Composition of a Limestone Forest Community on Guam

PHILIP H. MOORE[1]

Abstract

The vegetation of a limestone forest community was characterized at Pagat, a region on the windward northeastern coast of Guam. Because of the prevailing easterlies this part of the island receives the most rain, and the vegetation varies considerably from that of the leeward side. Thirty-eight species of seed plants were found on a transect 750 meters long, which extended from the plateau (120 m elevation) to the salt spray zone. Information on density, frequency, and percent cover was obtained for each species in 150 quadrats (2×5 m). A list of plants and their relative abundance are given for the lower terrace which was not included in the transect. The relationship between the amount of salt deposition and density of *Pemphis acidula* in the salt spray zone is also discussed.

INTRODUCTION

The vegetation covering the northern half of Guam is distinctly different from that which covers the southern half. Fosberg (1960) briefly describes the limestone forest community of Guam as consisting of several sub-communities with locally dominant species. He also categorizes the significant vegetation types with some of their variants, e.g., the *Artocarpus* forest, the mixed moist forest type, the *Cordia* type, the *Mammea* type, etc. He further states that few, if any, of them exactly represent the original forest, but are the results of man's modification. Almost nowhere on the island, at the present time, can any undisturbed vegetation areas be found. What is presently growing on the plateau and terraces is considered to be modified forest rather than part of a secondary succession. The flora of Guam is well known taxonomically (Stone, 1964a, 1964b, 1970) but there is now a need for quantitative studies on the plant communities.

The purpose of this study was to quantitatively describe the plant community of a mixed limestone forest which represents a type that covers the northeast portion of Guam. This part of the island is a broad block of raised limestone, bordered on both sides by steep cliffs. The plateau slopes to the southwest from about 185 meters at the north end to about 60 meters at the central part of the island (Tracey, *et al.* 1963). The surface, in the study area, is very irregular in relief, deeply solution pitted and of a highly permeable nature. This results in the absence of any permanent rivers or lakes. Soil distribution is patchy and for the most part only a few centimeters in depth.

A relatively undisturbed area at Pagat (Fig. 1) located on the northeastern side of the island was chosen as the site for this study. There were several reasons

[1] George Washington Senior High School, P. O. Box BL, Agana, Guam 96910.

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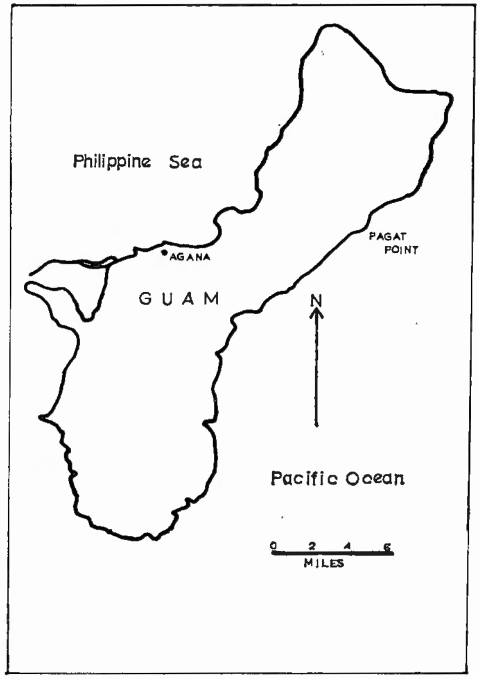

Fig. 1. Map of Guam showing location of Pagat study area.

for choosing the Pagat area-its relatively undisturbed condition, accessibility, and its representative nature in the limestone forest community. The plateau (120 m elevation) at Pagat has been burned in the past, perhaps yearly in places and used for grazing and other agricultural purposes. However, the escarpment which slopes rather steeply at an angle of 40° from the plateau to the first terrace (upper terrace) is relatively undisturbed and has probably existed in its present condition for many years. The terrace is wide and wooded, and extends for nearly 800 m to a transition zone separating it from a lower terrace 10 to 15 m above sea level. On this lower terrace, "harsh" conditions exist because of its exposure to salt spray.

METHODS

The transect method using many sample quadrats (Kuchler, 1967) seemed to offer the best means of obtaining an accurate sampling of the vegetation. The escarpment proved to be the most challenging part of the transect because of the steepness and the tangled condition of the undergrowth. This study was carried out over a nine month period from November 1969 to July 1970.

The transect line was run in a northeasterly direction from the escarpment to the lower terrace. However, it was not feasible to lay out a continuous straight line transect because of physical barriers and disturbed areas that had been cleared by man or burned over. It was necessary to shift over horizontally at times to avoid these places. A trail descending the escarpment was used as a working base. It was possible to avoid disturbed areas at the sides of the trail by selecting sites well back from the edge.

Quadrats (2×5 m) were established every five meters along the transect line, thus providing a total of 150 quadrats. The quadrats were arranged so that a quadrat north of the transect alternated with a quadrat south of the transect, thereby sampling an area 10 meters wide along the entire length.

Density and frequency values (Table 1) were obtained from each quadrat and the values pooled for all species in each consectuve 10 quadrats (100 sq. m) on the transect. The stem diameter of each plant, except small seedlings, was measured at approximately 0.3 m (1 ft.) above ground and the total area covered by each species was used to calculate the percent of cover (Table 2) for each consecutive 10 quadrats (100 sq. m) on the transect. The following size ranges were used in stem diameter measurements—less than 1 cm, 1–5 cm, 6–10 cm and greater than 10 cm. In computing percent of cover, average diameters were used for the first three ranges, but exact measurements of stem diameters were used for those greater than 10 cm. Because the percentage numbers were very small, the actual percent of cover was multiplied by 100; therefore, 1 unit equals 0.01 percent coverage.

The lower terrace was not included in the transect because of the spreading, gnarled condition of the woody plants and the presence of such species as *Pemphis acidula* and *Scaevola taccada* that spread over old coral heads in such a way that it was next to impossible to make individual counts and measure stem diameter. It was also felt that the area was an obvious ecotone and not significant to the rest of the transect. However, a list of the plants in this area and their relative dominance is given (Table 3). This terrace is divided into four zones in an attempt to show the distribution of species as they relate to the sea on one side and the limestone forest community on the other.

Some difficulties were experience, at first, in identification of seedlings of less than 1 cm. This was overcome by a process of elimination, that is, by careful comparison of seedlings with species in the immediate locality. Also helpful in this respect was the Guamanian owner of the land and several other local people who were familiar with the plants in the area. Varieties of ferns, mosses, liverworts, epiphytes, and lianas which occur in abundance, particularly where light is greatly reduced, were not considered in this study.

The method used to determined salt deposition was as follows. Filter papers, each having a total surface area of 353.2 sq. cm., were suspended just above ground level by a string attached to a heavy wire. The filter paper was thus allowed to swing freely in the air. These papers were exposed at five different stations for a period of two hours on four different days, under varying conditions of wind direction and intensity. Station 1 was on the cliff edge above the algal bench; stations 2 to 5 were located 20 m, 40 m, 60 m, and 80 m, respectively, inland from the sea. Salinity was determined by the Argentometric modification of the Mohr method for chloride. Points on the graph are average for each station for the four days.

Table 1. Density and frequency of each species in 10 quadrat plots or 100 sq. m. Author's collection number included.

SPECIES	COLL. NO.	01–10 d	01–10 f	11–20 d	11–20 f	21–30 d	21–30 f	31–40 d	31–40 f	41–50 d	41–50 f	51–60 d	51–60 f
Triphasia trifolia	219	1.11	10	1.31	10	.32	7	.58	10	.55	7	.13	6
Mammea odorata	34	.64	7	.25	3	.91	10	.07	4	.03	2	.18	5
Eugenia reinwardtiana	97	.20	7	.36	7	.18	7	.33	7	.41	5	.89	10
Aglaia mariannensis	117	.10	5	.52	9	.16	6	.45	8	.23	7	.30	9
Cynometra ramiflora	44	.09	6	.03	3	.04	2	.09	4	.03	1		
Colubrina asiatica	6	.05	5	.10	3								
Randia cochinchinensis	58	.02	1	.02	1	.01	1			.02	1		
Allophylus sp.	151	.02	1										
Bikkia tetrandra	92	.02	1										
Ficus prolixa	174	.01	1	.01	1			.01	1				
Polyscias sp.	153	.01	1	.01	1								
Morinda citrifolia	55	.01	1	.04	3	.03	2	.06	2	.03	3		
Planchonella obovata	104	.01	1	.06	3								
Guamia mariannae	106	.02	2	.17	6	.05	4	.45	8	.38	8	.25	9
Flagellaria indica	76	.01	1	.16	6	.06	3	.04	3	.03	3		
Pipturus argenteus	210	.12	3	.06	4	.05	3	.11	5	.21	4		
Pandanus fragrans	200	.01	1	.01	1			.06	5	.13	8	.14	7
Macaranga thompsonii	7	.01	1	.02	2								
Cycas circinalis	25	.01	1			.13	8	.05	4	.18	8	.36	10
Melanolepis multiglandulosa	75			.03	3	.03	2	.01	1	.04	2		
Premna obtusifolia	29			.04	3	.01	1	.01	1	.01	1	.01	1
Carica papaya	100			.02	2			.01	1	.05	2		
Intsia bijuga	47			.02	2	.02	2						
Cestrum diurnum	145			.01	1	.02	1						
Barringtonia asiatica	32					.26	3						
Psychotria mariana	57					.09	6	.22	6	.48	5	.22	7
Ochrosia oppositifolia	8					.01	1	.01	1	.14	5	.27	9
Guettarda speciosa	56							.01	1				
Pandanus dubius	23							.03	2				
Hibiscus tiliaceus	1											.05	4
Maytenus thompsonii	150											.01	1
Pisonia grandis	65											.01	1
Claoxylon marianum	166												
Terminalia catappa	35												
Entada sp.	249												
Eugenia javanica	98												
Callicarpa candicans	168												
Scaevola taccada	18												

Table 1. (Continued)
QUADRATS

61–70		71–80		81–90		91–100		101–110		111–120		121–130		131–140		141–150	
d	f	d	f	d	f	d	f	d	f	d	f	d	f	d	f	d	f
.05	3	.02	2	.06	5	.04	2					.01	1	.02	2		
.35	6	.50	7	.56	7	1.33	10	.87	9	.76	9	.63	10	.95	8	.71	6
.66	8	.17	7	.28	7	.29	6	.34	7	.40	10	.22	7	.08	3		
.18	7	.03	2	.11	5	.06	4	.19	6	.16	8	.23	6	.05	3		
.11	4	.06	3			.02	1	.03	3	.02	2			.01	1		
																.03	1
.02	1							.01	1	.01	1						
.05	3	.02	2	.03	1	.02	2	.02	2	.01	1	.04	3	.01	1		
		.02	1	.02	1	.03	3	.01	1	.02	2	.01	1				
.16	6	.16	8	.13	4	.14	6	.09	5	.20	6	.15	6				
				.01	1												
.15	5	.06	2	.16	6	.11	5	.12	3	.09	6	.06	4	.11	5	.01	1
.03	2	.01	1	.01	1							.01	1				
.02	1	.01	1			.01	1	.02	1	.01	1	.03	3	.01	1	.01	1
.15	7	.24	7	.29	9	.33	6	.20	8	.19	7	.42	8	.12	6	.11	5
		.03	2			.02	1							.01	1	.01	1
		.04	2	.01	1									.01	1		
												.01	1				
.01	1					.01	1	.01	1	.03	3			.01	1		
		.02	1	.03	2	.01	1										
						.01	1	.04	2			.10	1	.93	4	.03	1
.06	2	.05	4	.44	9	.13	3	.05	4	.01	1	.08	4	.08	4		
.29	5	.22	6	.05	3	.03	2			.06	4						
				.01	1			.14	5	.01	1	.14	5			.03	2
				.02	1												
.02	2	.01	1					.01	1					.01	1		
		.01	1														
								.01	1								
								.01	1	.01	1						
										.01	1						
																.08	3
																.06	2

Table 2. Percent of cover for each species in 10 quadrat plots or 100 sq. m. (one unit = .01 percent of cover).

SPECIES	QUADRATS														
	01/ 10	11/ 20	21/ 30	31/ 40	41/ 50	51/ 60	61/ 70	71/ 80	81/ 90	91/ 100	101/ 110	111/ 120	121/ 130	131/ 140	141/ 150
Triphasia trifolia	6.73	5.85	.16	5.8	1.1	.06	.02	.01	.03	.02			.005	.01	
Mammea odorata	18.40	1.28	35.03	1.15	.64	1.18	6.99	8.65	3.81	25.70	4.74	13.11	19.03	30.80	17.91
Eugenia reinwardtiana	.82	6.75	2.44	3.30	3.2	2.45	8.68	6.50	5.90	24.20	5.80	8.40	3.1	.67	
Aglaia mariannensis	.71	3.73	1.23	2.81	1.70	1.07	1.57	.51	3.32	.29	1.18	3.56	.77	.59	
Cynometra ramiflora	2.49	2.76	2.62	1.60	.01		2.00	.03		.57	1.50	.57		.005	
Colubrina asiatica	.15	1.01													
Randia cochinchinensis	.14	.01	.005		.01										
Allophylus sp.	.14														
Bikkia tetrandra	1.00														.30
Ficus prolixa	.50	.005		.07			.57				4.91	3.14			
Polyscias sp.	.07	.07													
Morinda citrifolia	.005	.22	.15	.16	1.34		.35	2.27	.64	.57	.14	.005	.08	.07	
Planchonella obovata	.005	.08						.01	.07	0.8	.005	.01	.07		
Guamia mariannae	.01	1.24	.65	4.47	2.99	.78	.80	2.36	3.67	2.35	.37	2.03	3.22		
Flagellaria indica	.07	1.56	.29	.01					.005						
Pipturus argenteus	3.01	1.92	2.69	7.19	8.80		2.36	2.58	6.31	4.66	4.70	3.23	2.15	5.11	1.61
Pandanus fragrans	2.27	.50		6.25	6.28	10.39	.64	1.77	.07				1.13		
Macaranga thompsonii	.07	1.61					3.60	.50		.07	.57	.07	.21	.50	.70
Cycas circinalis	.07		11.13	4.02	11.14	14.65	21.58	15.30	17.88	15.01	16.83	8.67	16.22	6.09	7.10
Melanolepis multiglandulosa		.15	.21	.50	.02			.64		.01				.07	.07
Premna obtusifolia		15.93	.005	10.75	5.72	10.18		.71	86.59					7.07	
Carica papaya		.51		.07	.52								.07		
Intsia bijuga		3.34	11.18				28.27			1.33	4.14	31.21		8.53	
Cestrum diurnum		.07	.14					.14	.21	.005					
Barringtonia asiatica			.19							.07	.28		.05	1.31	.30
Psychotria mariana			.18	.44	.74	.11	.16	.02	7.68	.63	3.73	.005	.10	.04	

Table 2. Continued

Ochrosia oppositifolia	2.54	1.33	1.84	8.47	2.15	7.67	2.28	5.32		.23			
Guettarda speciosa		.07											
Pandanus dubius		2.77											
Hibiscus tiliaceus				2.72			.07		5.94	.07	8.09		.90
Maytenus thompsonii				.07			.57						
Pisonia grandis				10.18	1.00	.07			254.47			91.61	
Claoxylon marianum						.07							
Terminalia catappa									.50				
Entada sp.									.07	.07			
Eugenia javanica										.50			
Callicarpa candicans													.30
Scaevola taccada													.60

Table 3. A species listing with relative dominance and collection numbers of plants found on lower terrace.
(Rank: 1=Abundant, 2=Common, 3=Occasional, 4=Rare).

SPECIES	COLL. NO.	ZONES			
		Transition	Terrace Edge of Transition	Light Salt Spray	Heavy Salt Spray
Aglaia mariannensis	117		3		
Bidens pilosa	88		1		
Bikkia tetrandra	92	2		3	2
Callicarpa candicans	168	3			
Cassytha filiformis	14	1	2		
Casuarina equisetifolia	21		2		
Cycas circinalis	25	2	2		
Cyperus sp.	164			1	2
Eugenia sp.	156			4 (small)	
Hedyotis sp.	155			1	2
Hibiscus tiliaceus	1	2			
Mammea odorata	34	1 (stunted)			
Maytenus thompsonii	150		4		
Morinda citrifolia	55	4			
Pandanus dubius	23	3			
Pemphis acidula	212			1	1
Phyllanthus sp.	162			1 (small)	
Psychotria mariana	57		4		
Scaevola taccada	18	2	3		
Tournefortia argentea	12		2		
Wedelia biflora	163		2	1	3

RESULTS AND DISCUSSION

Although in general terms, this whole area could be called a *Mammea-Guamia-Eugenia* forest, it is possible to define six vegetation zones (Fig. 2) between the plateau and the algal bench.

Zone 1. Escarpment (quadrats 1–30)—Dominants are *Triphasia*, *Mammea* and *Aglaia*.

Zone 2. Base of Escarpment (quadrats 30–60)—Dominants are *Eugenia, Guamia* and *Psychotria*.

Zone 3. Upper Terrace (quadrats 60–150)—Dominants are *Mammea* and *Eugenia*.

Zone 4. Transition Zone—(40 meters wide)—Dominants are *Mammea* and *Cassytha*, with *Bikkia, Cycas, Hibiscus* and *Scaevola*.

Zone 5. Terrace Edge of Transition Zone (40 meters wide)—Dominants are *Bidens* and *Wedelia*, with *Tournefortia, Cycas, Cassytha, Casuarina* and *Scaevola* commonly occurring.

Zone 6. Salt Spray Zone (80 meters wide)—Dominants are *Pemphis* and *Bikkia*.

Lying between each of these zones is a narrow transition or merging zone where one group of dominants is gradually replaced by another. At the base of the escarpment between quadrats 30–40, *Triphasia* and *Aglaia* are well established. This may be due to additional light caused by the inability of larger trees to become established on a talus slope. Zone 4, the transition zone, includes species from both the landward and the seaward side.

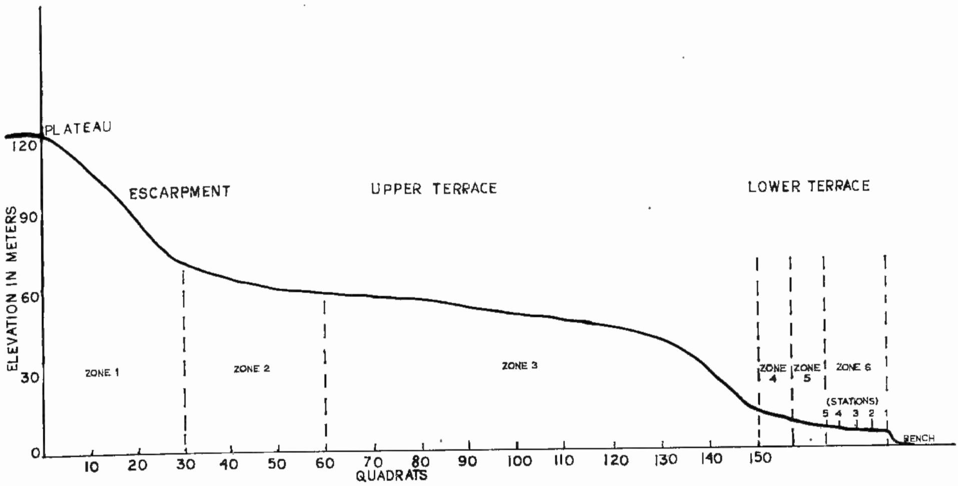

Fig. 2. Vertical and horizontal profile of transect at Pagat showing the vegetation zones.

The nine dominant species, *i.e.*, the plants that occur with the greatest frequency, are native to Guam, except for *Triphasia trifolia* which was introduced many years ago and is now considered to be naturalized (Fosberg, 1960). Figure 3 shows the densities of these nine species over the length of the transect.

A considerable range in density occurs among the dominants but causative factors such as soil type, historical circumstances or competition have not yet been conclusively demonstrated. Very little soil exists on the escarpment except in pockets. However, on the upper terrace a granular, friable, lateritic soil, containing a considerable amount of organic matter is present. This soil is believed to be Guam clay on Mariana limestone (Carroll and Hathaway, 1963). Where cultivated, this soil supports a variety of fruit and vegetable crops. The soil is reddish-brown indicating the presence of iron and aluminum oxides. It tends to accumulate in patches of considerable size, probably originating in place from the breakdown of parent material.

The large number of *Triphasia trifolia* occurring near the edge of the plateau may be the result of its introduction to the island many years ago; on the other hand, it may also be due to the orographic rain that falls here, additional light, less competition, soil condition, or a combination of all these. On the upper escarpment (first ten quadrats) the majority of specimens are juveniles and adults. In all other areas along the transect the vast majority of plants are in the seedling

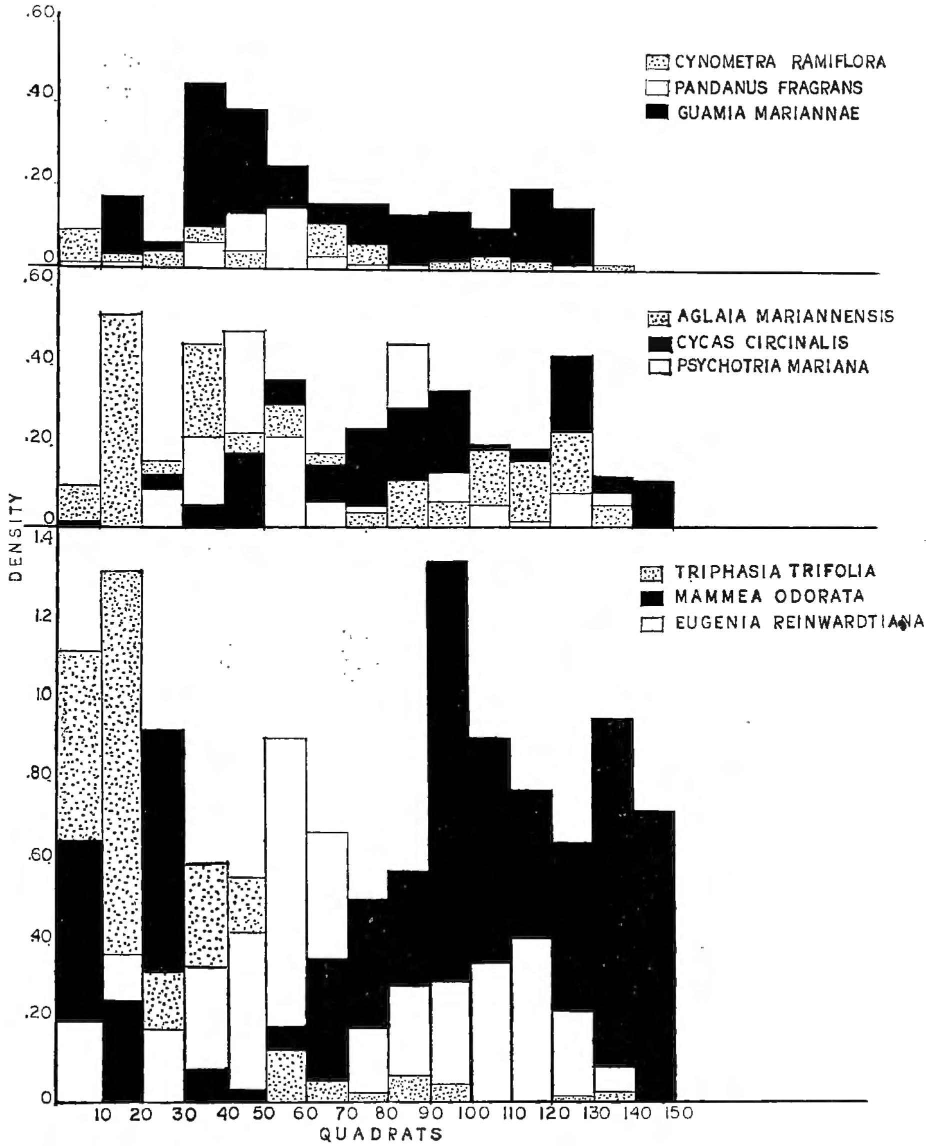

Fig. 3. Histogram showing comparative densities of the nine dominant plants on the transect.

range. This might indicate a gradual dispersal of this species through man's influence.

Mammea odorata occurs throughout the length of the transect. All size ranges are present, but the majority are young juveniles. Adult trees measure 10–40 cm in stem diameter. The ratio of size range is very similar in *Eugenia reinwardtiana*, but the percentage of seedlings is higher in *M. odorata* and the stem diameters in adults range from 10–50 cm.

Aglaia mariannensis, Psychotria mariana and *Cycas circinalis* are present in all stages of growth. The majority of plants of each species are seedlings and young juveniles. Five trees of *A. mariannensis* are 11–12 cm in diameter and eighteen trees range from 6–10 cm. Also, five adult trees of *P. mariana* occur which range in diameter from 11–18 cm and six trees range from 6–10 cm. Sixty-seven adults of *C. circinalis* are present and range in size from 11–30 cm in diameter, with sixty in the 6–10 cm range and thirty-six in the 1–5 cm range.

Pandanus fragrans occurs mostly near the base of the escarpment and consists largely of adults in the 11–17 cm range. Very few seedlings were present. Although both *Guamia mariannae* and *Cynometra ramiflora* occur consistently throughout the length of the transect with plants in all size ranges, the percent of adults and large juveniles of *C. ramiflora* is 30% while in *G. mariannae* it is 12%.

In addition to the above mentioned dominants, a few remarks should be made concerning other species. The largest number of *Ochrosia oppositifolia* were young juveniles, the number being twice that of seedlings and adults, respectively. *Intsia bijuga,* a tree of historical importance as a building material on the island was present on the transect, for the most part, only in the adult stage. The stem diameters range from 13–60 cm and the trees appear healthy in this location. Elsewhere on the island, they have few leaves and are usually covered with epiphytes. This species is frequently host to *Ficus spp.* (strangling figs). *Pisonia grandis* grows to a very large size on the upper terrace, the largest one measuring 180 cm in diameter. Of the seven plants found on the transect, three were under 10 cm in diameter and four were large adults. The native species *Pipturus argenteus* occurred quite consistently on the transect, growing straight and tall in places which receive the most light. The stem diameters of these plants were in the 8–15 cm range with very few less than 5 cm.

It should also be noted that *Barringtonia asiatica,* although infrequent on the transect, reaches a large size (30–75 cm in stem diameter). It is seemingly unable to successfully reproduce itself. This is perhaps due to lack of light or other, as yet unknown, inhibitors. The seeds germinate and hundreds of seedlings of uniform size appear but soon die. In several instances a *B. asiatica* tree of considerable size occurred just outside a quadrat but numerous seedlings were counted within the quadrat. This shows a high density figure but a low figure for per cent of cover. For example, in quadrat 21, twenty seedlings were counted that came from a *B. asiatica* tree with a 60 cm stem diameter, standing just outside the quadrat.

In the salt-spray zone, the dominant plant was *Pemphis acidula.* Other plants occur here also but can be found well away from the constant influence of salt spray. An attempt was made to correlate the salt content of the air with the density of *P. acidula* (Fig. 4). The largest number of *P. acidula* plants was found between stations 1 and 3; at station 4, they were considerably less abundant and at station 5, completely absent. At station 5, about half way across the lower terrace or 80 meters inland from the sea, two additional species appear that were not present in the heavy salt-spray zone. Inland from the 80 meter point, nine new species appear in a narrow belt designated as "the terrace edge of the transition zone". In the next section called the "transition zone" five new species appear. Eight of the species occurring in these last two zones also appear scattered throughout the length of the transect. All other species are confined to the lower terrace.

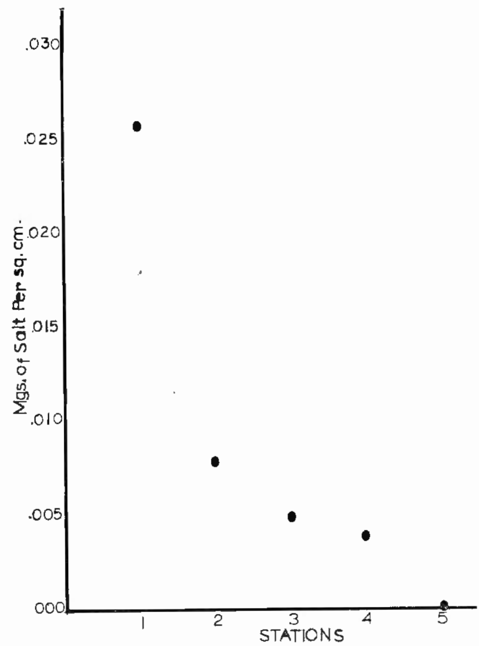

Fig. 4. Salt deposition in relationship to the abundance of *P. acidula* at Pagat.

Causative factors for this sudden increase in numbers of species almost certainly include the absence of salinity. Other factors may be rainfall, additional soil and shelter from the direct force of wind. Also, several species of trees reach a good size in this area, thus providing shade required for the growth of additional species.

As inconclusive as these results are, they may be of some interest when considered in the light of reports made by other investigators. For example, Chapman (1960), in his discussion of halophytes on salt marshes, found salt content of the soil to be an ecologically limiting factor in plant growth. Regarding seed germination in saline habitats, he states that halophytes germinate best under fresh water conditions but that some germination can be expected in up to 2% sodium chloride. Increasing the salt concentration apparently delays the start of germination. It may be the reduction of salinity during the rainy season on Guam that provides conditions requisite for germination of halophytes.

It has also been shown that sodium chloride is of no significant nutritive value in the case of most plants (Schimper, 1903), but in some plants salt has been found to be necessary. Halophytes can live on ordinary soil without the addition of salt but some of the most commonly cultivated plants, e.g., *Calophyllum inophyllum*, in the tropics grow naturally only on the saline soil of the beach. These plants may reach non-saline soil, by some means, and thrive there as long as competitors do not hinder their establishment. The competition of more vigorous plants thus excludes halophytes from all localities except those rich in salt. While dominant plants of the strand are tolerant of saline influence, there are degrees of tolerance among the different species (Wiens, 1965).

CONCLUSIONS

From the data collected it would be difficult, without a followup study, to come to any definite conclusion as to the stage of plant succession in this forest. However, it may be reasonable to assume that the many plants which occur along the length of the transect, in all stages of growth, are established and are reproducing themselves. This is true of the nine dominants as well as the majority of other species.

Intsia bijuga appears to be dying out. Although a few seedlings of *Pisonia grandis* were seen, the sample was too small to merit any conclusion as to its future. *Barringtonia asiatica*, as mentioned earlier, has difficulty reproducing. If the inhibiting factor for *B. asiatica* is shade, then the present adult trees could have become established in openings made by trees that fell during a past storm. Such storms occur frequently in this area.

It would be equally difficult to judge the forest's age or to assess exactly the changes that have occurred. It is improbable that the area has ever been logged because of the steepness of the initial slope from the plateau on the one side and the ruggedness of the coast on the other. Introduced species, e.g., *Cestrum, Triphasia* and *Carica*, appear to have moved in where the land has been disturbed. There does not seem to be any way to tell for certain, what changes these secondary species have made. They may simply represent additions to the forest or they may be replacements for something else.

These and other questions could possibly be answered with additional ecological data but it can be said that the majority of native species at Pagat are for the most part successfully growing.

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