpose a comprehensive series of treatment plots is to be established in the next three years (1961-3) in accordance with the Forest Research Programme 1959 - 63 (77).

253. In the past twelve years the method of working the peat swamp forests has been standardised throughout Sarawak. The relatively level surface of swamps and readily accessible rivers and deltaic channels on the margins simplify logging operations and management of peat swamp forests. Rail line extraction routes are constructed on precise bearings and the forest on either side is worked in blocks by the Kuda Kuda method hand logging (78) to a normal depth of two hundred fathoms (18.18 chains). A coupe comprises the forest on either side of one or more rail lines.

254. Initially it was intended that the Mixed Swamp Forest

would be worked on a girth limit system on a rotation of fifteen years. It was found however that the felling damage was particularly severe, and the number of intermediate girth trees of economic species was too few for this system to operate. The girth limit was therefore abandoned on all species except Gonystylus bancanus, on which it was reduced to forty eight inches. The forest is now worked on a tropical high forest system on a rotation of seventy years.

255. The degree of exploitation tends to vary within the coupe, dependent on the original stand of timber and with distance from the rail line. Close to the rail the forest is almost clear felled, but towards the back of blocks there are not infrequently patches of undisturbed forest. A second cause of variation depends on the state of the timber market, especially in Hong Kong and Japan. Licensees are required to fell certain obligatory species, usually Ramin (Gonystylus bancanus), Jongkong (Dactylocladus stenostenchys), Sepetir (Copaifera palustris), and the Merantis (Shorea spp.). If, however, the market is favourable other light hardwoods such as Terentang (Campnosperma coriacea), Geronggang (Cratoxylon spp.), Kepayang babi (Mezzettia leptopoda) Durian burong (Durio carinatus), Bintangor (Calophyllum spp.) are likely to be extracted. In the rare occurrence when the market is completely unselective the heavy hardwoods, including Entuyut (Tetramerista glabra), Menggris (Koompassia malaccensis) and Simpoh (Dillenia pulchella) may be felled. In general there is a tendency for more species to be marketed, and after 1965, when many licensees' coupes in Mixed Swamp Forest will be reduced, exploitation is expected to be heavier. There is a prohibition on the felling of Jelutong (Dyera lowii) which is tapped for the chicle gum.

Field Method

256. To determine the distribution of the smaller size classes, including seedlings saplings, poles and trees less than twelve inches girth, of economic species in primary peat swamp forest ten randomised transects, each ten links in width and 1/100 acre in area, were enumerated across all sample plots in the Rejang Delta. The following size classes were recorded :

(i) 2 to 5 feet high,

(ii) 5 to 10 feet high,

(iii) 10 feet high to 2 inches diameter,

(iv) 2 to 4 inches diameter.

Two randomised milliacre plots were enumerated on each transect to obtain date on seedlings less than two feet high. Similar transects were laid out in Sample Plots 19 - 23 on the Maludam Peninsula. In this latter survey however each transect was subdivided into ten milliacre plots and all regeneration of economic species recorded.

257. In order to obtain further information on the size class distribution of economic species in primary Mixed Swamp Forest five acres in the Naman Forest Reserve were completely enumerated by quarter chain square plots. Individuals were recorded in foot height classes from five to ten feet, and then in inch girth classes to twelve inches girth.

258. In 1958 a half chain linear sampling (L.S.$\frac{1}{2}$) was undertaken in the Naman Forest Reserve (Rejang Delta) to determine the composition, abundance, size class distribution, and dominance of economic species in forest that had been exploited during the previous

seven years. The technique followed the standard sampling procedure as used in Malaya (79) except that all regeneration was recorded of economic species down to five feet high in each half chain square plot. In addition the dominance class of the 'chosen' and 'secondary' trees was recorded. It was realised that a half-chain sampling in the coupes that had been exploited one to four years previously was unlikely to give reliable results as the regeneration would be too small, but by using standardised half-chain sampling throughout comparative data on changes in the composition, abundance and dominance of regeneration over seven contiguous annual coupes were obtainable.

Chapter 17.

Regeneration and Silviculture of Mixed Swamp Forest.

259. Variations in the floristic composition of the dominants in Mixed Swamp Forest are largely to be found in the relative abundance of the species in different localities rather than in the actual distribution of species. The principal dominants, i.e. Gonystylus bancanus, Dactylocladus stenostachys, Copaifera palustris, Dyera lowii, and three species of Shorea (S. teysmanniana, S. platycarpa, and S. scabrida) occur, in greater or lesser abundance, in all peat swamps. Shorea rugosa var. uliginosa is absent from northern Sarawak and Brunei but is of frequent occurrence elsewhere. The principal exception to this uniformity, already mentioned in Chapter 8, is the localised distribution of species in coastal and inland swamps. In the former Campnosperma coriacea is very abundant, whereas Melanorrhoea beccarii, Shorea inaequilateralis (bordering on Phasic Community 2) and to a lesser extent Dryobalanops rappa are of more frequent occurrence towards the landward limits of the peat swamps. Nevertheless the forest is sufficiently uniform for general considerations of regeneration and silviculture to be applicable in all localities.

Flowering and fruiting of principal dominants.

260. During the past five years records of flowering and fruiting of the principal dominants have be maintained. Further information has been obtained from reports and from labels on botanical specimens.

261. Gonystylus bancanus flowers and fruits regularly. Flowering usually occurs in the months of January to March, and the seeds are released in late April or May. The large seeds probably owe

their dispersal to animals, particularly squirrels, which are attracted by the conspicuous fleshy aril. Some of the larger birds, e.g. hornbills may also assist dispersal. It also is probable that the ikan kli (Clarias batrachus), a small swamp catfish that abounds in pools in this forest type, may be responsible for localised dispersion. The fish is said to have a peculiar flavour, attributed to the aril of Gonystylus, during a fruiting season. In the last five years fruiting has been recorded or reported in every year, except in 1958. Germination of the seed is rapid, usually within a few days of the it falling.

Dactylocladus stenostachys. Though this species flowers very frequently and fruits prolifically, there is very little information on the dispersal or germination of the seed. Seedlings are extremely rarely encountered in primary forest, despite the fact that they may be easily recognised. Trees may be found in flower during all periods of the year, most frequently perhaps in the middle of the dry season in June and July. Fruiting trees have been most often recorded in September and October. Copaifera palustris fruits irregularly though not infrequently. It would appear to be less subject to climatic influence than most species in the swamps; widespread fruiting of the species is rare, though individual trees may be found in fruit at all times of the year. The medium-sized fruit contains only one or two large seeds, which are probably dispersed in a similar manner to the seeds of Gonystylus bancanus, being possessed also of a bright fleshy aril. Dyera lowii has perhaps the most conspicuous fruit of any peat swamp species, but they are rarely encountered.

No general fruiting has occurred during the past ten years, though a localised fruiting occurred in the Rejang Delta in 1959. The enormous fruit produce innumerable minute seeds, which are adapted for wind dispersal. Shorea spp. (S. rugosa var. uliginosa, S. scabrida, S. teysmanniana, S. platycarpa and S. inaequilateralis) like many other members of the Dipterocarpaceae flower and fruit at irregular intervals and gregariously. Flowering is out of phase with the hill Dipterocarps. Whereas the latter in Sarawak usually flower in September or October, a flowering of the swamp Shoreas (and Dryobalanops rappa) generally occurs in February or March, the fruit setting about six weeks later. A moderate fruiting season in most localities was recorded in 1953, since when only localised fruiting has been reported. In 1961 (March) a widespread flowering occurred in the Batang Lupar swamps. Dispersion is probably largely by wind. Cratoxylon arborescens flowers and fruits very frequently producing a prolific amount of light seeds.

Table 37 . Calculated number per acre of seedlings, saplings and poles of economic species in Phasic Community 1.

	0-2' h.	2-5' h.	5-10' h.	10'h- 2" d.	2-4" d.	Total	Percent of plots regenerated 1/1000 acre plots 0-10' h.	0-4" d.	1/100 acre transects 2-10' h.	2-4" d.
Sample Plots 1 & 2										
Gonystylus bancanus	90	55	50	45		240			60	75
Copaifera palustris	15	30	40	20	15	120				
Dactylocladus stenostachys				5		5				
Shorea spp. (4)		15	25	5	5	50			90	100
Dryobalanops rappa		25	35	45		105				
Shorea inaequilateralis	135	20	15	15	10	195				
Dyera lowii			5	5	5	15				
Totals	240	145	170	140	35	730			95	100
Sample Plots 13 & 14										
Gonystylus bancanus	245	370	70	30		715			85	85
Copaifera palustris	5	20	25	5		55				
Dactylocladus stenostachys										
Shorea spp. (4)	15	125	120	30	5	295			95	95
Dyera lowii			10		5	15				
Totals	265	515	225	65	10	1080			100	100
									0-10'L	0-4" d
Sample Plots 19 & 20										
Gonystylus bancanus	115	145	105	40	20	425	25.5	27	70	75
Copaifera palustris	55	15	10	5	5	90				
Dactylocladus stenostachys							19.5	25.5	65	75
Shorea spp. (4)	205	10	55	20	20	310				
Dyera lowii		5	10	5	5	25				
Totals	375	175	180	70	50	850	36	41	80	95

Distribution and size class structure of regeneration.

262. The results, shown by calculated numbers of individuals per acre, of surveys of the smaller size classes of economic species in six sample plots in Mixed Swamp Forest are summarized in Table 37. These surveys are of course inadequate to give more than an impression of the abundance and frequence of regeneration, but the results have since been confirmed by later more extensive milliacre surveys. It will be noted that there is a relative abundance of seedlings and small saplings, up to ten feet high, of Gonystylus bancanus and the Shoreas. Moreover between sixty and one hundred percent of the transects (one hundredth of an acre) are regenerated with established seedlings or saplings. Dactylocladus stenostachys regeneration was negligible.

263. To obtain further information on the size class structure of the regeneration a survey in a localised area (Naman Forest Reserve) was undertaken. The results are included in Table 38. There is an abundance of established seedlings and saplings of Gonystylus bancanus, Shorea spp., Dryobalanops rappa and Copaifera palustris. The most significant feature is the almost total absence of poles, eight to twelve inches girth, of these species. As a forest guard observantly remarked one frequently finds young ramins and merantis the size of one's finger, but very rarely the thickness of one's arm. It would appear probable that there are two critical periods for the survival and development of these species in primary forest: first, when the nutritional reserves of the seed are exhausted when the seedling is becoming established, and second as a sapling or small pole, about six inches girth, when if the ecological conditions are favourable

Table 38 . Representation of saplings and poles of economic species in five acres of primary Mixed Swamp Forest.

	Height classes in feet						Girth classes in inches.										
	5	6	7	8	9	1	2	3	4	5	6	7	8	9	10	11	Totals
Gonystylus bancanus	36	24	19	8	5	2	7										
Shorea rugosa var. uliginosa	44	23	22	17	14	4	24	25	8	4							
Shorea teysmanniana	85	64	63	47	46	30	71	25	19	15	7	2					
Shorea platycarpa	11	13	6	6	5	2	10	3	1	2	1						
Shorea macrantha	20	14	10	23	20	5	33	14	5	8	1	2					
Shorea inaequilaterlis	12	10	9	6	10	1	16	3	5								
Copaifera palustris	20	30	38	28	15	8	44	17	7								
Dryobalanops rappa	117	106	109	61	56	71	87	32	14	6	2		2	1			
TOTAL	345	284	276	196	171	123	292	119	59	35	11	4	2	1		1	1919
Average per acre	69	56.8	552	392	342	246	584	238	118	7	2.2	08	04	02		0.2	383.8

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the individual will grow rapidly towards maturity. No regeneration of Dactylocladus stenostachys, or Cratoxylon arborescens was recorded during this survey.

Survey of regeneration in exploited forest

264. Surveys of regeneration in primary forest provide data on the advance growth on the ground at time of felling, but damage to the forest consequent of exploitation provides vastly different conditions, and the reaction of species to these conditions cannot be accurately foretold. The first linear regeneration survey in exploited forest was undertaken in 1958 in the Naman Forest Reserve. The forest had been logged by a series of parallel coupes during the previous seven years. Rail line extraction routes had served two consecutive coupes on opposite sides of the line. Within the immediate neighbourhood of the rail line therefore the forest had been completely cleared and remained open for two years. Three half chain linear regeneration transects were surveyed at right angles to the axis of the coupes, thus cutting across forest that had been exploited during the previous seven years. The results of this survey are summarized in Table 40. The total count of all size classes, five feet high and over, (Table 39) in each plot is of interest in showing changes in the abundance of species following exploitation. There is no significant change in the abundance of Gonystylus bancanus, Copaifera palustris, Dryobalanops rappa and the three Shoreas. The percentage of plots stocked is high and the numbers of individuals per acre remains relatively constant. Presumably mortalities are offset by the growth of seedlings less

Photograph 75 . Regrowth in Phasic Community, two years after exploitation. The Forester is holding a sapling of Shorea teysmanniana.

Photograph 76 . Regrowth in Phasic Community 1, about six months after the closure of the coupe. The seedling to the right of the Forester is a Shorea teysmanniana, and that in the left foreground a Shorea inaequilaterlis. Open areas near the rail line, such as shown, are likely to be colonised by seedlings of Cratoxylon spp and Dactylocladus stenostachys.

Table 59 . Representation of regeneration of economic species in exploited Mixed Swamp Forest (Phasic Community 1) in the Naman Forest Reserve.

Year of exploitation	No. of plots	% plots stocked	No. of individuals per acre	Numbers of samples stocked with individuals, 5' and up Numbers per sample. 1	2 - 5	6 - 10	11 - 20	21 +
(i) Gonystylus bancanus								
1957	84	70.2	102	15	29	8	7	
1956	96	58.3	135	18	20	10	7	2
1955	96	55.2	70	16	29	8		
1954	78	57.7	109	15	20	4	5	1
1952-3	180	59.5	63	45	53	8	1	
1951-2	186	66.6	96	37	63	19	5	
(ii) Copaifera palustris								
1957		34.5	23	19	10			
1956		62.5	84	30	15	14	1	
1955		68.8	84	33	19	14		
1954		46.2	42	18	16	2		
1952-3		31.1	36	28	18	10		
1951-2		27.9	26	26	23	3		
(iii) Shorea rugosa var. uliginosa								
1957	84	40.1	37	20	11	3		
1956	96	54.2	56	23	24	5		
1955	96	42.7	44	23	14	4		
1954	78	57.6	52	24	21		1	
1952-3	180	81.7	79	81	56	6	4	
1951-2	186	66.1	63	72	40	9	2	
(iv) Shorea teysmanniana								
1957		67.9	142	18	20	10	7	2
1956		62.5	145	20	25	2	8	5
1955		22.9	62	11	2	5	3	1
1954		69.2	109	24	22	4	3	1
1952-3		48.8	75	22	51	11	3	1
1951-2		56.9	109	44	37	10	12	3
(v) Shorea inaequilateralis								
1957	84	58.3	115	13	22	9	4	1
1956	96	64.6	69	26	31	4	1	
1955	96	56.3	69	22	24	7	1	
1954	78	74.4	111	17	27	13	1	
1952-3	180	31.7	31	29	23	5		
1951-2	186	52.2	81	30	40	16	10	1

Year of exploitation	No. of plots	% plots stocked	No. of individuals per acre	Numbers of sample stocked with individuals, 5' and up Numbers per sample. 1	2- 5	6 - 10	11-20	21 +
(vi) Dryobalanops rappa								
1957		92.1	211	8	42	20	4	3
1956		87.2	285	7	39	20	9	9
1955		89.6	172	13	49	17	6	1
1954		96.2	388	5	27	22	6	15
1952-3		75.5	186	28	55	26	25	2
1951-2		90.9	325	16	68	41	27	17
(vii) Dactylocladus stenostachys								
1957	84	4.8	3	3	1			
1956	96	3.2	1	3				
1955	96	17.7	68	5	5	1	3	3
1954	78	42.3	193	10	6	6	2	9
1952-3	180	24.4	90	13	11	5	7	8
1951-2	186	46.2	307	15	10	11	12	38
(viii) Cratoxylon arborescens & C. glaucum								
1957		20.2	13	12	5			
1956		33.3	26	17	15			
1955		40.6	141	8	14	8	3	6
1954		82.1	460	7	16	11	11	19
1952-3		46.1	166	20	25	12	15	11
1951-2		57.5	323	20	19	17	16	35

than five feet high, and possibly by recruitment from seedlings after exploitation, though the latter is probably exceptional owing to the removal of most mature trees and the periodicity of fruiting of most species. Dactylocladus stenostachys and the two species of Cratoxylon are clearly colonising species that tend to regenerate only in areas where the canopy has been completely opened. Regeneration of these species in the 1956-57 coupes is negligible but there is a rapid increase in their representation in coupes exploited previously. This regeneration is very largely found in the vicinity of the old rail lines where it is frequently very abundant. In the oldest coupe (1951-52) 38 and 35 half acre plots had more than twenty one individuals of Dactylocladus and Cratoxylon respectively.

265. The overall abundance of regeneration is not however the most important silvicultural feature in the regrowth. Greater consideration must be given to the frequence of the regeneration, and the dominance class of the 'chosen' and 'secondary' trees. Here reference should be made to Table 40. The percentage of samples with a chosen tree (column 3) exceeded ninety throughout, and over eighty per cent of the samples were represented by a secondary tree. In the forest exploited in the years 1956 and 1957 Gonystylus bancanus and Dryobalanops rappa provide the highest proportion of chosen and secondary trees, but there is a significant decrease in the representation of the former species as the chosen or secondary tree corresponding to the time lapse since exploitation (Col.7). This important feature has since been confirmed by extensive regeneration surveys, undertaken by Clarke (80), elsewhere in the

Table 40 . Summary of results of linear survey enumeration (L.S.½) in exploited Mixed Swamp Forest (Phasic Community 1) in the Naman Forest Reserve.

			Chosen trees by species and percentages of total number of plots.								Size classes of chosen tree by percentage of number of plots.					Dominance classes of chosen tree by percentages.			
(i) Year of exploitation	Number of samples	Percentage of samples with chosen tree	Shorea spp. (5)	Cratoxylon spp. (2)	Dyera lowii	Gonystylus bancanus	Dryobalanops rappa	Copaifera palustris	Dactylocladus stenostachys		5 -10L	10'h 2"d	2" 4"d	4 8"d	8 12"d	12"d +	D	SD	d +s
Chosen Tree																			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)		(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
1957	84	96	46		6	19	22	6			6	2	25	50	12	5		18	82
1956	96	99	48			15	26	6	3		9	10	27	39	10	5	15	18	67
1955	96	100	29	6	3	11	37	11	2		7	3	24	49	16	1	9	26	65
1954	78	100	36	14	4	4	41		2		5	2	24	62	7		58	20	22
1952-53	160	93	53	9		4	27	5	2		3		13	46	37	1	44	17	39
1951-52	186	95	33	9	4	6	39	2	12		3	4	8	58	24	3	50	23	27
(ii) Second tree																			
1957	84	83	44		3	14	34		1		10	6	39	38	6	1		13	87
1956	96	85	39	5		10	39	8			23	4	28	32	11	2	6	23	71
1955	96	80	42	12	3	10	25	8	2		17	5	40	31	5	2		14	86
1954	78	81	35	21		8	25		5		16	5	44	30	5		5	52	43
1952-53	180	87	58	6		8	18	5	6		4	5	21	59	11		2	30	58
1951-52	186	84	43	10	8	2	26		15		4	3	17	60	15	1	8	44	48

Rejang Delta. It indicates that Gonystylus bancanus does not react to a heavy opening of the canopy, and the advance growth of this species is being swamped by the faster growing Dipterocarps and other species. In the older coupes, previous to 1955, the principal species of chosen and secondary trees are the Shoreas, Dryobalanops rappa, and in more open areas Cratoxylon spp. and Dactylocladus stenostachys. In these coupes the dominance of the chosen trees is satisfactory, over seventy percent being either Dominant or Sub-dominant (Cols. 17 and 18).

266. Fast growing weed species that may dominate the regrowth of economic species include Litsea nidularis, Litsea resinosa, Litsea cylindrocarpa, Litsea gracilipes, Macaranga puncticulata (especially in localities completely clear felled), Phoebe sp. (4959), Elaeocarpus obtusifolius and Antidesma coriaceum.

267. In comparison with the peat swamp forests of Malaya, as described by Wyatt-Smith (76), the peat swamp forests of Sarawak and Brunei are of greater economic value. The former are only of the Mixed Swamp Forest type, and the representation of economic species is lower: Dactylocladus stenostachys, Shorea scabrida, Shorea inaequilateralis and Dryobalanops rappa of the more economically valuable species are absent from Malaya. Moreover Gonystylus bancanus is less frequent and apparently regenerates less freely. There is on the other hand no timber species in the Malayan swamps that does not occur in the Sarawak swamps, though certain species, e.g. Koompassia malaccensis and Tetramerista glabra, which are at present of no timber value in Sarawak, are exploited in Malaya. The results

of the regeneration surveys previously shown are not directly comparable with those reported by Wyatt-Smith. Nevertheless it is clear that regeneration both in primary and exploited forest in Sarawak is more abundant and widespread than in Malaya. The results of this and subsequent surveys tend to indicate that the majority of the middle and lower storey trees of the primary forest that remain standing after exploitation probably do not survive for more than a few years.

Silviculture.

268. From information gained, both in primary and exploited forest, in the course of this survey a preliminary list of the silvicultural characteristics or 'silvics' of the principal economic dominants may be prepared. A summary of these follows:

Gonystylus bancanus: Flowers and fruits regularly. Large seeds may be dispersed by animals though majority germinate in the immediate vicinity of mother trees. Survival rate of seedlings is high, and both seedlings and saplings are shade tolerant. Probably grows fast through pole stages under a partial opening of the canopy. Moderate light demander at maturity.

Dactylocladus stenostachys: Flowers frequently and fruits prolifically. Minute seeds have wide dispersal. Survival rate of seedlings under shade negligible, possible that seed does not germinate except under full light conditions. Very fast growth in young stages and strong light demander. Moderately shade tolerant at maturity.

Copaifera palustris: similar to Gonystylus bancanus.

Shorea spp. (S. rugosa var. uliginosa, S. teysmanniana, S. platycarpa S. scabrida, S. inaequilateralis): Flowers and fruits at irregular intervals and gregariously. Dispersal by wind within narrow radius of mother trees. Seedlings and saplings shade tolerant and survival rate moderately high. Fast growth to maturity under full light conditions.

Dryobalanops rappa: similar to Shorea spp., but probably more shade tolerant in younger stages.

Cratoxylon spp. (C. arborescens and C. glaucum) : Flowers and

fruits frequently producing an abundance of seed which is widely dispersed. Strong light demander and grows fast at all stages. Survival rate of seedlings under shade negligible.

269. The timber industry at present is largely based on the exploitation of Ramin (Gonystylus bancanus), but the results of this and subsequent surveys have shown clearly that in the regrowth Gonystylus bancanus is becoming increasingly dominated by faster growing species. Consideration must therefore been given to the objects of silviculture which will decide the next crop, as it is quite impracticable to alter or modify the system of exploitation to prevent such a drastic opening of the canopy. The basic problem is whether silvicultural treatment should be applied to favour Gonystylus at the expense of all other species, or whether treatment should be concentrated on obtaining in the next crop a high volume of timber per acre of fast growing merchantable species, particularly the Shoreas. It has been provisionally decided that, until further research is undertaken and an answer is found to the regeneration of Gonystylus, the dominant regrowth on the ground must be utilised. This is certainly the most realistic approach, and there can be little doubt that at the end of a seventy year rotation a high volume of merchantable timber per acre will be of great value, especially in South East Asia where in fifty years time a timber shortage is envisaged. (81) This policy does not necessarily mean the complete abandonment of Gonystylus. A strictly controlled girth limit at forty eight inches will ensure the retention of an estimated two undergirth Gonystylus stems per acre at least which, it is hoped, will

survive and develop into large trees in the next crop. Furthermore Gonystylus will receive preferential treatment where it is dominant or sub-dominant in the regrowth.

270. The following list shows in order of preference the 'preferred' and 'acceptable' species. It is based largely on the timber value of the species, but abundance and growth rates are also taken into consideration:

Preferred species :

Ramin (Gonystylus bancanus)

Jongkong(Dactylocladus stenostachys)

Meranti lop (Shorea scabrida)

Meranti lilin (Shorea teysmanniana)

Meranti buaya (Shorea rugosa var. uliginosa)

Meranti paya (Shorea platycarpa)

Kapur paya (Dryobalanops rappa)

Sepetir paya (Copaifera palustris)

Semayor (Shorea inaequilateralis)

Acceptable species :

Jelutong (Dyera lowii)

Perupok (Lophopetalum multinervium)

Durian burong (Durio carinatus)

Geronggang paya (Cratoxylon arborescens)

Geronggang padang (Cratoxylon glaucum)

Bintangor (Calophyllum spp.)

Terentang (Campnosperma coriacea)

271. No large scale silvicultural treatment of peat swamp forests has been attempted, but localised post felling treatment has been undertaken in certain reserves during the past five years. This has very largely been in accordance with the standard treatments for lowland dipterocarp forest in Malaya (82), involving a heavy poison girdling of all relics and weed species immediately after felling to release the regeneration of fast growing Shoreas. It had become increasingly apparent that this heavy and expensive treatment is not necessary and may even be undesirable in Mixed Swamp Forest especially where exploitation is relatively thorough. The results of the regeneration surveys have proved that adequate dominant regeneration of acceptable species can be expected without treatment. Heavy treatment is likely to encourage the regeneration of certain less favourable species such as Cratoxylon and Campnosperma, and also possibly result in too much regeneration which will require expensive thinnings at a later date. This heavy treatment has now been replaced by a selective treatment, as required, to release regeneration in areas of partially exploited or unexploited forest and to remove large weed trees and unmerchantable relics over sixteen inches diameter. It is doubtful whether even this treatment is necessary where the logging has been efficient and thorough in areas with an average, or above average, stand of timber.

272. In view of the heavy regeneration found in areas that had no immediate post-felling treatment it is now considered that a treatment seven to ten years after exploitation is likely to be of more value. The object of this treatment will be to release the crowns

of preferred or acceptable species, selecting where possible four stems per half chain square, or approximately 120 to 160 stems per acre. Dominant or codominant stems will require little or no treatment, and the treatment will be largely confined to subdominant stems of preferred species. No treatment of this nature has yet been applied and the precise details will require to be worked out in the field. One of the main problems is accessibility. All operations in peat swamp forests are hindered by the nature of the ground. Immediately after exploitation, before the rail line is removed, access is not difficult and is inexpensive, but for at least five years thereafter a dense thicket makes silvicultural operations quite impracticable.

273. It is envisaged that the dense regrowth may be liable to wind damage in the pole stages at about twenty to thirty years of age. A severe storm in 1957 flattened large areas of regeneration in the Dacrydium-Casuarina forests that had been exploited twenty five years previously. If no treatment is applied to dense regeneration in Mixed Swamp Forest similar conditions will probably exist.

274. With the arrival of a Silviculturist in 1960 intensive silvicultural research is being undertaken in the peat swamps. Three replicated series of treatment plots, in a form suitable for statistical analysis, are to be laid out in 1961-2. The first series will be to determine the value of immediate post felling treatment; the second to determine the value and practicability of treating the regrowth approximately ten years after exploitation, preference being

given the dominant stems of all preferred or acceptable species. The third series will be similar to the second but preference will be given to Gonystylus over all other species.

Chapter 18

Regeneration and Silviculture of Shorea albida forest

Introduction

275. Before considering the regeneration and silviculture of Shorea albida it is necessary to mention another peculiarity of this somewhat remarkable species. In 1951 two forms of the species were known: alan which produces a heavy timber of the Red Selangan group (50 - 55 lbs per cu. ft. or more), and meranti bunga (since termed alan bunga) producing a light weight timber, 35 - 40 lbs per cu. ft., in the Red Meranti group (Browne, 6). The former is obtained from the large, usually hollow, trees in Alan forest (P.C.2) whereas the latter is obtained from the dense pure stands of Shorea albida (P.C.3). There was a good deal of controversy about the different forms of the species and whether they represented distinct varieties. In order to clarify this point, which might have considerable bearing on the interpretation of the ecological results, sixty eight trees were felled in the different forest types encountered in the Loba Kabang Protected Forest. Three radial samples, approximately two inches square, from pith (or hollow) to bark were collected from each tree. The samples were examined by Brazier (83) who found a range in density of 20 - 57 lb. per cu. ft. in the timber. His results showed conclusively that the light weight and heavy timbers are produced by Shorea albida at different periods of growth, and that timber from each of the forest types may exhibit a similar range in specific gravity. The first formed, or juvenile, wood is moderately light but with increase in size there is an increase in specific gravity until a heavy wood of fairly uniform density is laid down (the adult wood). The girth class

representation of the species, previously described, and shown in Table 41, indicates that the small trees in Phasic Community 4 will produce only the light weight timber; the small and medium-sized trees in Phasic Community 3 will also produce light weight timber but larger trees are liable to have a band of the heavier timber on the periphery; whereas the large trees in Phasic Community 2 will generally provide only the heavier timber, the light weight timber having succumbed in rot and termites.

Flowering and Fruiting

276. The Dipterocarpaceae, especially the Shoreas, are well known for their periodicity of flowering and fruiting; a heavy flowering and fruiting can usually be expected every four to five years, though occasionally fruiting may occur on two consecutive years, as happened in 1958-9 with engkabang jantong (Shorea gysbertsiana), the most important producer of the commercial illipe nuts (84). Shorea albida is no exception. Indeed from the records available it would appear to flower and fruit even more irregularly and spasmodically than the other Shoreas. As with the other swamp Dipterocarps flowering and fruiting is out of phase with the hill Dipterocarps. In the past ten years flowering and fruiting has been reported or recorded by the author in the following localities:

1953 Localised fruiting in parts of the Baram swamps. Probably only a relatively few trees in any one locality fruited.

1954 A further localised fruiting in the Baram swamps.

March, 1954 A few trees flowered in the Loba Kabang Protected Forest (Rejang Delta). None of the trees under observation set fruit.

1954 Very heavy fruiting in the Maludam Peninsula, less so in the Lingga swamps on ther other side of the Batang Lupar.

February, 1960 Very localised fruiting of large trees, mostly in Phasic Community 2 in the Lassa Protected Forest and Daro Forest Reserve. No fruiting was recorded elsewhere in the Rejang Delta.

March, 1961 Very heavy flowering in swamps south of the Batang Lupar. Flying over the Lingga swamps the whole canopy appeared cream coloured. Approximately two thirds to three quarters of the canopy trees were in flower.

277. The most usual time for flowering is towards the end of the wet season, from February to April, and fruiting follows about six to eight weeks later. No extensive fruiting has occurred during the past ten years in many areas of Shorea albida forest, notably in the whole of the Rejang Delta or in the Badas swamps in Brunei. In the Rejang Delta it seems probable that there has not been a general fruiting for at least fifteen years. In 1951-2 the seedling was unknown and the author offered a small reward to the first member of the Forest Staff to find one.

278. The natural regeneration and silviculture of Shorea albida can be most conveniently considered separately in the three phasic communities (Nos. 2 - 4) where the species is dominant. Furthermore it is advisable to first consider Phasic Community 3, the Shorea albida consociation, where the species attains its maximum dominance.

Phasic Community 3 (Shorea albida consociation)

279. The almost total absence of natural regeneration of Shorea albida in the Rejang Delta in 1951-4 has already been mentioned. Only three seedlings were recorded in the milliacre regeneration survey of Sample Plots 15 and 16, and a search for seedlings elsewhere in the vicinity confirmed their general absence. The transect in the Maludam Peninsula, however, was enumerated in November 1955, a year after a very heavy fruiting, and here there was almost a carpet of seedlings. The results of the milliacre survey are shown in Table 42. The average number of seedlings per milliacre plot was 34.06 and all plots contained at least four seedlings. The total of 34,000 seedlings per acre gives an indication of the abundance of the regeneration. The area was revisited in 1958 and the vast majority of the seedlings had disappeared, except where a gap in the canopy had allowed light to penetrate to the swamp surface. It would appear that the survival rate of the seedlings under the canopy is low. Further evidence of this is required and ecological plots to determine the recruitment and survival of seedlings are to be laid out (1961).

280. No saplings or poles (less than 12 ins. girth) have been recorded in any of the sample plots. From these results and those included in Chapter 15 it seems apparent that Shorea albida is a very strong light demander and in its initial stages only develops where gaps have occurred in the canopy as a result of wind or lightning damage. Sapling stage regeneration in gaps has been recorded in the Baram swamps (Table 29) and on the Maludam Peninsula. It must be admitted, however, that no gap containing pole size regeneration

Table 42. Regeneration of Shorea albida in milliacre plots in Sample Plots in the Maludam Peninsula.

A. (S.P. 22 - P.C. 3)

Line No.	Plot Nos. 1	2	3	4	5	6	7	8	9	10	Total	Average
1	24	49	32	35	26	48	38	17	22	33	324	32.4
2	57	38	47	34	48	18	53	62	53	38	448	44.8
3	34	30	23	24	12	18	28	68	43	51	331	33.1
4	45	46	48	48	32	35	21	15	16	19	325	32.5
5	40	32	28	39	46	23	26	23	21	18	296	29.6
6	22	19	22	11	12	18	10	21	39	32	206	20.6
7	50	19	28	21	18	8	26	22	31	22	245	24.5
8	36	15	44	24	6	4	10	12	19	22	192	19.2
9	41	4	3	7	74	48	64	61	45	48	395	39.5
10	62	66	58	122	56	84	54	42	59	41	654	65.4
TOTALS	411	318	333	365	330	304	330	343	348	324	3406	34.06

B. (S.P. 21 - P.C. 2)

Line No.	Plot Nos. 1	2	3	4	5	6	7	8	9	10	Total	Average
1	48	71	95	46	67	36	84	56	56	91	650	65.0
2	47	40	84	58	49	54	54	52	48	53	539	53.9
3	1	17	36	33	48	53	51	26	17	27	309	30.9
4	4	16	21	34	74	15	18	30	20	11	243	24.3
5	8	32	64	51	20	7	60	49	41	53	385	38.5
6	103	72	16	7	1	1	2	3	1	5	211	21.1
7	3	8	15	32	20	18	4	2	3	37	142	14.2
8	11	14	15	10	8	5	8	9	4	3	87	8.7
9	5	7	16	11	1	6	8	9	22	14	99	9.9
10	10	-	1	3	4	3	14	7	2	4	48	4.8
TOTALS	240	277	363	285	292	198	303	243	214	298	2713	27.13

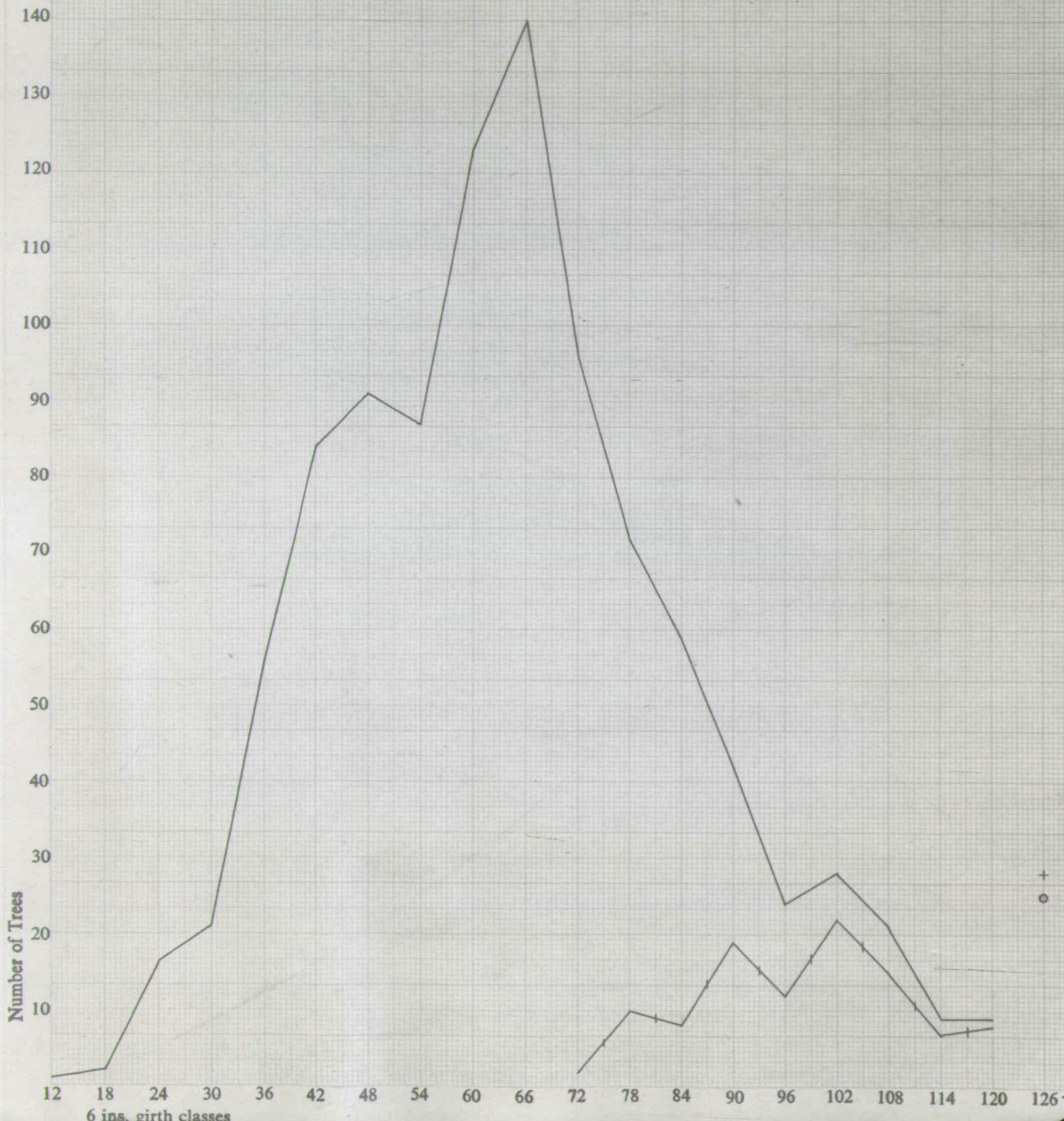
C. (S.P. 23 - P.C. 4)

Line No.	Plot Nos. 1	2	3	4	5	6	7	8	9	10	Total	Average
1										1	1	0.1
2												0.0
3	10	8	10	4	4	3	1	1			41	4.1
4	3		2	1	5	11	19	4	57	112	214	21.4
5			2								2	0.2
6				1							1	0.1
7									1		1	0.1
8												0.0
9	1	9	7	4	2	3	3	4	3	1	37	3.7
10	6	1		4	5	6	9	11	10	10	62	6.2
Totals	20	18	21	14	16	23	32	20	71	124	359	35.9

has yet been encountered. If this hypothesis on patch regeneration of Shorea albida is correct, then one might expect to find a tendency towards a mosaic of girth classes. To determine whether or not this was present all Shorea albida, over 12 inch girth in an eighteen acre block in the Maludam Peninsula were enumerated by quarter chain sub-plots. The results were examined by Vincent (85) who reported that no grouping could be detected. He considered that the area of the enumeration was too small to show grouping and, furthermore, that variations in rates of growth of trees would tend to obscure grouping by girth classes. The results are of interest, however, in showing the girth class representation of Shorea albida (see Figure 53). Only three trees less than twenty four inches girth were recorded, and the single tree of twelve inches girth was found beneath a small gap in the canopy which had probably been caused by lightning. It may be concluded that regeneration of Shorea albida that becomes established beneath a gap in the canopy grows very rapidly in its initial stages. Further evidence for this was provided by Brazier's (83) study of the timber density. He concluded that generally the light weight juvenile wood near the pith was caused by the vigorous growth of young trees.

281. In considering the natural regeneration of Shorea albida forest a significant feature, already mentioned in Chapter 15, is the ability of the species to regenerate a gap in the forest some years after the gap may have occurred. Generally in lowland

GIRTH CLASS REPRESENTATION OF SHOREA ALBIDA IN AN EIGHTEEN ACRE BLOCK IN PHASIC COMMUNITY 3 IN THE MELUDAM PENINSULA



dipterocarp forest it is considered that openings in the canopy will be regenerated by advance growth (Wyatt-Smith, 74). No other species in the Shorea albida consociation has the ability to replace the dominance of Shorea albida and the growth and density of lower storey species in gaps is apparently not unduly vigorous.

282. Intensive exploitation of the Shorea albida consociation has only recently (1960) started. In 1953-4, however, an area of approximately 600 acres in the Baram was clear felled. To study the regrowth of the forest two five acre sample plots were established in 1956. Regeneration of Shorea albida was sparse: a ten per cent milliacre survey of Sar. sample plot 36 showed only 9.2 per cent of the area was regenerated. Most of the seedlings were between one and two feet high, originating in all probability from seed produced in 1953 and 1954. Revisiting the area in 1958 it was a surprise to find that the regeneration had developed exceedingly well, and a count showed 609 largely vigorous saplings, the majority of which were over ten feet high and dominant in the regrowth. In areas, however, where there had been no regeneration on the ground at the time of, or immediately after, felling a dense mass of secondary species, very largely composed of understorey associates of Shorea albida, had developed. The most abundant weed species are Quercus sundaicus, Elacocarpus mastersii, Litsea resinosa, Eugenia spp., and Timonius peduncularis. To a large extent these originate from coppice or sucker shoots following felling damage. This dense thicket is likely to suppress any seedlings of Shorea albida that become

established after felling. Further evidence of this worthless secondary forest is to be found in the Badas swamp forests, which have been partially exploited during the past ten years. Regeneration of Shorea albida is negligible.

283. The general outlines on which the silviculture of Shorea albida in this community should be based are fairly clear. If advance growth is present at time of clear felling this can be expected to develop. Difficulties may be experienced in the sapling and pole stages. There are indications of this from Sar. Sample Plot 36, where the saplings have recently (1961) suffered a set-back. Owing to the paucity of regeneration it is impracticable to insist on exploitation being confined to areas where advance growth is adequate. When this is absent or inadequate planting, using wildings, will have to be resorted to. In heavy fruiting years it may be possible to collect seed, though this is likely to be the exception rather than the rule, and as the seed in all probability retains its viability for a very short period it will require to be sown in the nursery almost immediately. It is unlikely that direct sowings will produce satisfactory results. The use of wildings in swamp forest offers less immediate difficulties than in hill forest. They can be lifted by hand with the roots enclosed in peat soil and potted in plywood veneers or plastic pots on the spot. One five acre experimental plot has been planted in 1960 using this method. Further research is required to develop methods and techniques to ensure that the seedlings are in optimum condition when planted out. Jungle nursieres are likely to provide the most satisfactory and economic means of replanting

Shorea albida. Until further information is available on the growth rate of Shorea albida it is recommended that a final crop of sixty trees per acre on a seventy year rotation should be aimed at.

Phasic Community 2.

284. Regeneration of Shorea albida in phasic community 2 is usually negligible: in milliacre surveys in six sample plots in the Rejang Delta no seedling or sapling was recorded. After a seed year, however, seedlings may be abundant: a calculated total of 27,000 seedlings per acre was found in Sample Plot 21 in the Maludam Peninsula, following the heavy fruiting the previous year (cf. Table 42). There is no evidence that seedlings develop, probably owing to the relatively dense middle and lower storeys in this community. Complete gaps in the canopy, such as occur in Phasic Community 3, are of rare occurrence and this forest type is less liable to wind damage.

285. The typical girth class structure (cf. Table 41) shows few trees less than seventy two inches girth: only one tree less than sixty inches girth was recorded in eight sample plots. Shorea albida in this community has every appearance of being moribund, and is being gradually replaced by species of Phasic Community 1. This is most noticeable in the Rejang Delta. It would appear probable that in this latter locality at any rate Phasic Community 3 was previously very much more extensive, and the over mature Shorea albida in Phasic Community 2 are the remnants of former extensive areas of the Shorea albida consociation. This whole problem requires further detailed investigation. It is suspected, however, that the

Table 41. Girth class representation of Shorea albida in Phasic Communities

		Inches 12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126	132	138	144	150	156	plus	Total
P.C.2	17									1								1						1				3
	18																											
	17+18									1								1						1				3
	3								1		1		1	1					1	2						1	159"	8
	4												1	1		1				1	1							5
	3 + 4								1		1		2	2		1			1	3	1					1		13
	21										2			1	1			1								1	162	6
	26																	1			1			2				4
	27																		1		1		1			2	195", 215"	5
	26 + 27																	1	1		2		1	2		2		9
	33													2			1		1	1		3		2				10
									1	1	3		2	5	1	1	1	3	3	4	3	3	1	5		4		41
P.C.3	15				1			2	3	3	3	2	3	2	2	2	2											25
	16			2	1	2	1	1	1	5	1	3	6			1	2											26
	15 + 16			3	1	2	3	4	4	8	3	6	8	2	3	4												51
	22		1		3	2	1	3	3	6	4	3	2		3		1	1				1						34
	24							2	3	1	4	7	3	3	2		1			1									27
	25					2	1	1		1	3	2	2		1					1	1	1							16
	24 + 25					2	1	3	3	2	7	9	5	3	3		1			2	1	1							43
	34					1	2	1	2	4	7	1	4	4			1	1											27
	35				4		1	4	3	5	2	4	1	3	1	2													30
			1		10	6	7	13	15	21	28	20	18	18	9	5	7	2	2	1	2							185
P.C.4	9	3	5	3	3	6	4		2	3	3																	32
	10	4	6	5	6	2	1	1	3	4	2			1														35
	9 + 10	7	11	8	9	8	5	1	5	7	5			1														67
	11	4	7	13	6	8	6	8	1	2	1																	56
	12	9	6	13	16	7	10	6	8	1																		76
	11 + 12	13	13	26	22	15	16	14	9	3	1																	132

Table 41 (ctd)

Inches

	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126	132	138	144	150	156	plus	Total	
23		3		1	1		1		1			1	1														8	
28				2	5	5	7	5	8	6	3	2			2												45	
30									1				1		1												3	
36			5	8	11	16	7	4	7	1																	39	
37	2	9	25	8	10	18	9	8	3	3																	95	
38	6	13	16	10	20	11	9	3	3	1																	92	
39		4	12	20	16	13	12	3	4																		84	
	28	53	92	80	86	84	60	37	37	17	3	3	2		3													585
P.C.5 29	5	5	8	1	3	1																					23	
31	1	2	1	3	1	2	2	1	1		1																15	
	6	7	9	4	4	3	2	1	1		1																	38

cause of the ecological disequilibrium may be either subsidence of the land surface in the Delta (cf. Chapter 14) or a climatic change over the past two hundred years. Either factor would tend to affect the water table, which is of primary importance in the ecology of the peat swamp forests.

286. Silviculture in Phasic Community 2 should be in accordance with that in Phasic Community 1. Adequate regeneration of species to be favoured is usually present. If regeneration of Shorea albida occurs this should be accepted and it should be treated as a favoured species. The unnaturally open conditions caused by exploitation will probably allow this species to develop satisfactorily.

Phasic Community 4.

287. Silviculture in Phasic Community 4 is at present of only academic interest. The forest is not being exploited, and is indeed uneconomic to exploit for a sawmill industry. In the future the relatively high volumes obtainable per acre and low extraction costs may enable a pulp or chipboard industry to operate.

288. Regeneration is however, of ecological interest. All girth classes of Shorea albida are usually present (cf. Table 41), and poles and saplings, though rare, occur more frequently than in other communities. A feature of the community is that regeneration is largely vegetative, from coppice or sucker shoots. Wind damage is prevalent and coppicing of stumps is often encountered. This is also very noticeable in Combretocarpus rotundatus and to a less extent in

Photographs 77, 78 & 79 . Three photographs indicating the ability of Shorea albida to regenerate vegetatively following the die back or breakage by wind of the main stem.

Photograph 80 . The regeneration of Combretocarpus rotundatus by sucker shoots on a fallen stem.

Photograph 81 . A second photograph showing the vegetative regeneration of Combretocarpus rotundatus. There were twenty one stems growing from the fallen tree.

Litsea palustris. (see Plates 48-50). Small trees of Shorea albida whose crowns have failed to attain the upper canopy have the ability to throw off adventitious shoots, usually within ten feet of the ground, and another attempt at survival is made; the original crown and stem dying back. It would be of interest to determine whether anastomising of the roots occurs thus allowing the more vigorous trees to assist the suppressed. The dense mass of roots forming the 'platform' indicates that this is at least possible.

289. Seedling regeneration of all dominants is usually sparse, though once again after a seed year Shorea albida regeneration may be abundant (cf. Table 42). It is probable, however, that owing to the infertile conditions seedlings have difficulty in becoming established.

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PEAT SWAMP FORESTS OF REJANG DELTA

REFERENCE

(I) Mangrove

(II) Gonystylus Dactylocladus Neoscortechinia Association

(III) Shorea Albida Gonystylus Stemonurus Association

(IV) Shorea Albida Consociation

(V) Shorea Albida Litsea Parastemon Association

Dominance of species in (V): Shorea Albida, Litsea Palustris, Mixture

A
L
Mx

Ecological Transects & Sample Plots

Level Surveys

Level Surveys of B.s.p.Co.

N

Scale 0 5 10 Miles
1: 250, 000

112° 00′

2°30′

2°00′

111° 30′

CHINA SEA

Kuala Mukah
Mukah
Penakub
Batang Mukah
Kuala Oya
Oya
Kuala Igan
Igan
Kenyana
Sg. Bruan
Tanjong Sirik
P. Patok
Loba Balau
Dalat
Sg. Kut
Kut
Sg. Bakong
Sg. Matu
Matu
Btg. Jamoreng
Muara Lassa
Sg. Daro
PULAU BRUIT
Sg. Rasau
Sg. Baoh
Batang Oya
Tamin
Daro
Batang Lassa
Loba Kabang
Batang Igan
Sungei Retus
Sg. Siong
Kuala Paloh
Paloh
Loba Paloh
Sg. Baluga
Loba Buan
Batang Paloh
Muara Seredang
Sg. Senah
Loba Singat
Rantau Panjang
Sg. Pasai
Sungu Merah
Sibu
Bga Mugong
Loba Semah
Batang Loba-an
Loba Sedar
Loba Bunut
Loba Bunut Uku
Muara Payang
Sg. Salim
Belawei
Kuala Belawei
Sg. Belawei
Sg. Maralau
Loba Pulau
Loba Semarang
Binatang
Sg. Tulai
Sg. Assan
Sg. Naman
Durin
Batang Rejang
Tg. Jirejeh
Rejang
Gunong Ayer
Kuala Rejang
Batang
Btg. Selalang
Sarikei
Sg. Bintang
Kanowit
Sg. Sarikei
Sg. Nyelong
Sg. Selidap
Sg. Kanowit
Kuala Nyabor
Grigat
Loba Durian
Loba Sukong
Sg. Lumut
Selalang
Julau
Machan