THE DETERMINATION OF PLANT COMMUNITIES ALONG A COMPLEX ENVIRONMENTAL GRADIENT AT HILAAN BEACH, GUAM

by

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A belt transect 5 m x 290 m was established at Hilaan Beach. The transect extended from the beach, through a fresh water cenote and terminated at the base of the cliff which rises to the plateau of northern Guam. All vascular plants within each $5m^2$ subplot were identified and measured. From these data a profile diagram was drawn and species importance values computed, graphed and analyzed by statistical clustering.

Six distinct vegetational communities were distinguished and named according to computed dominance: *Scaevola*/*Messerschmidia*, *Cocos*, *Aglaia*/*Guamia*, *Pandanus dubius*/Marsh Ferns, and *Merrilliodendron*. Each community was described by species composition and physiognomy. Soil samples were mechanically and chemically analyzed. A strong correlation exists between the number of species present and exchangeable soil potassium, sodium and calcium.

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INTRODUCTION

Long before the discovery of Guam by Magellan in 1521, the indigenous Chamorro people of Guam commonly used plants and their products for food, medicine, and material culture (Safford, 1905). Stone (1970) has reviewed the various botanical expeditions which studied the flora of Guam. Additional significant floristic studies on Guam have been made by Safford (1905), Merrill (1914, 1919), Wagner and Grether (1948), Walker and Rodin (1949) and Stone (1970). In 1960, Fosberg described the vegetation of Guam. Moore (1973) studied the composition of vegetation along a transect at Pagat Point in the northeastern, windward, part of the Island.

Fosberg (1959) states that most forests presently on Guam are of second growth. The original forest that occurred on limestone was of large trees with a thick canopy. A long history of disturbance has left very little original primary forest. These remnants are in scattered patches on the northern plateau, on cliffs and relatively inaccessible terraces around the steep coasts.

The primary purpose of this study is to determine and describe the several plant communities apparent along a complex environmental gradient at Hilaan Beach on the leeward, western, side of Guam, 1.2 km northeast of Naval Communications Station Beach (Figure 1). The environmental gradient is complex because of a substratum cline extending from beach deposits to pitted limestone, an exposure cline away from the seacoast and an especially unique moisture cline involving the presence of Guam's only true fresh water cenote. Associated plant communities affect

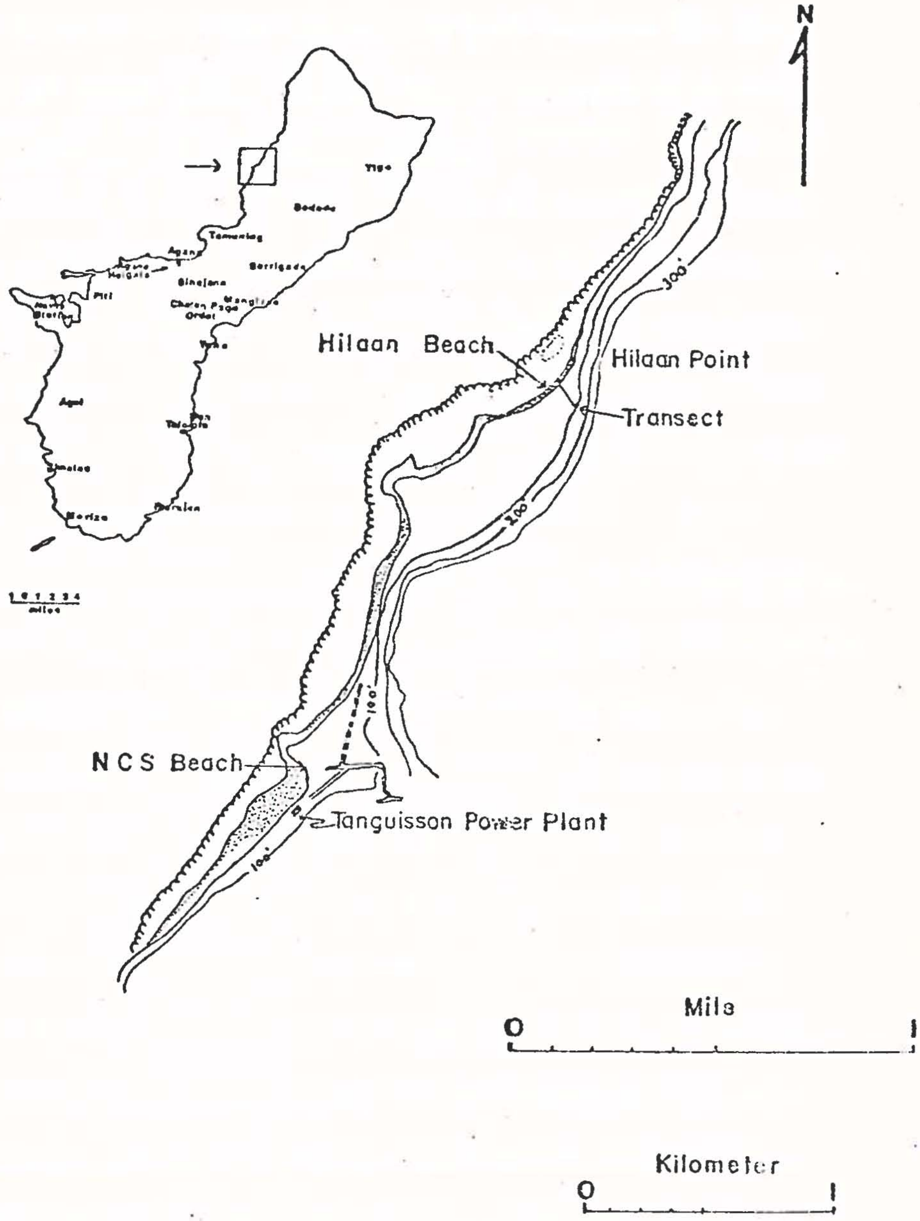

Figure 1. Map of Guam with an enlarged detail indicating the location of the Hilaan Beach transect. The transect is approximately 1.2 km north of Naval Communications Station Beach. Detailed map is after USGS, 1968. A major reef-flat hole is indicated by a dotted oval.

considerable change over relatively short distances, are basically undisturbed, well developed, and include rare and localized species. In addition to its scientific value the entire area between NCS Beach and Hilaan Point is of great scenic beauty and it is hoped that this study may somehow contribute to its preservation.

METHODS

Field Methods

The belt transect is useful for the study of gradient changes in vegetation as in profile studies or the analysis of transition zones between communities (Braun-Blanquet, 1932; Oosting, 1956; Kuchler, 1967; Shimwell, 1972). Becking (1957) asserts that subjective selection of sample plots is a major advantage as compared with objective sampling, making it possible to select the most typical sites. These suggestions were utilized in this study.

A belt transect 5 m wide and 290 m long was established perpendicular to the shore at Hilaan Beach. The entire transect was consecutively divided into 5 m^2 subplots and numbers were assigned to each. The first subplot was adjacent to the level of mean high tide and the last was at the base of the cliff which rises to the plateau of northern Guam. There were 58 contiguous subplots. To include the greatest possible number and diversity of plant communities the transect was aligned to bisect a nearly circular, 34 m diameter, cenote. Subplots 41 through 49 are within this fresh water filled limestone sink-hole.

All vascular plants rooted within the transect were identified and measured one subplot at a time. Height was determined with the aid of an extendible 9.9 m measuring pole. Trunk diameters at breast height (DBH) were taken most often with a diameter tape. Crown diameter and the position of each plant was noted. These measurements plus additional notes and sketches were eventually used to draw a profile diagram which was repeatedly checked and modified in the field.

Diameter at breast height and crown diameter were converted to area at breast height and area of crown. All measurements were then summed for species. Species data were then divided by subplot sums to obtain relative figures. For each subplot relative density, relative height, relative area at breast height, and relative crown area were computed for each species. These figures were summed for each species in each subplot to obtain species importance values. These composite values were used to reflect the distribution of species along the transect.

Species importance values were also used in a Fortran IV computer program to explore Sørensen's formula for the coefficient of community. Sørensen (1948) gives the similarily coefficient as $K=\frac{2C}{a+b}$. Where C is the number of species which two subplots have in common. The number of species in each of the two subplots is represented by a and b. This was used to find the similarity coefficient of all possible pairings within the 54 subplots with rooted vegetation. The resultant data were eventually used to compile a cluster diagram.

The relative humidity of the air near the cenote and at the beach was measured with a Bacharach sling psychrometer. This was performed at about noon during each visit. Air and water temperature at the cenote and at the seashore were determined with a Weston mercury-in-glass thermometer. Thermographs, Bacharach Case Model 14-7030 with a seven day movement, were occasionally used to record temperatures near the cenote and near the beach.

Visits to the study site for the purpose of collecting data commenced on May 24, 1975 and continued until March 27, 1976. About 41 days were spent in the field. Numerous herbarium specimens were collected and phenological observations recorded. Vouchers will be deposited in the University of Guam Herbarium.

Plant identifications were achieved mainly by reference to The Flora of Guam (Stone, 1970). Additional aid was obtained by comparisons with herbarium specimens and with the help of local authorities.

Soil Laboratory Methods

In each terrestrial subplot five soil samples were collected from a depth of 2 to 20 cm. These samples were pooled in the laboratory, air dried with the aid of an electric fan, and crushed with a wooden mallet. Portions passing through a 0.825 mm sieve were used in the determination of pH, salt concentration, and soil texture. Subsequent portions which passed through a 0.5 mm sieve were used to determine organic matter and the major cations. A Beckman pHASAR-I digital pH meter utilizing a 1:1 ratio of soil to water was used to measure pH. Texture, particle size distribution, was performed by the hydrometer method of Bouyoucos (1951). Salt concentration was determined through electrical conductance expressed in micromhos per cm using a 1:1 soil: water extract and a Beckman solu-bridge. Measurements of organic matter made use of the Walkley-Black method (Jackson, 1958).

The major cations sodium, potassium, calcium, and magnesium were extracted using a normal ammonium acetate pH $7 \pm .05$ solution. A 1:10 soil to ammonium acetate ratio was used. For calcium and magnesium determinations, a portion of the extracts were diluted to volume with a 1560 ppm lanthanum oxide solution to control interferences. Levels of the major cations were determined using a Perkin Elmer Model 305B atomic absorption spectrophotometer.

RESULTS AND DISCUSSIONS

Figure 2 is an illustration of the profile of plants 1 m or taller occurring within the entire 5 m x 290 m transect. This type of figure was developed by Richards (1952). Such a diagram can be used as a laboratory tool in determining plant communities along a transect. It can further be used to explore the exact nature of community boundaries and the presence of ecotones. It is also helpful in examining community physiognomy, i.e., trunk and crown character, stratification and species arrangement. Many of these observations are difficult to conclude while in the field. One can only stand and inspect one small part of the forest at a time and it is quite difficult, even for the experienced field botanist, to analyze a complex forest or transect without the aid of such a figure or model.

Figure 3 shows the distribution of species along the transect and is patterned after illustrations by Whittaker (1967). It was constructed by plotting the importance value (sum of relative density, relative area at breast height, relative height and relative crown area) of a species in each subplot in which it occurs and connecting these points with a curved line. This was repeated for the 22 species with greatest transect species importance values (Table 1). Detailed data are presented in Appendix A. The area under each curve is relative to the proportion of available spatial niche occupied by each species. Species are generally independently distributed along the transect, and discrete communities with definite composition and sharp boundaries are not common.

Figure 2. Profile diagram of the 5 m x 290 m transect. Height scale and subplot numbers are indicated. The lower strip of the diagram is a continuation of the upper strip. Arrows and numbers indicate the several communities. All individual plants taller than 1 m are included. See Table 1 for key to species abbreviations.

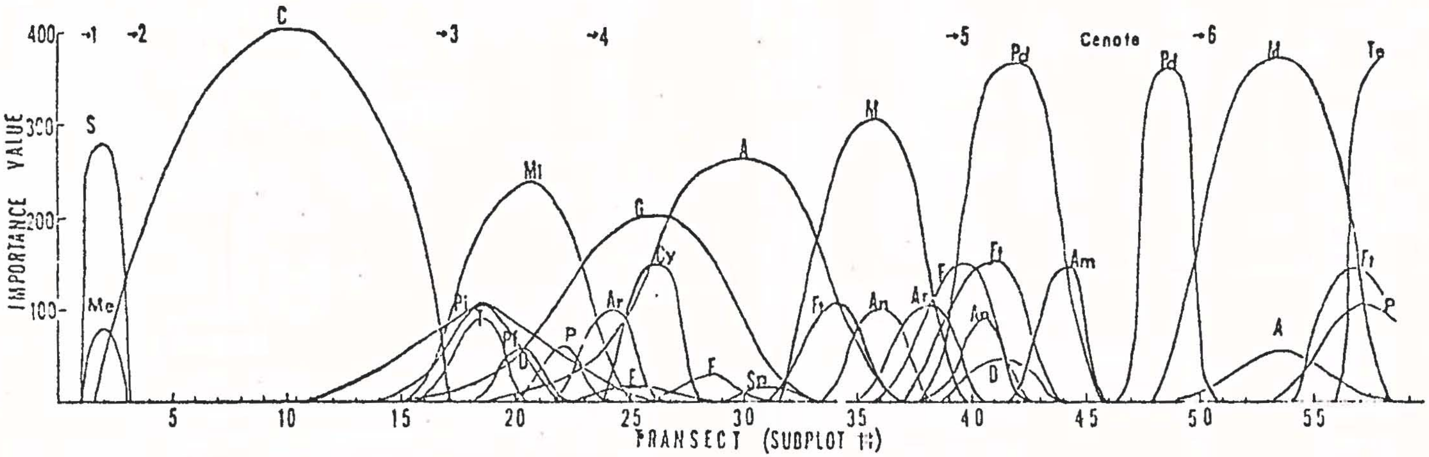

Figure 3. Distribution of species along the transect. Importance values for species in each subplot are plotted for the entire transect and these points have been connected by smoothed lines. The several communities are indicated by arrows and numbers. Letters refer to species as indicated in Table 1.

Table 1. Relative importance percent (RIP), growth-form, Raunkier life-form, and origin of on-transect plant species greater than 1 m tall. Species abbreviations as used in Figures 2,3, and 4

Plant species	Abbr.	R.I.P.	Growth-Form[1]	Life-Form[2]	Origin[3]
Cocos nucifera L.	C	23.90	Rt	P	Intro/not nat
Merrilliodendron megacarpum (Hemsley)Sleumer	M	14.20	Blet	P	Indig
Aglaia mariannensis Merrill	A	10.18	Blet	P	En
Pandanus dubius Sprengel	Pd	5.96	Rt	P	Indig
Mikania scandens (L.) Willd.	Mi	4.78	V	P	Intro/nat
Guamia mariannae (Safford)Merrill	G	4.16	Blet	P	En
Triphasia trifolia (Burm.f.)P. Wils.	T	3.90	Blets	P	Intro/nat
Flagellaria indica L.	F	3.21	V	P	Indig
Ficus prolixa G.Forster	Ft	3.16	Blest	P	Indig
Asplenium nidus L.	An	2.81	E/t	E	Indig
Piper guahamense DC.	Pi	2.46	Bles	P	Indig
Artocarpus mariannensis Trécul	Ar	2.28	Blet	P	Indig
Tectaria crenata Cavanilles	Te	2.08	F	H	Indig
Pteris tripartita Swartz	Pt	1.93	E/t	E	Indig
Cycas circinalis L.	Cy	1.54	Rt	P	Indig
Dendrocnide latifolia (Gaud.)W.L. Chew	D	1.37	Blet	P	Indig
Scaevola taccada (Gaertner)Roxburgh	S	1.36	Blet	P	Indig
Acrostichum aureum L.	Am	1.22	F	G	Indig
Guettarda speciosa L.	Gu	1.09	Blet	P	Indig
Pisonia grandis R. Brown	Pg	1.03	Blet	P	Indig
Carica papaya L.	P	0.95	Rt	P	Intro/nat
Pandanus fragrans Gaud.	Pf	0.90	Blet	P	Indig
Eugenia reinwardtiana DC.	E	0.79	Blet	P	Intro/nat
Claoxylon marianum Mueller-Argoviensis	Cl	0.76	Blet	P	En
Ochrosia oppositifolia (Lamarck)K. Schumann	O	0.57	Blet	P	Indig
Annona squamosa L.	Ao	0.51	Blet	P	Intro/not nat

Plant species	Abbr.	R.I.P.	Growth-Form[1]	Life-Form[2]	Origin[3]
Randia cochinchinensis (Lour.)Merrill	R	0.50	Blet	P	Indig
Messerschmidia argentea (L.f.)Johnston	Me	0.41	Blet	P	Indig
Alocasia macrorrhiza (L.)Schott	Al	0.41	Fo	H	Intro/not nat
Thelypteris interrupta (Willd.)Iwatsuki	Th	0.24	E/t	E	Indig
Morinda citrifolia L.		0.21	Blet	P	Indig
Merremia tuberosa (L.)Reudle		0.17	V	P	Intro/not nat
Discocalyx megacarpa Merrill		0.13	Blet	P	En
Streblus pendulinus (Endlicher)F. Von Mueller	Sp	0.13	Blet	P	Indig
Melanolepis multiglandulosa (Reinwardt)Reichb.f. & zoll.		0.13	Blet	P	Indig
Procris pedunculata (J.R. & G.Forster)Weddell		0.13	Fo	Ch	Indig
Planchonella obovata (R.Brown)Pierre		0.11	Blet	P	Indig
Clerodendrum inerme (L.)Gaertner		0.09	V	P	Indig
Momordica charantia L.		0.09	V	P	Intro/nat
Nephrolepis hirsutula (Forster)Presl	N	0.06	E	E	Indig
Bikkia tetrandra (Forst.f.)A. Rich	B	0.04	Blet	P	Indig
Pachyrrhizus erosus (L.)Urban		0.03	V	P	Intro/not nat
Mucuna gigantea (Willd.)DC	Mu	0.02	V	P	Indig

1 Growth-Form

Bles - Broad leaved evergreen shrub
Blest - Broad leaved evergreen strangling tree
Blets - Broad leaved evergreen thorn shrub
Blet - Broad leaved evergreen tree
Rt - Rosette tree
E/t - Epiphyte/terrestrial
F - Fern
Fo - Forb
Gr - Graminoid
To - Terrestrial orchid
V - Vine

2 Life-Form

E - Epiphyte
Ch - Chamaeophyte
G - Geophyte
P - Phanerophyte

3 Origin

En - Endemic
Intro/nat - Introduced and naturalized
Indig - Indigenous
Intro/not nat - Introduced and not naturalized

Species less than 1 m tall (Table 2) were not included in the above mentioned computations.

The coefficient of similarity (Figure 4) was used as a basis for cluster analysis. A set of subplots is joined into a cluster on the basis of species shared. The highest values in the similarity matrix are located to identify subplots that form the nucleus of the first cluster. The similarity level is then decreased by 0.1 and a search is made for new clusters. By 'single-linkage' additional subplots are then admitted to the first cluster. The process is repeated until all clusters have finally merged into a single cluster containing all of the subplots. Cluster analysis establishes internally homogeneous groups. Subplots within each group are relatively similar in their species composition.

Communities

By integrating the information gleaned from Figure 2, 3 and 4, six plant communities were identified along the transect. They are:

1) *Scaevola*/*Messerschmidia*,
2) *Cocos*,
3) *Mikania*,
4) *Aglaia*/*Guamia*,
5) *Pandanus dubius*/Marsh Ferns, and
6) *Merrilliodendron*.

In naming communities generic names are used for mono-specific species. See Table 3 for an indication of the subplots occupied by each community and a complete list of vascular plants occurring in each community. Also included are corresponding species importance values

Table 2. Transect density, growth-form, life-form, and origin of on-transect species less than 1 m tall. Abbreviations are as used in Table 1.

Plant species	Abbr.	Density	Growth-Form[1]	Life-Form[2]	Origin[3]
Allophylus timorensis (DC)Blume		1	Blet	P	Indig
Barringtonia asiatica (L.)Kurz	Ba	4	Blet	P	Indig
Davallia solida (Forster fil.)Swartz		3	E	E	Indig
Elatostema calcareum Merrill	El	26	Fo	Ch	Indig
Hedyotis foetida (Forster)J.E. Smith	Hf	118	V	P	Indig
Hernandia nymphaeifolia (Presl)Kubitzki	H	4	Blet	P	Indig
Jasminum marianum DC		16	Bles	P	Indig
Lepturus repens (G. Forster)R. Brown			Gr	Ch	Indig
Nervilia aragoana Gaud.	Na	16	To	G	Indig
Peperomia mariannensis C.DC	Pm	10	Fo	Ch	Indig
Phymatodes scolopendria (Burmann)Ching	Ps	115	E	E	Indig
Premna obtusifolia R. Brown		5	Blet	P	Indig

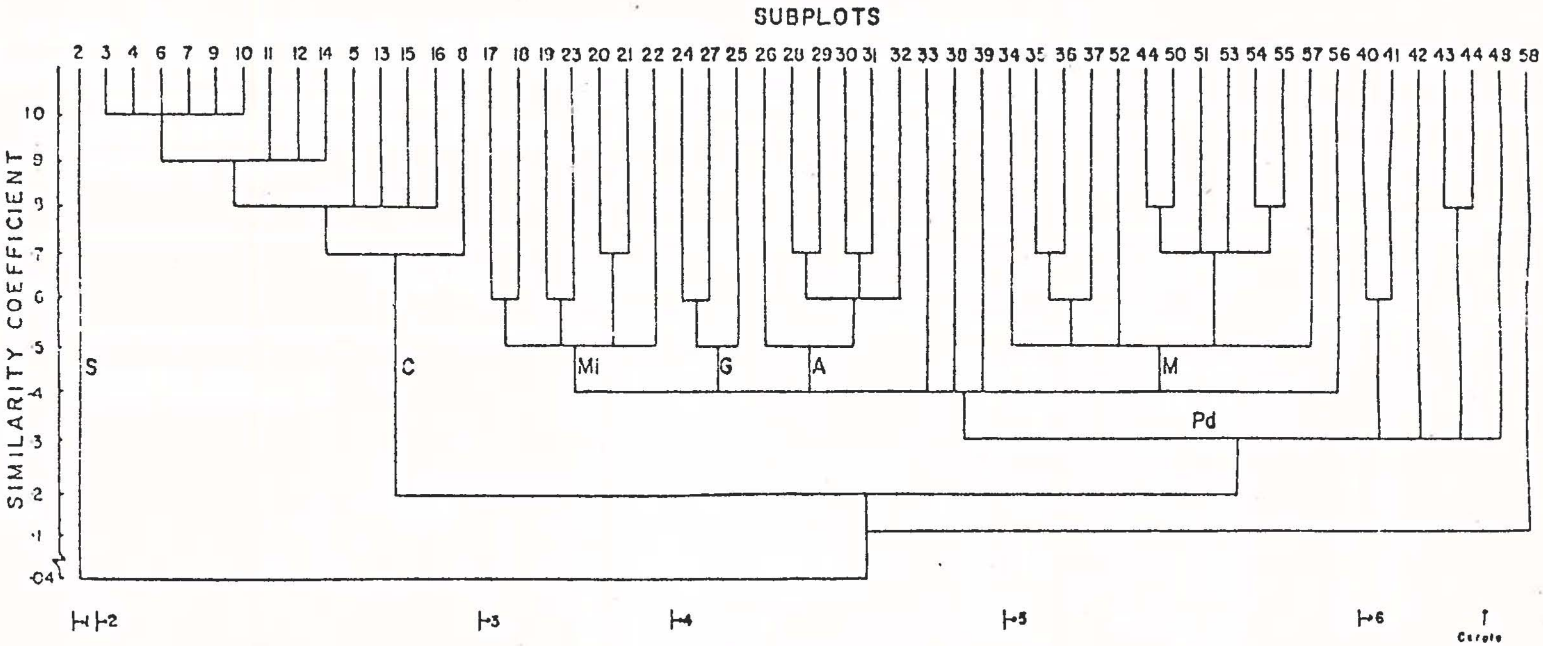

Figure 4. Cluster analysis of subplots. The similarity coefficients are expressed by horizontal lines. A value of 1.0 indicates that those subplots share all species. The several communities are emphasized by arrows and numbers. Letters refer to species as indicated in Table 1.

Table 3. Composition of communities along transect. Species importance values (SIV) are given. Relative importance percents (RIP) are in reference to each community. Species without values are less than 1 m tall. See Tables 1 and 2 for a list of complete scientific names.

Communities	Subplots	Species	S.I.V.	R.I.P.
1. *Scaevola/Messerschmidia*	2	*S. taccada*	293.96	73.49
		M. argentea	88.53	22.14
		C. nucifera	17.51	4.37
		B. asiatica		
2. *Cocos*	3-16	*C. nucifera*	5139.82	91.80
		P. guahamense	116.58	2.10
		O. oppositifolia	81.38	1.50
		A. nidus	56.53	1.00
		G. mariannae	46.93	0.80
		M. scandens	34.72	0.60
		T. trifolia	27.76	0.50
		Ag. mariannensis	27.34	0.50
		F. indica	23.91	0.40
		C. marianum	17.00	0.30
		N. hirsutula	13.05	0.20
		C. circinalis	11.34	0.20
		P. erosus	3.65	0.10
		D. solida		
		H. peltata		
		L. repens		
		P. obtusifolia		
		P. scolopendria		
3. *Mikania*	17-23	*M. scandens*	989.79	35.30
		P. guahamense	371.74	13.30
		T. trifolia	277.39	9.90

Communities	Subplots	Species	S.I.V.	R.I.P.
		Ag. mariannensis	227.47	8.10
		G. mariannae	187.32	6.70
		P. fragrans	169.46	6.10
		F. indica	150.32	5.40
		Ar. mariannensis	121.18	4.30
		D. latifolia	100.94	3.60
		C. papaya	76.17	2.70
		A. nidus	37.08	1.30
		M. tuberosa	35.65	1.30
		M. multiglandulosa	27.99	1.00
		M. charantia	9.15	0.30
		B. tetrandra	6.70	0.20
		M. citrifolia	4.81	0.20
		O. oppositifolia	4.30	0.20
		P. erosus	2.81	0.10
		H. foetida		
4. Aglaia/Guamia	24-39	Ag. mariannensis	1639.21	25.50
		M. megacarpum	890.13	14.00
		G. mariannae	653.08	10.30
		T. trifolia	456.99	7.20
		F. indica	453.20	7.10
		A. nidus	333.47	5.20
		Ar. mariannensis	297.76	4.70
		C. circinalis	260.66	4.10
		G. speciosa	235.95	3.70
		P. grandis	222.90	3.50
		E. reinwardtiana	150.86	2.40
		C. marianum	133.82	2.10
		P. dubius	124.78	2.00
		F. prolixa	119.42	1.90
		D. latifolia	114.66	1.80
		A. squamosa	110.87	1.70

Communities	Subplots	Species	S.I.V.	R.I.P.
		O. oppositifolia	37.01	0.60
		S. pendulinus	28.73	0.50
		P. obovata	24.13	0.40
		P. fragrans	19.18	0.30
		M. citrifolia	18.97	0.30
		D. megacarpa	17.50	0.30
		P. guahamense	13.88	0.20
		M. scandens	7.95	0.10
		M. gigantea	4.05	0.10
		A. timorensis		
		D. solida		
		E. calcareum		
		J. marianum		
		N. aragoana		
		P. mariannensis		
		P. obtusifolia		
5. Pandanus dubius/Marsh Ferns (45-47 no vegetation)	40-48	P. dubius	1162.63	48.40
		F. prolixa	356.30	14.80
		A. aureum	263.46	11.00
		P. tripartita	263.46	11.00
		A. nidus	149.82	6.20
		R. cochinchinensis	90.51	3.80
		D. latifolia	59.24	2.50
		A. macrorrhiza	21.93	0.90
		C. inerme	19.01	0.80
		F. indica	13.64	0.60
6. Merrilliodendron	49-58	M. megacarpum	2165.89	54.30
		T. crenata	448.09	11.20
		Ag. mariannensis	313.80	7.90
		F. prolixa	174.84	4.40
		P. tripartita	153.07	3.80

Communities	Subplots	Species	S.I.V.	R.I.P.
		C. papaya	128.08	3.20
		T. trifolia	79.94	2.00
		Ar. mariannensis	74.39	1.90
		A. macrorrhiza	67.57	1.70
		C. circinalis	60.43	1.50
		T. interrupta	50.84	1.30
		F. indica	49.05	1.20
		A. nidus	28.52	0.70
		P. dubius	28.18	0.70
		P. pedunculata	27.09	0.70
		P. guahamense	27.09	0.70
		D. latifolia	22.41	0.60
		M. citrifolia	21.67	0.50
		E. reinwardtiana	19.17	0.50
		R. cochinchinensis	15.97	0.40
		C. marianum	13.05	0.30
		D. megacarpa	11.05	0.30
		M. charantia	9.54	0.20
		E. calcareum		
		P. mariannensis		

and relative importance values as computed on a community basis for individuals 1 m or taller. Additional species represented only by individuals less than 1 m tall are also listed. A discussion of each community follows.

1) Scaevola/Messerschmidia Community

These two tree species form a discrete strand community slightly above the wave splash zone. It forms a continuous belt along adjacent sandy beaches but is replaced by Pemphis acidula on rocky cliffs and headlands. Although rooted only in subplot 2, the crowns of individuals extend well into subplots 1 and 3. Both species tend to branch low so that their crowns actually begin at ground level and extend to a height of about 7 m. A rather dense hedge-like barrier is thus formed. This community does not share species with the remainder of the transect and statistically joins the transect with a very low (0.04) similarity coefficient.

2) Cocos Community

This community is a near consociation as Cocos obtains a relative importance value within this zone of about 92%. This community is actually an abandoned coconut plantation which was originally planted and probably maintained until World War II. The oldest trees are quite regularly spaced and now act as seed trees. Piles of germinating and rotting nuts have accumulated beneath their crowns. Although frequent gaps occur, probably from wind-throw and old age death, the crowns of mature trees form a nearly continuous canopy between 9 and 20 m in height. The taller individuals generally occur further from the sea. The crowns of sub-adults form an open stratum between 4 and 10 m.

Juveniles and seedlings develop an often dense stratum less than 3 m tall. Twenty-two adults, 37 subadults and 299 juveniles, and seedlings were counted on subplots within this community. Statistically four subcommunities are evident. Most are dependent upon the appearance of secondary species. Many coconut trunks are laden with epiphytic ferns including: Asplenium nidus, Nephrolepis hirsutula, Phymatodes scolopendria, Davallia solida, Pyrrosia adnascens and Vittaria elongata.

3) Mikania Community

This very weedy and viny zone includes subplots 17 through 22. It begins quite abruptly with the discontinuation of Cocos and terminates gradually as it blends into a taller forest. It extends laterally in this same relative position and suggests being an ecotone. Mikania and four other species of vines densely wrap all trees and shrubs into a tangle which is very difficult to traverse. An even canopy of stratified tree crowns is absent. This results in a very irregular, lumpy appearance. Similarity coefficients identify four subdivisions within this zone. It is interesting to note that old Chamorro artifacts, especially pot sherds, are common on these subplots. Latte sites are found in this community slightly south of the transect (Reinman, 1968).

4) Aglaia/Guamia Community

Subplots 24 through 39 are occupied by a well developed forest of small to large trees with few low branches and little undergrowth. It presents minor problems when traversing on foot. Both Aglaia and Guamia are relatively small trees (averaging 2.3 cm and 2.7 cm DBH; 5 m and 6.6 m height, respectively) but their high density results in large relative importance values within the community. An important intrusion of Merrilliodendron occurs in subplots 34 through 38; this species forms a consociation later in the transect.

The largest trees of the transect Artocarpus mariannensis, Guettarda speciosa, Pisonia grandis and Ficus prolixa occur in this community but because of their sparse density they rank low in importance value. Because of their height they act as emergent trees which jutt above the surrounding vegetation. They form a nearly continuous overstory canopy between 7 and 22 m. A second stratum of tree crowns composed of Aglaia, Guamia, Dendrocnide latifolia, Eugenia reinwardtiana, and Annona squamosa is apparent between 5 and 15 m. It again is basically continuous but tends to be depressed when beneath the crowns of overstory species. A third stratum of mostly small trees occurs below 5 m. Members of this stratum are mostly new species not seen in the upper strata, e.g., Pandanus dubius, Triphasia trifolia, Cycas circinalis, P. fragrans, Streblus pendulinus, and Planchonella obovata but some are juvenile individuals of species normally found in the uppermost and intermediate strata.

Six subcommunities are apparent. Subplots 34 through 38, because of the presence of Merrilliodendron, are removed in the cluster analysis to combine with community number 6. The remaining five subcommunities are determined by Aglaia/Guamia, Ficus prolixa, Artocarpus mariannensis and Claoxylon marianum.

Numerous large clumps of the epiphytic fern Asplenium nidus are a characteristic feature of this community. Vines are not especially noticeable and other than Flagellaria indica and Mucuna gigantea they are lacking. This community terminates as it grades into the Pandanus dubius dominated zone at the edge of the cenote.

5) Pandanus dubius/Marsh Ferns Community

Subplots 40 through 44 on the near side of the cenote and subplot 48 on the far side, contain this community. It begins as *P. dubius* replaces the trees of the previous community. This occurs about 20 m from the flooded edge of the cenote. Because of the low branching, trunkless character and stilt roots of *P. dubius* this zone is very difficult to penetrate. Individual plants reach a height approaching 8 m. The belt of *Pandanus* trees extends into the water and to inspect them one must climb through their roots and branches while wading in soft ooze. At a point where the water is about 0.5 m deep *Pteris tripartita* grows intermingled within the *Pandanus*. At a depth of about 1 m both species terminate. A band of *Acrostichum aureum*, about 3 m wide, then extends to a water depth of about 1 m. The remainder of the pool, subplots 45 through 47, is open water reaching 2.3 m in depth and is free of major vegetation. The bands formed by *Pandanus* and the marsh ferns tend to encircle the majority of the cenote but are lacking on the generally rocky northwestern side. *Ficus prolixa* falsely obtains a large importance value within this community because of the presence of several displaced individuals. Where the transect leaves the far side of the cenote the marsh ferns are lacking and only a narrow band of rather small *Pandanus* are present.

6) Merrilliodendron Community

Merrilliodendron forms a near consociation within subplots 49 through 58, plus its earlier insertion into subplots 34 through 38. Mature trees form a nearly continuous canopy between 8 to 18 m in height. Those individuals nearest the cenote tend to lean to take advantage of the open space it presents. An intermediate stratum of subadults occupies the 5 to 14 m height. Numerous juveniles less than 5 m tall form a third stratum. The ground is often nearly carpeted with seedlings, the vast majority of which will not survive. As in the *Aglaia/Guamia* community there are numerous, often large, clumps of epiphytic ferns. This forest is quite free of shrubs and low branches and is comparatively easy to walk through. The community ends abruptly as one encounters the boulders which are strewn at the base of the cliff.

Fosberg (1959) describes the *Artocarpus* forest of the northern plateau of Guam as a discontinuous overstory of *Artocarpus* and *Ficus*. Beneath this is a continuous second story of lesser trees and an understory which is not sharply separated. This study was conducted at the base of the plateau within an area sheltered by the cliff. In such locations the overstory trees are often closer together and form the nearly continuous canopy reported in this study.

Moore (1973) studied a limestone forest on the windward coast of Guam. He found *Mammea* and *Eugenia* to be dominant. In the present study on the leeward side of the island *Mammea* was absent and *Eugenia* occurred only in small numbers.

Three tree strata are typical of highly developed tropical rain forests (Richards, 1952). The strata described in this study are of short stature when compared with the tropical rain forests of Africa, South America and Southeast Asia. This may be a reflection of evolutionary selection under typhoon pressure. Hence Stone (1971) suggests the name, "typhoon forests".

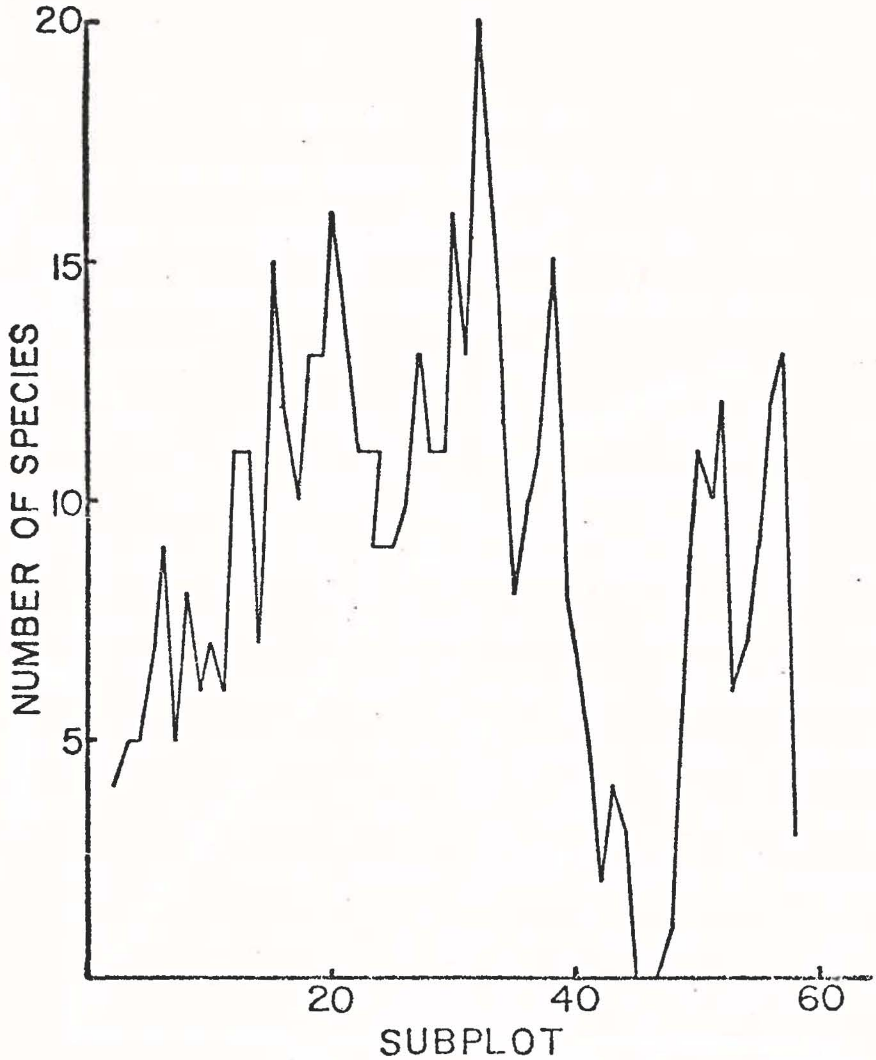

Figure 5. Number of species of vascular plants occurring in each subplot along the transect. A maximum of 20 species is achieved in subplot 32. The cenote is centered in subplot 46.

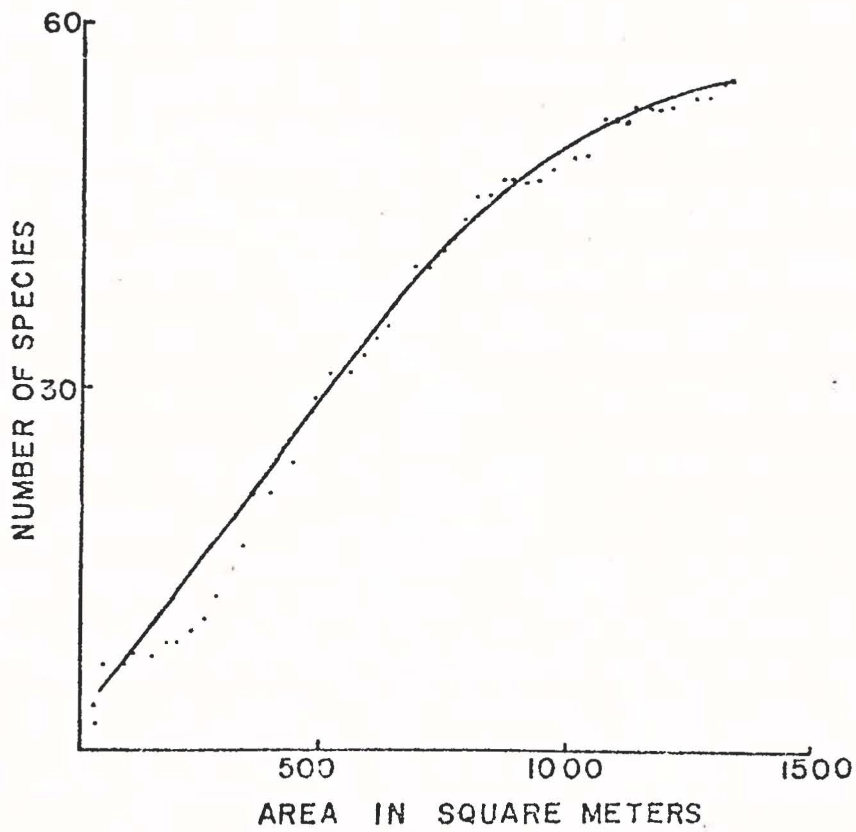

Figure 6. Species/area curve. The cumulative total of vascular plant species is plotted on area in square meters. Area is summed as one traverses the transect.

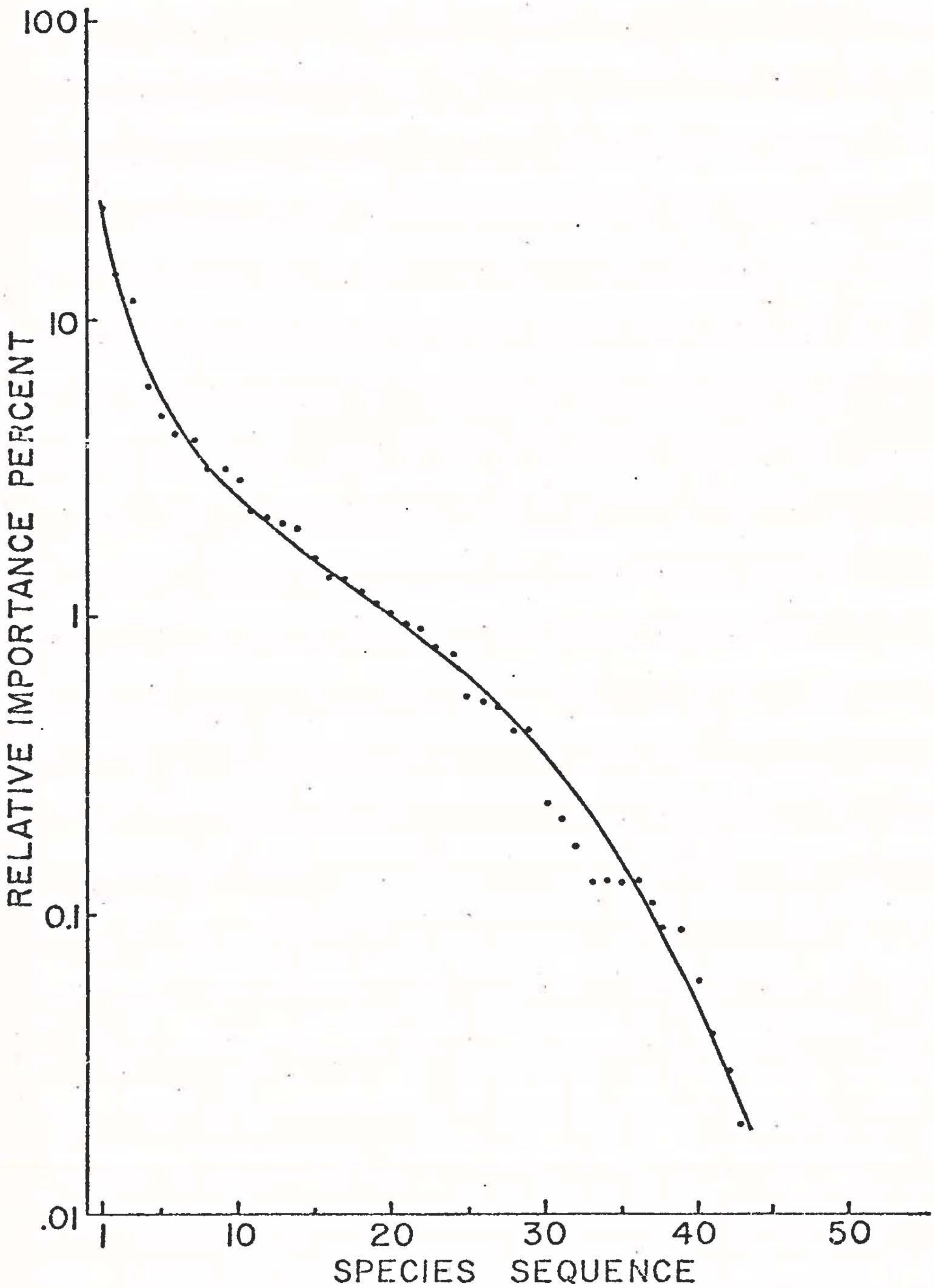

Figure 7. Relative importance percent plotted on species sequence. The resultant sigmoid curve on semilogarithmic coordinates indicates a log-normal distribution.

The tabulation of growth-form (Whittaker, 1975) of the 55 species of vascular plants in the transect reveals: 44% to be broad leaved evergreen trees; 14% vines; 10% epiphytes; 9% rosette trees; 7% forbs; 4% broad leaved evergreen shrubs; 4% terrestrial/aquatic ferns; and 2% each of broad leaved evergreen strangling trees, broad leaved evergreen thorn shrubs, graminoids and terrestrial orchids. See Table 1 for a growth-form determination of each species. The three dominant categories are those growth-forms which typify tropical forests (Richards, 1952).

A re-tabulation according to Raunkier's life-forms (Whittaker, 1975) indicates: 75% phanerophytes (perrenating bud high in air); 11% epiphytes (entire plant removed from the ground); 7% chamaephytes (bud near the ground); and 4% each of hemi-cryptophytes (bud on surface of ground) and geophytes (bud well buried). This tabulation also reflects typical tropical forests, perrenating buds removed from the protection of the ground. See Table 1 for a life-form determination of each species. Similar percentages were found by Richards (1952) in New South Wales, Australia and by Whittaker (1975) in India.

If the same species are tabulated by origin (Stone, 1970) it is seen that: 7% are endemic to Guam or the Mariana Islands; 75% are indigenous (occurring in Guam prior to human habitation); 9% are introduced and naturalized; and 9% are introduced and not naturalized. See Table 1 for the origin of each species. The introduced species are contained in the _Cocos_ community, _Mikania_ community and _Aglaia/Guamia_ community. It was also noted that all of the endemic species were found in the _Aglaia/Guamia_ community.

Plank buttressing of the lower trunk, though weakly developed, is apparent in Artocarpus mariannensis. Both species of Pandanus exhibit stilt (=prop) roots. Ficus prolixa is a typical strangler with aerial roots. These several features are commonly found among tropical trees.

Species taller than 1 m and present within the transect were statistically examined by the variance/mean ratio method (Whittaker, 1975) to determine their type of horizontal distribution. Ninety-eight percent were resolved to be of the clumped type of distribution and two percent (Davallia solida) were of the regularly spaced type. None were randomly distributed.

Phenological observations were made during visits to the study site. It was generally noted that there are two flowering seasons. The primary flowering period is in June but there is a secondary period in November. The later period involves the reflowering of many of those species which flowered earlier.

Environmental and Edaphic Factors

Water temperature of the cenote ($\bar{x}$ = 26.4^{o}C, range 21.5 - 29.4^{o}C) was consistantly lower than reef-flat sea temperature. It was also observed that cenote water temperature was always cooler than adjacent ambient air, while sea temperature was warmer than adjacent ambient air. Further, water and air temperature at the cenote were cooler and fluctuated less than corresponding temperature at the sea.

In July thermographs were kept for a week near the cenote and near the beach. Daily air temperature fluctuation at the cenote averaged 23.3 - 26.7^{o}C while at the beach it was 25.6 - 30^{o}C.

Relative humidity near the cenote was consistantly higher than on the open beach. Mid-day values were generally 90% and 80%, respectively. During rainy days relative himidity was generally uniform at both locations.

The general character of the substratum along the transect is: deep sand (mostly coral fragments) from subplot 1 through 15; gravelly limestone from subplot 16 through 24; deeply pitted coralline limestone with small pockets of soil occurring throughout the remainder of the transect. The cenote is within the latter zone but is edged and lined with soft ooze.

Soil texture analysis (Figure 8) reveals that all of the soils are highly sandy but the proportion of sand gradually decreases along the transect. Silt and clay show a reverse trend. The percent of organic matter increases to reach a high several subplots before the cenote.

Calcium obtains the highest value of the major cations. It is followed by potassium, sodium and magnesium (Figure 9). The first three ions increase in quantity along the transect to reach peaks several subplots before the cenote. Magnesium remains quite low and constant throughout the transect. Readings of ions within the water of the cenote are included in Figure 9.

Soil pH is shown in Figure 10. The first three subplots gave values higher than the pH of sea water (8.03). The remainder of the transect produced readings near pH 8. This is undoubtedly because of the alkaline nature of the limestone substratum. Water from the cenote had a pH of 7.28.

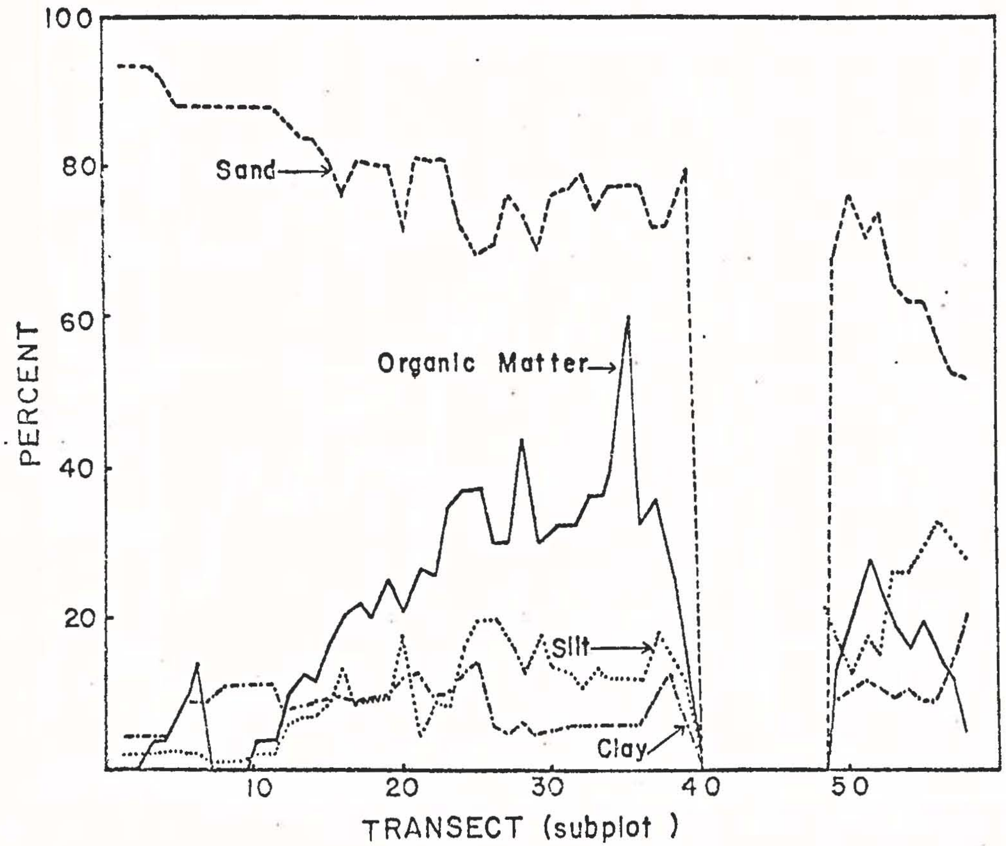

Figure 8. Mechanical analysis and organic matter content of soil within the transect. Percent sand, silt, clay and organic matter were determined for each subplot. The gap indicates the location of the cenote.

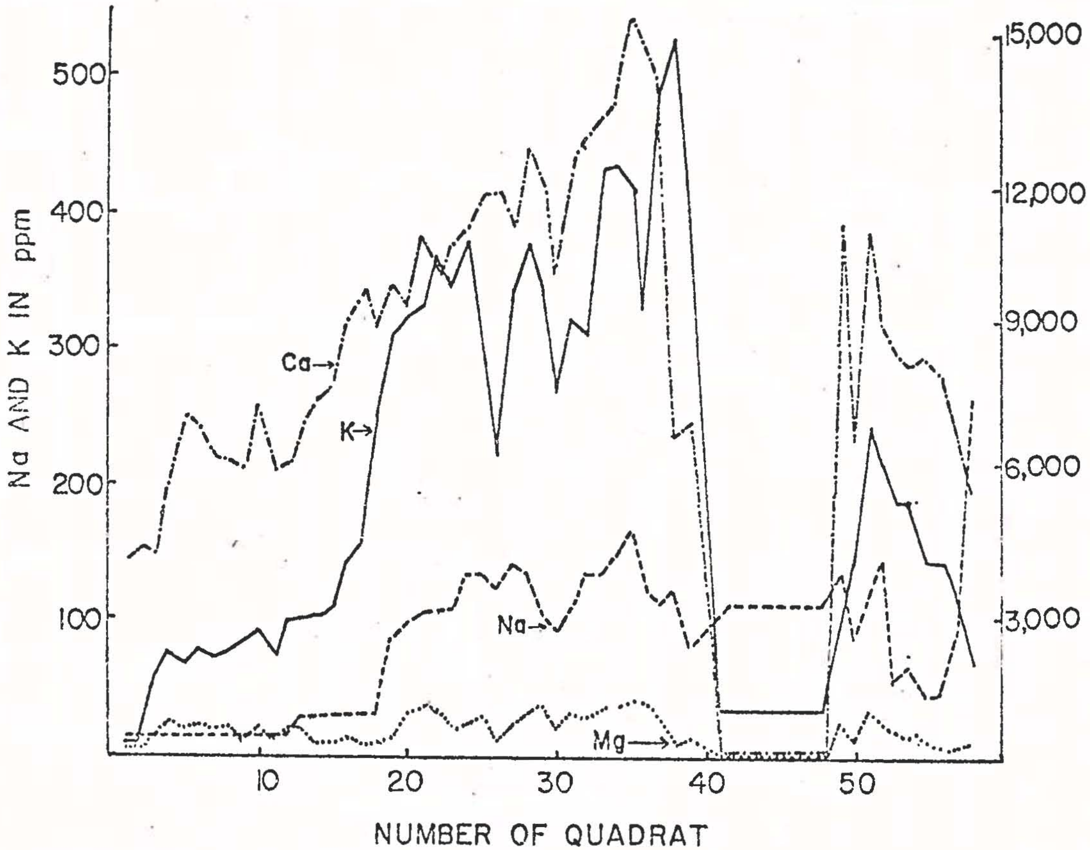

Figure 9. Sodium, potassium, magnesium and calcium concentrations within the transect. All, except calcium, generally increase as one moves away from the beach.

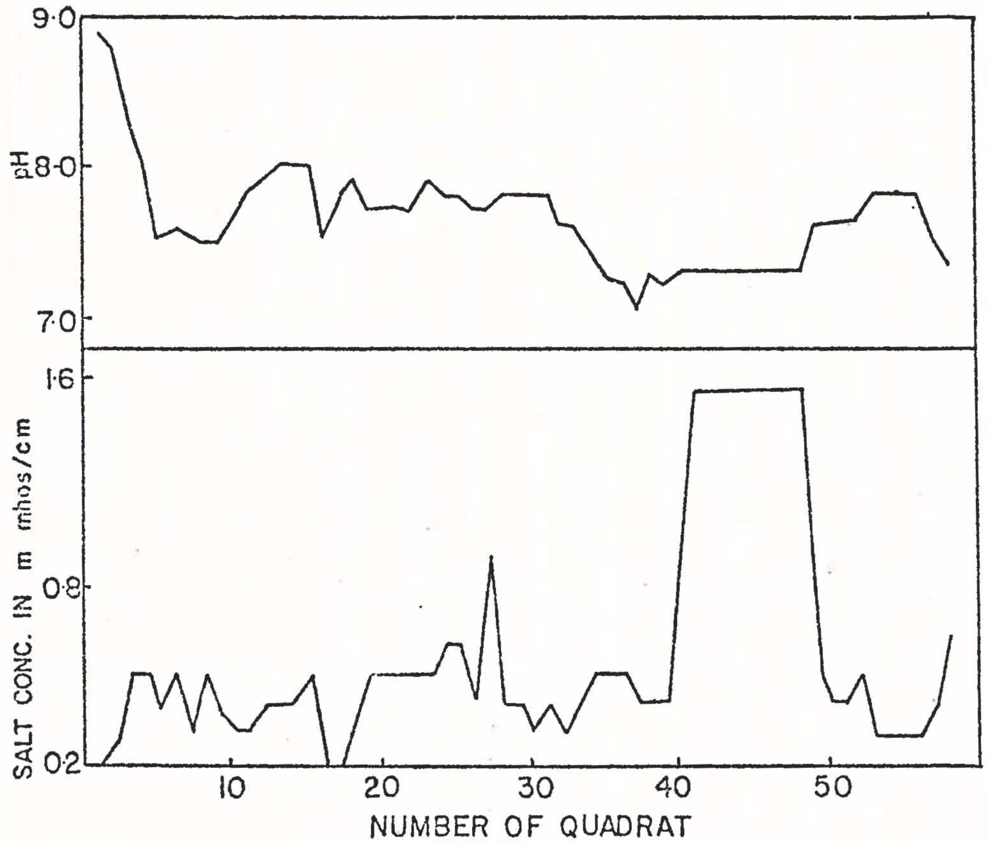

Figure 10. Soil pH and total salt concentration within the transect. Both determinations are relatively constant and lack distinct trends. A high salt concentration is evident within the water of the cenote.

Total salt concentration (Figure 10) along the transect is quite constant. Water from the cenote gave high readings. See Appendix B for details of soil analyses.

The species/area curve (Figure 6) and the species on subplots (Figure 7) showed the number of species to generally increase along the transect. The number of species occurring in each subplot was also statistically examined by regression analysis to determine their relationship with 10 different soil factors. Resultant correlation coefficients (r) are given in Table 4. Six factors showed significant relationships. Four did not. The six significant factors sand, silt, organic matter, potassium, sodium, and calcium are graphed in Figure 11.

Similar results are seen in the literature. Wikum and Wali (1974) resolved from a study in North Dakota that there was a high correlation between the number of species present, and potassium and calcium in the soil. Richmond and Mueller-Dombois (1972) did not observe significant correlation between species and salt concentration and pH in a study conducted in Oahu, Hawaii.

Table 4. Regression values of species on soil factors. Correlation coefficients (r) and levels of probability for the number of species occurring in a subplot in relationship to area and 10 different soil factors.

Factor	'r' Value	Levels of Probability
Area	.974	<.01
Organic matter	.490	<.01
Sodium	.492	<.01
Potassium	.527	<.01
Calcium	.490	<.01
Silt	.297	<.05
Sand	- .356	<.05
Salt	.042	>.05
pH	- .240	>.05
Magnesium	.223	>.05
Clay	- .010	>.05

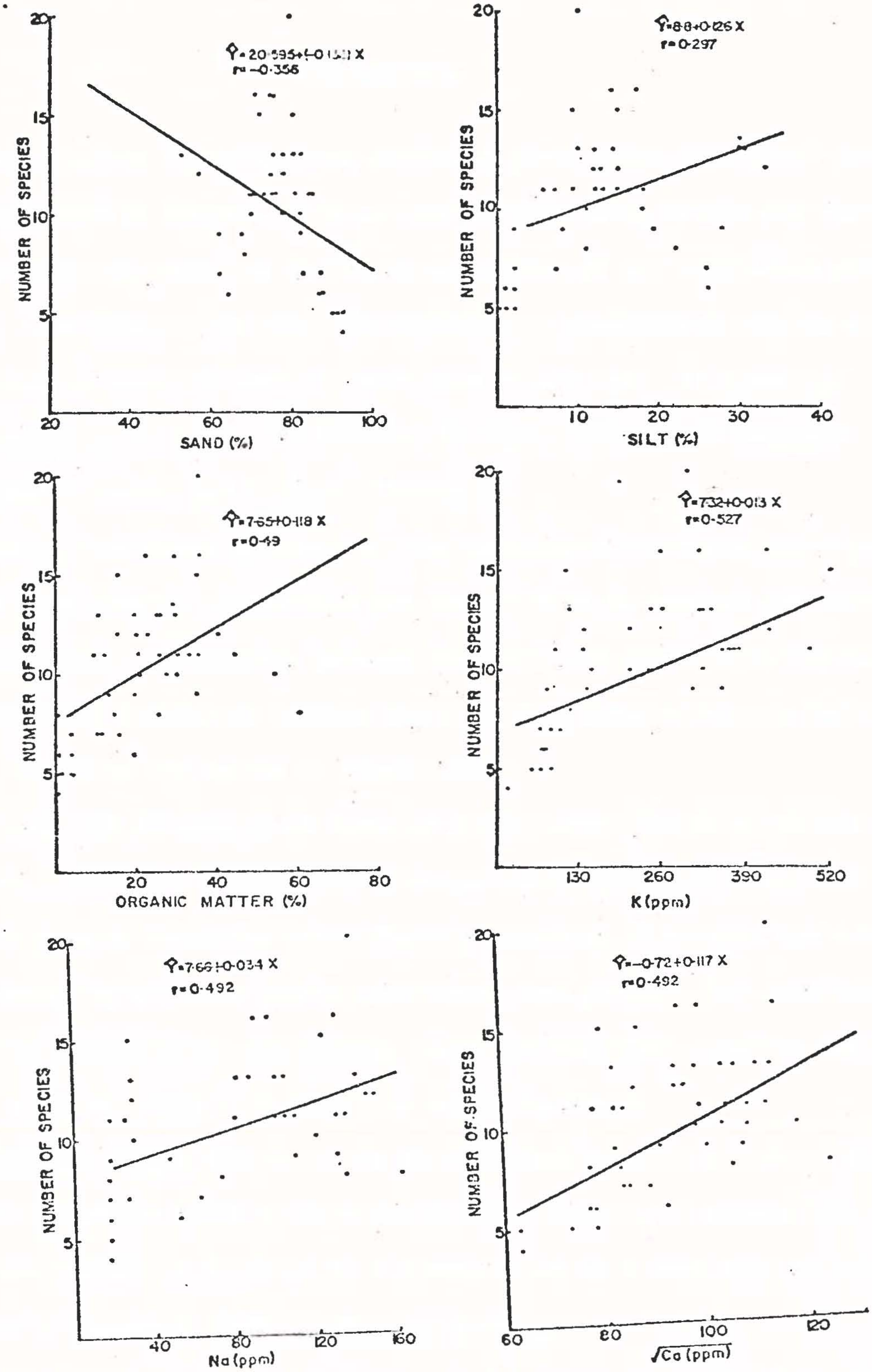

Figure 11. Relationship between number of species present in a subplot and six significant soil factors.

CONCLUSIONS

Quantitative investigations utilizing three major analytical devices, i.e., the profile diagram, plotted species importance values and statistical clustering, resulted in the determination of six vegetation communities. The communities named for dominant or co-dominant species as determined by computed species importance values are: 1) *Scaevola/Messerschmidia*; 2) *Cocos*; 3) *Mikania*; 4) *Aglaia/Guamia*; 5) *Pandanus dubius*/Marsh ferns; and 6) *Merrilliodendron*.

Though individual species are independently distributed along the gradient the several communities are recognizable by species composition and physiognomy. Boundaries between the first two communities are quite discrete while boundaries between the remaining communities are indistinct. Ecotones are narrow or nonexistent..

A total of 55 species of vascular plants were identified within the transect. The major growth-form is broad leaved evergreen tree, 44%. The most complex community *Aglaia/Guamia* contained 32 species and a vertical structure of three nearly continuous tree strata. The simplest community, *Scaevola/Messerschmidia*, contained only three species and formed a narrow hedge-like band just above the beach.

Pandanus dubius dominates the marsh community which occurs at the edge of the cenote which is bisected by the transect. A second less mesic environment is occupied by a consociation of a tree rare on Guam, but locally abundant, *Merrilliodendron megacarpum*.

Strong statistical correlations exist between the number of species occurring within a subplot or community and increased amounts of soil potassium, sodium, and calcium.

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APPENDIX A

SUMMARY OF FIELD DATA FOR PLANTS ONE METER AND TALLER

Subplot	Species	Density	Area at Breast Height (Cm^2)	Height (m)	Crown Area (Cm^2)	Relative Density	Relative Area Breast Height	Relative Height	Relative Crown Area	Species Impor-tance Value
1	No plants									
2	*Scaevola taccada*	7	908	28	2709	70.0	55.26	75.7	93.00	293.96
	Messerschimidia argentea	2	707	7	50	20.0	43.03	18.9	6.60	88.53
	Cocos nucifera	1	28	2	3	10.0	1.71	5.4	0.40	17.51
3	*C. nucifera*	17	6501	35	661	100.0	100.00	100.0	100.00	400.00
4	*C. nucifera*	20	25152	60	1452	100.0	100.00	100.0	100.00	400.00
5	*C. nucifera*	3	908	13	133	75.0	76.17	92.9	99.40	343.47
	Asplenium nidus	1	284	1	1	25.0	23.83	7.1	0.60	56.53
6	*C. nucifera*	5	6789	25	707	100.0	100.00	100.0	100.00	400.00
7	*C. nucifera*	1	755	10	50	100.0	100.00	100.0	100.00	400.00
8	*C. nucifera*	9	70841	13	707	90.0	74.88	56.5	97.24	318.62
	Ochrosia oppositifolia	1	2376	10	20	10.0	25.12	43.5	2.76	81.38
9	*C. nucifera*	29	20348	69	2043	100.0	100.00	100.0	100.00	400.00
10	*C. nucifera*	34	34289	98	2379	100.0	100.00	100.0	100.00	400.00
11	*C. nucifera*	42	35615	110	6218	87.5	99.94	93.2	99.50	380.16
	Piper guahamense	6	13	8	29	12.5	0.04	6.8	0.50	19.84
12	*C. nucifera*	43	53475	119	4654	86.0	99.94	90.8	99.00	375.74
	P. guahamense	5	20	9	39	10.0	0.03	6.9	0.80	17.73
	Nephrolepis hirsutula	1	7	2	1	2.0	0.02	0.5	0.10	3.62
	Claoxylon marianum	1	1	1	1	2.0	0.01	0.8	99.40	2.91
13	*C. nucifera*	28	32668	58	2827	77.9	99.91	73.4	0.11	350.61
	Aglaia mariannensis	2	7	4	3	5.5	0.02	5.1	0.11	10.73
	P. guahamense	2	1	3	3	5.5	0.01	3.8	0.11	9.42
	N. hirsutula	2	7	3	3	5.5	0.02	3.8	0.24	9.43
	Flagellaria indica	1	13	9	7	2.8	0.03	11.4	0.03	14.47
	C. marianum	1	1	2	1	2.8	0.01	2.5	98.50	5.34
14	*C. nucifera*	23	20348	62	1964	79.0	99.93	84.9	.35	362.33
	P. guahamense	4	3	5	7	13.8	.01	6.9		21.06

Subplot	Species	Density	Area at Breast Height (Cm^2)	Height (m)	Crown Area (Cm^2)	Relative Density	Relative Area Breast Height	Relative Height	Relative Crown Area	Species Importance Value
	Ag. mariannensis	1	3	3	3	3.6	.010	4.1	.15	7.860
	T. trifolia	1	7	3	20	3.6	.050	4.1	1.00	8.750
15	C. nucifera	34	26002	74	2206	63.0	99.460	65.5	92.88	320.840
	P. guahamense	10	95	14	95	18.5	.360	12.4	4.00	35.260
	T. trifolia	2	39	8	39	3.7	.140	7.0	1.64	12.580
	Mikania scandens	3	1	8	29	5.7	.005	7.0	1.20	13.905
	Guamia mariannae	1	3	2	3	1.8	.010	1.8	0.12	3.730
	Cycas circinalis	1	-	1	1	1.8	-	0.9	0.04	2.740
	Ag. mariannensis	1	1	2	1	1.8	.005	1.8	0.04	3.645
	C. marianum	1	1	2	1	1.8	.005	1.8	0.04	3.645
	Pachyrrhizus erosus	1	1	2	1	1.8	.005	1.8	0.04	3.645
16	C. nucifera	21	10262	48	855	58.3	98.090	52.2	79.46	288.050
	G. mariannae	4	154	15	154	11.1	1.480	16.3	14.32	43.200
	M. scandens	3	3	9	29	8.3	.020	9.8	2.69	20.810
	P. guahamense	3	3	4	7	8.3	.020	4.3	.65	13.270
	C. circinalis	1	29	4	13	2.8	.290	4.3	1.21	8.600
	C. marianum	1	1	2	1	2.8	.010	2.2	.09	5.100
	T. trifolia	1	7	3	3	2.8	.060	3.3	.27	6.430
	F. indica	1	3	5	13	2.8	.020	5.4	1.22	9.440
	Ag. mariannensis	1	1	2	1	2.8	.010	2.2	.09	5.100
17	M. scandens	9	13	28	416	25.7	.360	23.3	35.95	85.310
	P. guahamense	6	39	11	50	17.1	1.100	9.2	4.32	31.720
	G. mariannae	5	64	11	50	14.1	1.800	9.2	4.32	29.420
	T. trifolia	5	1964	24	314	14.1	55.530	20.0	27.13	116.760
	Pandanus fragrans	3	1452	28	255	8.6	41.040	23.3	22.04	94.980
	Ag. mariannensis	2	3	4	13	5.8	.080	3.3	1.12	10.300
	F. indica	2	1	7	29	5.8	.030	5.8	2.52	14.150
	Merremia tuberosa	2	1	5	29	5.8	.030	4.2	2.52	12.550
	Morinda citrifolia	1	1	2	1	3.0	.030	1.7	.08	4.810
18	P. guahamense	11	113	21	227	36.8	12.540	22.1	34.75	106.190
	M. scandens	6	3	21	177	20.0	.330	22.1	27.06	69.490

Subplot	Species	Density	Area at Breast Height (Cm^2)	Height (m)	Crown Area (Cm^2)	Relative Density	Relative Area Breast Height	Relative Height	Relative Crown Area	Species Importance Value
	T. trifolia	3	177	12	79	10.0	19.64	12.5	12.07	54.21
	F. indica	3	3	13	64	10.0	.33	13.7	9.78	33.81
	G. mariannae	3	3	7	13	10.0	.33	7.4	1.98	19.71
	Ag. mariannensis	1	3	3	7	3.3	.33	3.2	1.07	7.90
	P. fragrans	1	314	13	79	3.3	34.85	13.7	12.07	63.92
	M. tuberosa	1	1	3	7	3.3	.12	3.2	1.07	7.69
	A. nidus	1	284	2	1	3.3	31.53	2.1	.15	37.08
19	M. scandens	25	64	49	1320	43.8	6.55	32.2	69.25	151.80
	P. guahamense	8	79	15	113	14.0	8.09	9.9	5.92	37.91
	Ag. mariannensis	7	573	32	284	12.4	58.70	21.1	14.89	107.09
	G. mariannae	6	29	10	50	10.6	2.97	6.6	2.62	22.79
	F. indica	5	3	16	50	8.8	.33	10.5	2.62	22.25
	T. trifolia	2	50	11	29	3.6	5.12	7.2	1.52	17.44
	Melanolepis multiglandulosa	1	154	12	50	1.7	15.77	7.9	2.62	27.99
	P. fragrans	1	3	2	3	1.7	.33	1.3	.15	3.48
	Bikkia tetrandra	1	20	4	7	1.7	2.04	2.6	.36	6.70
	M. tuberosa	1	1	1	1	1.7	.10	0.7	.05	2.55
20	M. scandens	40	314	126	8820	52.6	6.25	55.8	93.29	207.94
	Ag. mariannensis	9	95	20	95	11.8	1.89	8.8	1.02	23.51
	P. guahamense	6	50	14	50	7.9	.98	6.2	.52	15.60
	T. trifolia	4	1520	16	255	5.5	30.29	7.1	2.69	45.58
	G. mariannae	3	7	4	7	3.9	.13	1.8	.07	5.90
	P. fragrans	3	3	6	39	3.9	.06	2.7	.42	7.08
	Momordica charantia	3	3	6	20	3.9	.06	2.7	.21	6.87
	Dendrocnide latifolia	2	3018	14	50	2.6	60.14	6.1	.52	69.36
	M. tuberosa	3	7	12	95	3.9	.13	5.2	1.02	10.25
	F. indica	2	3	6	20	2.6	.06	2.7	.21	5.57
	O. oppositifolia	1	1	2	3	1.4	.01	.9	.03	2.34
21	M. scandens	55	314	175	12463	63.0	18.96	62.3	95.24	239.50
	P. guahamense	8	39	14	64	9.2	2.35	5.0	.48	17.03
	F. indica	5	13	19	133	5.7	.78	6.8	1.04	14.32

Subplot	Species	Density	Area at Breast Height (Cm^2)	Height (m)	Crown Area (Cm^2)	Relative Density	Relative Area Breast Height	Relative Height	Relative Crown Area	Species Importance Value
	T. trifolia	4	227	14	133	4.6	13.74	5.0	1.040	24.380
	G. mariannae	5	380	21	154	5.7	22.94	7.5	1.170	37.310
	Ag. mariannensis	4	95	12	79	4.6	5.73	4.3	.609	15.239
	Carica papaya	2	133	10	13	2.4	8.03	3.6	.090	14.120
	M. charantia	1	1	3	3	1.2	.06	1.0	.020	2.280
	D. latifolia	1	452	8	39	1.2	27.29	2.8	.290	31.580
	O. oppositifolia	1	1	2	1	1.2	.06	0.7	.001	1.961
	Artocarpus mariannensis	1	1	3	3	1.2	.06	1.0	.020	2.280
22	P. guahamense	27	95	32	380	42.9	19.15	29.6	40.640	132.290
	M. scandens	20	13	35	380	31.7	2.62	32.5	40.640	107.460
	G. mariannae	5	79	13	95	7.9	15.92	12.0	10.160	45.980
	F. indica	5	3	9	50	7.9	.62	8.3	5.340	22.160
	T. trifolia	1	-	1	1	1.6	-	0.9	.110	2.610
	Ag. mariannensis	2	50	7	20	3.2	10.08	6.6	2.150	22.030
	C. papaya	1	255	9	7	1.6	51.41	8.3	.740	62.050
	P. erosus	1	1	1	1	1.6	.20	0.9	.110	2.810
	M. tuberosa	1	-	1	1	1.6	-	0.9	.110	2.610
23	M. scandens	16	50	33	661	37.1	4.87	29.7	56.620	128.290
	P. guahamense	6	29	11	50	14.0	2.82	9.9	4.280	31.000
	G. mariannae	6	7	9	39	14.0	.68	8.2	3.330	26.210
	Ag. mariannensis	6	64	16	79	14.0	6.24	14.4	6.760	41.400
	F. indica	5	7	16	133	11.6	.68	14.4	11.380	38.060
	T. trifolia	3	13	6	29	7.0	1.26	5.4	2.480	16.140
	Ar. mariannensis	1	855	20	177	2.3	83.45	18.0	15.150	118.900
24	Ag. mariannensis	10	255	29	177	30.3	14.42	23.0	17.160	84.880
	G. mariannae	7	1385	46	661	21.3	78.33	36.4	64.130	200.160
	F. indica	4	3	14	64	12.1	.16	11.1	6.200	29.560
	T. trifolia	4	64	14	95	12.1	3.61	11.1	9.230	36.040
	P. guahamense	2	-	2	3	6.1	-	1.6	.290	7.990
	M. scandens	2	3	2	1	6.1	.16	1.6	.090	7.950
	O. oppositifolia	1	13	7	13	3.0	.73	5.6	1.260	10.590

Subplot	Species	Density	Area at Breast Height (Cm^2)	Height (m)	Crown Area (Cm^2)	Relative Density	Relative Area Breast Height	Relative Height	Relative Crown Area	Species Importance Value
	<u>M. citrifolia</u>	1	39	7	13	3.0	2.27	5.6	1.26	12.13
	<u>Eugenia reinwardtiana</u>	1	3	4	3	3.0	.16	3.2	.29	6.65
	<u>Mucuna gigantea</u>	1	3	1	1	3.0	.16	.8	.09	4.05
25	<u>G. mariannae</u>	21	133	30	616	45.7	2.59	21.4	39.48	109.17
	<u>T. trifolia</u>	9	661	37	616	19.6	12.87	26.4	39.48	98.35
	<u>Ag. mariannensis</u>	7	491	27	133	15.3	9.56	19.3	8.54	52.70
	<u>Annona squamosa</u>	3	2827	22	113	6.5	55.07	15.7	7.24	84.51
	<u>D. latifolia</u>	2	908	12	50	4.3	17.68	8.6	3.22	33.80
	<u>E. reinwardtiana</u>	2	113	10	29	4.3	2.23	7.2	1.85	15.58
	<u>P. guahamense</u>	2	-	2	3	4.3	-	1.4	.19	5.89
26	<u>Ag. mariannensis</u>	4	13	7	13	28.6	1.81	19.4	12.87	62.68
	<u>F. indica</u>	3	-	3	7	21.4	-	8.4	6.93	36.73
	<u>C. circinalis</u>	2	616	8	29	14.3	85.31	22.2	28.71	150.52
	<u>M. megacarpum</u>	2	79	8	20	14.3	10.94	22.2	19.81	67.25
	<u>G. mariannae</u>	1	1	2	3	7.1	.13	5.6	2.97	15.80
	<u>T. trifolia</u>	2	13	8	29	14.3	1.81	22.2	28.71	67.02
27	<u>G. mariannae</u>	8	616	28	284	42.0	46.73	41.8	63.53	194.06
	<u>Ag. mariannensis</u>	6	20	10	20	31.5	1.54	14.9	4.47	52.41
	<u>F. indica</u>	1	-	1	1	5.3	-	1.5	.24	7.04
	<u>T. trifolia</u>	1	1	2	3	5.3	.07	3.0	.67	9.04
	<u>Guettarda speciosa</u>	1	661	17	133	5.3	50.15	25.4	29.75	110.60
	<u>C. circinalis</u>	1	13	2	3	5.3	.98	3.0	.67	9.95
	<u>E. reinwardtiana</u>	1	7	7	3	5.3	.53	10.4	.67	16.90
28	<u>Ag. mariannensis</u>	22	1385	64	804	66.7	51.66	59.3	76.35	254.01
	<u>G. mariannae</u>	2	13	6	13	6.1	.48	5.6	1.23	13.41
	<u>T. trifolia</u>	5	20	15	95	15.1	.74	13.9	9.02	38.76
	<u>E. reinwardtiana</u>	2	7	5	7	6.1	.26	4.6	.69	11.65
	<u>Pisonia grandis</u>	1	1257	17	133	3.0	46.86	15.7	12.62	78.18
	<u>Discocalyx megacarpa</u>	1	-	1	1	3.0	-	0.9	.09	3.99
29	<u>Ag. mariannensis</u>	22	804	54	661	57.9	26.66	43.9	56.98	185.44
	<u>T. trifolia</u>	5	113	16	177	13.3	3.74	13.0	15.26	45.30

Subplot	Species	Density	Area at Breast Height (Cm^2)	Height (m)	Crown Area (Cm2)	Relative Density	Relative Area Breast Height	Relative Height	Relative Crown Area	Species Importance Value
	E. reinwardtiana	4	39	13	39	10.6	1.29	10.6	3.36	25.85
	M. megacarpum	1	314	9	39	2.6	10.45	7.3	3.36	23.71
	G. mariannae	1	1	2	1	2.6	.03	1.6	.08	4.31
	P. grandis	1	1075	18	227	2.6	35.65	14.6	19.56	72.41
	O. oppositifolia	1	573	5	7	2.6	19.00	4.2	.62	26.42
	F. indica	1	1	2	1	2.6	.03	1.6	.08	4.31
	C. circinalis	1	95	3	7	2.6	3.15	2.4	.62	8.77
	D. megacarpa	1	-	1	1	2.6	-	0.8	.08	3.48
30	Ag. mariannensis	13	227	47	255	38.3	41.65	51.1	62.34	193.39
	G. mariannae	7	7	9	50	20.6	1.28	9.8	12.22	43.90
	T. trifolia	3	95	10	39	8.8	17.44	10.9	9.54	46.68
	F. indica	3	7	10	29	8.8	1.28	10.9	7.09	28.07
	E. reinwardtiana	2	-	2	1	5.9	-	2.2	.24	8.34
	C. circinalis	3	201	6	29	8.8	36.88	6.5	7.09	59.27
	D. megacarpa	2	1	3	3	5.9	.19	3.2	.74	10.03
	Planchonella obovata	1	7	5	3	2.9	1.28	5.4	.74	10.32
31	Ag. mariannensis	17	284	42	284	56.6	39.06	44.2	58.43	190.29
	C. circinalis	1	29	2	3	3.3	3.99	2.1	.62	10.01
	E. reinwardtiana	2	113	11	39	6.7	15.54	11.6	8.03	41.87
	D. latifolia	2	79	13	20	6.7	10.88	13.7	4.12	35.40
	Streblus pendulinus	2	7	7	7	6.7	.98	7.4	1.44	16.52
	T. trifolia	2	201	13	113	6.7	27.64	13.7	23.25	71.29
	G. mariannae	3	13	5	13	10.0	1.78	5.2	2.67	19.65
	P. obovata	1	1	2	7	3.3	.13	2.1	1.44	6.97
32	Ag. mariannensis	8	1521	38	201	34.8	78.08	60.3	60.91	234.09
	A. nidus	6	284	7	113	26.2	14.59	11.1	34.24	86.13
	P. fragrans	2	64	4	3	8.7	3.28	6.3	.90	19.18
	G. mariannae	2	-	2	3	8.7	-	3.2	.90	12.80
	S. pendulinus	2	-	2	1	8.7	-	3.2	.31	12.21
	D. latifolia	1	79	8	7	4.3	4.05	12.7	2.12	23.17
	C. circinalis	1	-	1	1	4.3	-	1.6	.31	6.21

Subplot	Species	Density	Area at Breast Height (Cm^2)	Height (m)	Crown Area (Cm^2)	Relative Density	Relative Area Breast Height	Relative Height	Relative Crown Area	Species Importance Value
	T. trifolia	1	-	1	1	4.3	-	1.6	.31	6.210
33	Ag. mariannensis	8	346	29	201	44.4	1.257	31.5	24.69	101.847
	G. mariannae	2	64	10	29	11.0	.230	10.9	3.56	25.690
	M. citrifolia	1	-	1	1	5.6	-	1.1	.14	6.840
	T. trifolia	2	1	4	3	11.0	.003	4.3	.36	15.663
	Ficus prolixa	1	14733	20	314	5.6	53.550	21.7	38.57	119.420
	G. speciosa	1	12265	20	255	5.6	44.580	21.7	31.32	103.200
	D. latifolia	1	7	3	3	5.6	.040	3.4	.36	9.400
	P. obovata	1	-	1	1	5.6	-	1.1	.14	6.840
	P. dubius	1	95	4	7	5.6	.340	4.3	.86	11.100
34	Ag. mariannensis	4	29	10	7	33.4	.800	15.9	1.98	52.080
	E. reinwardtiana	2	3	4	3	16.8	.080	6.3	.84	24.020
	A. nidus	1	-	1	3	8.3	-	1.6	.84	10.740
	P. dubius	1	20	3	7	8.3	.550	4.8	1.98	15.630
	M. megacarpum	1	314	13	79	8.3	8.700	20.6	22.37	59.970
	C. circinalis	1	29	3	7	8.3	.800	4.8	1.98	15.880
	Ar. mariannensis	1	3116	20	227	8.3	86.440	31.7	64.35	190.790
	F. prolixa	1	95	9	20	8.3	2.630	14.3	5.66	30.890
35	M. megacarpum	2	14733	13	20	50.0	100.000	86.7	60.60	297.300
	A. nidus	2	-	2	13	50.0	-	13.3	39.40	102.700
36	A. nidus	4	284	5	50	40.0	15.820	11.6	28.73	96.150
	M. megacarpum	3	1257	25	113	30.0	69.940	58.1	64.94	222.980
	D. latifolia	1	-	1	1	10.0	-	2.3	.59	12.890
	T. trifolia	1	1	2	3	10.0	.050	4.7	1.72	16.470
	Ag. mariannensis	1	255	10	7	10.0	14.190	23.3	4.02	51.510
37	F. indica	4	7	11	39	44.4	6.790	47.8	47.56	146.550
	M. megacarpum	3	95	9	39	33.4	92.240	39.2	47.56	212.400
	Ag. mariannensis	1	1	2	1	11.1	0.970	8.7	1.23	22.000
	A. nidus	1	-	1	3	11.1	-	4.3	3.65	19.050
38	Ag. mariannensis	7	346	39	177	31.8	4.040	28.9	29.14	93.880
	F. indica	5	3	13	50	22.8	.030	9.6	8.22	40.650

Subplot	Species	Density	Area at Breast Height (Cm^2)	Height (m)	Crown Area (Cm^2)	Relative Density	Relative Area Breast Height	Relative Height	Relative Crown Area	Species Importance Value
	G. mariannae	2	7	5	7	9.2	.08	3.7	1.15	14.13
	G. speciosa	1	154	15	29	4.5	1.79	11.1	4.76	22.15
	T. trifolia	1	1	2	1	4.5	.01	1.5	.16	6.17
	P. grandis	1	2827	22	113	4.5	32.93	16.3	18.58	72.31
	A. squamosa	1	346	13	50	4.5	4.04	9.6	8.22	26.36
	M. megacarpum	1	3	2	3	4.5	.03	1.5	.49	6.52
	Ar. mariannensis	1	4899	22	177	4.5	57.05	16.3	29.12	106.97
	Claoxylon marianum	2	-	2	1	9.2	-	1.5	.16	10.86
39	F. indica	3	7	16	133	42.8	3.56	47.1	66.83	160.29
	P. dubius	2	95	5	13	28.6	48.22	14.7	6.53	98.05
	C. marianum	1	95	12	50	14.3	48.22	35.3	25.14	122.96
	A. nidus	1	-	1	3	14.3	-	2.9	1.50	18.70
40	A. nidus	3	2552	5	29	33.4	43.02	10.6	9.41	96.43
	F. prolixa	2	2921	15	133	22.2	49.24	31.9	43.18	146.52
	P. dubius	2	79	14	95	22.2	1.33	29.8	30.84	84.17
	F. indica	1	-	1	1	11.1	-	2.2	0.34	13.64
	D. latifolia	1	380	12	50	11.1	6.41	25.5	16.23	59.24
41	A. nidus	3	284	4	39	16.0	9.68	10.3	17.41	53.39
	Alocasia macrorrhiza	1	79	3	7	8.4	2.69	7.7	3.14	21.93
	P. dubius	1	452	6	20	20.2	15.44	15.4	8.93	59.97
	F. prolixa	1	1886	13	79	41.2	64.44	33.3	35.26	174.20
	Randia cochinchinensis	1	227	13	79	14.2	7.75	33.3	35.26	90.51
42	P. dubius	8	6079	34	1662	86.3	97.52	82.9	97.70	364.42
	F. prolixa	2	154	7	39	13.7	2.48	17.1	2.30	35.58
43	Acrostichum aureum	10	7	30	314	41.7	3.61	38.5	35.12	118.93
	Pteris tripartita	10	7	30	314	41.7	3.61	38.5	35.12	118.93
	P. dubius	3	177	11	227	12.5	91.24	14.0	25.39	143.13
	Clerodendron inerme	1	3	7	39	4.1	1.54	9.0	4.37	19.01
44	A. aureum	10	7	30	314	47.6	3.66	46.2	47.07	144.53
	P. tripartita	10	7	30	314	47.6	3.66	46.2	47.07	144.53
	P. dubius	1	177	5	39	4.8	92.68	7.6	5.86	110.94

Subplot	Species	Density	Area at Breast Height (Cm^2)	Height (m)	Crown Area (Cm^2)	Relative Density	Relative Area Breast Height	Relative Height	Relative Crown Area	Species Importance Value
45,46,47	No plants									
48	*P. dubius*	6	661	17	284	100.0	100.00	100.0	100.00	400.00
49	*M. megacarpum*	2	1385	15	64	40.0	100.00	83.2	95.53	318.73
	P. tripartita	1	-	1	1	20.0	-	5.6	1.49	27.09
	Procris pedunculata	1	-	1	1	20.0	-	5.6	1.49	27.09
	P. guahamense	1	-	1	1	20.0	-	5.6	1.49	27.09
50	*M. megacarpum*	5	491	22	133	55.6	98.78	73.3	89.86	317.54
	P. tripartita	2	-	2	7	22.2	-	6.7	4.72	33.62
	D. latifolia	1	3	3	1	11.1	.61	10.0	.70	22.41
	T. trifolia	1	3	3	7	11.1	.61	10.0	4.72	26.43
51	*P. tripartita*	5	7	6	39	45.5	.30	18.1	28.46	92.36
	M. megacarpum	3	2290	21	95	27.2	99.58	63.6	69.35	259.73
	T. trifolia	1	1	2	1	9.1	.04	6.1	.73	15.97
	Ag. mariannensis	1	1	2	1	9.1	.04	6.1	.73	15.97
	R. cochinchinensis	1	1	2	1	9.1	.04	6.1	.73	15.97
52	*Ag. mariannensis*	4	13	8	7	33.4	1.04	16.3	4.09	54.83
	A. nidus	2	-	2	13	16.8	-	4.1	7.62	28.52
	Ar. mariannensis	1	133	13	50	8.3	10.36	26.5	29.23	74.39
	C. marianum	1	1	2	1	8.3	.07	4.1	.58	13.05
	C. circinalis	1	201	6	7	8.3	15.66	12.2	4.09	40.25
	M. megacarpum	1	855	14	79	8.3	66.64	28.6	46.19	149.73
	D. megacarpa	1	1	1	1	8.3	.07	2.1	.58	11.05
	P. dubius	1	79	3	13	8.3	6.16	6.1	7.62	28.18
53	*M. megacarpum*	12	2921	35	346	85.8	100.00	94.6	99.44	379.84
	Ag. mariannensis	1	-	1	1	7.1	-	2.7	.28	10.08
	Tectaria crenata	1	-	1	1	7.1	-	2.7	.28	10.08
54	*M. megacarpum*	2	4183	27	314	25.0	98.93	75.0	92.89	291.82
	Ag. mariannensis	2	3	3	13	25.0	.07	8.3	3.85	37.22
	A. macrorrhiza	2	39	3	7	25.0	.93	8.3	2.09	36.32
	T. crenata	1	-	1	1	12.5	-	2.8	.29	15.59
	T. trifolia	1	3	2	3	12.5	.07	5.6	.88	19.09

Subplot	Species	Density	Area at Breast Height (Cm^2)	Height (m)	Crown Area (Cm^2)	Relative Density	Relative Area Breast Height	Relative Height	Relative Crown Area	Species Importance Value
55	<u>T. crenata</u>	4	-	4	13	30.7	-	9.0	3.54	43.24
	<u>Ag. mariannensis</u>	3	13	5	7	23.1	.16	11.4	1.89	36.55
	<u>M. megacarpum</u>	3	7694	31	346	23.1	99.83	70.5	93.76	287.19
	<u>G. mariannae</u>	1	-	1	1	7.7	-	2.3	.27	10.27
	<u>T. trifolia</u>	1	-	1	1	7.7	-	2.3	.27	10.27
	<u>F. indica</u>	1	1	2	1	7.7	.01	4.5	.27	12.48
56	<u>C. papaya</u>	11	3	14	20	47.9	1.57	35.9	26.31	111.68
	<u>Ag. mariannensis</u>	5	39	10	7	22.0	20.53	25.6	9.22	77.35
	<u>T. trifolia</u>	1	-	1	1	4.3	-	2.6	1.32	8.22
	<u>C. circinalis</u>	1	13	2	3	4.3	6.84	5.1	3.94	20.18
	<u>Thelypteris interrupta</u>	1	-	1	3	4.3	-	2.6	3.94	10.84
	<u>T. crenata</u>	1	-	1	1	4.3	-	2.6	1.32	8.22
	<u>A. macrorrhiza</u>	1	39	2	1	4.3	20.53	5.1	1.32	31.25
	<u>M. citrifolia</u>	1	1	1	1	4.3	.53	2.6	1.32	8.75
	<u>F. prolixa</u>	1	95	7	39	4.3	50.00	17.9	51.31	123.51
57	<u>Ag. mariannensis</u>	7	50	15	20	33.2	3.94	29.4	15.26	81.80
	<u>F. indica</u>	3	7	6	13	14.3	.55	11.8	9.92	36.57
	<u>M. megacarpum</u>	3	1134	10	50	14.3	89.22	19.6	38.19	161.31
	<u>T. crenata</u>	2	7	2	3	9.5	.55	3.9	2.29	16.24
	<u>C. papaya</u>	2	3	3	1	9.5	.24	5.9	.76	16.40
	<u>M. charantia</u>	1	1	2	1	4.8	.08	3.9	.76	9.54
	<u>M. citrifolia</u>	1	1	1	1	4.8	.08	2.0	.76	7.64
	<u>E. reinwardtiana</u>	1	29	5	3	4.8	2.28	9.8	2.29	19.17
	<u>F. prolixa</u>	1	39	7	39	4.8	3.06	13.7	29.77	51.33
58	<u>T. crenata</u>	26	3317	38	1134	81.3	96.14	79.1	98.18	354.72
	<u>T. interrupta</u>	5	133	9	20	15.6	3.86	18.8	1.74	40.00
	<u>M. citrifolia</u>	1	-	1	1	3.1	-	2.1	.08	5.28

APPENDIX B

LABORATORY RESULTS OF SOIL ANALYSIS

Subplot	pH	Organic Matter (%)	Clay (%)	Silt (%)	Sand (%)	Total Salts (mmhos/cm)	Mg (ppm)	Ca (ppm)	K (ppm)	Na (ppm)
1	8.86	0.00	4.8	2	93	.24	184	3840	12	17
2	8.82	0.00	4.8	2	93	.25	188	4000	16	17
3	8.32	4.20	4.8	2	93	.46	436	3920	53	18
4	8.02	4.40	4.8	3	92	.50	636	5400	70	18
5	7.50	10.60	9.6	2	88	.44	488	6840	66	18
6	7.57	13.90	9.6	2	88	.49	560	6480	78	18
7	7.53	.34	9.6	1	89	.31	520	6120	73	18
8	7.46	0.00	10.8	1	88	.49	572	6000	76	17
9	7.48	0.00	10.8	1	88	.41	446	5960	79	17
10	7.63	3.80	10.8	2	87	.33	588	7040	87	17
11	7.84	4.30	10.8	2	87	.34	464	6040	70	17
12	7.87	9.60	8.1	6	86	.39	560	6160	93	18
13	7.96	12.10	8.6	7	84	.40	560	6800	93	26
14	7.96	11.70	9.6	7	83	.43	464	7290	97	27
15	7.97	16.00	9.6	9	81	.49	456	7610	111	28
16	7.48	20.10	9.6	13	77	.19	512	8800	140	29
17	7.79	21.20	8.6	9	82	.22	448	9520	150	29
18	7.86	19.70	9.6	10	80	.25	448	8800	245	29
19	7.71	25.20	9.6	10	80	.49	528	9600	300	82
20	7.74	22.80	12.2	17	71	.47	768	9120	320	98
21	7.73	26.60	12.6	5	82	.46	864	10640	330	101
22	7.66	25.80	9.6	9	81	.53	816	9840	365	104
23	7.87	35.30	9.6	8	82	.51	568	10000	340	110
24	7.76	36.00	12.4	15	73	.63	672	10960	380	134
25	7.84	36.60	14.4	19	67	.61	864	11520	290	132
26	7.66	29.70	6.2	18	70	.42	424	11600	210	121
27	7.67	29.40	4.8	14	76	.87	608	10640	340	142
28	7.77	44.50	6.4	12	74	.38	736	12560	375	130

Subplot	pH	Organic Matter (%)	Clay (%)	Silt (%)	Sand (%)	Total Salts (mmhos/cm)	Mg (ppm)	Ca (ppm)	K (ppm)	Na (ppm)
29	7.75	31.3	6.6	18	69	.39	944.0	11760	340	100
30	7.76	32.5	4.9	14	76	.27	528.0	9840	260	91
31	7.76	32.0	5.3	12	77	.37	816.0	12000	320	113
32	7.63	36.5	5.3	10	79	.32	760.0	12720	300	137
33	7.61	36.7	5.8	14	74	.40	904.0	13040	425	131
34	7.53	40.8	5.3	12	77	.51	1096.0	13360	430	148
35	7.24	61.6	5.3	11	78	.48	1216.0	15360	410	163
36	7.20	54.2	5.3	11	78	.53	1176.0	13920	325	120
37	7.05	33.3	10.4	18	71	.42	1000.0	10720	490	109
38	7.26	36.0	12.4	15	72	.39	392.0	6480	525	123
39	7.24	26.9	8.4	11	80	.42	464.0	6880	400	73
41	7.28	-	-	-	-	1.50	22.4	88	39	113
49	7.59	14.8	9.6	22	68	.45	704.0	11040	115	135
50	7.62	20.7	10.6	13	76	.42	448.0	6720	135	80
51	7.59	28.1	11.6	18	70	.40	752.0	10640	240	120
52	7.62	23.0	10.6	15	74	.48	632.0	9920	210	146
53	7.83	19.3	9.6	26	64	.31	552.0	8480	180	53
54	7.79	16.3	11.6	26	62	.31	576.0	8000	180	63
55	7.83	19.0	9.6	28	62	.29	448.0	8320	140	48
56	7.83	15.4	9.6	33	57	.25	336.0	7840	140	45
57	7.49	11.8	15.6	31	53	.35	384.0	6720	115	88
58	7.29	5.9	19.6	28	52	.67	448.0	5120	70	286